UNIVERSITAT JAUME I

ESCOLA SUPERIOR DE TECNOLOGIA I CIÈNCIES EXPERIMENTALS

GRADO EN INGENIERÍA ELÉCTRICA

Estudio energético y diseño de una instalación fotovoltaica aislada sobre cubierta para la empresa Glazura s.r.o en la Republica Checa

TFG GRADO EN INGENIERÍA ELÉCTRICA

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1. SCOPE AND PURPOSE

Increasingly in the last several decades, industrial energetic audits have exploded as companies increased their interest on reducing the energy bill and move towards a sustainable future. This has made energy audits greatly important. Their importance is magnified since energy spending is a major part of to industrial companies' costs (energy spending accounts around 10% of the average manufacturer's expenses). This growing trend should continue as energy costs are expected to continue their increase.

Most of the industrial factories usually find the same problems in their power consumption when they check the power income. They have some peaks during the days; that ones are really punished with high charges in the bill.

All the industries want to be as much efficient as possible to save as much money as they can, to be productive and doing a fast returnable capital investment.

This problem also affects the glazes, frits and ceramic colors factory of Glazura s.r.o. During the production process there are many machines working at the same time, and some of them operate less than one hour of work. This underlines the importance of where the problem comes due during a short period of time there is a big demand of power, and sometimes it is even higher than the power contracted. For that reason, the company is being penalized. But from another way round the main part of the day the power is much lower than the power contracted, what means they are losing money.

After the energetic study has been elaborated and assessed, in order to become more efficient and committed with the environment, the company bets for renewable energies. Therefore, an isolated photovoltaic installation able to assist half of daily company's consumption is designed. Thereby, it will decrease the grid consumption and it potentially allows to contract an energetic tariff more economic.

The objective of this project is to do an energetic study of the Company Glazura s.r.o. where is going to be studied all the production processes and all the machines taking part of the process, and the transformers and the compressors to try to do as much improvements as possible.

With this optimization the company wants to achieve energy savings and the corresponding economic savings. But also, the subsequent environmental savings as a decrease in electricity consumption always is associated with a decrease in the burning of fossil fuels.

Apart from the energy audit, another field of action proposed will be the control or management of power, consisting on rescheduling certain electrical with the goal to minimize, possible period variations in the power demand curve, preventing very high values to be reached. Also the shifting consumption from time periods with a given cost of electricity to other periods with lower energy cost will be studied.

Finally this project presents a budget with all the cost will mean all the changes made in the company to achieve the energy savings studied. Will be analyzed the measurements and budget as well as a financial study to check the viability of the project. In this financial study is going to be reflected the situation of Czech Republic about the photovoltaic energy and it could be compared with the situation in Spain.

2. BACKGROUND STUDY

2.1. Location

The factory belonging to the company Glazura s.r.o. that it is going to be analyzed in this project is located in the outskirts of Roudnice nad Labem, Czech Republic. It's a really good place for located the company because it is just 40 km far from Prague and next to the train station what it makes easier connections with the main clients and suppliers, due the merchandise is sent 78% by trucks and the other 27% by train.

The exact location of the factory is the next one:

- Latitude: 50° 25´ 55,52'' N
- Longitude: 14° 17´ 28,45" W

In the following figures 3.1 and 3.2 is possible to check the location of the company:

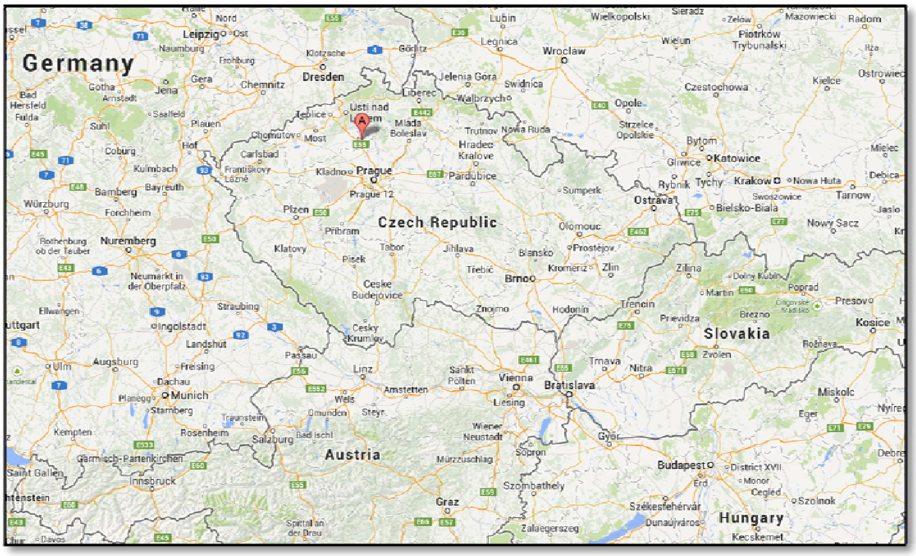


Figure 2.1 Location of the factory

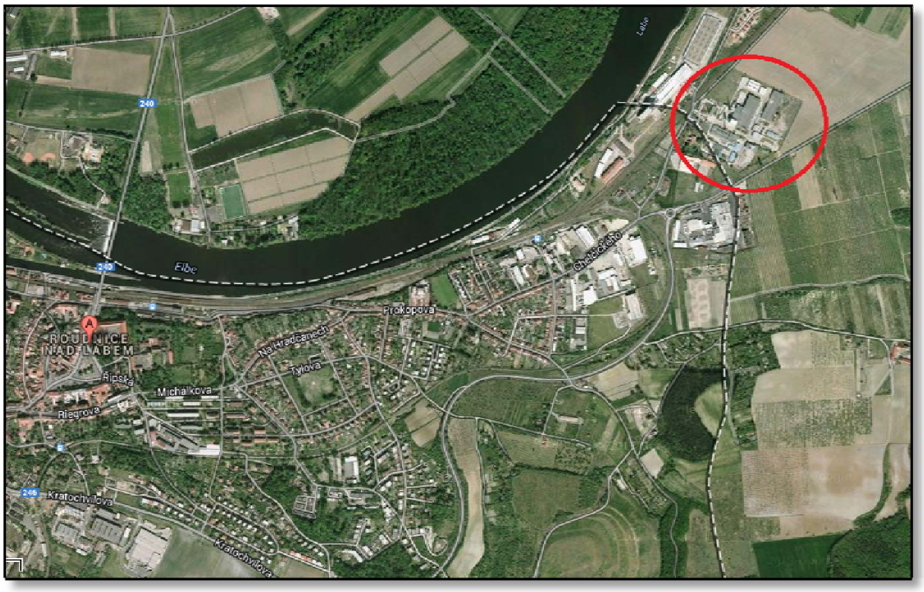


Figure 2.2 Localization of the company

2.2. The company

Torrecid Group is positioned in Central & Eastern Europe through Glazura s.r.o, a local company with long history in the Czech industry.

In 1925, it was founded by primary owner Evžen Frölich. The company called EFCO at that time, was centered on the production of frits, enrobes, glazes, ceramic pigments and colors, enamels, precious metals preparations and luster colors. The company also offered the ceramic bodies and raw-materials. Due to its comprehensive offer, the firm got a notable position in the European market. From this time, the current Glazura registered trademark.

From that time onwards, it is summarize his evolution through the following dates:

1939 - The owner of the company became German concern Degussa. The following war years entailed for the firm the reduction of the production and cessation of its development however.

1958 - After the difficult period of nationalization of the company and restructure of the production, the company in Roudnice nad Labem, is given a new name - Glazura s.p. (state public enterprise). The inclusion of the plant in the East block affected it by the loss of the contacts with the ever more advancing Western Europe. The seller's market has been concentrated on inland for the most part.

1991- Due to the social changes in 1989, Glazura became a part of Rako a.s., owned by German company Deutsche Steinzeug.

2003 - Glazura s.r.o. became a part of Torrecid group. Entering into the group represents the beginning of a totally new and radical period of Glazura. Thanks to the background of a successful international group and its business strategy, Glazura became a leader in Middle and Eastern European markets.

2010 - As a member of Torrecid Group, Glazura s.r.o. established a representative office in Russia.

Innovation

The success of a Torrecid Group is based, among others, on innovation. Glazura and its people participate in innovation of all the products, processes and services of the Group. Everyday all our staff and specialists in branch of frits, glazes and precious metals preparations are finding new solutions to provide our customers with the most competitive products with highest added value.

Products and Services

Frits

The frits are granulated vitrifiables of a special composition arising from the melting of ceramic raw materials and cooled hardly subsequently.

Figure 2.3 Frits

Glazes

The ceramic glazes are milled frits of a special composition with the addition of kaolin, ceramic pigments, coloring oxides, tarnishing agents and other added materials. They are intended for the surface treatment of ceramic products for using in ceramic industry, e.g. for the glazing of floor tiles, wall tiles, roof tiles, tableware, earthware and decorative ceramic as well.

Figure 2.4 Glazes

Ceramic colors

Generally, the ceramic colors are the powdery decorative materials, containing the fusible components pigmented for the most part by big quantity of ceramic pigments (or dyeing metals oxides) and eventually other additional materials. They are intended for the decoration of different ceramic materials, glass, porcelain, tableware, etc.

Figure 2.5 Ceramic colors

Ceramic pigments

The ceramic pigments are special inorganic materials of crystalloid character produced by the calcinations to high temperatures of metallic oxides. They are characterized by high temperature stability, high chemical resistance and guaranteed particles size. They are used for the coloring of ceramic glazes, ceramic body powders, tableware, sanitary ware, plastics and enamels industry.

Figure 2.6 Ceramic pigments

Precious metals preparations

The precious metals preparations are organic compounds of gold, silver, platinum and other metals in solvents organic, thickened by resin to the consistency able to application to glass, porcelain and wall tiles industry.

Figure 2.7 Precious metals preparations

Auxiliary Materials for Colors and for Precious Metals Preparations

Painting, lining and screen printing mediums, cover coats and thinners used to work with decorative materials.

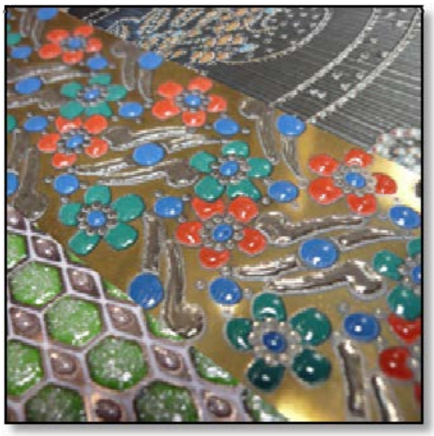


Figure 2.8 Auxiliary materials for colors

Services

The target of the Torrecid Group is to provide services to the customers solving their requests to create in tight cooperation with them the appropriate application procedures and in the case of needs to develop new and innovative products according to their demands. It is available the large laboratory and semi-industrials background.

Quality

The consistent quality of the products is ensured continuously by a technical final quality inspection. The control procedures are specified according to the customer’s needs and they are guaranteed by modern instrumentation.

Ecology

The company Glazura invests in the development of products, that do not burden the living environment, and also in the technologies, that decrease the possible negative influence of their production process. As examples, the recycling of the sewage water, the combustions products treatment and the utilization of thermal waste. The company Glazura s.r.o. holds of the certificate “Green firm”.

2.3. Situation photovoltaic energy in Czech Republic

2.3.1. General overview

Solid fuels made up most of the energy and electricity mix in 2010 in the Czech Republic. Together with nuclear power plants, they accounted for almost 90% of gross electricity consumption. Hydro power contributed more than 50% of renewable electricity, followed by biomass. As far as the 2020 target for RES is concerned, the Czech target is 13%. This indicator improved from 6.4% in 2006 to 9.2% in 2010. The share of cogeneration was 14.2% in 2010, showing a decrease compared in 2005 (16.8%).

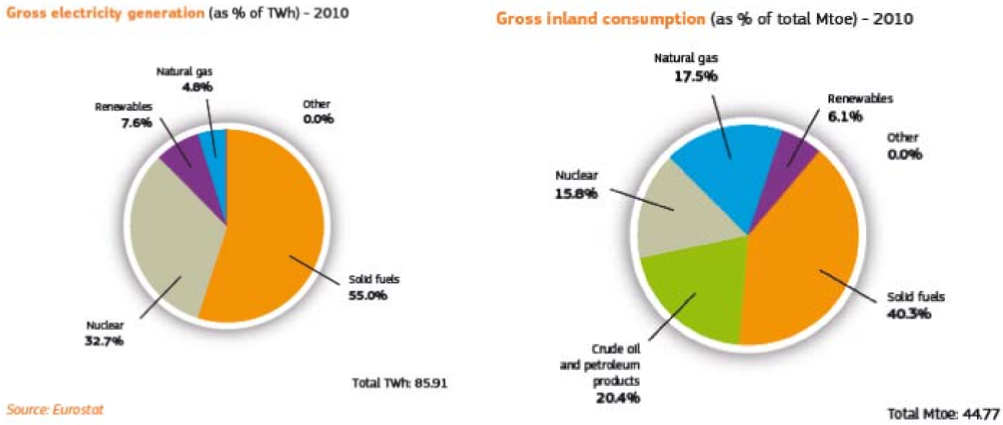


Figure 2.9 Gross electricity generation (as % of TWh) – 2010. Source: Eurostat

2.3.2. Regulation framework

General: As the Czech Republic had notified full transposition of the Third Package Directives by the end of September 2011, no infringement proceedings for non-transposition have been opened.

National Energy Regulator: The Czech National Authority, Energeticky regulačni uřad (ERO), in operation since 2001, employed 102 staff in 2010 with an annual budget of almost CZK 112 023 million (about EUR 4.43 million). Over the years, the regulator has acquired considerable independence from government and industry and is generally seen as a credible independent actor in the energy market. Its budget is not linked to any ministry and is decided by The Parliament.

Unbundling: CEPS is the country's electricity transmission operator, majority-owned by the state. The model chosen is ownership unbundling. The NRA notified its draft decision to the Commission in August and the Commission issued its opinion in October. With regard to gas, the transmission system operator GRID4GAS (formerly RWE Transgas Grid) will be operating as an ITO, due to be certified in autumn 2012. As far as distribution is concerned, there are six regional gas distribution companies serving more than 90 000 customers. Four are members of the RWE group and functionally unbundled. There are also 71 'local distribution companies' each serving fewer than 90 000 customers. For electricity, distribution is split between CEZ, E.ON and Prazska energetika, with a further 200-300 small local DSOs. CEZ, E.ON and Prazska energetika are also active in distribution and supply.

2.3.3. Wholesale markets

At generation level the market is highly concentrated. The incumbent and state-owned CEZ continues to be the dominant electricity producer, with a market share of 75% in 2010. No other company had a market share exceeding 5%. Electricity is traded at Power Exchange Central Europe a.s. (PXE) under bilateral contracts and on spot markets organized by the market operator OTE. Market integration through market coupling with Slovakia started in 2009 and volumes of traded electricity have been increasing. The market coupling of the Czech, Slovak and Hungarian day-ahead markets started on 11 September 2012.

There are plans to extend the market coupling project to other CEE countries. Uniform auction rules are in place with the other countries of the CEE region for the allocation of cross-border transmission capacities (coordinated explicit auctions based on the NTC method), while the possibility of introducing flow-based allocation (FBA) in the CEE region is being explored along with market coupling. The average Czech day ahead wholesale price in 2011 was 50.6€/MWh for base load power (an increase of 15.8% compared to 2010). With regard to liquidity, 8.4 TWh were traded on the spot day-ahead market (13% of national power consumption).

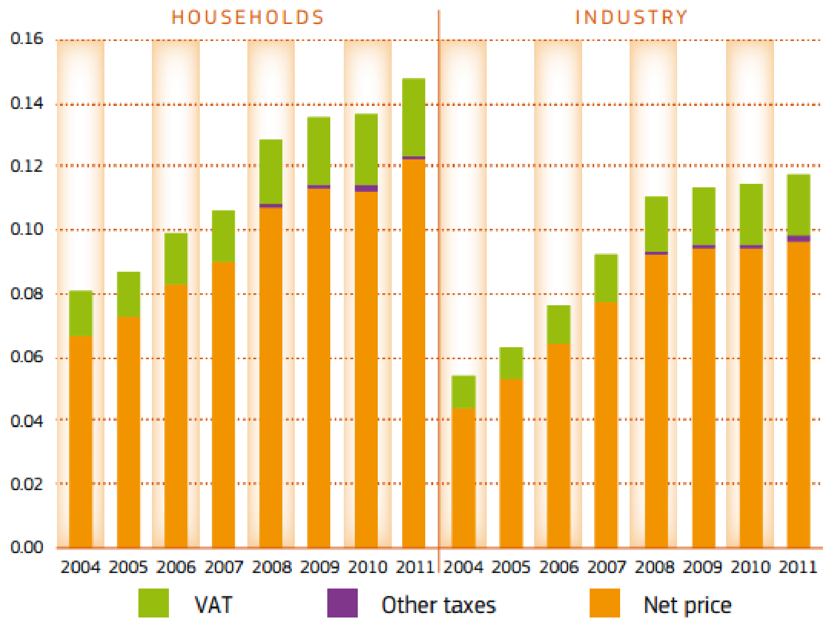


Figure 2.10 Electricity - Retail prices in Czech Republic (in €/kWh). Source: Eurostat

2.3.4. Retail markets

Market concentration is very high, as the market share of the three largest suppliers (CEZ, E.ON and PRE) is 95%. Supplier switching increased in absolute terms, i.e. almost four times more households switched their supplier in 2010. The switching rate, by number of meter points, was 3.3%. Power prices for households and industry have been increasing, mainly due to the grid energy price. Of the taxes paid, VAT accounts for the largest share. In 2011, the share of grid work costs accounted for 62% of the electricity price for households (without taxes), while energy and supply costs took up the remaining 38%. For industrial consumers, the shares were 34% and 66%, respectively. End-user prices are not regulated, but the correlation analysis does not show any significant correlation between wholesale and retail prices.

2.3.5. Infrastructure

The Czech Republic is a grid exporter of electricity. Moreover the Czech Republic has the highest overall level of interconnection capacity within the CEE region. However, transmission capacity is reduced because of loop flows originating mostly from Germany and flowing via Poland to the Czech Republic.

As a result of investment in the development of photovoltaic plants, the total installed capacity of photovoltaic plants has strongly increased. This is the result of a generous feed-in tariff. Installed capacity is able to satisfy peak demand.

The expansion of wind generation in northern Europe will place further constraints on the internal transmission grid.

ELECTRICITY	
Number of companies representing at least 95% of grid power generation	24
Number of main power-generation companies (1)	1
Market share of the largest power-generation company	73%
Number of electricity retailers	324
Number of main electricity retailers (2)	3
Switching rates (entire electricity retail market)	3,30%
Regulated prices for households - electricity	NO
Regulated prices for non-households - electricity	NO
HHI in power generation market (3)	> 5000
HHI in electricity retail market (3)	appr. 4000
Electricity market value (bn €) (4)	6810

Table 2.1 Czech Republic key indicators of the electricity

(1) Companies are considered as 'main' if they produce at least 5% of the national grid electricity generation.
(2) Retailers are considered as 'main' if they sell at least 5% of the total national electricity consumption.
(3) The HHI (Herfindahl-Hirschman Index) is a commonly accepted measure of market concentration. It is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers (the higher the index, the more concentrated the market).
Moderate concentration: 750-1 800; high concentration: 1 800-5 000; very high concentration: above 5 000.
(4) Market value is an estimation of the size of the retail electricity and gas markets. It is calculated using data on electricity and gas consumption in the household and non-household sectors and annual average retail prices.

2.3.6. Development of PV

The main specificity of the Czech Republic is de facto resistance against the RES and especially against photovoltaic which is accused of excessively increasing the cost of electricity for all segments of end users. The resistance is the main barrier to development of PV also.

In second half of 2013 the FiT is much lower than retail price of electricity for households or small enterprises. As a result of the FiT level a smaller PV systems are installed on rooftop, and number of installations in the second half of 2013 is forecasted to be much smaller than in previous periods. For next year FiT will be entirely suspended.

Czech Republic it is in the top 10 European countries with more MWp installed as it can be checked on the figure 2.3. In 2011 it was the fifth country with more MW peak installed in Europe and in 2013 it descends to the position eight due as the same problem as Spain, the reduction of financial helps from the government.

PV in Europe (Mwpeak)				
#	Country	2011	2012	2013
1	Germany	24,875	32,698	36,013
2	Italy	12,764	16,361	17,614
3	Spain	4,214	4,516	4,705
4	France	2,831	4,027	4,697
5	Belgium	1,812	2,649	2,983
6	United Kingdom	1,014	1,657	2739
7	Greece	631.3	1,543	2,585
8	Czech Republic	1,959	2,022	2,132
9	Romania	2.9	49.3	1,022
10	Bulgaria	132.7	933	1,01

Figure 2.11 PV Europe (MWpeak)

But taking into account Czech Republic it is not one of the biggest countries in Europe, a better comparison will be the one made on the figure 2.4. where is compared the W peak installed per capita. Where in 2011 Czech Republic was in the third position and in 2013 it descends to the position 5.

PV per capita				
#	Country	2011	2012	2013
1	Germany	304.3	399.5	447.2
2	Italy	210.5	269.0	295.1
3	Belgium	165.5	240.0	267.3
4	Greece	55.8	136.7	233.7
5	Czech Republic	186.0	192.5	202.8
6	Luxembourg	59.9	89.9	186.2
7	Bulgaria	17.7	127.4	139.9
8	Slovenia	44.1	105.7	123.8
9	Spain	91.3	97.8	100.7
10	Slovakia	89.8	95.7	99.3

Figure 2.12 PV installed capacity per capita in Europe (W peak)

Recommendations are focused entirely to types of grid-metering. It is expected that symmetric grid-metering with no other cost will be not accepted, thus some types of payment are discussed.

Due the big number of PV installations in the country and the technical and transportation system limitations, the discussion over PV installations is nowadays focused on the various types of possible grid-metering strategy to be allowed among them, the following are being evaluated.

First of it is asymmetric grid-metering – this means more electricity is delivered to the grid than it is withdrawn back. No other cost (such the usual charge for transmission and distribution of electricity) would be charged in this case. It is acceptable to deliver up to twice electricity than it is withdrawn while average market price difference of electricity between usual production time and usual consumption time is much smaller.

The second option is a payment for the service of the virtual accumulation of electricity in the grid. The payment would be lower than cost of accumulation of electricity in batteries. This is lower than the usual charge for transmission and distribution of electricity.

The third option is symmetric grid-metering with usual charge for transmission and distribution of electricity.

3. STANDARDS AND REFERENCES

3.1. Legislation and standards reviewed

For the development of this project, the following legislation has taken into account.

- Directive 89/654/EEC and Council Directive 89/391/EEC in workplace requirements
- UNE 157001-2002. General criteria for project development.
- National technical standards.
- UNE
- Recommendations of the European Commission
- Codes of Practice
- The current state law

Regarding PV installations, the European Union is making a significant commitment to renewable energy in recent years. Not only to reduce emissions of greenhouse gases but also as a necessary measure to reduce energy dependence.

The following are some guidelines approved by the European Parliament:

- Directive 2001/77/EC of the European Parliament and of the Council of 27 September, on the promotion of electricity produced from renewable energy sources in the internal electricity market.
- European Directive 2003/30/EC of 8 May, on promoting the use of biofuels and other renewable fuels for transport.
- European Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity restructuring.
- European Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources.
- Contemplate mandatory renewable energy targets for the EU and for each of the Member States in the year

And finally some national regulations have been considered from the European directives and take into account the following international standards.

These regulations may be based on national standards derived from the IEC 60364: Low-voltage electrical installations.

IEC 60038	IEC standard voltages
IEC 60076	Power transformers
IEC 60146	Semiconductor converters
IEC 60255	Measuring relays and protection equipment
IEC 60269	Low-voltage fuses - General
IEC 60282	High-voltage fuses
IEC 60287	Electric cables

IEC 60364	Low-voltage electrical installations
IEC 60446	Basic and safety principles for man
IEC 60479	Effects of current on human beings and livestock
IEC 60529	Degrees of protection provided by enclosures (IP code)
IEC 60644	Specification for high-voltage fuse
IEC 60664	Insulation coordination for equipment within low
IEC 60715	Dimensions of low-voltage switchgear and control gear.
IEC 60724	Short-circuit temperature limits
IEC 60755	General requirements for residual current operated protective devices
IEC 60787	Application guide for the selection of high-voltage current-limiting fuses
IEC 60831	Shunt power capacitors
IEC 60947	Low-voltage switchgear and control gear
IEC 61000	Electromagnetic compatibility (EMC)
IEC 61140	Protection against electric shocks
IEC 61201	Use of conventional touch voltage limits
IEC 61439	Low-voltage switchgear and control gear assemblies
IEC 61643	Low-voltage surge protective devices
IEC 61921	Power capacitors
IEC 62271	High-voltage switchgear and control gear
IEC 62305	Protection against lightning

3.2. Web Pages

The following web pages have been consulted through the project

Photon Data base- www.photon.info

Photovoltaic panels: http://www.gs-power.com/

Photovoltaic company: http://www.solarmax.com/east/en/

Electric protections: http://www.moeller.grid/en/

Solar energy research center: http://www.censolar.es/

Research: http://ec.europa.eu/

http://www.czech.cz/en/Home-en

http://www.czech.cz/en/Home-en

http://www.electrical-installation.org/enwiki/Main_Page

http://re.jrc.ec.europa.eu/pvgis/

http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

3.3. Software

The following software has been considered during the development of this project.

Microsoft Excel: to do all the tables and the financial part.

PV Syst: To do a previous evaluation of the photovoltaic installation.

Xenie Sofis: Own software from the factory to evaluate the consumption of the company

4. ENERGETIC STUDY

4.1. Production system of the company

To analyze properly the factory, first it has to be studied all the process that the company does and all the machinery involved in each department and the power installed in each one. There is a description of each department in the annex 3. In the figure 4.1 it is showing the production system diagram of the whole company.

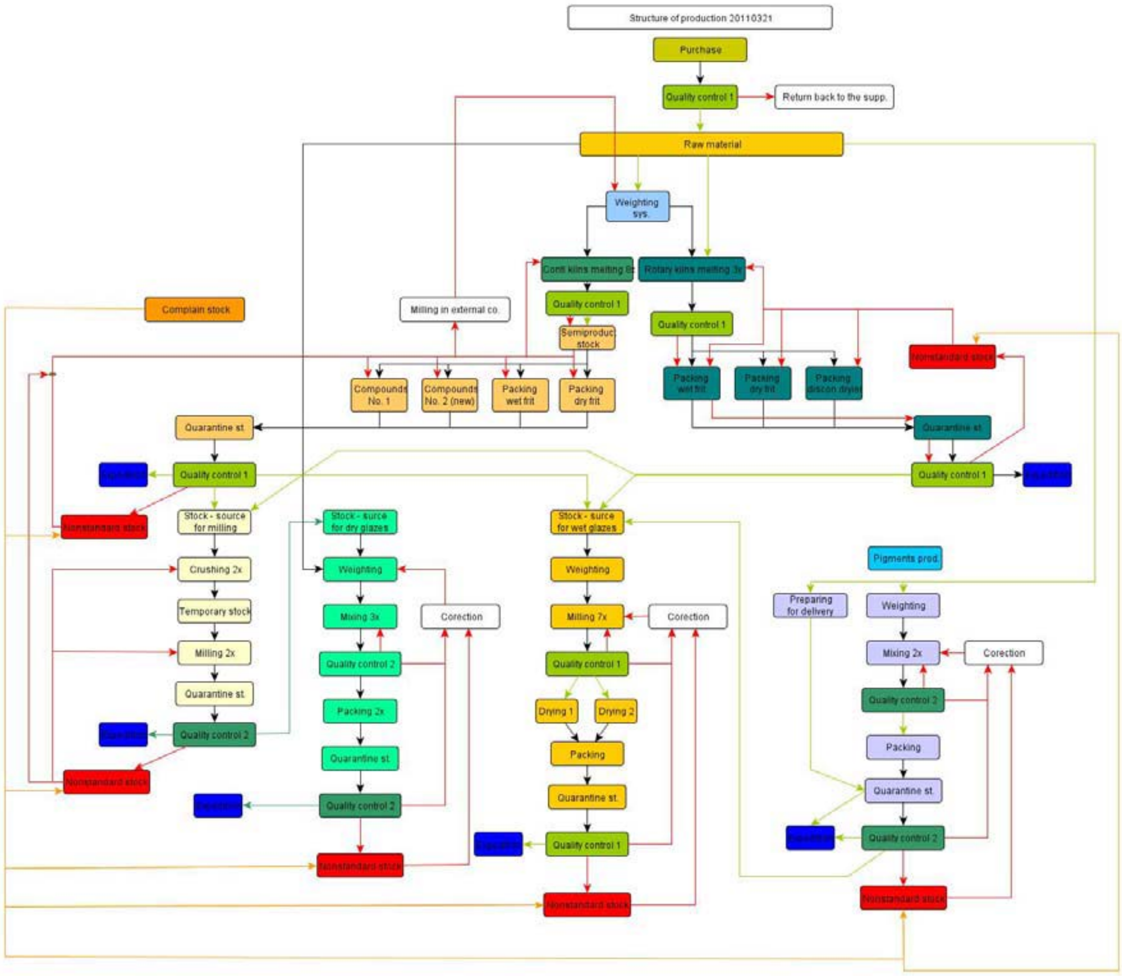


Figure 4.1 Company production system

4.2. Power installed

In the table 4.1 can be checked the main machinery installed in each department and its work time:

DEPARTMENT	SHIFT	MAIN MACHINERY	POWER (KW)	TOTAL POWER (KW)
FRITS	24h	3x Compressor	90	405
	Monday to Monday	Mixer	60	
	Nonstop	Dust extractor	75	
COLOR FRIT	12h	Mixer	77	92
	Monday to Friday	Dryer	15	
DRY MILLING	12h	Crasher	110	220
	Monday to Friday	Mill	110	
WET MILLING	12h	Mill	49,5	69,5
	Monday to Friday	Dryer	20	
PIGMENTS PLANT	12h	2x Mixer	40	91
	Monday to Friday	Small mixer	11	
PILOT PLANT	12h	Hydraulic pressure machine	14,8	196,8
	Monday to Friday	Dryer	49	
		Oven	133	

Table 4.1 Main machinery in each department

4.3. The electrical installation of the plant

The electrical installation of the plant, where the study is done, it is connected to the grid of the company ČEZ a.s. of 22kV, where are connected three elements.

In the electrical installation of the whole factory, there are three transformers, two connected in parallel and the other one in serie.

- The transformer one (T1) 22/0, 4 KV of 630 kVA which powers the dry grinding mill process and the dryers, the administration building, the compressors and illumination of the transformer station, the gas regulation station.

- Transformer two (T2) 22/0,4 KV of 630 kVA which powers the substations of the kilns (K5, K6, K7, K8), the dust extraction system, the old substation and the rotary kilns.

- Transformer three (T3) 22/0,4 KV of 630 kVA which powers the glazes substation, the compound line, weighting facilities and the wet grinding mill process.

The **power installed** in the plant is, therefore, 1.890 kVA.

Transformer	Power (KVA)
Total T1	630
Total T2	630
Total T3	630
Total power	1890

Table 4.2 Apparent power transformers installed in the plant.

4.4. Reactive power compensation in the plant

It has to be mentioned too that every transformer has its own capacitor battery.

Capacitor banks are very useful equipment can reduce surcharges why generated reactive power, thereby obtaining a saving in electricity bill.

Figure 4.2 Capacitor's battery inside of the transformer

To be sure that these capacitors bank are well dimensioned and they are working properly in the annex 3 has been calculated the proper capacitor banks according to the features of the installation of the factory and in the table 4.3 can be checked the results obtained:

	Units	T3	T2	T1
S	KVA	630,00	630,00	630,00
V1	V	22000,00	22000,00	22000,00
I1	A	16,50	16,50	16,50
V2	V	400,00	400,00	400,00
I2	A	909,00	910,00	910,00
Po	W	929,00	1161,70	1512,00
Io	%	0,00	0,01	0,01
Pcc	W	6520,26	1785,10	8051,90
Ecc (U k)	%	0,06	0,06	0,06
Cos fi o		0,76	0,26	0,20
Sin fi o		0,65	0,96	0,98
I fe	A	0,02	0,03	0,04
I u	A	0,02	0,11	0,19
R Fe	Ohms	520990,31	416630,80	320105,82
X u	Ohms	604917,89	113352,02	65139,53
Cos fi cc		0,17	0,05	0,22
Sin fi cc		0,99	1,00	0,98
V Rcc	V	131,72	36,06	162,66
V Xcc	V	786,50	742,17	736,74
Rcc	Ohms	7,98	2,19	9,86
Xcc	Ohms	47,67	44,98	44,65
P average	KW	556,00	1372,00	783,00
cos fi average		0,97	0,97	0,97
C		0,91	2,25	1,28
P load	W	5408,72	9016,77	13246,53
Losses	W	6337,72	10178,47	14758,53
Efficiency	%	0,99	0,99	0,98
Copt		0,38	0,81	0,43
Max Effic.	%	0,96	0,99	0,96
Q void	VAr	800,11	4269,88	7430,20
Q load	VAr	32294,88	185566,20	59995,81
Q total	VAr	33094,99	189836,09	67426,01
	KVAr	33,09	189,84	67,43
Battery power	KVAr	506,40	3083,53	1004,30

Table 4.3 Capacitor bank dimensions

The results were positive for the company due they have a really good dimensioned bank's capacitor and this can be checked from the reactive consumption, analyzed in the internal software, where can be verify its good running.

From the software, as we can see in the figure 4.3, we obtained an average cos fi of 0,97 what it means the compensation of the reactive power is well done, and the company is taking it into account even if they are not penalized for them.

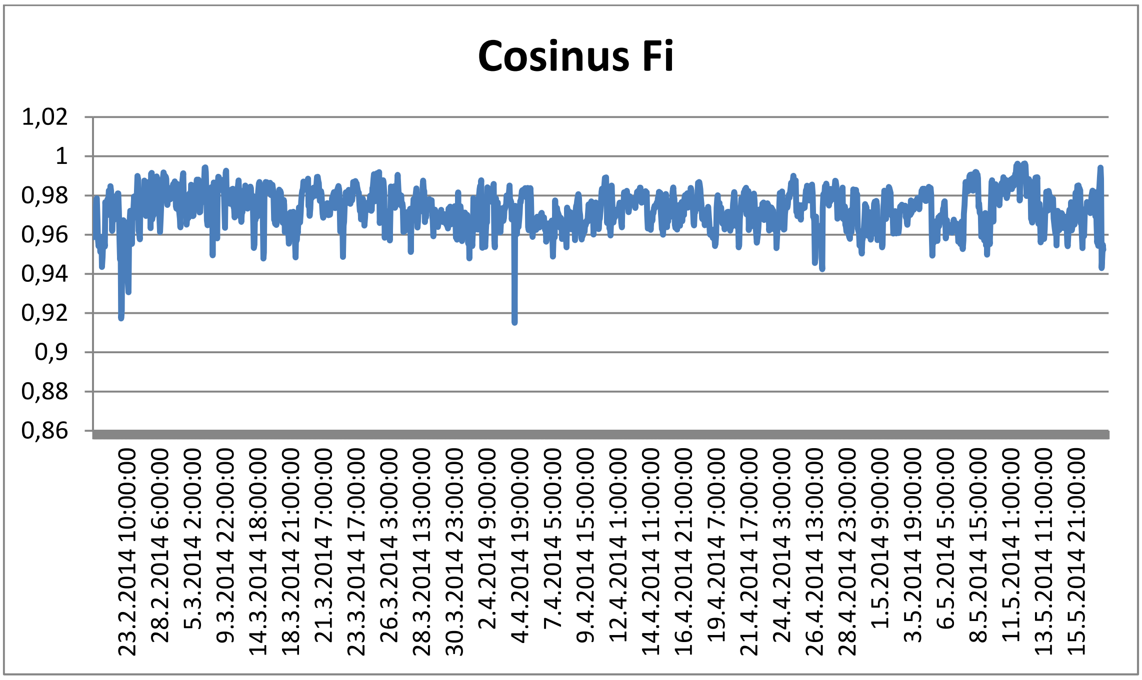


Figure 4.3 Cosine fi

4.5. Economic and energetic consumption evaluation

This section describes the tariff hired by the company and how much are they spending monthly, as it can be checked in the table 4.4 and 4.5:

TARIFF HIRED		
WEEK DAY	60,57	€/MWh
WEEKEND DAY	32,86	€/MWh

Table 4.4 Rates from the company tariff

	KWh	€
January	426766	44.519,79 €
February	467224	48.672,93 €
March	494687	47.764,72 €
April	446409	43.883,87 €
May	385924	38.450,83 €
June	434743	42.532,73 €
July	357307	36.494,85 €
August	321907	32.793,47 €
September	374475	37.789,99 €
October	409481	40.168,46 €
November	439390	44.913,08 €
December	393991	40.243,12 €
TOTAL	4952304	498.227,84 €

Table 4.5 Monthly company's receipt of 2013

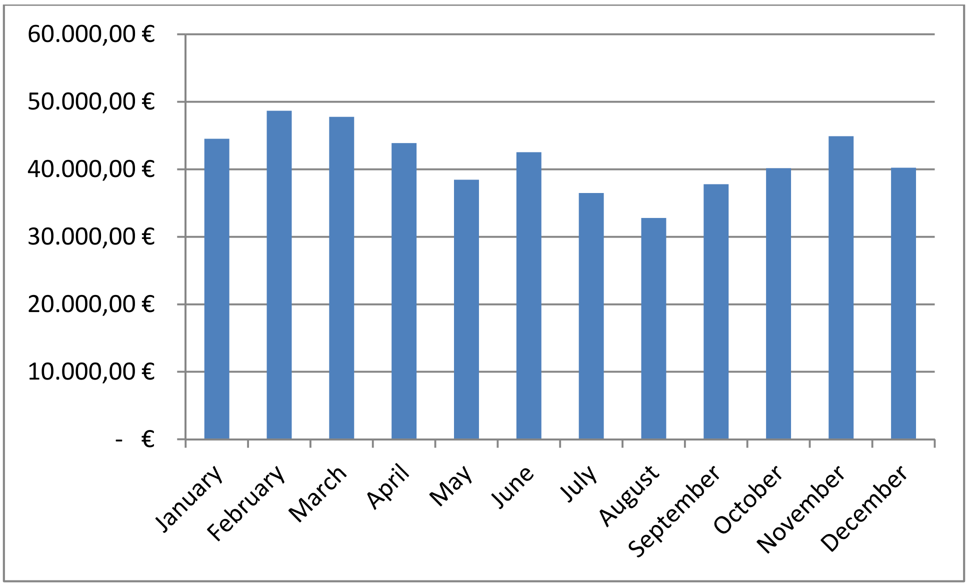


Figure 4.4 Chart of monthly company's receipt

As seen previously, the term power is one of the most important in the electrical bills. To determine the cost, the factory has a maximeter installed by the electrical company, which records the maximum value of the active power demanded each month.

The maximeter is registering the active energy consumed during an interval of 15 minutes. At the end of that interval divided power between 15 minutes to obtain a power value. If the power value is greater than the peak demand was recorded in the previous period, the new value will be displayed by the maximeter, if not, the value of the previous period is retained.

This calculation method makes, for example, a motor starting point for one minute measured does not influences the maximeter directly due the maximeter is taken the average of the remaining 14 minutes interval calculation.

Always seek the power recorded by the maximeter is less than the contracted, otherwise it is severely penalized. Neither interested in hiring a very high power because the tariff will be more expensive and they will pay power that they do not need.

For one hand, one of the objectives of the study is to decrease the value of the power recorded by the maximeter, then allowing a reduction in the value of the contracted power. This objective can be achieved in two ways:

1. Reducing the power consumption itself.
2. Consuming the same, but better distributed in time, with fewer peaks.

The first is accomplished trying to optimize the consumption as many as possible, minimizing losses.

The second is achieved by reducing the peak powers of each individual consume as well as the total power curve, shifting consumption from the peaks to the valleys.

For the other hand, it is necessary to do a comprehensive study of the general consumption of the plant and the each particularly consumption. The study of consumption also will reduce energy consumption, thereby reducing this term, which also has a lot of weight in the amount of the electric bill.

To make the overall study of the plant and the use of each line, has been necessary the data from various sources.

This data is taken from 15 grid work analyzers located at the processing center and at the entrance of each control center. Each analyzer can display the instantaneous values of the main electrical variables (simple and compound voltage, current, power factor, active, reactive and apparent power, reactive and active energy) and the recorded maximum and minimum for each of them.

All the electrometers from the beginning of February are connected to the internal software called “Xenie Sofis” the one is receiving all the data from all the company and where it can be checked the historical of consumption, the instantaneous consumption of all the company and from each department. With this software has been analyzed all the departments as can be checked in the annex 3.

As an example in the figure 4.5 can be checked a week day consumption of the transformer 2 where is connected the kilns number 7 and 8 in black and red respectively, the dust extraction system in blue, the kilns number 5 and 6 in green, the pilot plant in military green and finally the rotary kilns in dark blue.

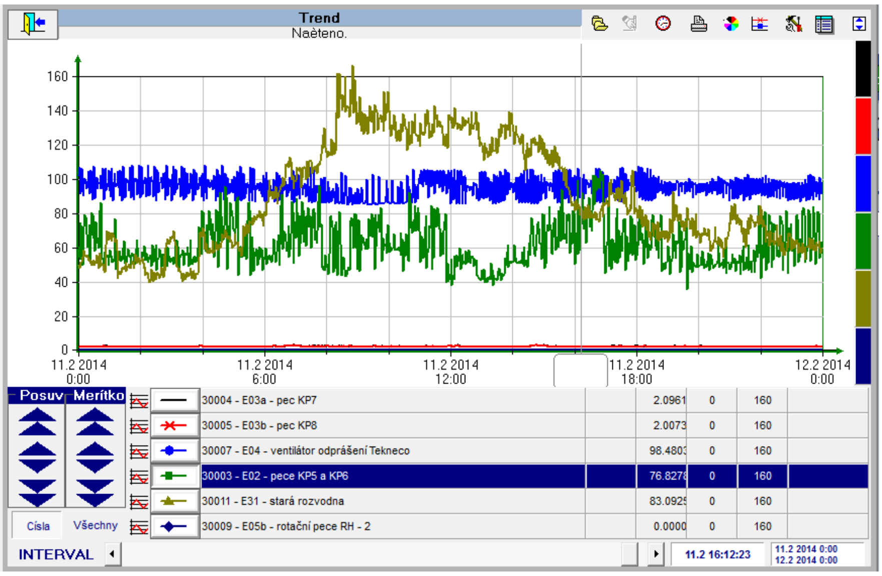


Figure 4.5 T2 Consumption of a week day

4.6. Compressors

The air compressor is a device that converts power from an electric motor into kinetic energy by compressing and pressurizing air, which, on command, can be released in quick bursts. These compressors have positive-displacement methods of air compression.

Figure 4.6 Compressor from dry milling department

Positive displacement air compressors work by forcing air into a chamber whose volume is decreased to compress the air. Piston type air compressors use this principle by pumping air into an air chamber through the use of the constant motion of pistons. They use one way valves to guide air into a chamber, where the air is compressed. Rotary screw compressors also use positive displacement compression by matching two helical screws that, when turned, guide air into a chamber, whose volume is decreased as the screws turn. Vane compressors use a slotted rotor with varied blade placement to guide air into a chamber and compress the volume. It is a type of compressor that delivers a fixed volume of air at high pressure. Common types of positive displacement compressors include piston compressors and rotary screw compressors.

In Glazura s.r.o there are install two groups of compressors, the first one is in the dry milling department and it is compound by three compressors two of them with 55kW, those ones are working to its 100% of power alternately helping the third smaller compressor with 36kW, installed with a frequency converter, this one is the main one, which is working all time.

The other group of compressor is installed in the compounds line, this group is made for 3 compressors with 90kW each, and follows the same technology as the other group, one of them has a frequency converter and is working all time and the other two are working alternately helping it.

The frequency converters are install due many fixed speed motor load applications that are supplied direct from AC line power can save energy when they are operated at variable speed. Such energy cost savings are especially pronounced in variable torque centrifugal fan and pump applications, where the loads' torque and power vary with the square and cube, respectively, of the speed. This change gives a large power reduction compared to fixed speed operation for a relatively small reduction in speed. For example, at 63% speed a motor load consumes only 25% of its full speed power. This is in accordance with affinity laws that define the relationship between various centrifugal load variables.

Fixed speed operated loads subject the motor to a high starting torque and to current surges that are up to eight times the full load current. AC drives instead gradually ramp the motor up to operating speed to lessen mechanical and electrical stress, reducing maintenance and repair costs, and extending the life of the motor and the driven equipment.

Variable speed drives can also run a motor in specialized patterns to further minimize mechanical and electrical stress. For example, an S-curve pattern can be applied to a conveyor application for smoother deceleration and acceleration control, which reduces the backlash that can occur when a conveyor is accelerating or decelerating.

Besides, all the compressors are connected to software (figure 4.7), where it can be checked the work time of each one and the pressure.

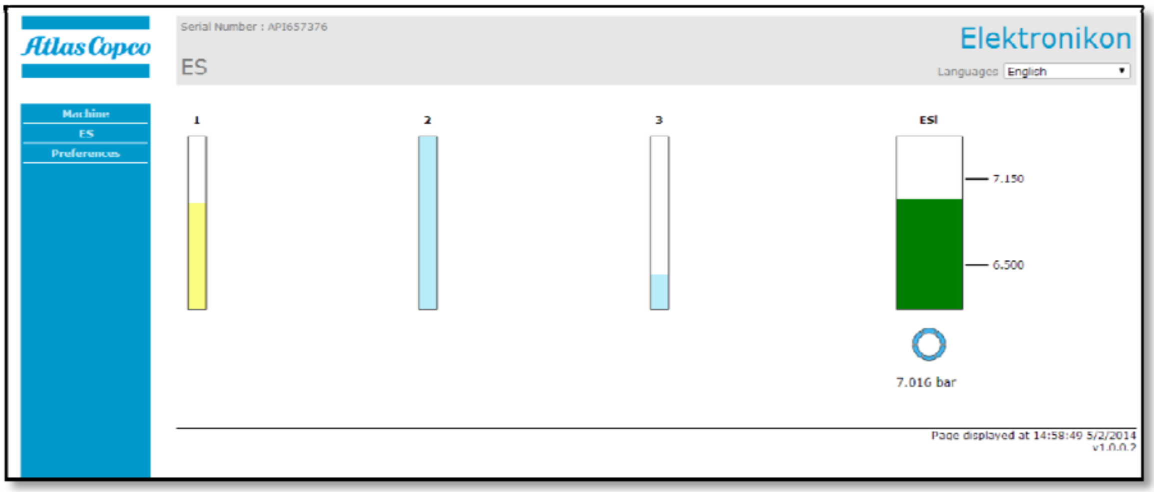


Figure 4.7 Software of the compressors

4.7. Analysis Result

Once done the energetic study about the production of the company and all the technologies are involved in each process and check the consumption in its steps. Besides has been studied the hired tariff and their individual consumptions from the main energetic sources.

It is decided to pay special attention in the consumption energetic curve, taking advantage of the new software installed is able to show in instantaneous consumption of each source to avoid the consumption peaks and try to do the curve as flat as possible in order to save energy, money and possible penalties due to overconsumption.

Related with the reactive energy, it has to be highlighted; previously to the energetic study the company was very aware of the importance of the compensation of this energy. They have done a very good job installing the capacitor batteries in the proper sites with the proper size, as it has been checked after the energetic study, getting an average of the cos fi near to 0,97.

Has to be underlined the installation of the compressors, where Glazura s.r.o. has installed the frequency converter in the smaller compressor and this one is been assisted for two bigger working alternately in order to save energy and extend the work life of the compressors.

As a conclusion of this energetic study is going to be modify the consumption curve to get an energetic demand as flat as possible. Explaining to the employees that they have to check the data of the instantaneous consumption in the software before to connect a big consumption, and they have to prioritize the process in order to reschedule them.

In addition is contemplated the possibility of the PV installation over one of the roofs of the company.

With this solution they will be able to produce their own energy in order to consume it or sell it, obtained in both cases incomes.

5. DESIGN REQUIREMENTS

5.1. Power to install

The power to install it going to be determinate according to two main facts:

1. The area available to install the panels.
2. What amount of energy is profitable for the factory.

On the one hand the area chosen for the installation is the roof of one of the largest buildings in the factory figure 5.1.

It has 160m length and 50m width, what makes an area of has 8000m^2 available for the PV installation.

The roof is totally flat, oriented to the south and without any obstacle that could generate any type shadow during the day, what will do the installation much easier and efficient.

Figure 5.1 Building chosen for the PV installation

On the other hand the power chosen to install depends on the consumption of the factory and technology to use, for this reason both facts are going to be studied.

Taking into account this is the regular consumption of the (figure 5.2) it is decided to install a power able to lower the consumption curve during the peak and more expensive hours, according to the electric tariff. Thereby the factory could hire a cheaper tariff, and reduce significantly the cost of the electricity.

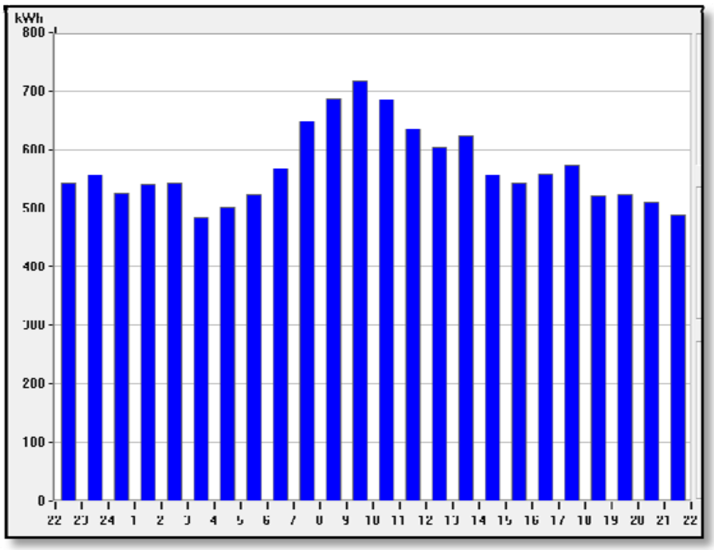


Figure 5.2 Regular consumption in the factory

First of all it has to be studied the different PV technologies exist right now in the market and the power each one is able to generate in order to choose the best option according to the characteristics of the roof where is going to be installed. The power of the plant that could be generated in these 8000m^2, can be estimated knowing the module efficiency and the average radiation of the area (1000W/ m^2 according to the PVGIS). In the table 5.1 there is a summarize of the main technologies studied:

CELL MATERIAL	MODULE EFFICIENCY	SURFACE NEED FOR A 1 KWp
Monocrystaline silicon	13-19%	5 - 8 m^2
Polycrystalline silicon	11-15%	7 - 9 m^2
Micromorphous tandem cell	8-10%	10 - 12 m^2
Thin-film copper-indium-dieseline (CIS)	10-12%	8 - 10 m^2
Thin-film cadmium telluride (CdTe)	9-11%	9 - 11 m^2
Amorphous silicon (a-Si)	5-8%	13 - 20 m^2

Table 5.1 PV Technologies

Knowing the area needed to generate 1kWp, we can guess the power can be installed over the roof, as can be checked in the table 5.2:

CELL MATERIAL	AREA m^2	m^2/KWp AVERAGE	POWER KWp
Monocrystaline silicon	8000	6,5	1.231
Polycrystalline silicon		7,5	1.067
Micromorphous tandem cell		11	727
Thin-film copper-indium-dieseline (CIS)		9	889
Thin-film cadmium telluride (CdTe)		10	800
Amorphous silicon (a-Si)		15	533

Table 5.2

As can be checked on the table, and knowing there is not any restrictions from the suppliers, the best technology options is the ones are using crystalline silicon for this reason and because it's cheaper prize, it is going to be chosen the polycrystalline silicon. In the annex I (PV installation calculation) can be checked that after all the calculation the maximum power finally installed is 488kWp.

Therefore, the consumption curve will be similar to the one in the figure 5.3, but has to be mentioned that the peak there is from 7h to 8h has to be replaced to the time where the PV installation is working in order to do not get any penalty from the electric company.

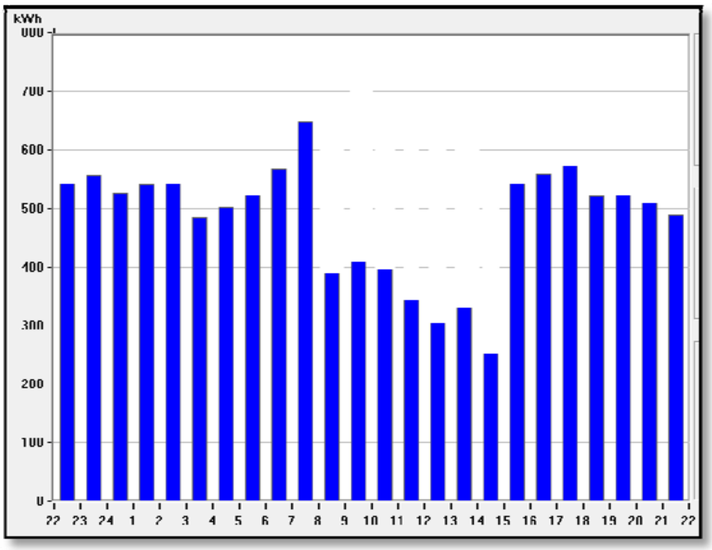


Figure 5.3 New consumption curve

5.2. Connection

Due there is so many photovoltaic installations in this area, the installation which is going to be designed is not going to be allowed to connect to the grid, for this reason the installation is going to be designed as a insolated installation, and all the energy generated will be used by the company.
The installation will be connected to low voltage due there is not any consumption in medium voltage.

5.3. Industrial unit description

The factory where the PV plant is going to be installed is located at a remote place where no shadows are going to affect the panels. The factory presents a flat roof and its dimensions are the following:

- $Length_1$: 160 m
- $Light_1$: 50 m
- Total area: 8000m^2

Regarding the internal structure of the factory. It presents the following characteristics:

- Distance between frames: 5 meters.
- Height of columns: 10 meters.
- Ridge Height: 10 meters.
- Roof slope of 0% (0 °)

An important fact for the modules location is to know the orientation of the factory; in this case the longitudinal part is oriented to the south.

The building blocks that make up the industrial unit are described below.

Outdoor's porch.

The pillars are laminated profile HEB 160 and 180.
The beams are rolled section IPE 300.

Indoor's porch.

The pillars are laminated profile HEB 240.
The beams are rolled section IPE 330.

The Saltier profiles that formed steel braces 16mm diameter.

The cover material is sandwich panel consisting of two galvanized steel plates 40 mm thick and a core of rigid polyurethane foam and 30 mm thick.

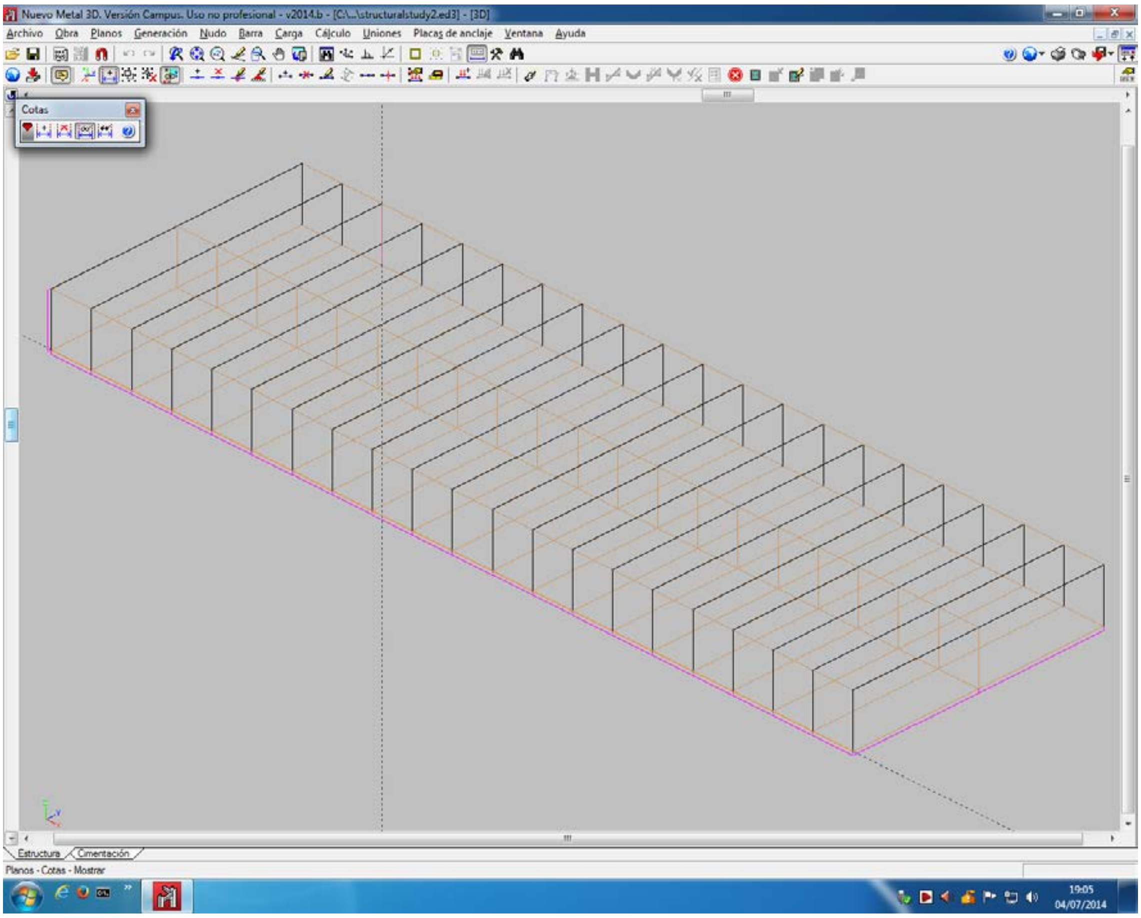


Figure 5.4 Factory's Structure

5.4. Load and stress of the PV system determination

The load has being studied is the one produced by the PV modules plus the rest of the elements of the installation (wires, aluminum structure, anchorage…).
The weight of each modules is 20 kg and it occupied a surface of 1,8m2, so the load per square meter is around 20 kg, plus the weight of the rest of the elements that has being consider a load of 35 kg per square meter to be sure that the factory's structure can resist all the weight of the installation without problems.

5.5. Service load determination

In this study has been consider too the overload due the maintenance of the roof and the installation. The value of the overload is 0,4 kN/m^2 which is written in the EN 1991. This overload is independent to the snow and wind loads, basically because they are incompatible.

As can be checked in the annex 4 the structure of the warehouse is well sized with a 40% of oversizing.

For this reason the PV installation can be installed without any kind of problem or restriction. The installation do not alter the structural safety (stability and resistance) and release to service (deformability), set in the EN 1991, the PV system can be installed on the factory.

6. INSTALLATION'S DESCRIPTION AND DESIGN

6.1. Elements of installation

6.1.1. Photovoltaic modules

Among the different modules analyzed all of them in the catalogues of producers in the market, the module that provides global best features is the photovoltaic module GS Power brand, model 270Wp MONO of polycrystalline cells.

The criterion used to select the module can be found in the annex I "FV Calculations", paragraph 1,

The parameters defining these modules are defined in Table 6.1.

Selected module	
Designation	
Brand	GS POWER
Model	270 Wp MONO
Mechanical properties	
Dimensions	1650 mm x 1010 mm x 42mm
Weight	19 Kg
Electrical Specifications (Standard Conditions, Irradiance 1000 W/m2	
The cell temperature 25 ° C; Spectrum 1,5 MA)	
Power	199,16 Wp
Maximum power (P_{MPP})	270 Wp
Short-circuit current (Isc)	9.26 A
Open circuit voltage (VSC)	38,47 V
Current in MPP (IPMP)	6.74 A
MPP voltage (VPMP)	29,74 V
Efficiency (η),	16.2%
Temperature coefficient (γ):	-0.43% / ° C
Properties for system design	
Voltage at (VSYS) system	1000V
Maximum current system (IR)	16A

Table 6.1 Features of the selected module

The peak power of 270 Wp is the parameter that is used to size the solar field. This value refers to standard test conditions in measuring (STC). Standard conditions refer to solar radiation of 1000 W/m^2, cell temperature of 25°C and a spectrum of radiation normalized AM 1.5 G (air mass 1.5 global).

GS Power, offers 12 years warranty in material and manufacturing workmanship and the efficiency of the photovoltaic module decrease up to 80% in 30 years.

6.1.2. PV installation

The PV installation is formed by 1809 modules from GS Power company and the model 270 Wp MONO with a total power of 488 kWp, with an inverter from ABB company, PVS800-57-0500kW-A with a nominal power of 600 kWp.

In the Annex I "PV installation Calculation" can be checked all the calculations related with the PV installation.

The modules are installed on the roof of the factory with an inclination is 30° with the regard to the horizontal and oriented to the south 0^o, as it can be checked in the layout 3.

The modules are fitted and secured with a structure with galvanized screws, to prevent corrosion of fasteners. The structure is designed for mounting on the place, due to facilitate transportation thereof. The structure can be checked in the layout 5.

PV installation features	
Number of modules	1809
in Serie	20
Branches	86
SC current	796 A
Max voltage	658,4 V
Peak power	488 kWp
Number of inverters	1
Orientation	0
Inclination	30

Table 6.2

Due it has the entire surface of the large deck do not have space problems. The modules will be placed horizontally, 30 rows of 60 modules each. Adding up the total of 1800 modules and leaving 10% of space for maintenance. It can be checked In the layout 2.

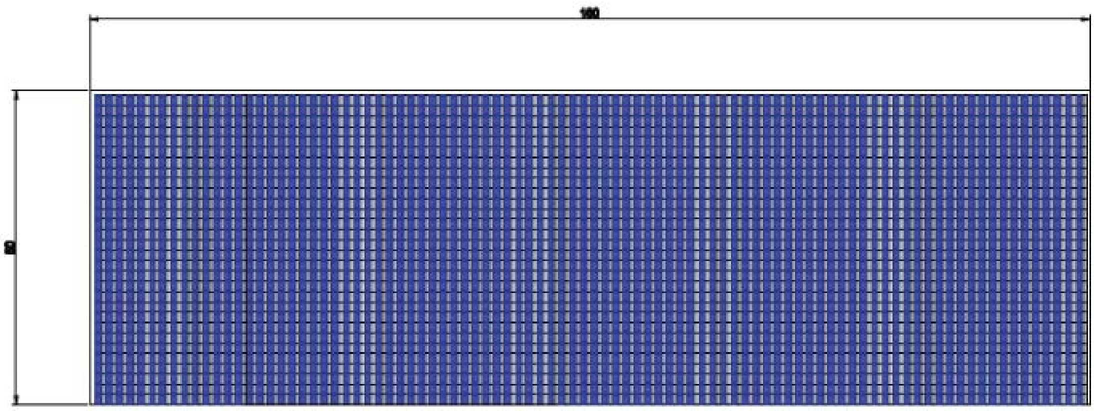


Figure 6.1 Module distribution

The modules are placed in horizontal due, as it can be checked in the layout 3, because if the module assembly vertically, the height of the building would be greater, there will be major wind currents, although they were not enough to break them, you can make more strength on the modules, so that the installation of the modules is done horizontally.

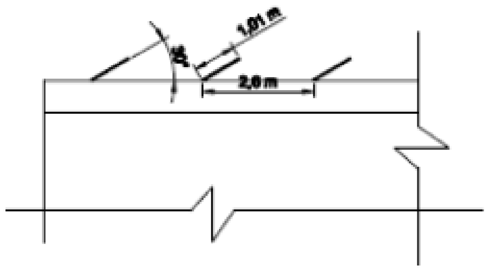


Figure 6.2 modules position

6.2. Wiring and piping

The conductors' sections for the different parts of the installation are summarized in the table 6.3. These correspond to the highest section obtained in the different calculation methods considered in the annex.

Place	Section (mm^2)
Modules - DC protection box	6
DC protection box - Inverter	50
Inverter - AC protection box	300
AC protection box - Transformer	630

Table 6.3 Conductors' sections

Ground conductors are formed of the same material as the phase conductors, and their section is also determined in the table 6.4, accomplishing the corresponding regulations.

Place	Protection section (mm^2)
Modules - DC protection box	6
DC protection box - Inverter	25
Inverter - AC protection box	150
AC protection box - Transformer	400

Table 6.4 Ground conductors' sections

Phase and protection wiring are placed within a tube to protect the wiring of the physical (mechanical impacts, high and low temperatures, water, rats…), chemical (corrosion), and electrical effects.

The tubes also serve to install the cables in a structured and organized manner. These are made of PVC and present the following diameters (according to IEC 60000).

Place	Casing diameter (mm)
Modules - DC protection box	25
DC protection box - Inverter	40
Inverter - AC protection box	75
AC protection box - Transformer	225

Table 6.5 Casing diameter

The fuses and switch disconnectors installed in each branch interrupt excessive current (DC) so that further damage by overheating or fire is prevented. In the table 6.6 can be checked the details of the branch where the fuses and switches are installed:

DC PROTECTION SIZING	
Fuse in each branch	DC switch disconnectors
I_B =8,46 A; I_Z = 36A; I_N = 16A;	Intensity of service = 90.945 A Ampacity by conductor (S = 35mm^2) I_Z = 104 A Gauge is selected: I_N = 100A PdC = 22 KA 3-pole

Table 6.6

In the table 6.7 can be checked the features of the AC protections selected in order to protect an electrical circuit from damage caused by overload or short circuit and check the balance between the energized conductor and the return neutral conductor.

AC protection sizing details:

AC PROTECTION SIZING				
MCB, Miniature circuit breakers	RCD, Residual-current device	Main switch border	Differential switch	AC Fuse
I_N = 611 A	I_N=630A	I_N=611 A	I_N=611A	I_N = 630 A;
I_r = 0.97 · I_N		I_r=0,97· I_N		I_Z = 730 A;
P_{dC} = 25 KA		P_{dC}= 25 KA		
4-pole		4 poles		

Table 6.7

The surge arrester is installed near the end of any conductor which is long enough before the conductor lands on its intended electrical component. The purpose is to divert damaging lightning-induced transients safely to ground through property changes to its varistor in parallel arrangement to the conductor inside the unit. In the table 6.8 is the sizing summarize:

SURGE ARRESTER
V_{SC_SIST}= 769.4 V;
V_{MPP_SIST} = 648 V;
U_N = 1000V.

Table 6.8

The installation is connected to ground to prevent user contact with dangerous voltage if electrical insulation fails. In the table 6.9 is the ground wire sizing summarize:

GROUND WIRE SIZING
Rt, max=800Ohms
Npikes=3
Rt= 125Ohms

Table 6.9

6.3. Support structure

One of the most important elements in a photovoltaic system to ensure the perfect profiting of solar radiation is the support structure. This is responsible for sustaining the solar modules, giving the best tilt for modules receive the highest radiation throughout the year. The optimum angle for this design is 30 ° above the horizontal, as shown in the layout 4 and calculations in Annex I.

The structures are built entirely from aluminum and stainless steel screws. These materials ensure long life and no maintenance of the structure.

The support consists of several elements:

- Structure specific angle with aluminum L-shaped profile consisting of 40 x 40 x 4
- H-section profile of 42 x 40 for anchorage between the modules and the support structure.
- Fasteners and screws (stainless steel)

All the aluminum of the support structure is made by 6063 aluminum alloy. The standard controlling its composition is maintained by The Aluminum Association. It has generally good mechanical properties and is heat treatable and wieldable, mostly used in extruded shapes for architecture, particularly window frames, door frames, roofs, and sign frames. It is typically produced with very smooth surfaces fit for anodizing.

Angular profiles are placed transversely on the structure and these are arranged two H with screws sustention on which can be easily set. The distance between the guides is determined by the location of the structure modules, in this case are located at a distance of 98 cm.

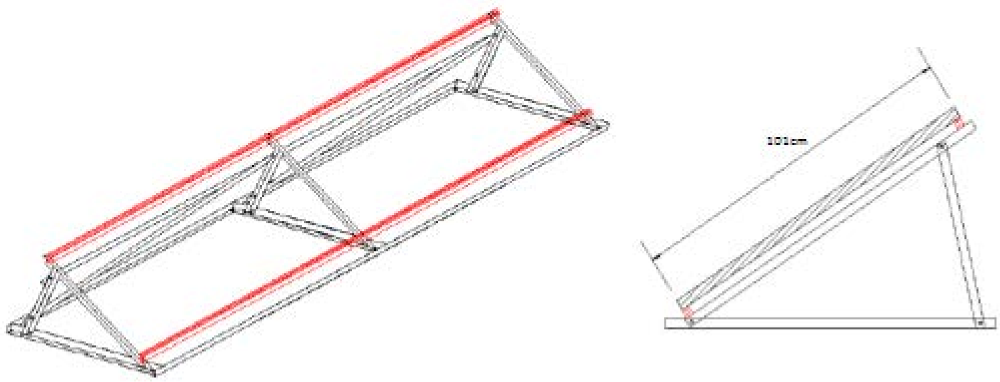


Figure 6.3 Structure support. Perspective view and side module.

As the figure shows, the support structure has two modules in a horizontal arrangement, however, as in the cover accommodates six per row, the support structure can fit six modules for structure.

7. ENERGETIC RESULT

7.1. Estimated annual energy

The electricity production a PV plant through are whole year depends on both parameters of the energy source, (solar radiation in the region) and the elements and factors of the PV system.

The drops ohmic losses in the wiring, in DC conditions, and other three-phase alternating current. The installed capacity of the plant is 488 kW whence the % losses are:

Pmax	$P_{DC,Ohm}$
488000 W	0,011%

Table 7.1

To determine the DC losses, the following information is required:

- Temperature coefficient associated with power = -0.43 % / º C cell temperature under DC losses coefficient operating conditions = 47 º C:

DC Losses Coefficient				
Ohm (%)	Mismatch	Dust and dirt (%)	Angular	PNOM (%)
0,011	2	2	3	0

Table 7.2

In the table 7.3 can be checked a summarize of all the types of losses analyzed and calculated in the annex I, and finally the monthly performance ratio got it for the PV generator:

Month	(1-LTEMP)	(1-LDC)	nSMPP	nINV	(1-Lohm)	(1-Lothers)	PR
January	0,9						0,81
February	0,9						0,81
March	0,89						0,80
April	0,88						0,79
May	0,87						0,78
June	0,85	0,989	0,94	0,986	0,999	0,98	0,76
July	0,84						0,75
August	0,84						0,75
September	0,85						0,76
October	0,87						0,78
November	0,89						0,80
December	0,9						0,81

Table 7.3 The rated power of the PV generator

Taking into account the hours of sun power for each of the different months, we can deduce the number of peak solar hours (PSH) per month. These are:

Month	PSH	Days	PSH/Month
January	0,93	31	28,83
February	1,63	28	45,64
March	2,64	31	81,84
April	3,8	30	114
May	4,85	31	150,35
June	4,6	30	138
July	4,97	31	154,07
August	4,31	31	133,61
September	3,04	30	91,2
October	1,87	31	57,97
November	0,915	30	27,45
December	0,7	31	21,7

Table 7.4

Therefore, if the rated power of the PV plant is the already introduced 488 kW (P= 1809 modules of 270 Wp/module), the resulting energy obtained each month and the total energy generated throughout the year are stated in the following table:

Month	PSH/Month		PR	Energy (Wh)	Energy (MWh)
January	28,83	488430	0,81	11405963,89	11
February	47,27		0,81	18701349,74	19
March	81,84		0,8	31978488,96	32
April	114		0,79	43988005,8	44
May	150,35		0,78	57279651,39	57
June	138		0,76	51226538,4	51
July	154,07		0,75	56439307,58	56
August	133,61		0,75	48944349,23	49
September	94,24		0,76	34982528,83	35
October	57,97		0,78	22085143,94	22
November	27,45		0,8	10725922,8	11
December	21,7		0,81	8585134,11	9
			TOTAL	**396.342.385**	

Table 7.5 Energy production

7.2. Emissions reduction

7.2.1. CO_2 Reduction

Every kWh generated by a PV system equals energy savings generated by other sources of energy, in all likelihood dirty in terms of pollution, which leads to a reduction of emissions.

One of the most important sources of pollution are the greenhouse gases, and they seriously affect the climate of the Earth. One of the most significant among these is gas CO_2 generated in the combustion of any carbonaceous materials.

To calculate the CO_2 savings obtained thanks to the clean energy production of a PV system, we can use the average emission per unit of electricity generated in the Czech Republic.

Month	Energy (kWh)	CO_2 (T)
January	12513	7,270
February	18041	10,482
March	36833	21,400
April	42394	24,631
May	58508	33,993
June	57713	33,531
July	55404	32,190
August	58120	33,768
September	41223	23,951
October	28973	16,833
November	15827	9,195
December	13676	7,946
	439.224,50	255,189

Table 7.6

With this installation, 255,189 tons of CO_2 per year will be saved.

7.2.2. NOx and SO_2 Reduction

Similarly, the values used to calculate the reduction of sulfur oxide and nitrogen. The emissions values used are in the table 7.7 and the total savings in the table 6.8:

SO_2	17,22 g/kWh
No_x	5,43 g/kWh

Table 7.7

Month	Energy (kWh)	SO2 (Kg)	NOx (Kg)
January	12513	215,465	67,943
February	18041	310,671	97,964
March	36833	634,259	200,001
April	42394	730,021	230,198
May	58508	1007,509	317,699
June	57713	993,813	313,380
July	55404	954,060	300,845
August	58120	1000,828	315,592
September	41223	709,866	223,843
October	28973	498,911	157,322
November	15827	272,533	85,938
December	13676	235,509	74,263
	439.224,50	7563,446	2384,989

Table 7.8 Amount of SO_2 and NOx Kg savings

With this installation, 7,563 tons of SO_2 and 2,38 tons of NO_x per year will be saved per year

8. FEASIBILITY STUDY

8.1. Introduction

The objective at this section is to determine the economic viability of a PV system as an alternate energy source when compared to electricity buying from the grid. The economic analysis will consider a number of factors such as energy generated, power and maintenance cost, VAT, inflation.

The following analysis is performed for a 30 years period (standard life of the PV module).

It considers the cash flow per year, NPV, IRR and PB There are tools usually used to calculate the viability of the project for the investors.

It is important to take into account that nowadays Czech Republic is in the same situation as Spain, the government is not giving any helps or bonus to build or to sell the PV energy. Therefore the only incomes this installation is going to have is the own energy generated, and for that reason, it is consume from the grid. With this reduction of consumption from the grid, it is possible to hire a cheaper tariff has to be taking into consideration.

8.2. Assumptions and estimations

the following three hypotheses In are going to be studied in the financial study:

1. A yearly 10% increment in the €/kWh electricity cost, this hypothesis is coming from the electric price rise in Spain experienced in the last seven years the price of the electricity increase an 80%.

2. Half of the increment of the last hypothesis, what means a yearly 5% €/kWh increment.

3. Consider the possibility to be connected to the gird and sell the energy generated for 0,28€/kWh as well as yearly 5% increment €/kWh in the cost.

8.3. Project profitability

8.3.1. Hypotheses 1

In the table 8.1 there is a summary of all the standards taken into account to analyze the profitability of the hypotheses 1:

HYPOTHESIS 1	
Yearly €/kWh Rise	10%
VAT	21%
Yearly VAT Rise	0,06%
Interest	12%
inflation	10%
Real interest	1,82%
IRR	7,43
PBA	7,44
PB	7,40%
Amortization	16 years

Table 8.1

In the figure 8.1 can be checked that the hypotheses 1 start to have incomes from the 16th year of the work life of the installation:

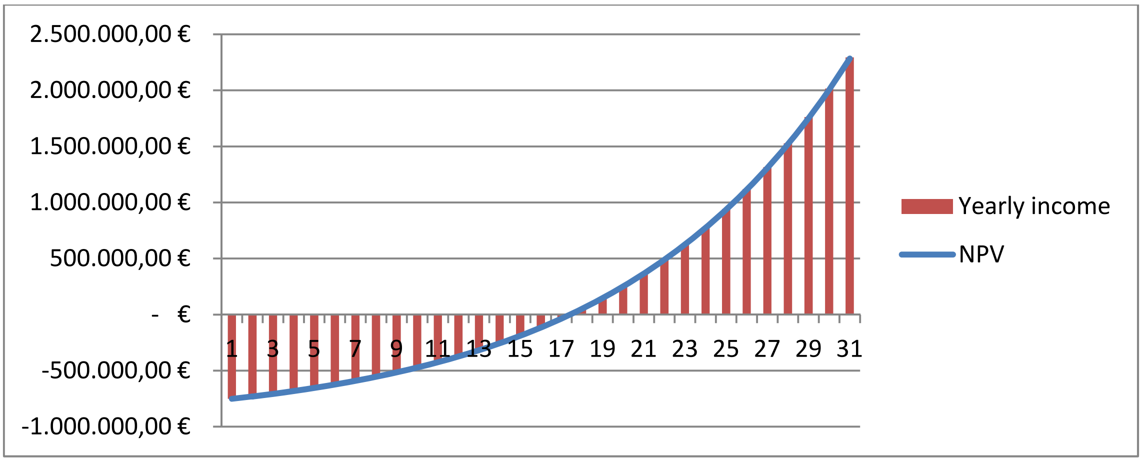


Figure 8.1

8.3.2. Hypotheses 2

In the table 8.2 there is a summary of all the standards taken into account to analyze the profitability of the hypotheses 2:

HYPOTHESIS 2	
Yearly €/kWh Rise	5%
VAT	21%
Yearly VAT Rise	0,06%
Interest	12%
inflation	10%
Real interest	1,82%
IRR	1,65%
PBA	17,95
PB	17,88
Amortization	21 years

Table 8.2

In the figure 8.2 can be checked that the hypotheses 2 start to have incomes from the 21st year of the work life of the installation:

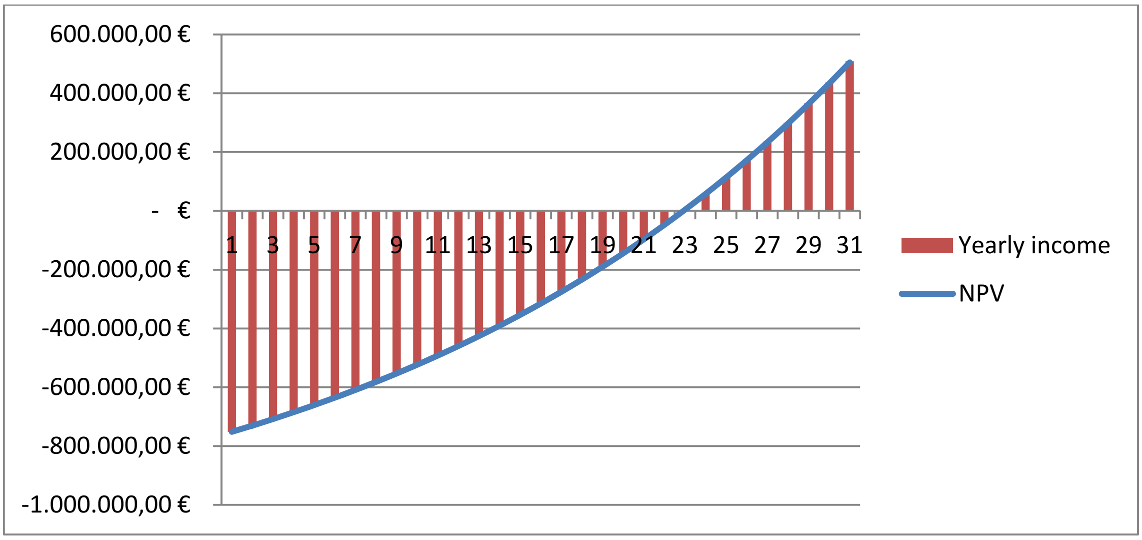


Figure 8.2

8.3.3. Hypotheses 3

In the table 8.3 there is a summary of all the standards taken into account to analyze the profitability of the hypotheses 3:

HYPOTHESIS 3	
Yearly €/kWh Rise	5%
VAT	21%
Yearly VAT Rise	0,06%
Interest	12%
inflation	10%
Real interest	1,82%
IRR	7,50%
PBA	3,15
PB	3,14
Amortization	5 years

Table 8.3

In the figure 8.3 can be checked that the hypotheses 3 start to have incomes from the 5th year of the work life of the installation:

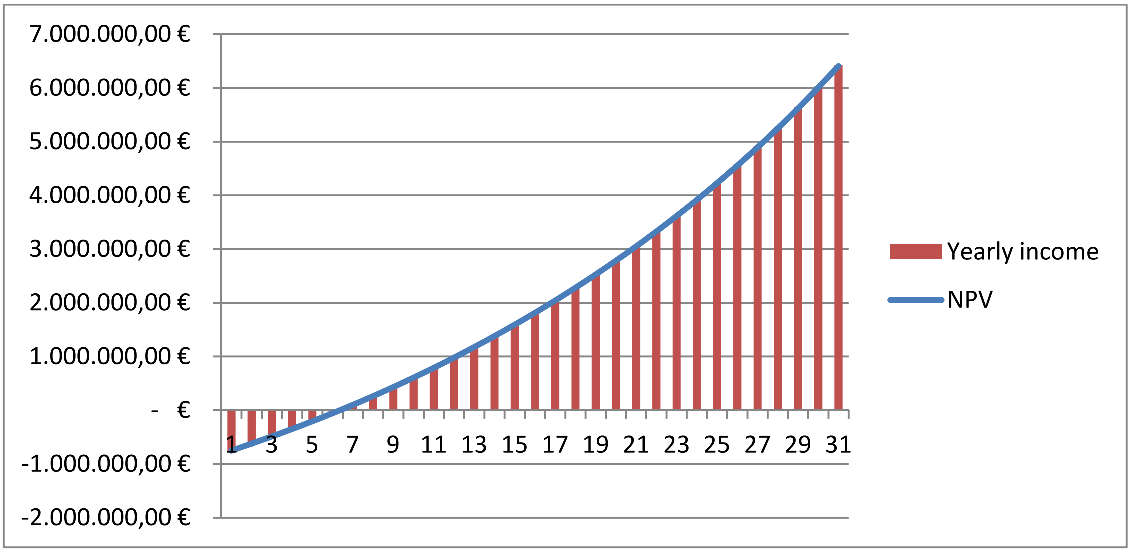


Figure 8.3

8.4. Analysis Result

As it can be reflected in the tables and graphics introduced previously, it is pretty obvious that the best option with the lowest payback whence the most profitable is the hypotheses 3 (the one is connected to the grid even if the yearly €/kWh rise estimated is the half of the hypotheses 1), it presents a payoff of around 5 years.

But as is has been explained along the project, this option is unfortunately unfeasible due the government restrictions to connect new installations because the big amount of solar energy installed in this area.

	HYPOTHESES 1	HYPOTHESES 2	HYPOTHESES 3
Yearly €/kWh Rise	10%	5%	5%
IRR	4,5%	1,65%	7,5%
PBA	7,43	17,95	3,15
PB	7,4	17,88	3,14
Amortization	16 years	21 years	5 years

Table 8.4 The three hypotheses studied

For this reason, nowadays the best option will be the one explained in the hypotheses 1, but it has to be mentioned, rarely an industrial project as this one, it is executed with such a long amortization. For that reason, the best option could be postpone the project until there was a change in the energetic law and an installation like this one could be connected to the grid again. The hypotheses 3 the amortization will be in slightly five years.

BACKGROUND STUDY

Index

1. INTRODUCTION

1.1. Scope & Purpose

The scope of this document is to provide solar PV system designers and installers with information to ensure that a grid-connected PV system meets current European standards and best practice recommendations. It is primarily aimed at typical grid connected systems.

This document has been written to be the technical standard to which MCS registered installation companies are expected to meet in order to gain and / or maintain their MCS certification. To this end this guide is quoted by the MCS Photovoltaic standard (MIS 3002).

1.2. Layout of the Guide

This guide is split into two main parts, the first detailing issues that need to be addressed during the design phase of a project, and the second covering installation and site based work.

It is important to note, however, that many 'design' issues covered in the first section may have a significant impact on the practical installation process covered in the second.

1.3. Standards and Regulations

The following documents are of particular relevance for the design and installation of a PV system, where referenced throughout the guide the most recent edition should be referred to:

- Engineering Recommendation G83 (current edition) – Recommendations for the connection of small scale embedded generators (up to 16A per phase) in parallel with public low voltage distribution networks

- Engineering Recommendation G59 (current edition) – Recommendations for the connection of generating plant to the distribution systems of licensed distribution network operators.

- BS 7671 (current edition) - Requirements for electrical installations (all parts – but in particular Part 7-712 Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems)

- BS EN 62446 (current edition) - Grid connected photovoltaic systems - Minimum requirements for system documentation, commissioning tests and inspection.

1.4. Safety

From the outset, the designer and installer of a PV system must consider the potential hazards carefully, and systematically devise methods to minimize the risks. This will include both mitigating potential hazards present during and after the installation phase.

The long-term safety of the system can be achieved only by ensuring that the system and components are correctly designed and specified from the outset, followed by correct installation, operation and maintenance of the system. Consideration of operation under both normal and fault conditions is essential in the design stage to ensure the required level of safety. This aspect is covered in the DESIGN section of this guide.

It is then important to ensure that the long-term safety of the system is not compromised by a poor installation or subsequent poor maintenance. Much of this comes down to the quality of the installation and system inspection and testing regime. This is covered in the installation section of this guide.

Similarly, much can be done during the planning and design stage to ensure that the installation is safe for the installers. In some circumstances the application of the CDM regulations will be required. All key safety issues affecting the design and installation process are discussed in the guide.

The main safety issues are:

- The supply from PV modules cannot be switched off, so special precautions should be made to ensure that live parts are either not accessible or cannot be touched during installation, use and maintenance.

- PV modules are current-limiting devices, which require a non-standard approach when designing fault protection systems, as fuses are not likely to operate under short-circuit conditions.

- PV systems include d.c. wiring, with which few electrical installers are familiar.

- The installation of PV systems presents a unique combination of hazards – due to risk of electric shock, falling and simultaneous manual handling difficulty. All of these hazards are encountered as a matter of course on a building site, but rarely all at once. While roofers may be accustomed to minimizing risks of falling or injury due to manual handling problems, they may not be used to dealing with the risk of electric shock. Similarly, electricians would be familiar with electric shock hazards but not with handling large objects at heights.

1.5. Ready Reference to the Guide

Example schematics for the two main types of system are shown in the following 2 figures to help when reading this Guide. They should not be used for a particular installation without taking into account the special circumstances of each individual installation.

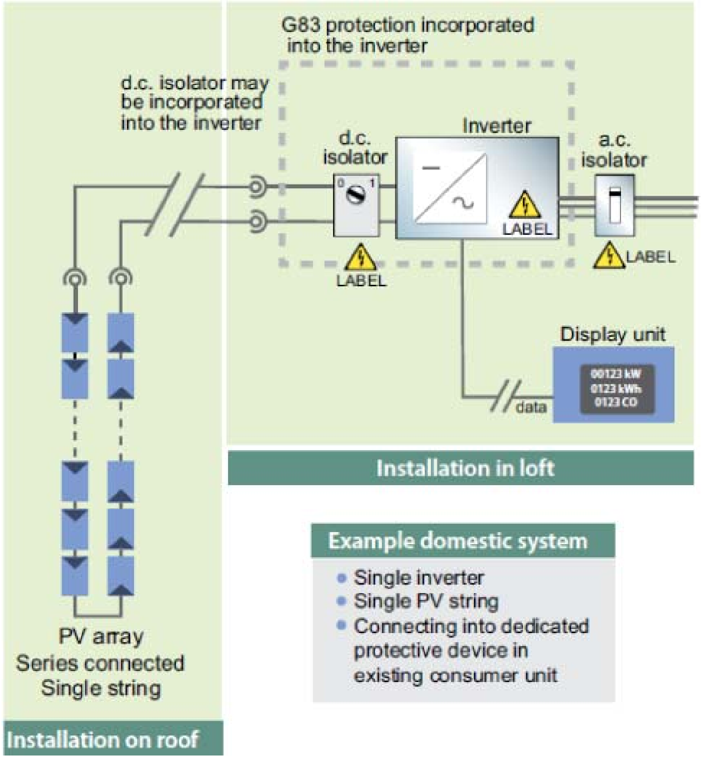


Figure 1.1 Single phase layout

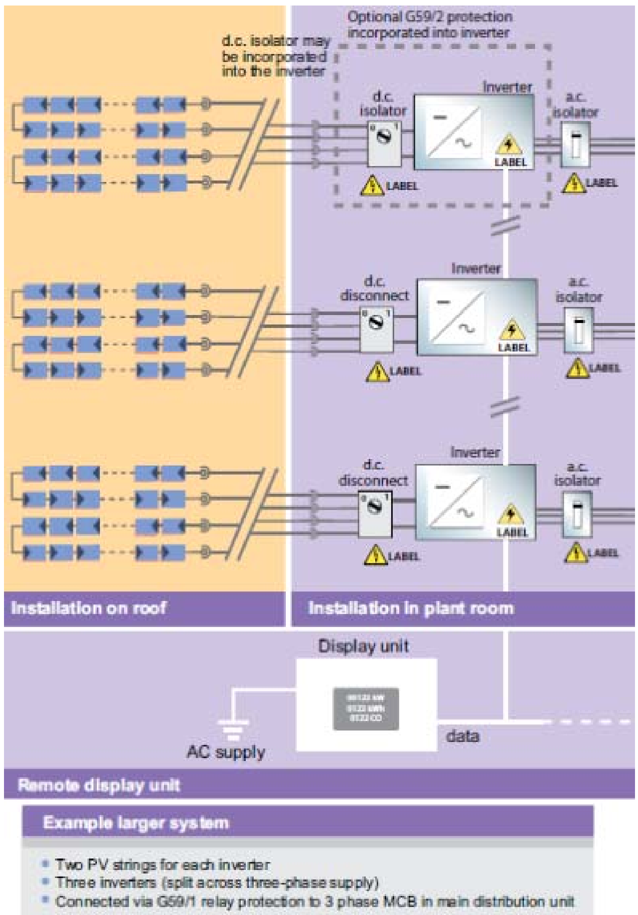


Figure 1.2 Three phases layout

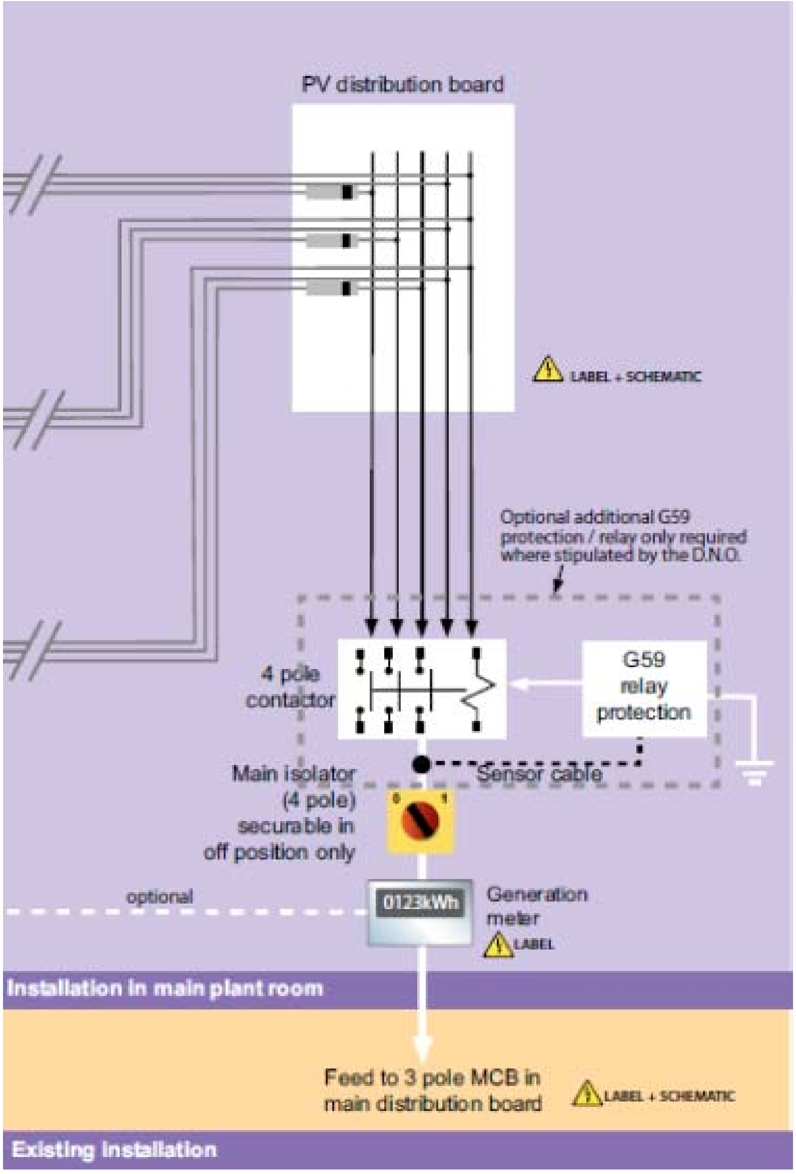


Figure 1.3

1.6. Definitions

a.c. Side
Part of a PV installation from the a.c. terminals of the PV inverter to the point of connection of the PV supply cable to the electrical installation.

d.c. Side
Part of a PV installation from a PV cell to the d.c. terminals of the PV inverter.

Distribution Network Operator (DNO)
The organization that owns or operates a Distribution Network and is responsible for confirming requirements for the connection of generating units to that Network.

Earthing

Connection of the exposed-conductive-parts of an installation to the main earthing terminal of that installation.

Electricity Network
An electrical system supplied by one or more sources of voltage and comprising all the conductors and other electrical and associated equipment used to conduct electricity for the purposes of conveying energy to one or more Customer's installations, street electrical fixtures, or other Networks.

Equipotential Zone
Where exposed-conductive parts and extraneous-conductive parts are maintained at substantially the same voltage.

Exposed-Conductive-Part
Conductive part of equipment which can be touched and which is not normally live, but which can become live when basic insulation fails.

Extraneous-Conductive-Part
A conductive part liable to introduce a potential, generally Earth potential, and not forming part of the electrical system.

Isc (stc) Short-Circuit Current
Short-circuit current of a PV module, PV string, PV array or PV generator under standard test conditions.

Islanding
Any situation where a section of electricity Network, containing generation, becomes physically disconnected from the DNOs distribution Network or User's distribution Network; and one or more generators maintains a supply of electrical energy to that isolated Network.

Isolating Transformer
Transformer where the input & output windings are electrically separated by double or reinforced insulation.

Isolation
A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy.

Isolator
A mechanical switching device which, in the open position, complies with the requirements specified for the isolating function. An isolator is otherwise known as a disconnector.

Lightning Protection
A means of applying protective measures to afford protection to persons, property and livestock against the effects of a lightning strike.

PME – Protective Multiple Earthing
An earthing arrangement, found in TN-C-S systems, in which the supply neutral conductor is used to connect the earthing conductor of an installation with Earth, in accordance with the Electrical Safety, Quality and Continuity Regulations 2002.

Protective Equipotential Bonding - (also referred to as Equipotential Bonding)
Electrical connection maintaining various exposed-conductive-parts and extraneous-conductive parts at substantially the same potential.

PV a.c. Module
Integrated module/convertor assembly where the electrical interface terminals are a.c. only. No access is provided to the d.c. side.

PV Array
Mechanically and electrically integrated assembly of PV modules, and other necessary components, to form a d.c. power supply unit.

PV Array Cable
Output cable of a PV array.

PV Array Junction Box
Enclosure where all PV strings of any PV array are electrically connected and where protection devices can be located.

PV String
A number of PV modules are connected in series to generate the required output voltage.

PV Cell
Basic PV device which can generate electricity when exposed to light such as solar radiation.

PV Charge Controller
A device that provides the interface between the PV array and a battery.

PV d.c. Main Cable
Cable connecting the PV array junction box to the d.c. terminals of the PV convertor.

PV Grid-Connected System
A PV generator operating in ‘parallel’ with the existing electricity network.

PV Installation
Erected equipment of a PV power supply system.

PV Inverter (also known a PV Convertor)
Device which converts d.c. voltage and d.c. current into a.c. voltage and a.c. current.

PV Kilowatts Peak (kWp)
Unit for defining the rating of a PV module where kWp = watts generated at stc.

PV Module Maximum Series Fuse
A value provided by the module manufacturer on the module nameplate & datasheet (a requirement of IEC61730-2)

PV Module
Smallest completely environmentally protected assembly of interconnected PV cells.

PV MPP Tracker (MPPT)
A component of the d.c. input side of an inverter designed to maximize the input from the array by tracking voltage and current.

PV Self-Cleaning
The cleaning effect from rain, hail etc. on PV arrays which are sufficiently steeply inclined.

PV String Cable
Cable connecting PV modules to form a PV string.

PV String Fuse
A fuse for an individual PV string.

PV Supply Cable
Cable connecting the AC terminals of the PV convertor to a distribution circuit of the electrical installation.

PV Standard Test Conditions (stc)
Test conditions specified for PV cells and modules (25°C, light intensity 1000W/m2, air mass 1.5) V_{oc} Open circuit d.c. voltage.

2. DESIGN

2.1. Design Part 1 – d.c. System

2.1.1. PV Modules

2.1.1.1. Standard Modules

Modules must comply with the following international standards:

- IEC 61215 in the case of crystalline types
- IEC 61646 in the case of thin film types
- IEC 61730 - Photovoltaic (PV) module safety qualification
- Modules must also carry a CE mark

The use of Class II modules is generally recommended, and strongly recommended for array opencircuit voltages of greater than 120 V.

For an installation to comply with the requirements of MCS - modules must be certificated and listed on the MCS product database.

2.1.2. System – Voltage and Current Ratings (Minimum)

All d.c. component ratings (cables, isolators / disconnectors, switches, connectors, etc.) of the system must be derived from the maximum voltage and current of the relevant part of the PV array adjusted in accordance with the safety factors as below. This must take into account system voltage/currents of the series/parallel connected modules making up the array. It must also take into account the maximum output of the individual modules.

When considering the voltage and current requirements of the d.c. system, the maximum values that could occur need to be assessed. The maximum values originate from two PV module ratings – the open-circuit voltage (Voc) and the short-circuit current (Isc) which are obtained from the module manufacturer. The values of Voc and Isc provided by the module manufacturer are those at standard test conditions (stc) – irradiance of 1000 W/m2, air mass 1.5 and cell temperature of 25°C.

Operation of a module outside of standard test conditions can considerably affect the values of Voc (stc), Isc (stc). In the field, irradiance and particularly temperature can vary considerably from stc values. The following multiplication factors allow for the maximum values that may be experienced under UK conditions.

Mono- and multi-crystalline silicon modules - All d.c. components must be rated, as a minimum, at:

- Voltage: Voc(stc) x 1.15
- Current: Isc(stc) x 1.25

All other module types - All d.c. components must be rated, as a minimum, from:

- Specific calculations of worst case Voc and Isc, calculated from manufacturer's data for a temperature range of -15°C to 80°C and irradiance up to 1,250 W/m2
- A calculation of any increase in Voc or Isc over the initial period of operation. This increase is to be applied in addition to that calculated above.

2.1.3. PV String & Array Voltages

It is always desirable to keep voltages low to minimize associated risks, however in many systems; the d.c. voltage will exceed levels that are considered to reduce the risk to a minimum (usually around 120V d.c.)

Where this is the case, double insulation is usually applied as the method of shock protection. In this instance the use of suitably rated cables, connectors and enclosures along with controlled installation techniques becomes fundamentally important to providing this protective measure as defined in BS 7671- Section 412. Similarly, double insulation of the d.c. circuit greatly minimizes the risk of creating accidental shock current paths and the risk of fire.

Where the PV array voltage exceeds 120V:
Double insulation (insulation comprising both basic & supplementary insulation) or reinforced insulation, appropriate barriers and separation of parts must be applied to all parts of the d.c. circuit to facilitate a level of protection equivalent to the protective measure "double or reinforced insulation" as defined in BS 7671- Section 412.

Where the PV array open circuit voltage exceeds 1000V:
Due to the added complexities and dangers associated with systems of a higher voltage than normal, the PV array should not be installed on a building. In addition, access should be restricted to only competent, skilled or instructed persons.

2.1.4. D.C. Cables – General

2.1.4.1. Cable Sizing

Cables should be sized in accordance with BS 7671. These calculations shall also take into account the multiplication factors in 2.1.2 of this guide. Guidance on a method of cable sizing including any de-rating factor requiring to be applied and typical current carrying capacities for common cable types are provided in Appendix 4 of BS 7671.

Cables should be sized such that the overall voltage drop, at array maximum operating power (stc), between the array and the inverter is <3%.

2.1.4.2. Cable Type and Installation Method

To minimize the risk of faults, PV d.c. cable runs should be kept as short as practicable. Note: See also section 2.1.12 (additional d.c. switches for long cable runs).

The cables used for wiring the d.c. section of a grid-connected PV system need to be selected to ensure that they can withstand the extremes of the environmental, voltage and current conditions, under which they may be expected to operate. This will include heating effects of both the current and solar gain, especially where installed in close proximity to the PV modules Purpose designed "PV cables" are readily available and it is expected that all installations would use such cables. An IEC PV cable standard is under development and it is expected cables in compliance with this standard will be required once it is issued. In the interim, it is recommended that cables should comply with UL 4703, or TUV 2 Pfg 1169 08.2007.

External cables should be UV stable and water resistant. Where cables are likely to be subjected external movement, i.e. those mounted immediately behind the array, it is recommended that they be flexible (multi-stranded) to allow for thermal/wind movement of arrays/modules.

Because PV array cables almost exclusively rely on double or reinforced insulation as their means of shock protection they should not be buried in walls or otherwise hidden in the building structure as mechanical damage would be very difficult to detect and may lead to increase instances of shock and fire risk.

Where this cannot be avoided conductors should be suitably protected from mechanical damage, suitable methods may include the use of metallic trunking or conduit or the use of steel wire armoured cable in accordance with BS 7671.Exterior cable colour coding is not required for PV systems. Consideration must be given to the UV resistance of all cables installed outside or in a location that may be subject to UV exposure, PV cables are therefore commonly black in colour to assist in UV resistance.

Where long cable runs are necessary (e.g. over 20m), labels should be fixed along the d.c. cables as follows:
Labelling fixed every 5 to 10m is considered sufficient to identify the cable on straight runs where a clear view is possible between labels.
Where multiple PV sub-arrays and or string conductors enter a junction box they should be

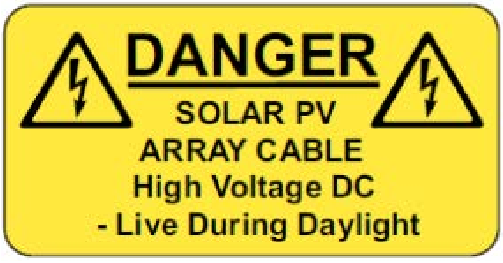


Figure 2.1

grouped or identified in pairs so that positive and negative conductors of the same circuit may easily be clearly distinguished from other pairs.

2.1.5. String Cables

In a PV array formed from a number of strings, fault conditions can give rise to fault currents flowing though parts of the d.c. system. Two key problems need addressing – overloaded string cables and excessive module reverse currents, both of which can present a considerable fire risk.

For small systems where it is determined that string fuses are not required for module protection (maximum reverse currents less than module reverse current rating), a common approach is to ensure that the string cables are suitably rated such that they may safely carry the maximum possible fault current.

This method relies on oversizing the string cables such that any fault current can be safely accommodated. Such a method does not clear the fault but simply prevents a fire risk from overloaded cables. See also section 2.1.10 - string fuses.

For an array of N parallel connected strings, with each string formed of M series connected modules:

String cables must be rated as a minimum as follows:

- Voltage > Voc (stc) x M x 1.15
- Current > Isc(stc) x (N-1) x 1.25
- The cable Current Carrying Capacity (Iz) must be calculated according to the requirements of BS 7671. This shall include factors taking into account installation conditions such as cable installation method, solar gains and grouping etc.

Where a system includes string fuses, the cable size may be reduced, but in all cases the Iz after de-rating factors have been applied must exceed the string fuse rating and must exceed the Isc (stc) x 1.25.

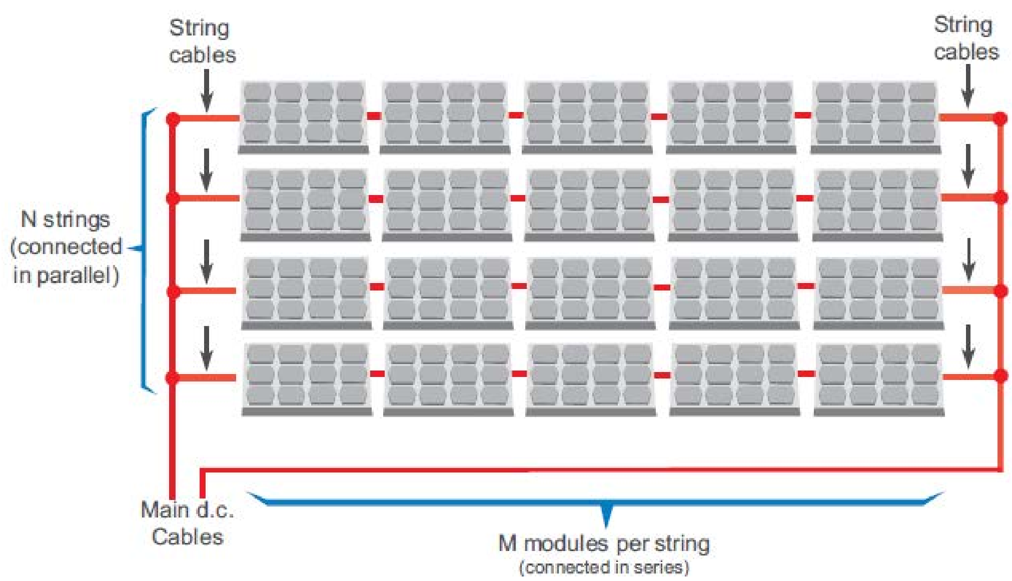


Figure 2.2

2.1.6. Main d.c. Cable

For a system of N parallel connected strings, with each formed of M series connected modules: d.c. main cables must be rated as a minimum as follows:

- Voltage: Voc (stc) x M x 1.15
- Current: Isc(stc) x N x 1.25

The cable Current Carrying Capacity (Iz) must be calculated according to the requirements of BS 7671 to include cable de-rating factors to take into account factors such as cable installation method and grouping.

2.1.7. d.c. Plug and Socket Connectors

PV specific plug and socket connectors are commonly fitted to module cables by the manufacturer. Such connectors provide a secure, durable and effective electrical contact. They also simplify and increase the safety of installation works.

Plugs and socket connectors mated together in a PV system shall be of the same type from the same manufacturer and shall comply with the requirements of BS EN 50521. Different brands may only be interconnected where a test report has been provided confirming compatibility of the two types to the requirements of BS EN 50521.

Figure 2.3

2.1.8. Other Inline Cable Junctions

In general cable junctions shall either be by an approved plug and socket connector or contained within a d.c. Junction Box (see below). However in certain limited circumstances it may be necessary for an in-line cable junction to be made (e.g. soldered extension to a module flying lead) although this should be avoided if at all possible.

2.1.9. PV Array d.c. Junction Box

If there is more than one string, the d.c. junction box (sometimes called a combiner box) is normally the point at which they are connected together in parallel. The box may also contain string fuses and test points.

The d.c. junction box must be labelled with - 'PV array d.c. junction box, Danger contains live parts during daylight'. All labels must be clear, legible, located so as to be easily visible, durably constructed and affixed to last lifetime of the installation.

2.1.10. String Fuses

The short circuit current of a module is little more than the operating current, so in a single string system, a circuit fuse would simply not detect or operate to clear a short circuit fault. In systems with multiple strings some fault scenarios can result in the current from several adjacent strings flowing through a single string and the prospective fault current may be such that overcurrent protective devices are required. Hence, the selection of overcurrent protective measures depends upon the system design and the number of strings.

While string cable sizes can be increased as the number of parallel connected strings (and the potential fault current) increases, the ability of a module to withstand the reverse current must also be considered.

2.1.10.1. String Fuse Selection

The following requirements apply where the PV array provides the only source of fault current, such as in a typical grid connected system with no battery.

2.1.11. Blocking Diodes

Blocking diodes are not commonly used in a gridconnect system as their function is better served by the installation of a string fuse. However, for multi-string arrays with some types of PV module, particularly thin-film types, it may not be possible to provide adequate overcurrent / reverse current protection with string fuses or MCBs alone.

This is due to the fact it may not be possible to specify a fuse/MCB which is greater than Isc x 1.25 but less than the reverse current rating of the module. In this situation blocking diodes should be used in addition to string fuses.

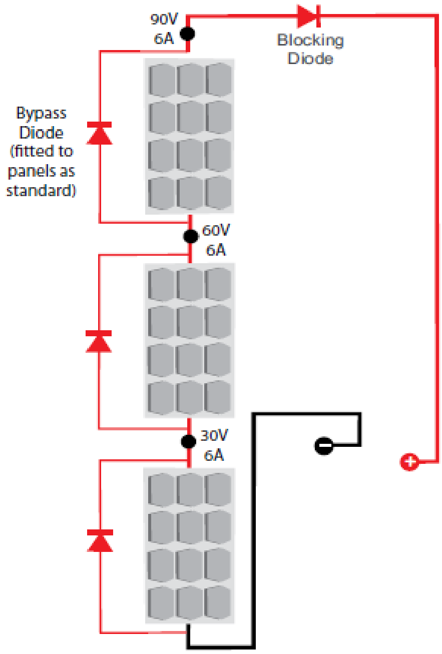


Figure 2.4

2.1.12. d.c. Isolation and Switching

The following table describes the requirements for both isolation and switching in the d.c. side of the PV array circuit:

d.c. Circuit	Switching	Insulation
String	Not required	Readily accessible means string isolation
Sub array	Optional	Readily accessible means of Sub Array isolation
Array	Readily accessible load switch disconector on d.c. side of inverter	

Table 2.1

2.1.13. Isolation

Isolation is defined as a function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy (from BS 7671).

2.2. Design Part 2 – Earthing, Protective Equipotential Bonding and Lightning Protection

2.2.1. Lightning Protection

Whilst this installation guide does not cover specific guidance on selection, or application of lightning protection, it was felt that a brief overview was required as given below. Where further information is required, this can be referenced from BS EN 62305.

In most cases the ceraunic value (number of thunderstorm days per year for a given installation location in the UK) does not reach a level at which particular protective measures need to be applied. However where buildings or structures are considered to be at greater risk, for example very tall, or in an exposed location, the designer of the a.c. electrical system may have chosen to design or apply protective measures such as installation of conductive air rods or tapes.

If the building or dwelling is fitted with a lightning protection system (LPS), a suitably qualified person should be consulted as to whether, in this particular case, the array frame should be connected to the LPS, and if so what size conductor should be used.

Where an LPS is fitted, PV system components should be mounted away from lightning rods and associated conductors (see BS EN 62305). For example, an inverter should not be mounted on an inside wall that has a lightning protection system down conductor running just the other side of the brickwork on the outside of the building.

Where there is a perceived increase in risk of direct lightning strike as a consequence of the installation of the PV system, specialists in lightning protection should be consulted with a view to installing a separate lightning protection system in accordance with BS EN 62305.

2.2.2. Earthing

Earthing is a means of connecting the exposed conductive parts to the main earthing terminal; typically this definition means the connection of metallic casings of fixtures and fittings to the main earthing terminal via a circuit protective conductor (cpc).

Importantly, it must be noted that we only make this connection when the accessory or appliance requires it. This connection is required when it is considered to be a class I appliance or accessory and is reliant on a connection with earth for safety using 'automatic disconnection of supply' (ADS) as the fault protective measure.

2.2.3. Protective Equipotential Bonding

Protective equipotential bonding is a measure applied to parts of the electrical installation which, under fault conditions may otherwise have a different potential to earth. By applying this measure the risk of electric shock is limited as there should be little or no difference in voltages (potential difference) between the parts that may otherwise become live. These parts are categorized as either Exposed-Conductive-Parts or Extraneous-Conductive-Parts.

In most PV systems there are no parts that are considered *to* be an exposed-conductive-part or extraneous-conductive-part, therefore protective equipotential bonding is not usually required. For guidance on when to consider protective equipotential bonding please see the decision tree on the next page.

On the d.c. side of the PV installation the designer will have usually already selected double or reinforced insulation as the protective measure and therefore the component parts of the installation will be isolated and will not require protective equipotential bonding.

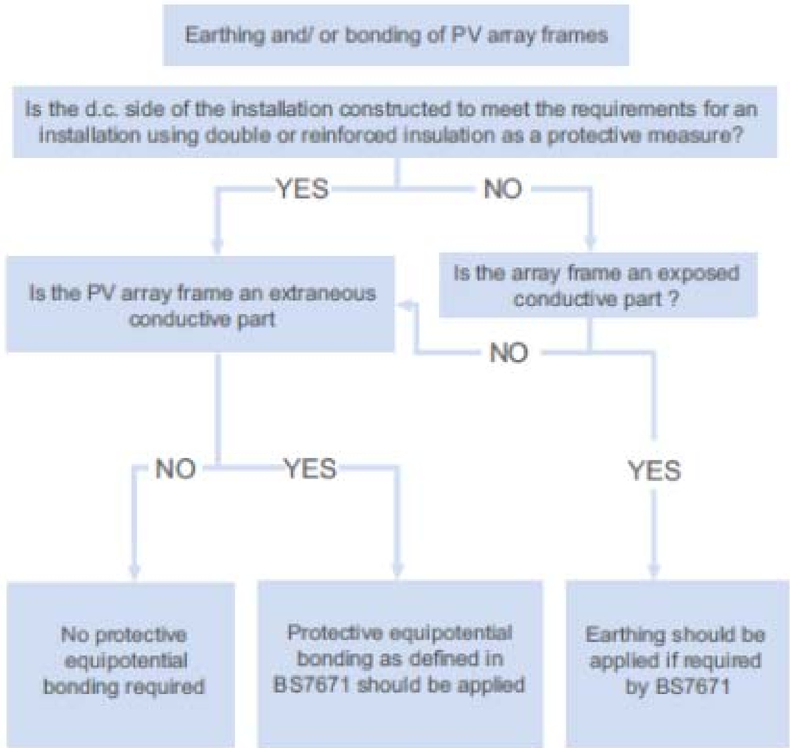


Figure 2.5 Earthing and or Bonding Decision Tree

2.2.4. Determining an Extraneous-Conductive-Part

The frame of the array has to be assessed as to whether it is likely to introduce a potential into the installation. This aim of this assessment is to find out if the frame has any direct contact with ground that would make it introduce a potential

2.2.5. Surge Protection Measures

All d.c. cables should be installed to provide as short runs as possible and positive and negative cables of the same string or main d.c. supply should be installed together, avoiding the creation of loops in the system. This requirement includes any associated earth/bonding conductors.

Long cables (e.g. PV main d.c. cables over about 50 m) should be installed in earthed metal conduit or trunking, or be screened cables such as armoured.

2.3. Design Part 3 – a.c. System

2.3.1. A.C. Cabling

The PV system inverter(s) should be installed on a dedicated final circuit to the requirements of BS 7671 in which:

- No current-using equipment is connected.
- No provision is made for the connection of current-using equipment.
- No socket-outlets are permitted.

Where a single circuit feeds more than one inverter, the protective device for that circuit shall be less than the maximum MCB rating recommended by the inverter manufacturer(s). An inverter must not be connected by means of a plug with contacts which may be live when exposed and a.c. cables are to be specified and installed in accordance with BS 7671.

The a.c. cable connecting the inverter(s) to the consumer unit should be sized to minimize voltage drop. A 1% drop or less is recommended. However in larger installations this may not be practicable or economic due to the very large size of cable resulting. In this case the designer should minimize voltage drop as far as possible and must remain within voltage drop limits as prescribed by BS 7671.

2.3.2. RCD Protection

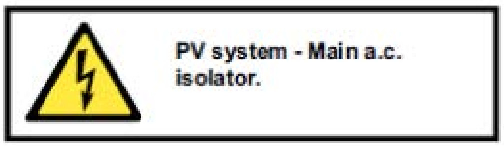
Where an electrical installation includes a PV power supply system that cannot prevent d.c. fault currents from entering the a.c. side of the installation, and where an RCD is needed to satisfy the general requirements of the electrical installation in accordance with BS 7671, then the selected RCD should be a Type B RCCB as defined in IEC 62423. Where any doubt exists about the capability of the inverter to prevent d.c. fault currents entering the a.c. side of the system then the manufacturer shall be consulted.

2.3.3. A.C. Isolation and Switching

To comply with the requirements of Engineering Recommendations G83 / G59:
The PV system shall be connected to an isolation switch that fulfils the following conditions:

- Isolates line and neutral conductors
- Be securable in the OFF position
- Located in an accessible location

This switch shall clearly show the ON and OFF positions and be labelled as 'PV system – main a.c. isolator'



2.3.4. Inverters

Inverters must carry a Type Test certificate to the requirements of Engineering Recommendation G83 or G59 (as applicable – see section 2.4.1) unless specifically agreed by an engineer employed by or appointed by the DNO for this purpose, and in writing.

The sizing of an inverter for a grid connected PV system is influenced by a number of factors, including:

- Array voltage fluctuations due to operating temperature
- The maximum permissible d.c. input voltage of the inverter
- The MPP (maximum power point) voltage range of the inverter

- The desired inverter – array power ratio

2.3.5. a.c. Cable Protection

Protection for the cable from the inverter(s) must be provided at the distribution board. This protective measure shall be specified and installed in accordance with the requirements of BS 7671.

In very many cases the current limiting nature of the PV array and inverter(s) omits the requirements for overload protection and therefore the designer only need to consider fault current protection.

The protection afforded at the origin of the circuit (the distribution board) in accordance with BS 7671, means there is no requirement for additional overcurrent protection to be installed at the inverter end of the a.c. installation.

2.3.6. Metering

Inverter output meter: As a minimum, metering at the inverter output should be installed to display/record energy delivered by the PV system (kWh). In addition it is highly recommended for instantaneous power output (kW) to be displayed.

This will not only add to customer satisfaction it should lead to more effective fault detection. An approved kWh meter as detailed in the “Metering Guidance” document issued by MCS, connected to measure generation, will be required to facilitate payments of any financial incentives (e.g. Feed in Tariff payments).

3. MAINTENANCE

3.1. Solar Panel Maintenance

The solar array (a number of solar panels connected together) is often thought to be maintenance free. However, occasional maintenance and inspection of the solar array must be performed to ensure the optimal use of the solar panels. This can be done by keeping the surface (glass) area of the module clean from any excess dirt.

1. To remove a layer of dust and dirt from the modules, simply wash the panel with water. If the module has thick dirt or grime and bird droppings, which are harder to remove, wash with cold water and rub the panel surface with a sponge. Do not use a metal brush to clean solar panel surface. Detergents should not be used.

2. A visual inspection of the modules can then be done to check for defects in the modules such as cracks, chips, de-lamination, fogged glazing, water leaks and discoloration. If any obvious defects are found, note their location in the system logbook, so they can be monitored in the future in case further deterioration affects the modules' output.

3. The condition of the array mounting frame should also be noted. Items to observe should include the array mounting bolts (e.g. bolt rusting) and checks to ensure that the frame and modules are firmly secured. The junction boxes should also be checked to ensure that the wires are not chewed by rodents or insects.

Take adequate precautions while doing maintenance of the solar panels since these are located on rooftops and there is the risk of falling off.

3.2. Inverter

This component can be maintained by minimizing dust accumulation. A dry cloth should be used to wipe away any accumulated dirt/dust. A visual inspection should be done to ensure that all the indicators such as LED lights are working and that the wires leading to and from this device are not loose.

3.3. Wiring and Connections

Wiring installations should be checked for any cracks, breaks or deterioration in the insulation/conduits. Inspect panel boxes to ensure that they have not become a home for rodents and insects. Also inspect connections for any corrosion and/or burning. Switches should not spark when turned on or off. The following sections of conduit and wiring should be checked for any signs of damage:

- Solar panels to the charge controller
- Charge controller to the battery bank
- Inverter/charger to the battery bank
- Generator to Inverter/charger
- Inverter/charger and Generator to the AC outlets
- Battery bank to the DC outlets/load.

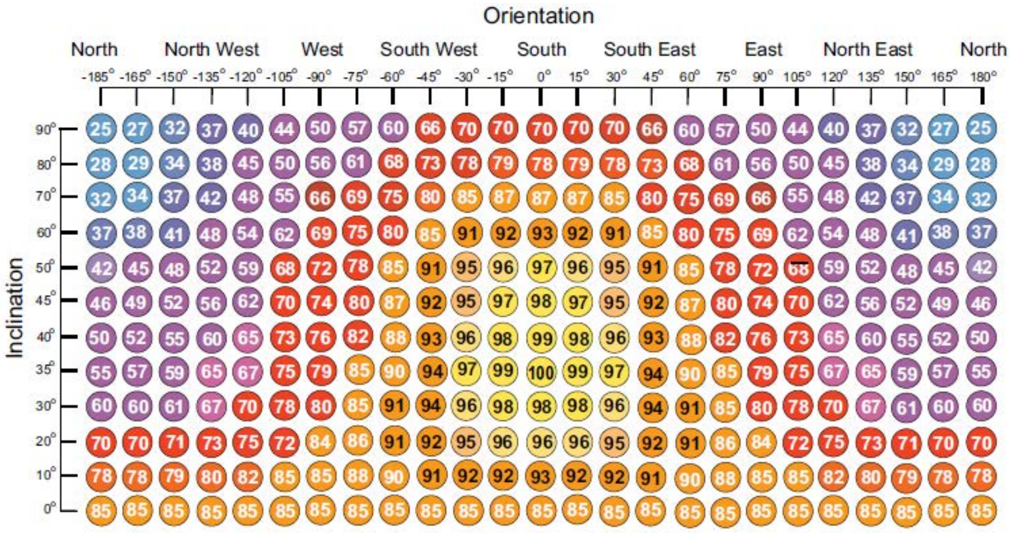
If damage is found, consult with the installer as soon as possible. All ground wires should be checked to ensure they are not broken.

4. SYSTEM PERFORMANCE

4.1. Array Orientation and Inclination

The effect of variations in array orientation and inclination on system performance is shown in the chart below. The example shown is for a location in the middle of the UK and represents the percentage of maximum yield you may expect to get for different angles and orientations.

This chart is indicative only and should not be used for the calculation of performance estimates



4.2. Shade Effects

Shade makes a big impact on the performance of a PV system. Even a small degree of shading on part of an array can have a very significant impact on the overall array output. Shade is one element of system performance that can be specifically addressed during system design – by careful selection of array location, equipment selection and layout and in the electrical design (string design to minimize shade effects).

Shading from objects adjacent to the array (for example: vent pipes, chimneys, and satellite dishes) can have a very significant impact on the system performance. Where such shading is apparent, either the array should be repositioned out of the shade zone, or where possible the object casting the shade should be relocated.

4.3. Geographical Location

The amount of irradiance that falls onto the earth's surface alters across the Czech Republic according to several factors. The most significant factor is the location in respect of latitude (distance from the equator).
Generally speaking the further the array is from the equator the less irradiation there will be; subsequently the further North the installation is the less output can be expected from a PV system.

The variation in irradiance across the CZ is shown on the following map:

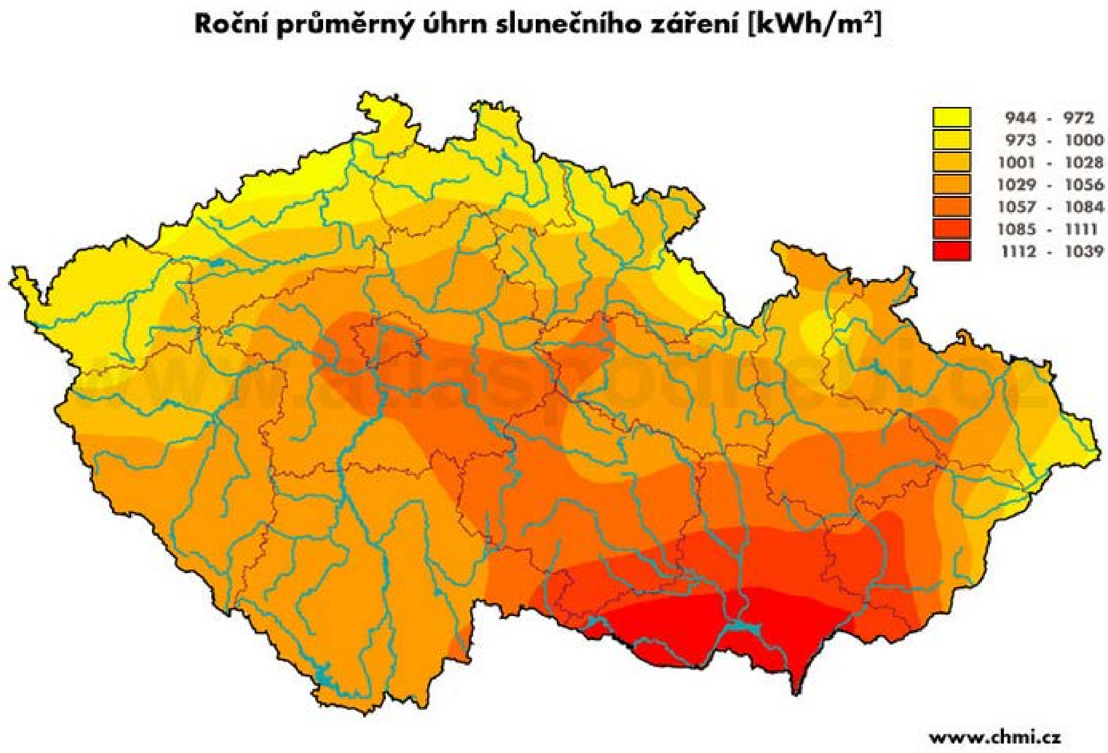


Figure 4.1. Yearly total of global irradiation in kWh/m^2

4.4. Temperature Effects

Module temperature–An increase in module temperature results in a decrease in performance (e.g. 0.5% per 1°C above stc for a crystalline module). Sufficient ventilation must be provided behind an array for cooling (typically a minimum 25mm vented air gap to the rear). For building integrated systems, this is usually addressed by the provision of a vented air space behind the modules. On a conventional pitched roof, batten cavity ventilation is typically achieved by the use of counter battens over the roof membrane and by the installation of eaves and ridge ventilation.

4.5. Other Factors

A variety of other factors will also affect system performance, including:

- Panel characteristics & manufacturing tolerances
- Inverter efficiency
- Inverter – array matching
- Cable losses
- Soiling of the array (more relevant in certain locations)
- Grid availability
- Equipment availability (system down-time due to equipment failures)

4.6. Photovoltaic Performance Estimation

As can be seen above, the annual performance of a grid connected PV system depends on a large number of factors. Against this background, the methodology described below is necessarily simplified in order to create a standard method that can be used to achieve a reasonable estimation of performance without it being an unduly complex procedure.

The purpose of a standardized procedure is intended to prevent miss-selling and overestimation of PV systems – such that all customers will receive a system performance estimation completed to a standardized procedure.

4.7. Site Evaluation

Inclination, orientation and shading are the three main site factors that influence the performance of a PV system. While drawings, maps or photos are a suitable means to determine inclination and orientation, an accurate estimation of any shade effects will typically require a site visit.

In some circumstances however, data may need to be estimated or taken remotely. In such circumstances, any performance estimate provided to a customer should include the following statement:
"This system performance calculation has been undertaken using estimated values for array orientation, inclination or shading. Actual performance may be significantly lower or higher if the characteristics of the installed system vary from the estimated values."

In all cases where inclination, orientation or shade has been estimated at quotation stage, e.g. for a new build development, a site survey shall be undertaken before installation commences.

4.7.1. Standard Estimation Method

The approach is as follows:

1. Establish the electrical rating of the PV array in kilowatts peak (kWp)
2. Determine the postcode region
3. Determine the array pitch
4. Determine the array orientation
5. Look up kWh/kWp (Kk) from the appropriate location specific table
6. Determine the shading factor of the array (SF) according to any objects blocking the horizon - using shade factor

4.7.2. Orientation

The orientation of the array is to be measured or determined from plan. The required value is the azimuth angle of the PV modules relative to due south. Hence, an array facing due south has an azimuth value of 0°; an array facing either SW or SE has an azimuth value of 45°; and an array facing either East or West has an azimuth value of 90°.

The azimuth value is to be rounded to the nearest 5°.

4.7.3. Inclination

The Inclination (or pitch) of the array is to be measured or determined from plan. The required value is the degrees from horizontal. Hence, an inclination of 0° represents a horizontal array; 90° represents a vertical array.

The inclination value is to be rounded to the nearest 1°.

5. INSTALLATION/SITEWORK

5.1. General

Standard health and safety practice and conventional electrical installation practice must apply to the installation of a PV system. Issues such as working on roofs or standard domestic a.c. wiring are covered thoroughly in other publications and are not detailed in this guide. Attention shall be paid to the location of accessories and equipment to ensure that any future service and maintenance can be carried out.

5.2. PV Specific Hazards

When compiling a method statement and risk assessment for the installation of a PV system, there are a number of PV specific hazards that need to be addressed. These will be in addition to standard considerations such as PPE (Personal Protective Equipment), working at height, manual handling, handling glass and the application of the construction design and management (CDM) regulations.

- PV modules produce electricity when exposed to daylight and individual modules cannot be switched off. Therefore unlike most other electrical installation work, the installation of a PV system typically involves working on a live system.

- As current limiting devices, PV module string circuits cannot rely on fuse protection for automatic disconnection of supply under fault conditions, as the short-circuit current is little more than the operating current. Once established, a fault may remain a hazard, perhaps undetected, for a considerable time.

- Good wiring design and installation practice will serve to protect both the system installers and any persons subsequently coming into contact with the system from an electric shock hazard (operator, owner, cleaner, service engineers, etc).

- Undetected, fault currents can also develop into a fire hazard. Without fuse protection to clear such faults, protection from this fire hazard can be achieved only by both a good d.c. system design and a careful installation.

- PV presents a unique combination of hazards – due to risk of shock, falling, and simultaneous manual handling difficulty. All of these hazards are encountered as a matter of course on a building site, but rarely all at once. While roofers may be accustomed to minimizing risks of falling or injury due to manual handling problems, they may not be used to dealing with the risk of electric shock. Similarly, electricians would be familiar with electric shock hazards but will not be used to handling large objects at heights.

5.3. d.c. Circuits – Installation

5.3.1. Personnel

All persons working on the live d.c. cabling of a Photovoltaic (PV) system must be experienced / trained in working with such systems and fully acquainted with the voltages present on that system in particular.

Plug and socket connectors simplify and increase the safety of installation works. They are recommended in particular for any installation being performed by a non-PV specialist – e.g. a PV array being installed by a roofer.

5.3.2. Sequence of Works

All d.c. wiring should if possible be completed prior to installing a PV array. This will allow effective electrical isolation of the d.c. system (via the d.c. switch-disconnector and PV module cable connectors) while the array is installed; and effective electrical isolation of the PV array while the inverter is installed.
Typically this would require an installation sequence of:

- d.c. switch-disconnector and d.c. junction box(es)

- String/array positive and negative cables - from the d.c. disconnect/junction box to either end of the PV string/array.

- PV array main cables from d.c. switch to inverter.

This should be carried out in such a way that it should never be necessary for an installer to work in any enclosure or situation featuring simultaneously accessible live PV string positive and negative parts.

Where it is not possible to pre-install a d.c. isolator (e.g. a new-build project where a PV array is installed prior to the plant room being completed), cable ends/ connectors should be put temporarily into an isolation box and suitably labeled.

Cables are to be well supported, especially those cables exposed to the wind. Cables must be routed in prescribed zones or within mechanical protection, fully supported / cable tied (using UV stabilized ties) and they must also be protected from sharp edges.

5.3.3. Live Working

Due to the nature of PV installation work live working is almost unavoidable. However, given the nature of the system design and so long as the system is designed to fully meet the requirements set out for shock protection by the use of double or reinforced insulation, working on one conductor only represents only a small risk which is usually mitigated by the use of appropriate tooling and operative care.

If it is unavoidable to work in any enclosure containing both positive and negative connections that are simultaneously live, work must be performed either by utilizing insulating gloves & tools, insulating materials for shrouding purposes and appropriate personal protective equipment.

These situations are only likely to arise whilst working on larger systems and wherever possible these situations should be avoided.
A temporary warning sign and barrier must be posted for any period while live PV array cables or other d.c. cables are being installed.

A means to prevent the need for live working may be to work at night (with appropriate task lighting). Covering an array is also sometimes suggested as an alternative method. However, covering a PV array is not generally recommended due to the practical problems of keeping the array covered as the installation proceeds and protecting the covering from the effects of the weather.

5.3.4. Shock Hazard (Safe Working Practices)

It is important to note that, despite all the above precautions, an installer or service engineer may still encounter an electric shock hazard, therefore:

Always test for the presence of voltage of parts before touching any part of the system.

5.3.5. Array Mounting

The manufacturer's instructions should always be observed when designing a PV array mounting structure. In particular, attention shall be paid to the clamping zones as prescribed by each manufacturer as these will often vary.

5.3.6. Load Calculations

The design and specification of the PV array mounting system should take into account the wind and snow loads to be expected. Wind loads vary considerably across the UK and are influenced by factors such as site altitude, building height and local topography.

Even where an approved mounting system kit is utilized, site specific calculations will be required to ensure that the system proposed is sufficient to withstand the imposed loads.

For each site the imposed wind and snow loads should be derived using the procedures within Eurocode- 1 (BS EN 1991-1).

The pressure coefficients (Cp) used to calculate wind loads shall be derived as follows:

- For PV arrays that are mounted above, and parallel to, an inclined roof where there is a clear gap between the array and the roof - the pressure coefficients shall be taken from BRE digest 489 or from recognized test data commissioned for the specific purpose of determining the wind loads on solar systems.

- For flat roof systems - the pressure coefficients shall be taken from BRE digest 489 or from recognized test data commissioned for the specific purpose of determining the wind loads on solar systems.

- For roof integrated, nominally airtight systems - the pressure coefficients shall be taken from Eurocode-1.

- For roof integrated, air permeable "PV tile" type systems - the pressure coefficients shall be taken from BS5534 and treating the PV array as roof tiles

In determining the appropriate pressure coefficient to use in calculations, the location of the PV array on the roof needs to be determined as some, or all, of the array may be in the "Edge Zone" as defined in BS EN 1991-1.

Pressure coefficients for the Edge Zone will be higher than those in the Central Zone of the roof. BRE digest 489 and the other sources listed above include pressure coefficient values for both Edge and Central zones.

Calculating a safety factor for the derived load
As described within Eurocode-1 tables A1.1 and A1.2, safety factors need to be applied to the calculated loads. Taken in isolation, a safety factor of 1.5 should be applied to the derived wind and snow loads and a factor of 1.0 to the dead load (self-weight).

However, in normal use solar panels may be designated with a lower consequence of failure than for the supporting building structure, in accordance with Table B1 of EN 1990: 2002 + A1:2005 Consequence Class CC1. As a result the partial factor for design wind and snow loads may be multiplied by 0.9 (Factor KFI for Reliability Class RC1 from Table B3 of EN 1990: 2002 +A1 : 2005). Hence a safety factor of 1.35 should be applied to the derived wind and snow loads. Load calculations shall be undertaken by a suitably competent person.

5.3.7. Fixing Calculations

The PV array fixings (type and quantity) shall be checked to ensure that they can withstand the imposed (dead) load and wind uplift loads as calculated. Examples of how this can be achieved include:

- For systems approved to MCS012 - ensuring that the imposed loads are within the range specified by the product manufacturer (and then installing according to the manufacturer's instructions)

- Using fixing data from Eurocode 5 - design of timber structures

- Using fixing bracket test data

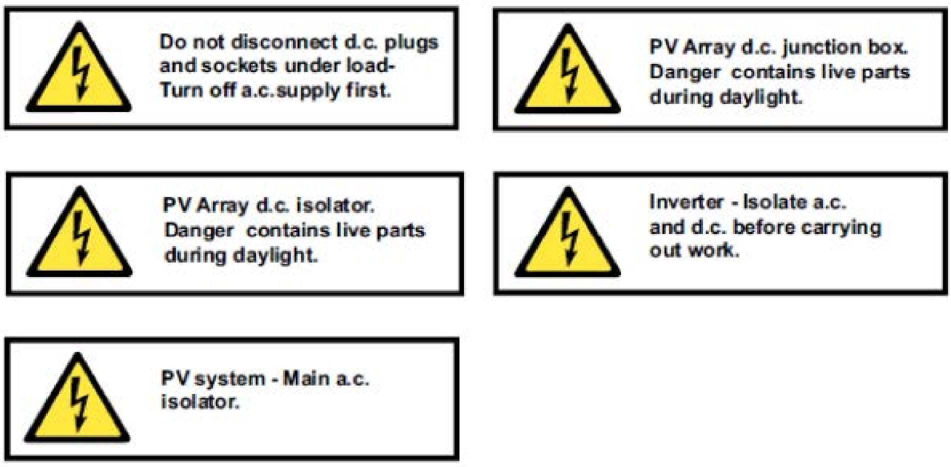
In all cases it is expected an appropriate safety factor to have been applied to the fixing withstand capacity

Fixing calculations shall be carried out by a suitably competent person.

6. SINGS AND LABELS

All labels must be clear, easily visible, constructed and affixed to last and remain legible for the lifetime of the system.

Requirements for labelling are contained within the relevant sections of this guide. Example labels can be seen below.



MEASUREMETS AND BUDGET

Index

1. MEASUREMENTS

In this document is going to be show all the tools need to achieve the Project.

PV MODULES		
Concept	Quantity	Units
PV Panel 270 Wp GS Power	1809	Ut.

INVERTER		
Concept	Quantity	Units
ABB PVS800 57- 0500kW-A	1	Ut.

STRUCTURE		
Concept	Quantity	Units
Aluminum structure to inclined the module	1809	Ut.
Attachments H Helmut	1809	Ut.

ELECTRIC BOXES		
Concept	Quantity	Units
Connection box Solarmax	1	Ut.
Polyester Electric cabinet set into	1	Ut.
Electric cabinet set into and tools chassis	1	Ut.
DC Protection box	1	Ut.
AC protection box	2	Ut.

WIRING		
Concept	Quantity	Units
Single pole cable RV-K 06/1kV phase S=6 mm²	1720	m
Protection single pole cable RV-K 06/1kV phase S=6 mm²	1720	m
Single pole cable RV-K 06/1kV phase S=35 mm²	16	m
Protection single pole cable RV-K 06/1kV phase S=25 mm²	16	m
Single pole cable RV-K 06/1kV phase S=300 mm²	3	m
Protection single pole cable RV-K 06/1kV phase S=150 mm²	3	m
Single pole cable RV-K 06/1kV phase S=240 mm²	25	m
Protection single pole cable RV-K 06/1kV phase S=300 mm²	25	m

PIPES		
Concept	Quantity	Units
PVC pipe Ø=25 mm	1720	m
PVC pipe Ø=40 mm	16	m
PVC pipe Ø=75 mm	3	m
PVC pipe Ø=225 mm	25	m

ELECTRIC PROTECTIONS		
Concept	Quantity	Units
Industrial fuse gG, 16 A, 900V, 30 kA	86	Ut.
Industrial fuse gG, 200 A, 900V, 120 kA	11	Ut.
Switch disconnector, 100A, 22kA	11	Ut.
Pole circuit breaker, 400V, 630A, 25kA	2	Ut.
Auto valve-lightning rod	1	Ut.
Discharger	3	Ut.

GROUND INTALLATION		
Concept	Quantity	Units
Grounding	1	Ut.

CIVIL WORK		
Concept	Quantity	Units
Trench	15	m3

SAFETY		
Concept	Quantity	Units
Costs safety and health at work	1	Ut.

LAW PROCESSING		
Concept	Quantity	Units
Development of project	1	Ut.
Processing and legalization	1	Ut.

2. BUDGET

2.1. Unit prices

PV MODULES					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	Ut.	Supply and installation of the 270Wp PV panels from the brand GS POWER with aluminum frame, multitouch connectors, poly-crystal technology and completely installed over the structure by screws			
1	Ut.	PV Module	157,22	157,22	
0,3	h	Electrician	16,18	4,85	
0,3	h	Assistant E.	14,68	4,40	
0,3	h	Fitter	15,82	4,75	
0,3	h	Assistant F.	13,54	4,06	
2	%	Auxiliary tools	175,29	3,51	
3	%	Indirect costs	178,79	5,36	
				TOTAL	184,16

INVERTER					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	Ut.	Supply and installation of central three phase inverter to use the energy in the company with a maximum power of 500kW and 1000V input voltage			
1	Ut.	ABB PVS800 57- 0500kW-A	83036,27	83036,27	
0,7	h	Electrician	16,18	11,33	
0,7	h	Assistant E.	14,68	10,28	
2	%	Auxiliary tools	83057,87	1661,16	
3	%	Indirect costs	84719,03	2541,57	
				TOTAL	87260,60

STRUCTURE					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1		Aluminum frame with stainless steel screws, mounted on a double lane or hollow profile, deck sheet with straps metal and double H-beam profile for installation photovoltaic, fully assembled modules. Even gathering in covered with self-propelled crane.			
1	Ut.	Structure	38,00	38,00	
0,5	h	Fitter	15,45	7,73	
0,5	h	Assistant F.	13,54	6,77	
0,06	h	Crane	89,45	5,37	
2	%	Auxiliary tools	57,86	1,16	
3	%	Indirect costs	59,02	1,77	
				TOTAL	60,79

ELECTRIC BOXES					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	Ut.	Supply and installation of junction box attached Max plus, electronic monitoring system branches alarm by MaxWeb xp, integrated LCD screen, aluminum casing with corrosion-proof protection type IP65, fully placed, connected and tested.			
1	Ut.	Junction box Max connect plus	65,45	65,45	
0,5	h	Electrician	16,18	8,09	
0,5	h	Assistant E.	14,68	7,34	
2	%	Auxiliary tools	80,88	1,6176	
3	%	Indirect costs	82,50	2,47	
				TOTAL	84,97
1	Ut.	Supply and installation of reinforced polyester rack set into			
1	Ut.	Polyester Electric cabinet set into	105,78	105,78	
0,15	h	Electrician	16,18	2,427	
0,15	h	Assistant E.	14,68	2,202	
2	%	Auxiliary tools	110,41	2,21	
3	%	Indirect costs	112,62	3,38	
				TOTAL	116,00
1	Ut.	Supply and installation of switchgear and chassis mounting rack			
1	Ut.	Electric cabinet set into and switchgear chassis	185,76	185,76	
0,2	h	Electrician	16,18	3,236	
0,2	h	Assistant E.	14,68	2,936	
2	%	Auxiliary tools	191,93	3,84	

3 %	Indirect costs	195,77	5,87	
		TOTAL		201,64
1 Ut.	Supply and installation mural inside cabinet, equipped with terminals, single-pole fuse bases provided to place maximum intensity 40 A, for protection of single-phase line formed by an insulating, auto ventilated sealable envelope, according flammability regulations and IP 43 protection. Fully assembled and tested.			
1 Ut.	General protection box, equipped with terminals, single-pole fuse bases provided to place maximum intensity 40 A	120	120	
1 Ut.	Auxiliary material for electrical installations	4,5	4,5	
0,3 h	Electrician	16,18	4,854	
0,3 h	Assistant E.	14,68	4,404	
2 %	Auxiliary tools	133,76	2,68	
3 %	Indirect costs	136,43	4,09	
		TOTAL		140,53
1	Supply and installation of the general enclosure, equipped with terminals, single-pole bases provided to place 250A peak current fuse, to protect the input general line, consisting of an insulating envelope, seal, and self-cooling, flammability according rules and degree of protection IP 43. Fully assembled and tested.			
1	General protection box, equipped with terminals, single-pole bases provided to place 250 A peak current fuses.	155,52	155,52	
1	Auxiliary material for electrical installations	4,5	4,5	
0,3 h	Electrician	16,18	4,854	
0,3 h	Assistant E.	14,68	4,404	
2 %	Auxiliary tools	169,28	3,39	
3 %	Indirect costs	172,66	5,18	
		TOTAL		177,84

WIRING					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	m	Single pole cable RV-K 06/1kV phase S=6 mm²			
1	m	Single pole cable	1,86	1,86	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,2	h	Electrician	16,18	3,236	
0,2	h	Assistant E.	14,68	2,936	
2	%	Auxiliary tools	8,65	0,17	
3	%	Indirect costs	8,83	0,26	
				TOTAL	9,09
1	m	Protection single pole cable RV-K 06/1kV phase S=6 mm²			
1	m	Single pole cable	1,86	1,86	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,2	h	Electrician	16,18	3,236	
0,2	h	Assistant E.	14,68	2,936	
2	%	Auxiliary tools	8,65	0,17	
3	%	Indirect costs	8,83	0,26	
				TOTAL	9,09
1	m	Single pole cable RV-K 06/1kV phase S=35 mm²			
1	m	Single pole cable	5,3	5,3	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,2	h	Electrician	16,18	3,236	
0,2	h	Assistant E.	14,68	2,936	
2	%	Auxiliary tools	12,09	0,24	
3	%	Indirect costs	12,34	0,37	
				TOTAL	12,71
1	m	Protection single pole cable RV-K 06/1kV phase S=25 mm²			
1	m	Single pole cable	3,2	3,2	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,2	h	Electrician	16,18	3,236	
0,2	h	Assistant E.	14,68	2,936	
2	%	Auxiliary tools	9,99	0,20	
3	%	Indirect costs	10,19	0,31	
				TOTAL	10,50

1	m	Single pole cable RV-K 06/1kV phase S=300 mm²			
1	m	Single pole cable	11,3	11,3	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,2	h	Electrician	16,18	3,236	
0,2	h	Assistant E.	14,68	2,936	
2	%	Auxiliary tools	18,09	0,36	
3	%	Indirect costs	18,46	0,55	
			TOTAL		19,01
1	m	Protection single pole cable RV-K 06/1kV phase S=150 mm²			
1	m	Single pole cable	7,78	7,78	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,2	h	Electrician	16,18	3,236	
0,2	h	Assistant E.	14,68	2,936	
2	%	Auxiliary tools	14,57	0,29	
3	%	Indirect costs	14,87	0,45	
			TOTAL		15,31
1	m	Single pole cable RV-K 06/1kV phase S=240 mm²			
1	m	Single pole cable	8,98	8,98	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,2	h	Electrician	16,18	3,236	
0,2	h	Assistant E.	14,68	2,936	
2	%	Auxiliary tools	15,77	0,32	
3	%	Indirect costs	16,09	0,48	
			TOTAL		16,57
1	m	Protection single pole cable RV-K 06/1kV phase S=300 mm²			
1	m	Single pole cable	11,3	11,3	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,2	h	Electrician	16,18	3,236	
0,2	h	Assistant E.	14,68	2,936	
2	%	Auxiliary tools	18,09	0,36	
3	%	Indirect costs	18,46	0,55	
			TOTAL		19,01

PIPES					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	m	Supply and installation of rigid and smooth PVC pipe Ø = 25 mm for electrical installations, flame retardant, insulating, fully mounted on surface or wall, including the proportional parts of sleeves and elbows			
1	m	PVC pipe Ø=25 mm	2,05	2,05	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,22	h	Electrician	16,18	3,5596	
0,22	h	Assistant E.	14,68	3,2296	
2	%	Auxiliary tools	9,46	0,19	
3	%	Indirect costs	9,65	0,29	
				TOTAL	9,94
1	m	Supply and installation of rigid and smooth PVC pipe Ø = 40 mm for electrical installations, flame retardant, insulating, fully mounted on surface or wall, including the proportional parts of sleeves and elbows			
1	m	PVC pipe Ø=40 mm	3,8	3,8	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,22	h	Electrician	16,18	3,5596	
0,22	h	Assistant E.	14,68	3,2296	
2	%	Auxiliary tools	11,21	0,22	
3	%	Indirect costs	11,44	0,34	
				TOTAL	11,78
1	m	Supply and installation of rigid and smooth PVC pipe Ø = 75 mm for electrical installations, flame retardant, insulating, fully mounted on surface or wall, including the proportional parts of sleeves and elbows			
1	m	PVC pipe Ø=75 mm	7,4	7,4	
0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,22	h	Electrician	16,18	3,5596	
0,22	h	Assistant E.	14,68	3,2296	
2	%	Auxiliary tools	14,81	0,30	
3	%	Indirect costs	15,11	0,45	
				TOTAL	15,56
1	m	Supply and installation of rigid and smooth PVC pipe Ø = 225 mm for electrical installations, flame retardant, insulating, fully mounted on surface or wall, including the proportional parts of sleeves and elbows			
1	m	PVC pipe Ø=225 mm	10,5	10,5	

0,42	Ut.	Auxiliary material for electrical installations	1,48	0,6216	
0,22	h	Electrician	16,18	3,5596	
0,22	h	Assistant E.	14,68	3,2296	
2	%	Auxiliary tools	17,91	0,36	
3	%	Indirect costs	18,27	0,55	
			TOTAL		18,82

ELECTRIC PROTECTIONS					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	Ut.	Supply and installation of Industrial fuse gG, 16 A, 900V, 30kA			
1	Ut.	Industrial fuse gG, 16 A, 900V, 30 kA	3,2	3,2	
0,02	h	Electrician	16,18	0,3236	
0,02	h	Assistant E.	14,68	0,2936	
2	%	Auxiliary tools	3,82	0,08	
3	%	Indirect costs	3,89	0,12	
				TOTAL	4,01
1	Ut.	Supply and installation of Industrial fuse gG, 200 A, 900V, 120 kA			
1	Ut.	Industrial fuse gG, 200 A, 900V, 120 kA	5,4	5,4	
0,02	h	Electrician	16,18	0,3236	
0,02	h	Assistant E.	14,68	0,2936	
2	%	Auxiliary tools	6,02	0,12	
3	%	Indirect costs	6,14	0,18	
				TOTAL	6,32
1	Ut.	Supply and installation of Switch disconnector, 100A, 22kA			
1	Ut.	Switch disconnector, 100A, 22kA	325,57	325,57	
0,15	h	Electrician	16,18	2,427	
0,15	h	Assistant E.	14,68	2,202	
2	%	Auxiliary tools	330,20	6,60	
3	%	Indirect costs	336,80	10,10	
				TOTAL	346,91
1	Ut.	Supply and installation of Pole circuit breaker, 400V, 630A, 25kA			
1	Ut.	Pole circuit breaker, 400V, 630A, 25kA	426,67	426,67	
0,15	h	Electrician	16,18	2,427	
0,15	h	Assistant E.	14,68	2,202	
2	%	Auxiliary tools	431,30	8,63	
3	%	Indirect costs	439,92	13,20	
				TOTAL	453,12
1	Ut.	Supply and installation of Auto valve-lightning rod			
1	Ut.	Auto valve-lightning rod	94,00	94,00	
0,17	h	Electrician	16,18	2,75	
0,17	h	Assistant E.	14,68	2,50	

2	%	Auxiliary tools	99,25	1,98	
3	%	Indirect costs	101,23	3,04	
				TOTAL	104,27
1	Ut.	Supply and installation of discharger			
1	Ut.	Discharger	250,10	250,10	
0,17	h	Electrician	16,18	2,75	
0,17	h	Assistant E.	14,68	2,50	
2	%	Auxiliary tools	255,35	5,11	
3	%	Indirect costs	260,45	7,81	
				TOTAL	268,27

GROUND INTALLATION					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	Ut.	Supply and installation of grounding, with two steel copper electrodes 2 meters in length. Fully assembled, connected and tested.			
2	m	Electrode for network grounding copper plated with 300 microns, made of steel, 15 mm in diameter and 2 meters long	18,00	36,00	
2,5	m	Bare copper conductor, 35 mm ²	2,81	7,03	
2	Ut.	U-bolt clamp for connecting spear	1,00	2,00	
1	Ut.	Registration box polypropylene ground, 300 x 300 mm, with manhole cover	72,00	72,00	
1	Ut.	Bridge to check grounding of electrical installation	43,00	43,00	
0,3	m^3	Earth excavation itself	0,60	0,18	
0,66	Ut.	5 kg bag of mineral salts to improve conductivity grounding	3,50	2,31	
1	Ut.	Auxiliary material for ground facilities.	1,15	1,15	
0,028	Ut.	Wheeled Loader 75 hp	37,80	1,06	
0,3	h	Electrician	14,68	4,40	
0,3	h	Assistant E.	169,13	3,38	
2	%	Auxiliary tools	172,51	5,18	
3	%	Indirect costs	177,69	5,33	
				TOTAL	183,02

GROUND INTALLATION					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	Ut.	Supply and installation of grounding, with two steel copper electrodes 2 meters in length. Fully assembled, connected and tested.			
2	m	Electrode for network grounding copper plated with 300 microns, made of steel, 15 mm in diameter and 2 meters long	18,00	36,00	
2,5	m	Bare copper conductor, 35 mm ²	2,81	7,03	
2	Ut.	U-bolt clamp for connecting spear	1,00	2,00	
1	Ut.	Registration box polypropylene ground, 300 x 300 mm, with manhole cover	72,00	72,00	
1	Ut.	Bridge to check grounding of electrical installation	43,00	43,00	
0,3	m^3	Earth excavation itself	0,60	0,18	
0,66	Ut.	5 kg bag of mineral salts to improve conductivity grounding	3,50	2,31	
1	Ut.	Auxiliary material for ground facilities.	1,15	1,15	
0,028	Ut.	Wheeled Loader 75 hp	37,80	1,06	
0,3	h	Electrician	14,68	4,40	
0,3	h	Assistant E.	169,13	3,38	
2	%	Auxiliary tools	172,51	5,18	
3	%	Indirect costs	177,69	5,33	
				TOTAL	183,02

CIVIL WORK					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	m^3	Excavation of land for formation of trenches to a depth of 1.5 m in semi-hard clay soil, mechanically. Including transport machinery, refined walls and bottom of excavation, removal of land outside the excavation and backfilling with soil from the same excavation.			
0,5	h	Hydraulic backhoe wheeled 100hp.	43,54	21,77	
0,35	h	construction laborer	14,31	5,01	
2	%	Auxiliary tools	26,78	0,80	
3	%	Indirect costs	27,58	0,83	
				TOTAL	28,41

SAFETY					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	Ut.	Costs safety and health at work			
1	Ut.	Safety and health	1000	1000	
				TOTAL	1000,00

LAW PROCESSING					
Quantity	Ut.	Concept	Price (€)	Subtotal (€)	Cost(€)
1	Ut.	Development of project, Processing and legalization			
1	Ut.	Drafting document collection, in situ measurements and preparation of areas relating to project	1956	1956	
1	Ut.	Processing and provision of administrative documentation for the legalization and wireless network installation	950	950	
				TOTAL	2906

2.2. Partial sums

PV MODULES				
Units	Concept	Quantity	Price (€)	Total (€)
Ut.	Supply and installation of the 270Wp PV panels from the brand GS POWER	1809	184,16	333137,248
TOTAL PV MODULES (€)				333137,248

INVERTER				
Units	Concept	Quantity	Price (€)	Total (€)
Ut.	Supply and installation of central three phase inverter	1	87260,60	87260,6003
TOTAL INVERTER (€)				87260,6003

STRUCTURE				
Units	Concept	Quantity	Price (€)	Total (€)
Ut.	Supply and installation of the structure	1809	60,79	109969,11
TOTAL STRUCTURE (€)				109969,11

ELECTRIC BOXES				
Units	Concept	Quantity	Price (€)	Total (€)
Ut.	Supply and installation of junction box attached Max plus	1	84,97	84,97
Ut.	Supply and installation of reinforced polyester rack set into	1	116	116
Ut.	Supply and installation of switchgear and chassis mounting rack	1	201,64	201,64
Ut.	Supply and installation DC protection box	1	140,53	140,53
Ut.	Supply and installation AC protection box	2	177,84	355,68
TOTAL ELECTRIC BOXES (€)				898,82

WIRING				
Units	Concept	Quantity	Price (€)	Total (€)
m	Single phase pole cable RV-K 06/1kV S=6 mm²	1720	9,09	15634,8
m	Protection single pole cable RV-K 06/1kV S=6 mm²	1720	9,09	15634,8
m	Single pole cable RV-K 06/1kV S=35 mm²	16	12,71	203,36
m	Protection single pole cable RV-K 06/1kV S=25 mm²	16	10,5	168
m	Single pole cable RV-K 06/1kV S=300 mm²	3	19,01	57,03
m	Protection single pole cable RV-K 06/1kV S=150 mm²	3	15,31	45,93
m	Single pole cable RV-K 06/1kV S=240 mm²	25	16,57	414,25
m	Protection single pole cable RV-K 06/1kV S=300 mm²	25	19,01	475,25
TOTAL WIRING (€)				32633,42

PIPES				
Units	Concept	Quantity	Price (€)	Total (€)
m	PVC pipe Ø=25 mm	16	9,94	159,04
m	PVC pipe Ø=25 mm	16	11,78	188,48
m	PVC pipe Ø=25 mm	3	15,56	46,68
m	PVC pipe Ø=25 mm	25	18,82	470,5
TOTAL PIPES (€)				864,7

ELECTRIC PROTECTIONS				
Units	Concept	Quantity	Price (€)	Total (€)
Ut.	Industrial fuse gG, 16 A, 900V, 30 kA	86	3,80	326,92
Ut.	Industrial fuse gG, 200 A, 900V, 120 kA	11	6,11	67,24
Ut.	Switch disconnector, 100A, 22kA	11	345,34	3.798,74
Ut.	Pole circuit breaker, 400V, 630A, 25kA	2	451,56	903,11
Ut.	Auto valve-lightning rod	1	102,49	102,49
Ut.	Discharger	3	266,49	799,47
TOTAL ELECTRIC PROTECTIONS (€)				5.997,97

GROUND INTALLATION				
Units	Concept	Quantity	Price (€)	Total (€)
Ut.	Supply and installation of grounding, with two steel copper electrodes 2 meters in length. Fully assembled, connected and tested.	1	183,02	183,02
TOTAL GROUND INTALLATION (€)				183,02

CIVIL WORK				
Units	Concept	Quantity	Price (€)	Total (€)
m^3	Excavation of land for formation of trenches to a depth of 1.5 m	15	28,41	426,15
TOTAL CIVIL WORK (€)				426,15

SAFETY				
Units	Concept	Quantity	Price (€)	Total (€)
Ut.	Costs safety and health at work	1	1000	1000
TOTAL SAFETY (€)				1000,00

LAW PROCESSING				
Units	Concept	Quantity	Price (€)	Total (€)
Ut.	Development of project, Processing and legalization	1	2906	2906
TOTAL LAW PROCESSING (€)				2906,00

2.3. Material Budget

PV MODULES	321.170,82 €
INVERTER	87.253,29 €
STRUCTURE	80.822,26 €
ELECTRIC BOXES	880,54 €
WIRING	25.265,48 €
PIPES	726,66 €
ELECTRIC PROTECTIONS	5.997,97 €
GROUND INTALLATION	10,76 €
CIVIL WORK	426,14 €
SAFETY	1.000,00 €
LAW PROCESSING	2.906,00 €
MATERIAL EXECUTION BUDGET	**526.459,91 €**

The material execution budget is five hundred twenty six thousand four hundred fifty nine Euros and ninety one cents.

2.4. Execution budget

MATERIAL EXECUTION BUDGET		526.459,91 €
Overhead costs	12%	63.175,19 €
Industrial benefit	6%	31.587,59 €
		621.222,69 €
VAT	21%	130.456,77 €
EXECUTION BUDGET		**751.679,46 €**

The execution budget is seven hundred fifty one thousands six hundred seventy nine Euros and forty six cents.

FINANCIAL ANALYSIS

Index

1. INTRODUCTION

The objective is to determine the economic viability of a PV system as an alternate energy source when compared to electricity from the grid. The economic analysis will consider a number of factors such as energy generated, wattage and maintenance cost, VAT, inflation.

In the following economic analysis it is going to be showed the prediction of the viability of the photovoltaic installation during 30 years of work life. It will be study the cash flow per year, NPV, IRR and PB, tools use to calculate usually to rate the viability of the project for the investors.

It has to take into account, nowadays Czech Republic is in the same situation as Spain, the government is not giving any helps or bonus to build or to sell the PV energy. Then the only incomes this installation it goes to have is the own energy is generated and for that reason it is not being consuming from the grid, and with this reduction of consumption from the grid has to take into consideration the possibility to hire a cheaper tariff.

2. DEFINITIONS

The income statement is one that reflects the differences arising in the course of an accounting period between the flows of revenues and expenses attributable to the same period. Resume operations on a limited period, the project period is 30 years, which is the period that is assumed in this photovoltaic installations.

2.1. Update financial flows

The behavior of a project throughout its life, forced to work with financial ratios that consider the time during which the receipts and payments related to the project will occur.

To compare the economic flows of different years need to be adapted to a common base, which is normally the time of year current home or investment.
Usually called pass from variables Euros to constant Euros.
Assuming the interest rate is fixed and inflation is constant over the period, the conversion factor from variables Euros to constant Euros is (1 + ir) n.

2.2. Annual incomes

The incomes of this installation actually are zero. But that is why it is not connecting to the grid and the energy generated is not being sold. For another hand is the company who is using this energy to work so it is not consuming the energy from the grid, what it means the cost of his consumption is much lower than usually and 100% sure they will never overcome the limit of the maximum power allowed.

Also has to been taken into account in the financial study is going to be studied three hypotheses:

1. It is being studying the hypotheses of a yearly 10% €/kWh increment, this hypotheses is coming from the electric price rise in Spain due in the last seven years the price of the electricity increase an 80%.

2. In this one will be studied the half of the increment of the last hypotheses, what it means a yearly 5% €/kWh increment.

3. Last hypotheses will be about the possibility to sell the energy generated as well as yearly 5% €/kWh increment.

2.3. Outlays

2.3.1. Cost of the installation

The cost of the installation it is detailed described in the measurements and budget documents.

2.3.2. Maintenance

Solar panels generally require very little maintenance since there are no moving parts. A few times a year, the panels should be inspected for any dirt or debris that may collect on them. Always make sure you are safety conscious when inspecting panels and don't take any needless risks! If your panels are too high up on the roof to see very well from the ground, use caution with ladders.

Professional solar panel cleaners are also in abundance and can come out periodically to clean them throughout the year. Check local listings for high-rated, reputable solar panel cleaning companies. This is a better choice for panels that are too high to reach well with a garden hose or if you want a more thorough cleaning.

Standard solar panel maintenance is the best way to make sure they are always producing efficiently.

The maintenance yearly cost will be 0,80% of all the power install.

2.3.3. Amortization

The investment has a useful operating life, when the time comes, they must have the financial resources necessary to replace it at the end of its useful life.

The redemption value is the value of the investment divided between elected, these being equal to the life it is considered.

2.4. Financing

As a big company it is consider the can afford the price of the installation without request a loan to the bank.

2.5. Operating profit

2.5.1. Profit

The profits of the installation is the money is being saving from the electric income due the company will generate their own energy, decreasing the power consumption therefore the tariff hired could be cheaper and the consumption coming from the power station much lower.

2.5.2. Cash flow

Cash flow is the movement of money into or out of a business, project, or financial product. It is usually measured during a specified, limited period of time. Measurement of cash flow can be used for calculating other parameters that give information on a company's value and situation. Cash flow can be used, for example, for calculating parameters: it discloses cash movements over the period. To determine a project's rate of return or value. The time of cash flows into and out of projects are used as inputs in financial models such as internal rate of return and grid present value.

2.5.3. VAT

A type of consumption tax that is placed on a product, whenever value is added at a stage of production and at final sale. Value-added tax (VAT) is most often used in the European Union. The amount of value-added tax that the user pays is the cost of the product, less any of the costs of materials used in the product that have already been taxed.

In Czech Republic the VAT is 21%but according to the pass data and statics is been considerate an increment of 0,06 % yearly.

3. PROJECT'S PROFITABILITY

To study the behavior of the PV system needed to track every year, taking into account the effect of capital market performance, due you should perform an upgrade of the cash flows.

3.1. Present Value - NPV

The difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of an investment or project.

NPV analysis is sensitive to the reliability of future cash inflows that an investment or project will yield.

Formula:

$$NPV = \varepsilon_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

Where

t– The time of the cash flow in years.

r – The discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.); the opportunity cost of capital

Ct – The grid cash flow i.e. cash inflow – cash outflow, at time t .

For educational purposes, **Co** is commonly placed to the left of the sum to emphasize its role as (minus) the investment.

If...	It means...	Then...
NPV > 0	the investment would add value to the firm	the project may be accepted
NPV < 0	the investment would subtract value from the firm	the project should be rejected
NPV = 0	the investment would neither gain nor lose value for the firm	We should be indifferent in the decision whether to accept or reject the project. Decision should be based on other criteria, e.g., strategic positioning or other factors not explicitly included in the calculation.

3.2. Internal rate of return (IRR)

The discount rate often used in capital budgeting that makes the grid present value of all cash flows from a particular project equal to zero. Generally speaking, the higher a project's internal rate of return, the more desirable it is to undertake the project. As such, IRR can be used to rank several prospective projects a firm is considering. Assuming all other factors are equal among the various projects, the project with the highest IRR would probably be considered the best and undertaken first.

$$i_r \ to\ make \qquad \varepsilon_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0 = 0$$

3.3. Pay-Back period(PB)

The length of time required to recover the cost of an investment. The payback period of a given investment or project is an important determinant of whether to undertake the position or project, as longer payback periods are typically not desirable for investment positions.

Calculated as:
Payback Period = Cost of Project / Annual Cash Inflows

4. VIABILITY STUDY

4.1. Hypotheses 1: Yearly 10% €/kWh increment

In the table 4.1 there is a summary of all the standards taken into account to analyze the profitability of the hypotheses 1:

HYPOTHESIS 1	
Yearly €/kWh Rise	10%
VAT	21%
Yearly VAT Rise	0,06%
Interest	12%
inflation	10%
Real interest	1,82%
IRR	7,43
PBA	7,44
PB	7,40%
Amortization	16 years

Table 4.1

In the figure 4.1 can be checked that the hypotheses 1 start to have incomes from the 16th year of the work life of the installation:

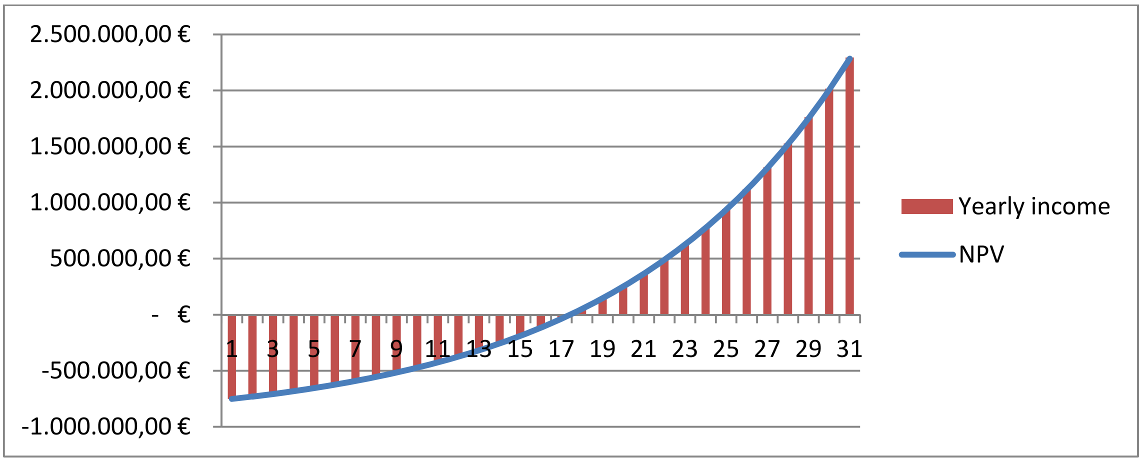


Figure 4.1

4.2. Hypotheses 2: Yearly 5% €/kWh increment

In the table 4.2 there is a summary of all the standards taken into account to analyze the profitability of the hypotheses 2:

HYPOTHESIS 2	
Yearly €/kWh Rise	5%
VAT	21%
Yearly VAT Rise	0,06%
Interest	12%
inflation	10%
Real interest	1,82%
IRR	1,65%
PBA	17,95
PB	17,88
Amortization	21 years

Table 4.2

In the figure 4.2 can be checked that the hypotheses 2 start to have incomes from the 21st year of the work life of the installation:

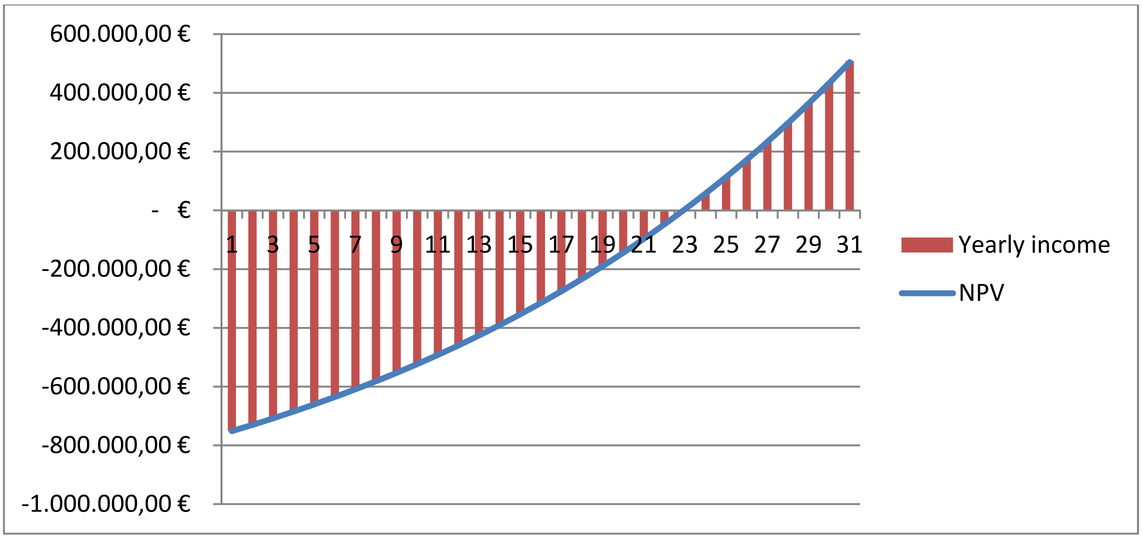


Figure 4.2

4.3. Hypotheses 3: Yearly 5% €/kWh increment grid connected

In the table 4.3 there is a summary of all the standards taken into account to analyze the profitability of the hypotheses 3:

HYPOTHESIS 3	
Yearly €/kWh Rise	5%
VAT	21%
Yearly VAT Rise	0,06%
Interest	12%
inflation	10%
Real interest	1,82%
IRR	7,50%
PBA	3,15
PB	3,14
Amortization	5 years

Table 4.3

In the figure 4.3 can be checked that the hypotheses 3 start to have incomes from the 5th year of the work life of the installation:

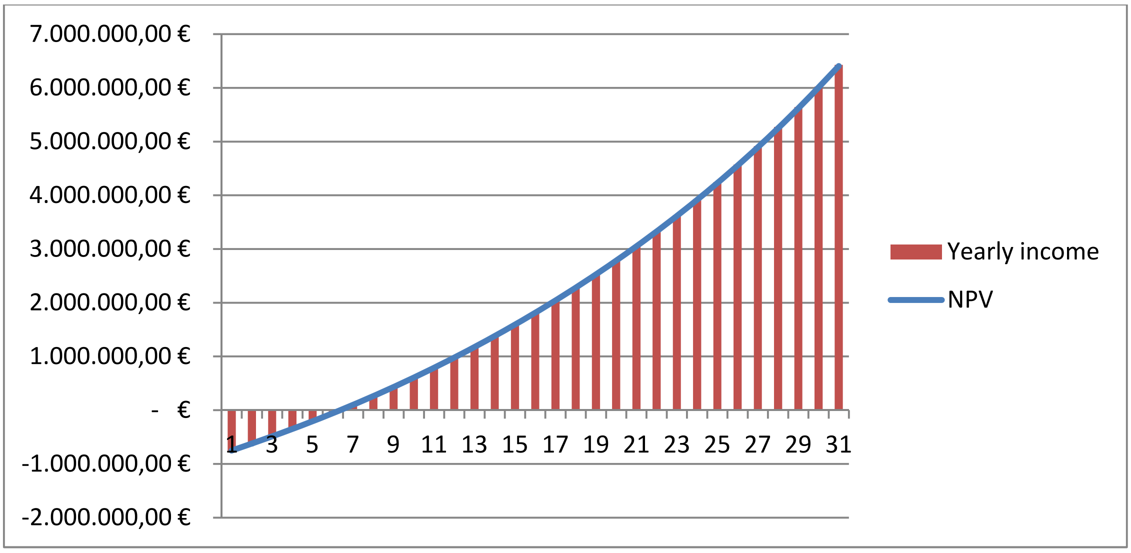


Figure 4.3

5. ANALYSIS RESULTS

As it can be reflected in the tables and graphics introduced previously, it is pretty obvious that the best option with the lowest payback whence the most profitable is the hypotheses 3 (the one is connected to the grid even if the yearly €/kWh rise estimated is the half of the hypotheses 1), it presents a payoff of around 5 years.

But as is has been explained along the project, this option is unfortunately unfeasible due the government restrictions to connect new installations because the big amount of solar energy installed in this area.

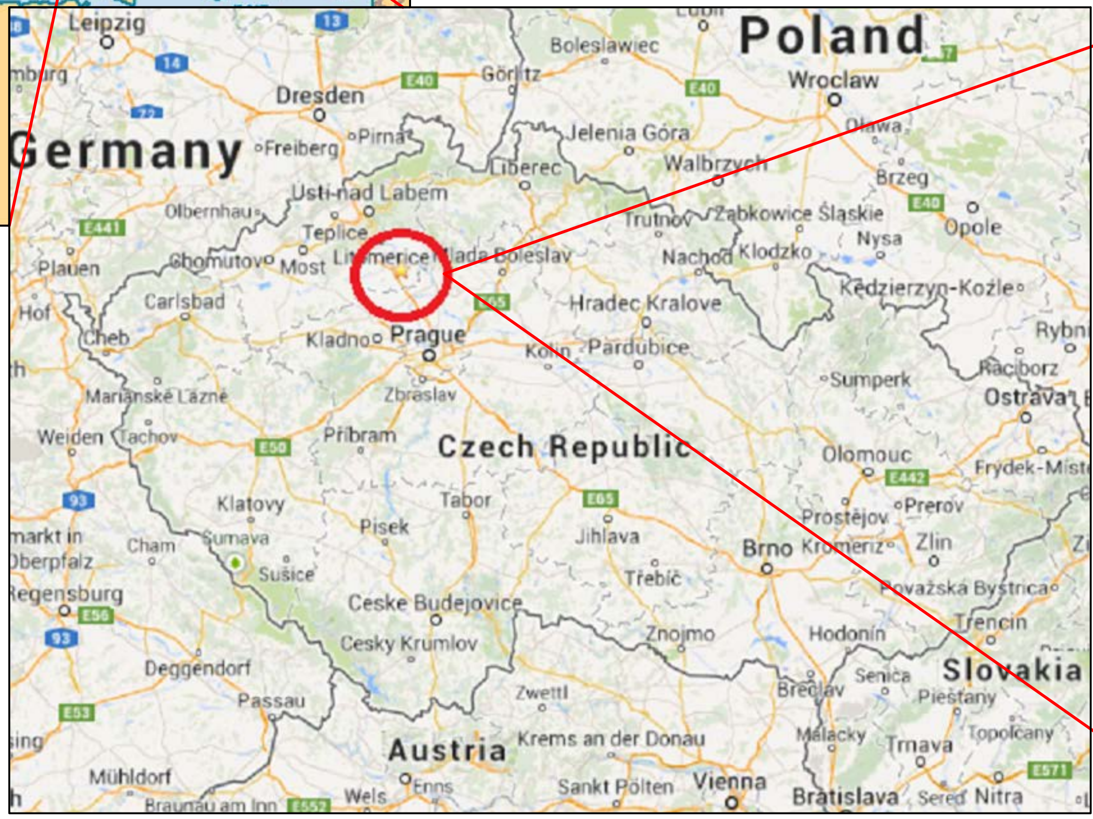
	HYPOTHESES 1	HYPOTHESES 2	HYPOTHESES 3
Yearly €/kWh Rise	10%	5%	5%
IRR	4,5%	1,65%	7,5%
PBA	7,43	17,95	3,15
PB	7,4	17,88	3,14
Amortization	16 years	21 years	5 years

Table 5.1 The three hypotheses studied

For this reason, nowadays the best option will be the one explained in the hypotheses 1, but it has to be mentioned, rarely an industrial project as this one, it is executed with such a long amortization. For that reason, the best option could be postpone the project until there was a change in the energetic law and an installation like this one could be connected to the grid again. The hypotheses 3 the amortization will be in slightly five years.

LAYOUT

Index



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SUPERVISOR	23/05/2014	PAVEL BAUER
CLIENT	22/06/2014	GLAZURA S.R.O.

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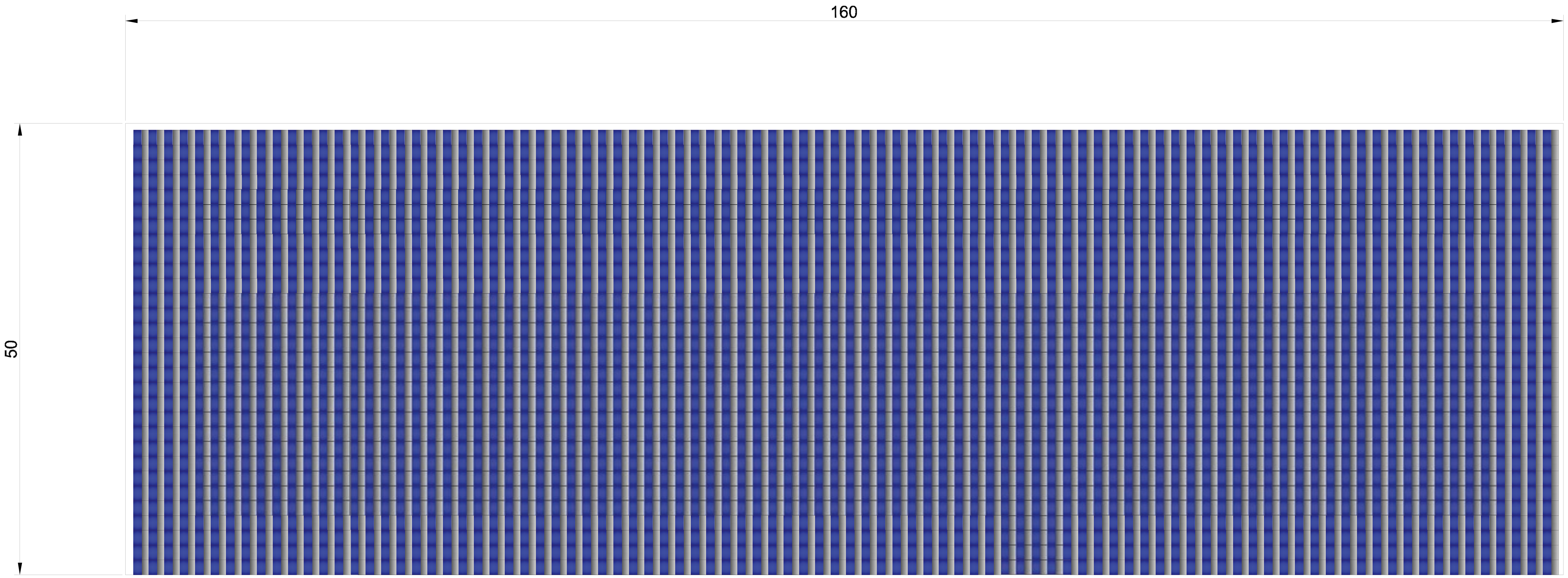
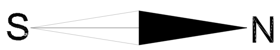
SCALE	TITLE	DRAWING
1:10000	LOCATION	1





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SCALE	TITLE	DRAWING
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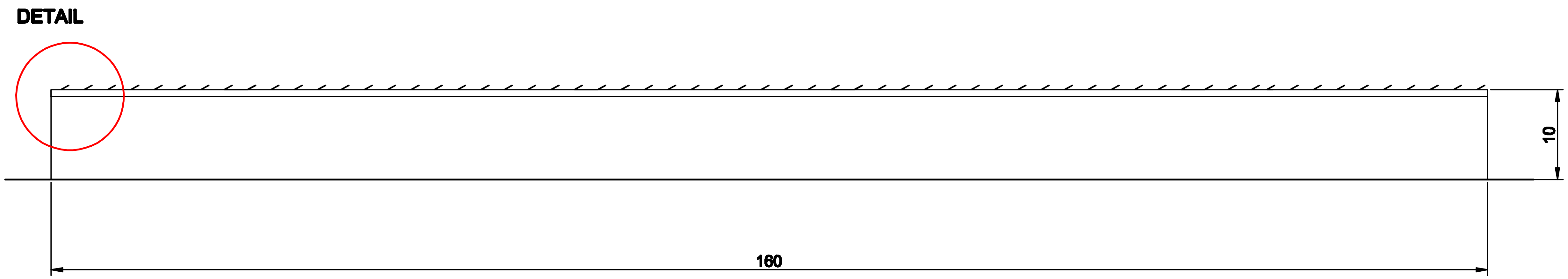

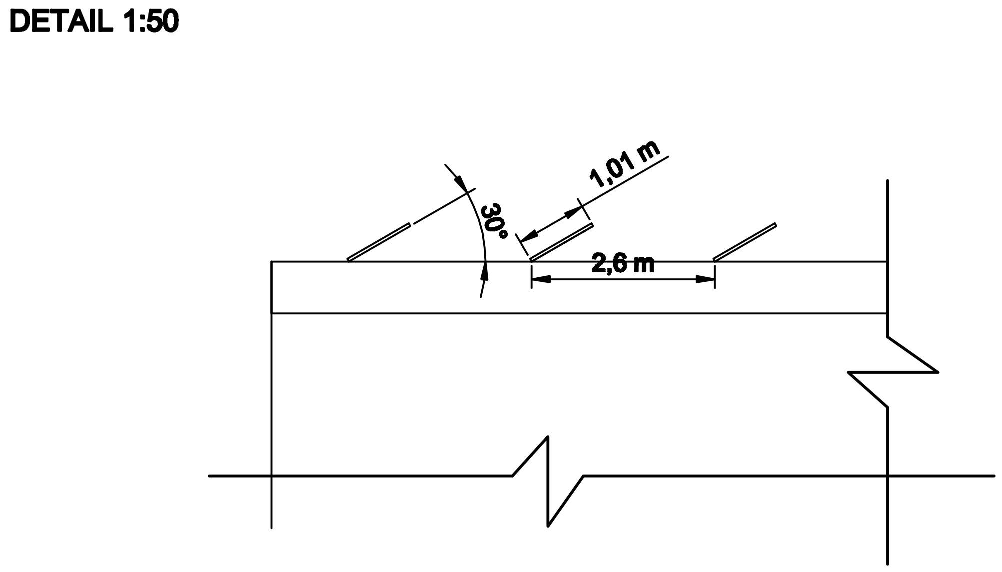

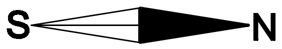

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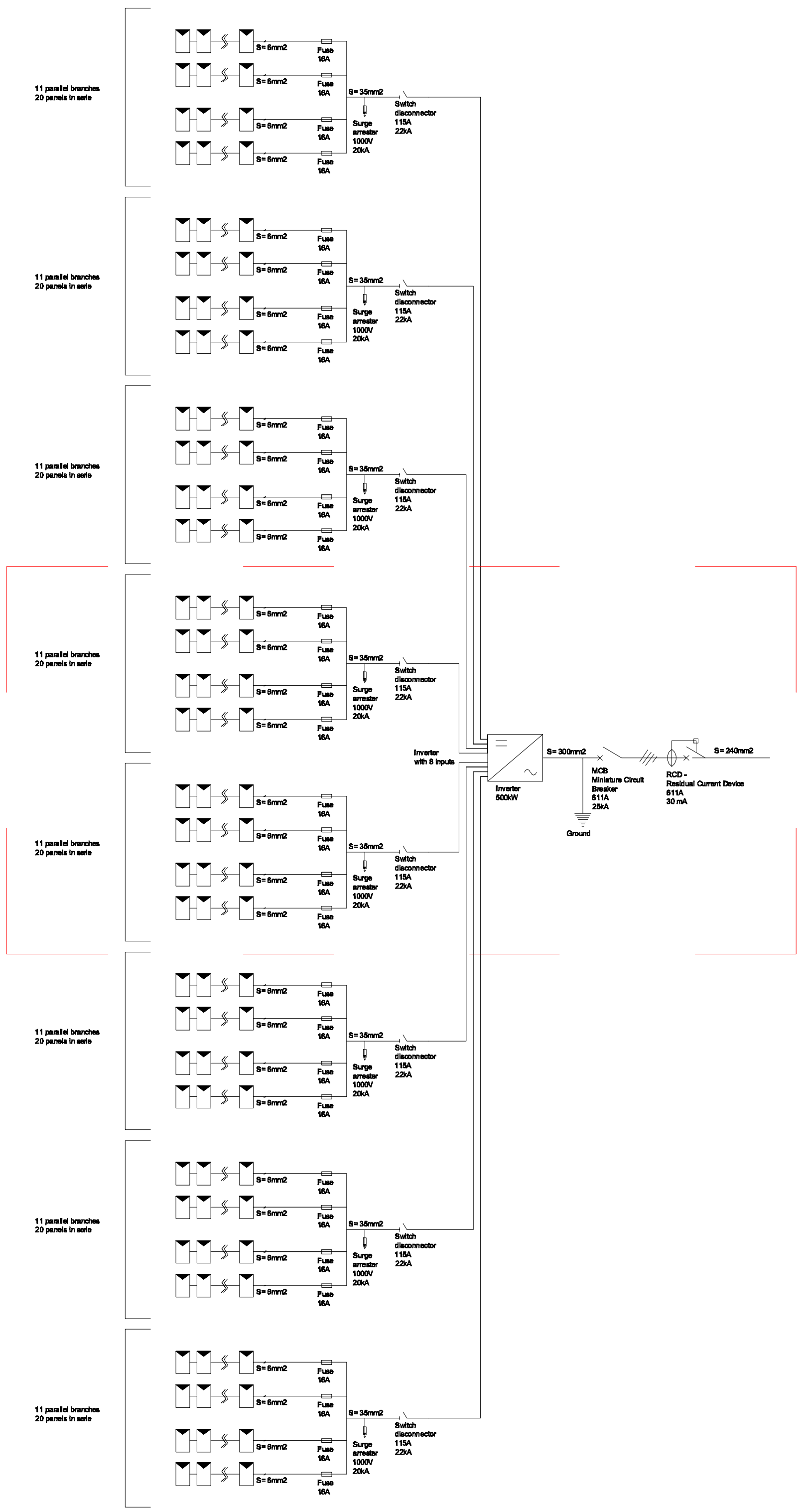
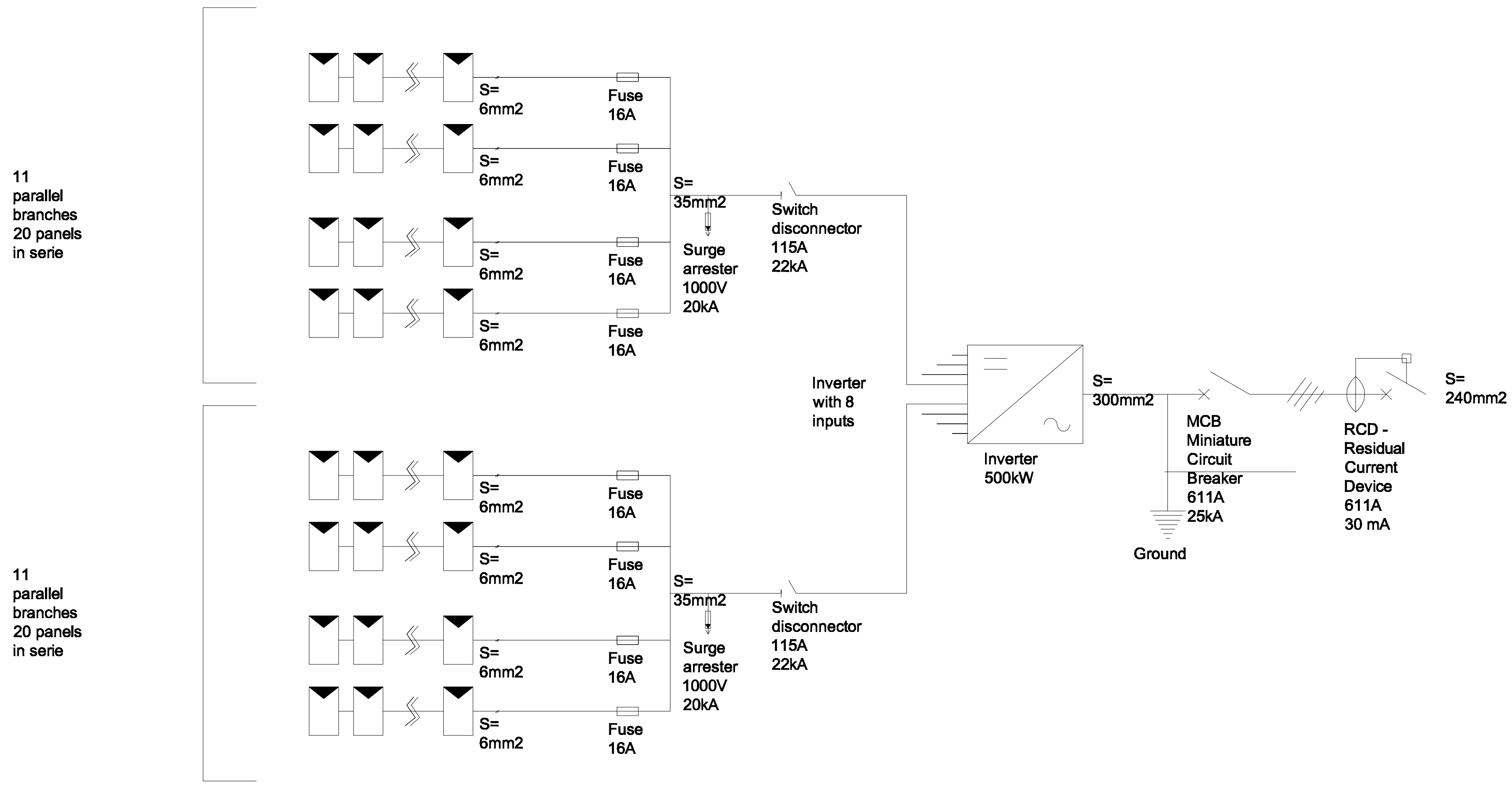
SCALE	TITLE	DRAWING
1:250	DETAIL MODULES LAYOUT	3





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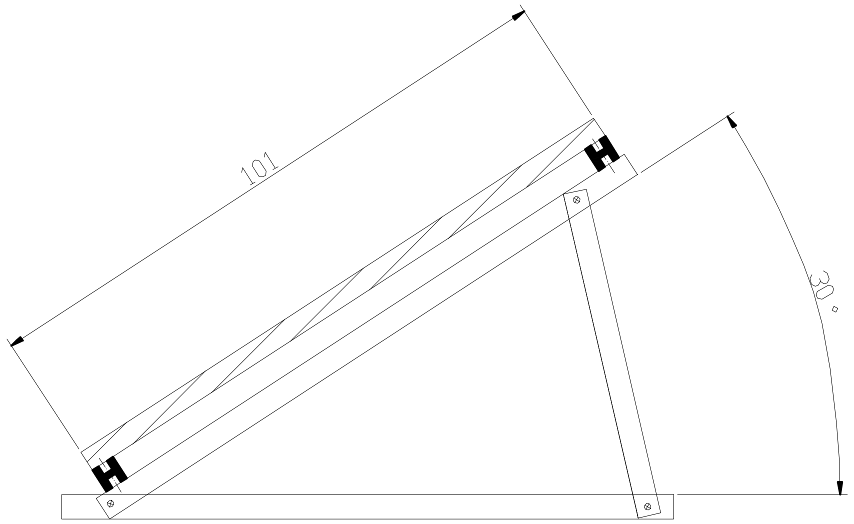
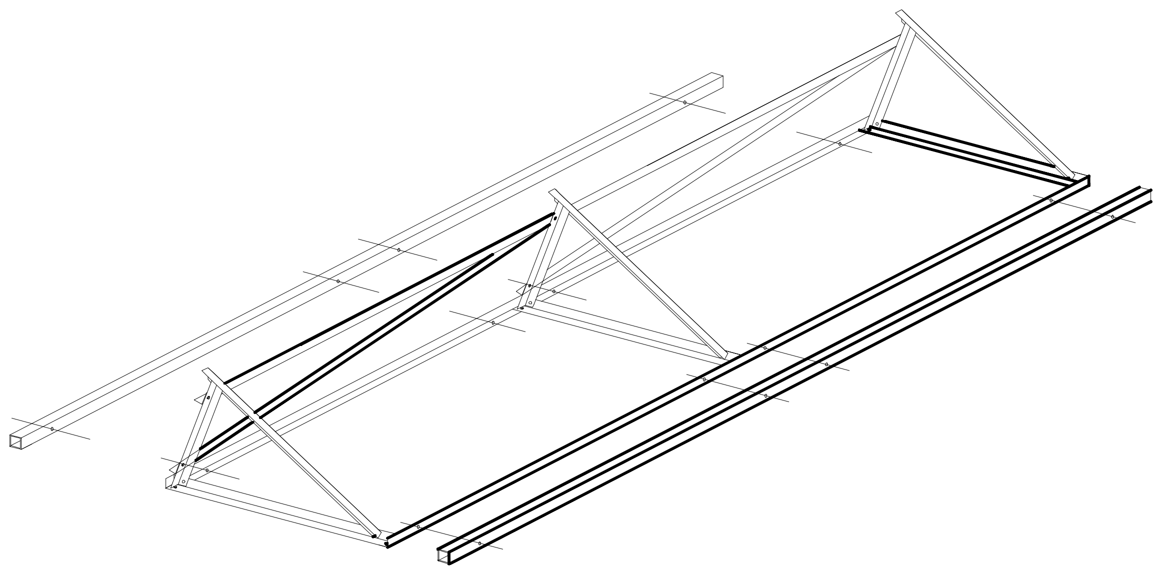
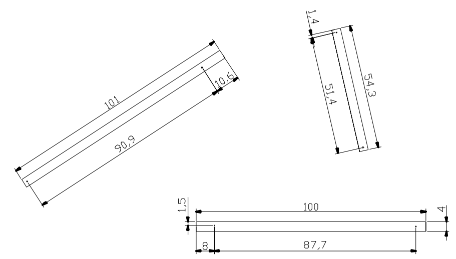
SCALE	TITLE	DRAWING
NON-SCALE	SINGLE LINE DIAGRAM	4



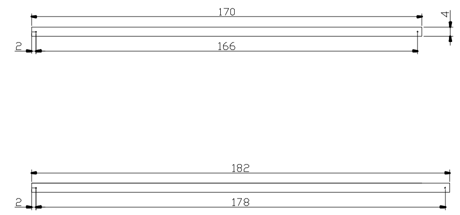


PARTS BREAKDOWN

Unints in cm



Diagonal and horizontal reinforcement



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SCALE	TITLE	DRAWING
NON-SCALE	MODULE SUPPORT STRUCTURE	5

ANNEXES

ANNEX INDEX

ANNEX I

PV INSTALLATION CALCULATION

Index

1. SELECTION OF THE PHOTOVOLTAIC PANEL

Nowadays there a big competition and variety of photovoltaic panels and it makes very hard to chose the best one for your all your needs. In this project is going to be done a comparison between a few panels with the most reliable characteristics in order to choose the best one. All the panels have been chose are the ones with the highest efficiency inside of the brand.

In the following table it is being show the panels.

Brand	Model	Type	P (W)	Efficiency (%)
REC	REC250PE	Poli	250	15,1
Sharp	SHRP60P6L	Poli	250	15,1
Sharp	SHRP 60M6L	Mono	250	15,1
Bisol	BMU245	Poli	245	15,3
GS POWER	270Wp	Poli	270	15,9
Bisol	BMU246	Mono	250	15,7
Bisol	BS245P	Poli	245	14,9
Q-cells	Q.PRO.G2.250	Poli	250	14,8
Q-cells	Q.PEAK.265	Mono	265	15

1.1 Chosen panels

After check the characteristics of each, monocrystaline shows that are more efficient, however also influence other parameters to determine the module to be installed as tolerance, temperature coefficient of losses, security and of course the price.

Tolerance is indicative of the quality of the cells and their connections. If it is positive, indicates that all modules in standard conditions produce more power than rated, so for module selection, it has to be care about those with a negative or less than +5 tolerances. In next table, the tolerances of the modules are shown in the following table.

Brand	Model	Type	P (W)	Tolerance
REC	REC250PE	Poli	250	"+5-0"
Sharp	SHRP60P6L	Poli	250	"+3-0"
Sharp	SHRP60M6L	Mono	250	"+3-0"
Bisol	BMU245	Poli	245	"+6-0"
GS POWER	270Wp	Poli	270	"+5-0"
Bisol	BMU246	Mono	250	"+4-0"
Bisol	BS245P	Poli	245	"+3-3"
Q-cells	Q.PRO.G2.250	Poli	250	"+5-0"
Q-cells	Q.PEAK.265	Mono	265	"+4-0"

1.2. Tolerance of the modules.

Warranty is also an important factor so that the guarantees have been compiled for each of the modules.

- REC has 10 years warranty in material and manufacturing workmanship. Concerning the reduction in the efficiency of the photovoltaic module provides 97% the first year and degradation 0, 7 year.
- Bisol, offers 10 years warranty in material and manufacturing workmanship. On the reduction of the efficiency of the photovoltaic module offers 90% during the first 10 years and 80% up to 25 years.
- Q.Cells, offers 10 years warranty material and workmanship manufacturing. Concerning the reduction in the efficiency of the photovoltaic module provides 97% the first year and degradation 0, 6 per year.
- Sharp has 10 years warranty in material and manufacturing workmanship. Concerning the reduction in the efficiency of the photovoltaic module provides 96% the first year and a degradation of 0, 667 per year.
- GSPOWER offers a 12 year warranty in material and manufacturing workmanship. On the reduction of the efficiency of the photovoltaic module offers 92% after the 12 years, 80% up to 30 years.

Brand	Model	Type	P (W)	AverageWaranty
REC	REC250PE	Poli	250	90,74%
Sharp	SHRP60P6L	Poli	250	88,40%
Sharp	SHRP60M6L	Mono	250	88,40%
Bisol	BMU245	Poli	245	88,70%
GS POWER	270Wp	Poli	270	94,20%
Bisol	BMU246	Mono	250	88,77%
Bisol	BS245P	Poli	245	91,26%
Q-cells	Q.PRO.G2.250	Poli	250	93,74%
Q-cells	Q.PEAK.265	Mono	265	93,74%

1.3 Average guaranteed efficiency during the first 25 years

The power loss due to temperature variations, are also a factor to consider, in next table the values of temperature coefficient and standard operating temperature conditions are indicated.

Brand	Model	Type	P (W)	Coef. Tª (%/ºC)	NOTC (ºC)
REC	REC250PE	Poli	250	-0,43	47,9
Sharp	SHRP60P6L	Poli	250	-0,4	45
Sharp	SHRP60M6L	Mono	250	-0,37	44
Bisol	BMU245	Poli	245	-0,46	47
GS POWER	270Wp	Poli	270	-0,44	47,5
Bisol	BMU246	Mono	250	-0,463	47,5
Bisol	BS245P	Poli	245	-0,4	46
Q-cells	Q.PRO.G2.250	Poli	250	-0,45	45
Q-cells	Q.PEAK.265	Mono	265	-0,42	45

1.4 Temperature coefficients of the modules.

The temperature coefficient indicates the power loss and the variation of temperature, is given by the manufacturer.

NOTC indicates the temperature of normal cell operation is given by the manufacturer.

For the power loss due to the temperature variation, it is needs to know the average annual daytime temperature; this data is obtained from WMO (World Meteorological Organization), and has a value of 8 in Roudnice nad Labem.

The equation for the temperature of the cell is given by:

$$T_{cell} = T_{atmosphere+}H \cdot (T_{ONC} - 20)/800$$

The temperature at which the modules are tested is 25 ° C and the irradiance of 1000 W/m^2.

Substituting the values into the equation, the cell temperature is calculated for each model, the variation of temperature with respect to 25 ° C and then the temperature coefficient is obtained losses are obtained.

Brand	Model	Type	P (W)	Correction Factor
REC	REC250PE	Poli	250	86,67%
Sharp	SHRP60P6L	Poli	250	89,98%
Sharp	SHRP60M6L	Mono	250	91,19%
Bisol	BMU245	Poli	245	87,33%
GS POWER	270Wp	Poli	270	90,01%
Bisol	BMU246	Mono	250	86,95%
Bisol	BS245P	Poli	245	89,98%
Q-cells	Q.PRO.G2.250	Poli	250	88,73%
Q-cells	Q.PEAK.265	Mono	265	88,22%

Table 1.5 Correction factor

Finally, the price. At this point you should get the ratio Euros / W, because although the cost of each module is different, the power per module too, and cannot be compared.

Brand	Model	Type	P (W)	Price	€/W
REC	REC250PE	Poli	250	373,61 €	1,49 €
Sharp	SHRP60P6L	Poli	250	369,15 €	1,48 €
Sharp	SHRP60M6L	Mono	250	385,91 €	1,54 €
Bisol	BMU245	Poli	245	361,14 €	1,47 €
GS POWER	270Wp	Poli	270	157,40 €	0,58 €
Bisol	BMU246	Mono	250	361,08 €	1,44 €
Bisol	BS245P	Poli	245	372,10 €	1,52 €
Q-cells	Q.PRO.G2.250	Poli	250	352,58 €	1,41 €
Q-cells	Q.PEAK.265	Mono	265	365,93 €	1,38 €

Table 1.6 Price per unit and the price per watt

With all these features, it is going to be made a selection criterion to find out what is the best module according to the needs.

1.1. Selection Criteria

Decision taken, according to the Analytic Hierarchy Process (AHP).

AHP builds a hierarchy (ranking) of decision items using comparisons between each pair of items expressed as a matrix. Paired comparisons produce weighting scores that measure how much importance items and criteria have with each other.

The preference scale for pair-wise comparisons of two items ranges from the maximum value 9 to 1/9 (0.111 in decimal from). Let aij represent the comparison between item-i (left) and item-j (right). If item-i is 5 times (strong importance) more important than item-j for a given criteria or product, then the comparison aji = 1/aij = 1/5 (0.200) or the reciprocal value for the paired comparison between both items.

AHP Scale of Importance (aij)	Efficiency (%)	Tolerance	Correction factor	Average Warranty	€/W		IMPORTANCE
Efficiency (%)	1	4	1	7	1/2	1,70	27%
Tolerance	1/4	1	1/4	1/3	1/5	0,33	5%
Correction Coef.	1	4	1	3	1/2	1,43	23%
AverageWarant y	1/7	3	1/3	1	2/7	0,53	8%
€/W	2	5	2	3,50	1	2,34	37%
						6,33	

Table 1.7

After that according to the importance given to each characteristic we can analyzed what is the best choice for the needs of the project.

	Efficiency (%)	Tolerance	Correction Factor	AverageWaranty	€/W	
REC	0,7	0,8	0,7	1	0,8	0,767
Sharp	0,7	0,5	0,9	0,8	0,8	0,780
Sharp	0,7	0,5	1	0,8	0,7	0,766
Bisol	0,8	1	0,9	0,8	0,8	0,833
GS POWER	1	0,8	0,7	1	1	0,922
Bisol	0,9	0,7	0,7	0,8	0,8	0,799
Bisol	0,6	0,4	0,9	0,9	0,7	0,719
Q-cells	0,6	0,8	0,8	1	0,8	0,763
Q-cells	0,6	0,4	0,8	1	0,8	0,742

Table 1.8

FAVOURITE	0,922	GS POWER

Selected module	
Designation	
Brand	GS POWER
Model	270 Wp MONO
Mechanical properties	
Dimensions	1650 mm x 1010 mm x 42mm
Weight	19 Kg
Electrical Specifications (Standard Conditions, Irradiance 1000 W/m2	
The cell temperature 25 ° C; Spectrum 1,5 MA)	
Power	199,16 Wp
Maximum power (P_{MPP})	270 Wp
Short-circuit current (Isc)	9.26 A
Open circuit voltage (VSC)	38,47 V
Current in MPP (IPMP)	6.74 A
MPP voltage (VPMP)	29,74 V
Efficiency (η),	16.2%
Temperature coefficient (γ):	-0.43% / ° C
Properties for system design	
Voltage at (VSYS) system	1000V
Maximum current system (IR)	16A

Table 1.9

2. PV GENERATOR SIZING AND INVERTER

2.1. Number of modules

The number of modules is given by the power that is wanted to install, in this case it is wanted to install approximately 366kW.

As each module is 270W, the number of modules required is estimated to reach 391 kW.

$$Number\ of\ modules = \frac{391000W}{270W/module} = 1448\ modules$$

But we have to oversize it a 25% to warranty the well working of the system due the possibility of the decrease of the power because of the losses.

$$Number\ of\ modules = \frac{391000W * 1{,}25}{270W/module} = 1809\ modules$$

2.2. Layout of the photovoltaic panels

To determine the distribution of PV modules have to know the data of the inverter to be installed.

Inverter	
Denomination	
Brand	ABB
Model	PVS 800
Input DC	
Power	500 kW
Maximum power (P_{MPP})	600 kW
Voltage	450-825 V
Max. Input voltage	1000V
Input current	1145A
Output AC	
Power	500kW
Output	300V
System data	
Max. Efficiency	98,60%
Size	2630x2130x646
Weight	1800 kg

Table 2.1

By PVSYST software, an installation scheme consists of 20 modules in series of 86 parallel strings of modules is obtained. However, looking at the inlet of the generator to the inverter can be seen that there are 8 entries, so the 86 branches enter the three terminals distributed, leading to the connection of 11 branches of 20 modules per terminal.

Solar field checking is performed to verify that the operating values are among the inverter.
The association of 20 modules in series per branch:

Voltage setting circuit for the solar field is calculated from the open voltage of each circuit module.
V_{SC_MODULE}=38,47V;
V_{SC_SIST}=20·38,47V =769,4V; (Maximum voltage inverter = 1000 V) OK

The voltage at the maximum power point for the solar field is calculated from the voltage at the maximum power point of each module.

V_{MPP_MODULE}=32,42 V
V_{MPP_SIST} =20·32,42 V =648,4V; (Inverter voltage range = 450 to 825 V) OK

The maximum current per branch is the same as the module.
$ISC_{\_MODULE}$= I_{SC_BRANCH}=9,26 A.

The maximum intensity in the MPP by branch is given by the current of each module in the MPP.
I_{MPP_MODULE}= I_{MPP_BRANCH}=8,46 A.

The association 11 parallel branches:
The current 11 branches obtained from load current of each branch.
I_{SC_MODULE}= I_{SC_BRANCH}= 9,26A
I_{SC_SIST} = 11·9,28 A=102,08 A;

The association of 86 (8x11) branches in parallel:
The total current of the system is obtained from load current of each branch.

I_{SC_MODULE}= I_{SC_BRANCH}= 9,26A
I_{SC_SIST} = 86·9,26 A=796,36 A; (Inverter current range = 0 ... 1145 A) OK

The current in the MPP is obtained from the current MPP for each branch, knowing that there are 11 branches.

Total panels	1809
Peak power	488,37 KWp
Branches	86
Modules per branch	20

Table 2.2 Characteristics of the installation

3. CALCULATION OF THE TILT, GUIDANCE AND SEPARATION OF PANELS

In this section, tilt, orientation and optimum separation is obtained for maximum amount of energy.

3.1. Orientation and tilt

The optimal orientation is ensuring the most hours of sun so the orientation is toward the south. It is estimated that annual losses of energy generation are 0.02% per degree of deviation from Ecuador observer.

The optimum tilt is a little more difficult to achieve, as this varies depending on the latitude, however, the tables have TZB reporting on solar energy incident on a surface in every Czech province depending tilt.

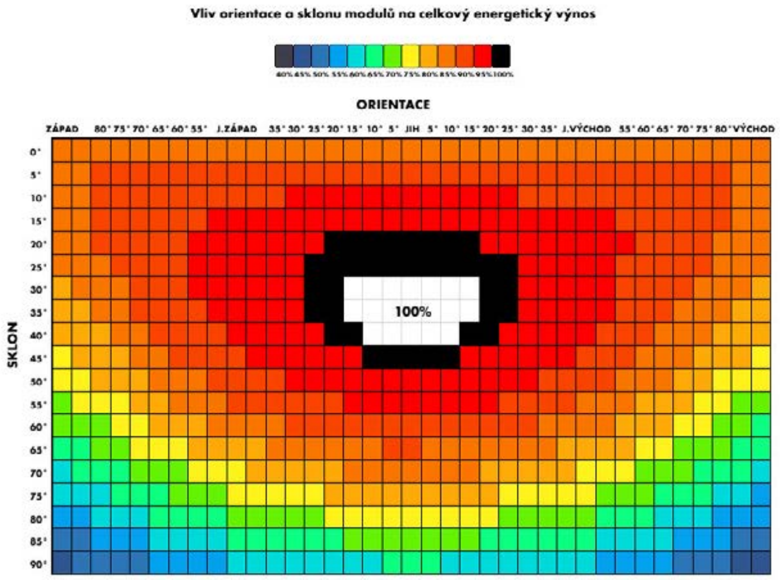


Table 3.1Radiation as according to the inclination and orientation

This table shows that the radiation is higher when the inclination is 30 ° to the horizontal and oriented to the south 0^{o} .

3.2. Optimal separation

The shadow on the solar modules makes its performance decreases if the partial shade and can even make the module no longer operating, so when the sun shines on a module, this casts a shadow, so to be separate modules so that the projection of the shading does not impinge on other modules.

The separation rows of modules is determined by the IDEA, which states that at solar noon worst day (minimum solar height) of the period of use, the shadow of the upper edge of a line projected onto the lower edge of the next row .

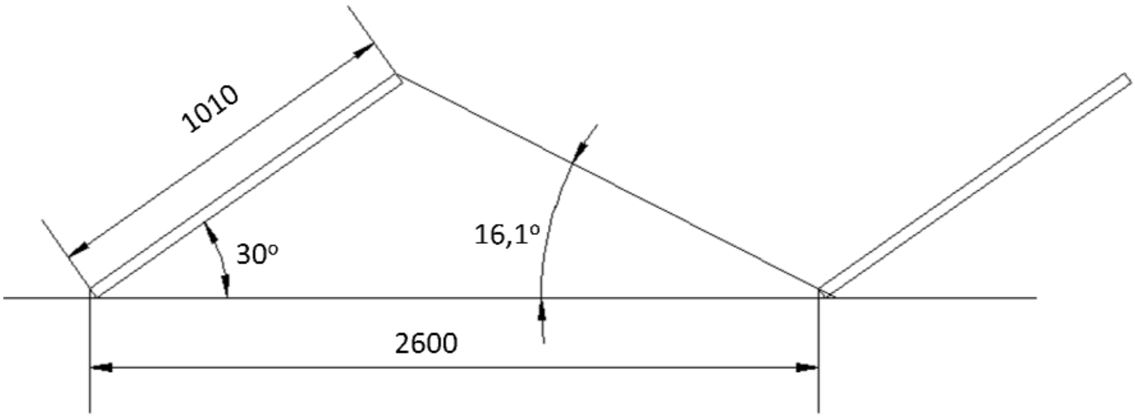
The minimum solar height noon on December 21 and according to IDEA can be calculated using the latitude of the location of the latitude is given.

H (°) = (90°-latitude) -23.5°

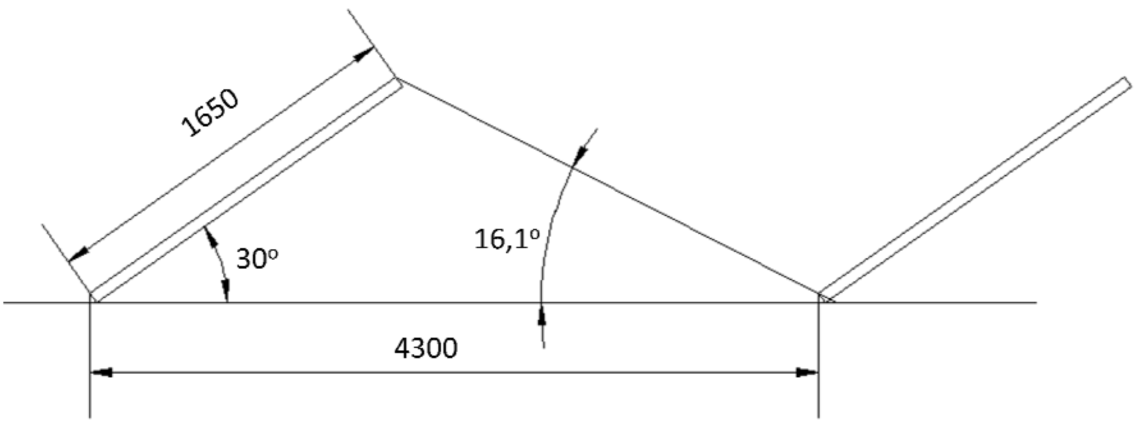
Since the latitude of the PV system 50° 24’ (50,4°)

H (°) = (90° -50,4) -23.5° = 16,1°

The photovoltaic module can be placed on the cover in landscape or portrait, so at first both calculations.



3.1Landscape or horizontal module Distance=2,6m



3.2 Vertical module Distance=4,3 m

One factor that may influence the installation and placement of the modules on the cover is the existing slope of the same, however, being the south-facing ship this value does not affect too much, this is shown in the next section.

3.3. Distribution module on the roof

Due it has the entire surface of the large deck do not have space problems. The modules will be placed horizontally, 30 rows of 51 modules each in the largest part of the building and 15 rows of 19 modules in the smaller part. Adding up the total of 1815 modules over 1809 are needed and leaving 10% of space for maintenance.

The modules are placed in landscape since the shadow is smaller. If the module assembly vertically, place the height of the facility would be greater, there will be major wind currents, although they were not enough, you can make more strength on the modules, so that the installation of the modules is done background.

4. MODULE STRUCTURE

4.1. Support structure

The structure of the solar panels must withstand surges of wind and snow, as indicated by the technical building code NBE-AE-88. For this purpose, the assumption of a worst case installation is performed.

4.1.1. Wind's Overload

In case of wind, according to regulations, its speed can cause dangerous dynamic pressure values. The dynamic pressure dependents on the wind speed it is directly to the height of the structure that the modules support in the field.

According to Table 5.1 of the NBE-AE-88 (Expressed in Table 3.1 of this project), the wind speed is 28 m / s and the dynamic pressure is 50 kg/m2.

Dynamic pressure					
High over the ground (m) Normal		Exposed		Wind speed	Wind dynamic pressure
From	To	From	To	(m/s)	(Kg/m2)
0	10	-		28	50
11	30	-		34	75
31	100	0	30	40	100
Over 100		31	100	45	125
-		Over 100		49	150

Table 4.1 Wind dynamic pressure (Table 5.1 NBE-AE-88).

Look how it affects this pressure to the structure, It is being find the force exerted by the wind on the structure, knowing that the force of the wind through the surface of the 30 modules that make up the structure at an angle of 30 ° (angle of modules).

The wind power is calculated by the follow formula:

$$f_v = w \cdot S \cdot sin\ \alpha$$

$$f_v = 50 \cdot 37{,}5 \cdot sin\ 30 = 937kp = 9kN$$

Where:

w = dynamic pressure (kg/m^2)

S = gather structure panel assembly surface

Sin α= inclination angle respect to horizontal

Wind forces should support the structure is 945 kp which is equivalent to 9.4 kN.

To see the overhead exercise the wind on the surface of the structure, the data help featuring NBE-AE/88 coefficient on wind resistance (Table 5.2).

$$p = c \cdot w$$

$$p = (+0{,}2) \cdot 50 = 10Kg/m^2$$

Where:

c = coefficient on wind resistance (Table 5.2)
w = dynamic pressure (kg/m^2)

Doing the sum of the initial pressure and the dynamic one, the total is $60kg/m^2$.

4.1.2. Snow 's Overload

According to NBE-AE-88, in case of snow, the worst weather event would be an overload of snow mixed with hail, with a load of 400 kg/m3.

The plates are placed on a metal structure. Each structure brings together 14 modules at an inclination of 35 º and the expected load is for a horizontal surface, therefore, this load is corrected.

According to the technical code for inclinations less than 60 °, the following expression is used:

$$p' = p \cdot cos\alpha$$

$$p' = 400 \cdot cos30^o = 346{,}4\ kg/m^3$$

It should consider overloading the snow conditions of 346,4 kg/m3.

Meteorological data from 1962, the highest recorded snowfall occurred in that year, and was 38 cm of snow, so we put ourselves in the most critical case. If this data attached to the load, the new pressure is:

$$p'' = p' \cdot h_m$$

$$p'' = 346{,}4\ \cdot 0{,}38 = 131{,}6\ kg/m^3$$

Where:

P’’=the new value pressure

H_m= The maximum snow storm

Therefore, the snow will overload 131,6 kg / m^2.

Wind Overload	Snow Overload	Structure characteristics
(Kg/m^2)	(Kg/m^2)	(Kg/m^2)
60	131,6	160

Table 4.2

Thus we can ensure that the structure will withstand sustained overloads of meteorological origin.

5. WIRING

The association of modules in series takes advantage of the characteristics of the PV module wiring boxes. Parallel connections of each subfield in the box are made continuous. In this case the inverter takes continuous. Disconnections advised in order to be able to partially separate the PV generator.

All drivers must be copper. The cable sizing is done to limit the voltage drops from the PV modules to the inverter input with values lower than 1%. From the inverter to the CGP is 2 %.

The cables used for interconnection must be protected against degradation, due to the weather: solar radiation, UV, and environmental conditions of high ambient temperature. PVC can be used, as this also provides isolation of 1000 V.

Since there are two criteria for dimensioning the leads are calculated by both methods, the size of the section for each section and for each method in the summary section of larger size is selected to meet two criteria.

5.1. Calculation of the phase voltage drop

It is a criterion based on REBT, which indicates the maximum voltage drop that can occur in the cable by flowing high intensity is below a certain value. According to REBT to the lines of force, considered as such interconnecting wiring of PV modules must not exceed 1.5%, however as books of photovoltaic systems is recommended to reduce this to 1%, which is the value used in this project. For three-phase AC lines should not exceed 1.5%.

To DC and CA monophasic:

$$\Delta U(\%) = \frac{2 \cdot I_{MPP} \cdot \rho \cdot L}{S \cdot U_N} x100$$

For three-phase AC (cos ϕ = 1):

$$\Delta U(\%) = \frac{\sqrt{3} \cdot I_{MPP} \cdot \rho \cdot L}{S \cdot U_N} x100$$

Or

$$\Delta U(\%) = \frac{(\frac{P}{\eta}) \cdot \rho \cdot L}{S \cdot (U_N)^2} x100$$

Where:

IMPP: current flowing through the cable when modules operate at the maximum power point (A).
ρ: resistivity wire PVC (0.01725 · mm2 / m for copper).
L: Cable length (m).
S: Conductor (mm2).
A: Tension when modules operate at the point of maximum power (V).
P: Power (W).

5.1.1. Wiring modules - DC protection box

It is intended wiring interconnecting branches forming modules 20 modules each. Then each arm is at a distance from the continuous protective casing, thereby a table for each branch is performed. The current flowing through them is continued.

I_{MPP}=8,46A;
V_{MPP}=648,4 V;

L = length of each branch interconnection (22m) + length to the inverter.

Line	Length (m)	Line	Length (m)	Line	Length (m)	Line	Length (m)
L1.1.1	98	L1.2.1	85	L1.3.1	71	L1.4.1	56
L1.1.2	95	L1.2.2	82	L1.3.2	68	L1.4.2	53
L1.1.3	92	L1.2.3	79	L1.3.3	65	L1.4.3	50
L1.1.4	89	L1.2.4	76	L1.3.4	62	L1.4.4	48
L1.1.5	86	L1.2.5	73	L1.3.5	59	L1.4.5	45
L1.1.6	83	L1.2.6	70	L1.3.6	56	L1.4.6	43
L1.1.7	80	L1.2.7	67	L1.3.7	53	L1.4.7	40
L1.1.8	77	L1.2.8	64	L1.3.8	50	L1.4.8	37
L1.1.9	74	L1.2.9	64	L1.3.9	47	L1.4.9	35
L1.1.10	71	L1.2.10	61	L1.3.10	44	L1.4.10	32
L1.1.11	68	L1.2.11	58	L1.3.11	41	L1.4.11	30
L1.1.12	65	L1.2.12	55	L1.3.12	38	L1.4.12	27
L1.1.13	62	L1.2.13	55	L1.3.13	35	L1.4.13	24
L1.1.14	59	L1.2.14	52	L1.3.14	32	L1.4.14	22
L1.1.15	56	L1.2.15	49	L1.3.15	29	L1.4.15	19
L1.1.16	53	L1.2.16	46	L1.3.16	26	L1.4.16	17
L1.1.17	50	L1.2.17	46	L1.3.17	23	L1.4.17	14
L1.1.18	47	L1.2.18	43	L1.3.18	20	L1.4.18	11
L1.1.19	44	L1.2.19	40	L1.3.19	17	L1.4.19	9
L1.1.20	41	L1.2.20	37	L1.3.20	14	L1.4.20	6
L1.1.21	38	L1.2.21	37	L1.3.21	11	L1.4.21	4
L1.1.22	35	L1.2.22	34	L1.3.22	8	L1.4.22	2

Table 5.1 Length of current lines between the modules and the enclosure DC

To check if fulfills, just consider the longest line.

The minimum section according to the RBT for copper is 6 mm2, so check whether it complies or section is increased.

Line	Section (mm^2)	Length (m)	I_{MMP}(A)	U_{MMP}(V)	ΔU(%)
L1.1.1	6	98	8,46	648,4	0,735

Table 5.2 Longest line and voltage drop.

For all lines fulfills, and also is less than 1%.

5.1.2. Wiring DC protection box - inverter

It is about a DC wiring it arrives to the inverter.

Line	Section (mm^2)	Length (m)	I_{MMP}(A)	U_{MMP}(V)	ΔU(%)
L2.1	6	2	90,945	648,4	0,16
L2.2	6	2	90,945	648,4	0,16
L2.3	6	2	90,945	648,4	0,16
L2.4	6	2	90,945	648,4	0,16

Table 5.3

The wiring coming from line 1 and 2 are DC cable so the sum of both voltage drops may not exceed the value of 1%.

ΔUL1.1+ΔUL2 = 0,735+0,16 =0,89 % < 1%

5.1.3. Wiring inverter - AC protection box

This is three phase wiring that connects the inverter box ac protections.
According to REBT voltage drop shall not exceed 1.5%.
Values to calculate the voltage drop is obtained from the output of the inverter.
P = 500kW;
η = 98,6%;
cos ϕ = 1;
UN = 300V;
Because the inverter is located near protection box to AC, just a cable length of 3 meters is required.

Line	Section (mm^2)	Length (m)	P (kW)	η (%)	U_N (V)	ΔU(%)
L3	70	3	500	98,6	300	0,41

Table 5.4

5.1.4. Wiring AC protection box - transformer

This is the phase cable running from the box AC protection to the factory transformer.

The length of buried cable to be installed is 25 m.

This calculation must take into account the voltage drop between the inverter and the connection point must not exceed 1.5%.

Line	Section (mm^2)	Length (m)	P (kW)	η (%)	UN (V)	cos ϕ	ΔU(%)
L4	185	25	500	96,8	300	0,98	1,31

Table 5.5 Length and voltage drop of the AC line, between protection box and the AC transformer.

As this wiring and former AC cable form, must have in mind that the sum of the two voltage drops cannot exceed the value of 1.5%.

$U_{L3}(\%)+ U_{L4}(\%)=1,723\ \% > 1,5\%$.

It can increase section of L3 or L4. It will be increase L4 due it has higher voltage drop.

Line	Section (mm^2)	Length (m)	P (kW)	η (%)	UN (V)	cos ϕ	ΔU(%)
L4	240	25	500	96,8	300	0,98	1,01

Table 5.6 Length and voltage drop of the AC line, between protection box and the transformer.

$U_{L3}(\%)+ U_{L4}(\%)=1,42\ \% > 1,5\%$.

5.2. Calculation of the phase. Thermal criteria

The thermal criteria or criterion of maximum intensity is based on REBT that whereby drivers must not exceed the maximum permissible current flowing for them when the maximum intensity of service.

$I_{DESIGN} < I_{MAX}$

$I_{DESIGN} = 1.25 \cdot I$

Safety factors and correction factors based on the layout and characteristics of the driver to the maximum current that can flow through the driver apply.

5.2.1. Wiring modules - DC protection box

It is the wirer intended to interconnecting branches forming modules of 20 panels each. Then each branch is some distance from the inverter, so that is why there is a table for each branch is performed. The current flowing through them is still current.

These cables are placed on the deck of the warehouse, tibos inside PVC.

I_{MPP} = 8,46 A;

The maximum operating current is applied a safety factor

$I_{DESIGN} = 1.25 \cdot I_{MPP}$ = 10,575 A

Correction coefficients (According REBT):

- For this case there is no correction coefficient as it is conductive tube at a temperature below 40 ° C.

		1	2	3	4	5	6	7	8	9	10	11
A	Conductores aislados en tubos empotrados en paredes aislantes		3x PVC	2x PVC		3x XLPE o EPR	2x XLPE o EPR					
A2	Cables multiconductores en tubos empotrados en paredes aislantes	3x PVC	2x PVC		3x XLPE o EPR	2x XLPE o EPR						
B	Conductores aislados en tubos[2] en montaje superficial o empotrados en obra				3x PVC	2x PVC			3x XLPE o EPR	2x XLPE o EPR		
B2	Cables multiconductores en tubos[2] en montaje superficial o emprotrados en obra			3x PVC	2x PVC		3x XLPE o EPR		2x XLPE o EPR			
C	Cables multiconductores directamente sobre la pared[1]					3x PVC	2x PVC		3x XLPE o EPR	2x XLPE o EPR		
E	Cables multiconductores al aire libre[4]. Distancia a la pared no inferior a 0.3D[5]						3x PVC		2x PVC	3x XLPE o EPR	2x XLPE o EPR	
F	Cables unipolares en contacto mutuo[4]. Distancia a la pared no inferior a D[5]							3x PVC			3x XLPE o EPR[1]	
G	Cables unipolares separados mínimo D[5]									3x PVC[1]		3x XLPE o EPR
	mm²	1	2	3	4	5	6	7	8	9	10	11
Cobre	1,5	11	11,5	13	13,5	15	16	-	18	21	24	-
	2,5	15	16	17,5	18,5	21	22	-	25	29	33	-
	4	20	21	23	24	27	30	-	34	38	45	-
	6	25	27	30	32	36	37	-	44	49	57	-
	10	34	37	40	44	50	52	-	60	68	76	-
	16	45	49	54	59	66	70	-	80	91	105	-
	25	59	64	70	77	84	88	96	106	116	123	166
	35		77	86	96	104	110	119	131	144	154	206
	50		94	103	117	125	133	145	159	175	188	250
	70				149	160	171	188	202	224	244	321
	95				180	194	207	230	245	271	296	391
	120				208	225	240	267	284	314	348	455
	150				236	260	278	310	338	363	404	525
	185				268	297	317	354	386	415	464	601
	240				315	350	374	419	455	490	552	711
	300				360	404	423	484	524	565	640	821

1) A partir de 25 mm² de sección.
2) Incluyendo canales para instalaciones -canaletas- y conductos de sección no circular.
3) O en bandeja no perforada.
4) O en bandeja perforada.
5) D es el diámetro del cable.

This case corresponds to a type B installation since it is insulated in conduit mounting surface. And for two load conductors with PVC insulation, the capacity immediately increased the maximum current is 15 A and corresponds to a cross section of 1.5 mm^2.

I_{DESIGN} = 10,575 < I_{MAX} = 15 A; Complies with S = 1.5 mm^2

Therefore, as the cord used in the wiring of the modules is 6 mm^2 also fits.

Wiring between protection box and the inverter DC

5.2.2. Wiring DC protection box- inverter

I_{MPP} = (8,46 A · 86 branches)/8 inputs = 90,945 A;

$I_{DESIGN\ MPP}$ = 1.25 · I = 113.68 A;

Correction coefficients (According REBT):

- In this case no correction coefficients, as it is tube-driving at a temperature of 40 ° C.

From Table 1. Entering in row B for being unipolar conductors in conduit, in column 3 x PVC, exceeding the I_{DESIGN}. I get a section of 50 mm^2 for capacity of 117 A.

I_{DESIGN} = 90,945 <I_{MAX} = 117 A; Complies with S = 50 mm^2

5.2.3. Wiring inverter- AC protection box

This is three phase wiring that connects the inverter box ac protections.
In this case I have the power supplied by the inverter, so I use the following formula:

P_N= 500kW;
η = 0.986;
cos ϕ = 1
U_N = 300 V;

$$I_{INVERTER} = \frac{\frac{P_N}{\eta}}{\sqrt{3} \cdot U_N \cdot cos\varphi} x100 = 451{,}8\ A$$

I_{DESIGN} =1,25· $I_{INVERTER}$=564 A;

Correction coefficients (According REBT):
In this case there are not correction coefficients, as it is tube-driving at a temperature of 40 ° C.

From Table 1. Entering in row B for being one-pole conductors in conduit, in column 2x XLPE, exceeding the I_{DESIGN}. It is got a 300 mm^2 section for capacity of 565 A

I_{DESIGN} = 564 < I_{MAX} = 565 A; Complies with S = 300 mm^2

5.2.4. Wiring AC protection box - transformer

This is the three phase cable running from the AC box protections to the transformer located in the factory.

The cable is buried in a tube with a length of 25 m.
Correction coefficients:

- Correction factor for a line with four single conductors located within the same tube: 0.97.

From Table 21SE obtains the maximum allowable intensity in this case

Table 21. Carrying capacities for cables with copper conductors buried installation for the RBT-ITC-07

SECCIÓN NOMINAL mm^2	Terna de cables unipolares (1) (2)			1cable tripolar o tetrapolar (3)		
						
	TIPO DE AISLAMIENTO					
	XLPE	EPR	PVC	XLPE	EPR	PVC
6	72	70	63	66	64	56
10	96	94	85	88	85	75
16	125	120	110	115	110	97
25	160	155	140	150	140	125
35	190	185	170	180	175	150
50	230	225	200	215	205	180
70	280	270	245	260	250	220
95	335	325	290	310	305	265
120	380	375	335	355	350	305
150	425	415	370	400	390	340
185	480	470	420	450	440	385
240	550	540	485	520	505	445
300	620	610	550	590	565	505
400	705	690	615	665	645	570
500	790	775	685	-	-	-
630	885	870	770	-	-	-

$I_{DESIGN} = 1.25 \cdot I_{INVERTER} = 564$ A;

As we increase the section fails:
For a section of 400 mm^2, corresponds to an $I_{MAX, ADM=}$ 615 A
$I_{MAX} = 615 \cdot 0.8 = 492$ A

$I_{DESIGN} = 564 > I_{MAX} = 492$ A, not satisfied with a $S = 400\ mm^2$

As we increase the section fails:
For a section of 630 mm^2, corresponds to an $I_{MAX, ADM} = 770$ A
$I_{MAX} = 770 \cdot 0,8 = 616$ A
$I_{DESIGN} = 564 < I_{MAX} = 616$ A; Complies with $S = 630\ mm^2$

5.3. Final design of the phase

The size of the wire has to be the higher section between all the methods has been studied.

Place	Section (mm^2)
Modules - DC protection box	6
DC protection box - Inverter	50
Inverter - AC protection box	300
AC protection box - Transformer	630

Table 5.7

5.4. Protection wiring dimensioning

Exposed-conductive-parts used in the manufacturing process of electrical equipment are separated from the live parts of the equipment by the "basic insulation". Failure of the basic insulation will result in the exposed-conductive-parts being alive. Touching a normally dead part of electrical equipment which has become live due to the failure of its insulation, is referred to as an indirect contact.

Protective conductors are formed of the same material as the phase conductors, and its section is determined by the following table.

Installation section S(mm^2)	**Minimum protection section Sp (mm^2)**
$S \leq 16$	Sp = S
$16 \leq 35$	Sp = 16
$S > 35$	Sp = S/2

Table 5.8. Link between the section phase and the minimum section of protective conductors.

Under the table leads to non-standard values higher standard section are used.

For wiring between the modules and DC protection box phase cable is 6 mm^2. Then the table is obtained that under sections 16 mm^2 protective conductors is equal to the phase section.

For wiring between DC protection box and the inverter cable is 50 mm^2. Then according to the table the section chosen will be the half of the phase conductor, 25 mm^2.

For wiring between inverter and AC protection box is 300 mm^2. Then according to the table the section chosen will be the half of the phase conductor, 150 mm^2.

For wiring between AC protection box and the transformer is 630 mm^2. Then according to the table the section chosen will be the half of the phase conductor 315 mm^2, however, as there is no standard of 315 mm^2 section immediately above standard is chosen to be 400 mm^2.

Place	Section (mm^2)	Protection section (mm^2)
Modules - DC protection box	6	6
DC protection box - Inverter	35	25
Inverter - AC protection box	300	150
AC protection box - Transformer	240	400

Table 5.9

6. SIZING PIPING

Phase and protection wiring are placed inside of a tube to protect the wiring of the physical, chemical and electrical effects as well of impacts, high and low temperatures, water, corrosion...

They also serve to install a structured and organized manner.

The protection casing is made of PVC.

The sizing is obtained from table 5.1.

Nominal section unipolar (mm^2)	**Outdoor pipe diameter (mm)**				
	Number of links				
	1	2	3	4	5
1,5	12	12	10	16	20
2,5	12	16	20	20	20
4	12	16	20	20	25
6	12	16	25	25	25
10	16	25	25	32	32
16	20	25	32	32	40
25	25	32	40	40	50
35	25	40	40	50	50
50	32	40	50	50	63
70	32	50	63	63	63
95	40	50	63	75	75
120	40	63	75	75	-
150	50	63	75	-	-
185	50	75	-	-	-
240	63	75	-	-	-

Table 6.1 Minimum outside diameters of the tubes according to the section number and the corresponding drivers to ITC-BT-21

For wiring between the modules and DC protection box the cable is 6 mm^2. The number of leads is two, since it is single phase, but also there is a wire intended for protection, whence it is considered to be three cables.

According to the table, is obtained, for 6 mm^2 sections and three wires, the outside diameter of the protective tube is 25 mm.

For wiring between DC protection box and the inverter is 35 mm^2. Being single phase and having the protection wire, there are three cables. From the table is obtained for 35 mm^2 sections and three wires, the outside diameter of the protective tube is 40 mm.

For wiring between inverter and AC protection box is 150 mm^2. When the cable has, three-phase and protection wire, have five cables. Then from the table is obtained for 150 mm^2 sections and five wires, the outside diameter of the protective tube is 75 mm.

For wiring between AC protection box and the transformer is 240 mm^2. As this is a buried section of 20 meters, so that in this case the table 5.2 is used for sizing.

Nominal section unipolar (mm^2)	**Outdoor pipe diameter (mm)**				
	Number of links				
	≤ 6	7	8	9	10
1,5	25	32	32	32	32
2,5	32	32	40	40	40
4	40	40	40	40	50
6	50	50	50	63	63
10	63	63	63	75	75
16	63	75	75	75	90
25	90	90	90	110	110
35	90	110	110	110	125
50	110	110	125	125	140
70	125	125	140	160	160
95	140	140	160	160	180
120	160	160	180	180	200
150	180	180	200	200	225
185	180	200	225	225	250
240	225	225	250	250	-

Table 6.2 Minimum outside diameters of pipes buried in the number and selection of drivers for the ITC-BT-21

From this table it is obtained for 240 mm^2 three-phase sections, three wires plus the protective one so finally the sum it is 5 wires. Whence it is get the outside diameter of the protective tube is 225 mm

Place	Section (mm^2)	Protection section (mm^2)	Casing diameter (mm)
Modules - DC protection box	6	6	25
DC protection box - Inverter	35	25	40
Inverter - AC protection box	300	150	75
AC protection box - Transformer	240	400	225

Table 6.3

7. PROTECTION SIZING

7.1. String fuses sizing

The short circuit current of a module is little more than the operating current, so in a single string system, a circuit fuse would simply not detect or operate to clear a short circuit fault.

In systems with multiple strings some fault scenarios can result in the current from several adjacent strings flowing through a single string and the prospective fault current may be such that overcurrent protective devices are required. Hence, the selection of overcurrent protective measures depends upon the system design and the number of strings.

While string cable sizes can be increased as the number of parallel connected strings (and the potential fault current) increases, the ability of a module to withstand the reverse current must also be considered.

The requirements for the proper calibration UNE 20-460-4-43:

$I_B \leq I_N \leq I_Z$
$I_2 \leq 1.45 \cdot I_Z$
where:
I_B = current of the circuit
I_Z = conductor ampacity steady state
I_N = nominal rated current of the protective device regulated (gauge)
I_2 = conventional current ensuring effective operation of the device protection (trip or fusion)

And because it fuses type standard gG (EN 60269) must meet that $I_2 \leq 1.6 \cdot I_N$

7.2. Circuit breakers sizing

To determine the calibration circuit breakers against short circuits, it must meet three conditions:

- The breaking capacity must be equal or greater than the maximum short circuit current under that point of the installation.

$$PdC > I_{SCMAX}$$

- The protective device must have a drive current of less than the minimum short-circuit current under that point electromagnetic shutter installation.

$$I_a < I_{SCMIN}$$

- Weather cut against short circuits breaker must not exceed it takes the driver to reach its allowable temperature.

$(I^2t)_{shot\ IA} < (I^2t)_{Permissible\ conductor} = K^2S^2$

Where:

$(I^2t)_{shot\ IA}$: The specified operating power protection device.
K^2S^2: Maximum tolerable duration energy for short cable section S.
K: constant depending on the material of the conductor and the insulation.

Where I_a is the current controlled by a tripping type C, that is, I_a is equal to between 5 and 10 times the IN. $I_a = 10 \cdot I_N$ is taken.

And to protect against overload and short circuit

- $I_B \leq I_N \leq I_Z$
- $I_2 < 1.45\ I_Z$. He always keeps in circuit breaker, since $I_2 = 1.45 \cdot I_N$.

7.3. DC sizing protections

7.3.1. Fuse in each branch

In electronics and electrical engineering, a fuse is a type of low resistance resistor that acts as sacrificial device to provide overcurrent protection, of either the load or source circuit. It is essential component is a metal wire or strip that melts when too much current flows through it, interrupting the circuit that it connects. Short circuits, overloading, mismatched loads, or device failure are the prime reasons for excessive current. Fuses are an alternative to circuit breakers.

Details of the branch where the fuses are installed:
Maximum current per branch: 8,46 A
Ampacity by conductor ($S = 6mm^2$) = 36A

First a caliber greater than the current branch is selected, in this case 16 A, and the conditions are checked.
I_B =8,46 A;
I_Z = 36A;
I_N = 16A;
$I_B \leq I_N \leq I_Z$; 8,46≤ 16 ≤ 36 ; OK

$I_2 \leq 1{,}45 \cdot I_Z$;
$I_2 \leq 1{,}6 \cdot I_N$;

$1{,}6 \cdot I_N \leq 1{,}45 \cdot I_Z$;
$I_N \leq 0{,}90625 \cdot I_Z$;
$I_N \leq 0{,}90625 \cdot 36$; 16 ≤ 32,63; OK

7.3.2. DC switch disconnections

Interrupter switches to isolate the portion of the circuit current flow at will. A switch-disconnector is installed to protect the inverter input.

Intensity of service = 90.945 A
Ampacity by conductor ($S = 35mm^2$) I_Z = 104 A

Gauge is selected: I_N = 115A

It is verified that meets:

- $I_B \leq I_N \leq I_Z$
  90.945 ≤ 100 ≤ 104; OK

Interrupter switch Features:
I_N = 100 A
PdC = 22 KA
3-pole

7.4. AC protections sizing

7.4.1. MCB, Miniature circuit breakers

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current flow. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect an individual household appliance up to large switchgear designed to protect high voltage circuits feeding an entire city.

The current and voltage of the inverter output are:

Intensity of service = 564 A

Ampacity by conductor (buried cable, S = 400mm^2) I_Z = 615 A

Shorting front calculation calculating circuit current is obtained from the equivalent single-phase using the formula:

$$I''_k = \frac{U_{nT}}{\sqrt{3}\,Z_k}$$

U_{nT} is the secondary standard voltage of the transformer

Z_K is the equivalent impedance of the circuit to be analyzed. It is calculated as the impedance of the circuit, referred to the secondary of the transformer, the elements tours of the short circuit current, between the point of the event and the place is considered constant voltage (infinite power, across the primary of the transformer).

$$Z_k = Z_{TRAFO} + Z_L$$

Z_L is the impedance of the conductors and is calculated as:

$$Z_L = \sqrt{R_L^2 + X_L^2}$$

Where:

$$R_L = \rho \cdot \frac{l}{S};$$

$$\rho_{Cu} = \frac{1}{58} \Omega \frac{mm}{m}$$

$$X_L = 0 \; to \; sections \; smaller \; than \; 120mm^2$$

$$X_L = 80 \frac{m\Omega}{Km} \; for \; underground \; sections \; higher \; than \; 120 \; mm^2$$

Z_{TR} is the impedance of the distribution transformer.

- The value of inductive and resistive components winding of the transformer, from where are coming its voltage drops, given by ε_{CC} = 4%, with X_{CC} = 0.95 = 0.31 Z_{CC} and R_{CC} X_{CC}

$$Z_{cc} = \frac{\varepsilon_{cc} \cdot U_{nT}^2}{100 \cdot S_{nT}}$$

Short is calculated only on the secondary of transformer:

$$Z_{cc} = \frac{\varepsilon_{cc} \cdot U_{nT}^2}{100 \cdot S_{nT}} = \frac{4}{100} \cdot \frac{400^2}{630 \cdot 10^3} = 10{,}15m\Omega$$

$$X_{cc} = 0{,}95 \cdot Z_{cc} = 9{,}65m\Omega$$
$$R_{cc} = 0{,}31 \cdot X_{cc} = 3m\Omega$$

Now it is calculated at the beginning of the line, where will the circuit breaker, which is at a distance of 25 meters from the secondary.

$$R_L = \frac{L}{\rho \cdot S} = \frac{25}{58 \cdot 240} = 1{,}8m\Omega$$
$$X_L = 80 \frac{m\Omega}{Km} \cdot 0{,}025km = 2m\Omega$$

$$Z_k = \sqrt{(R_{cc} + R_L)^2 + (X_{cc} + X_L)^2}$$

$$Z_k = \sqrt{(3 + 1{,}8)^2 + (9{,}65 + 2)^2} = 12{,}6m\Omega$$

$$I''_K = \frac{U_{nT}}{\sqrt{3} \cdot Z_K} = \frac{400}{\sqrt{3} \cdot 12{,}6 \cdot 10^{-3}} = 18{,}32\ kA$$

And also the end of this line that is 3 meters long and a section of 300mm^2.

$$R_L = \frac{L}{\rho \cdot S} = \frac{3}{58 \cdot 300} = 0{,}17 m\Omega$$

$$X_L = 80 \frac{m\Omega}{Km} \cdot 0{,}003 km = 0{,}024 m\Omega$$

$$Z_k = \sqrt{(R_{cc} + R_L)^2 + (X_{cc} + X_L)^2}$$

$$Z_k = \sqrt{(3 + 0{,}17)^2 + (9{,}65 + 0{,}024)^2} = 10{,}18 m\Omega$$

$$I''_K = \frac{U_{nT}}{\sqrt{3} \cdot Z_K} = \frac{400}{\sqrt{3} \cdot 10{,}18 \cdot 10^{-3}} = 22{,}68\ kA$$

$P_{dC} > I_{CCMAX}$ =18,32 kA,
Ia < I_{CCMIN} = 18,32 KA therefore as it is a type C curve ($I_a = 10 \cdot I_N$), you can select a size of
$10 \cdot I_N$ <14.18 kA, then IN <1.42 kA.

Another restriction is that it must pass the current through the cable under normal conditions; it cannot be less than the current section 300 mm^2, which is 564 A. So looking for a next and superior value to 564 A.

For this case the possible sizes of the circuit-breaker
I_N = 550-630 A
P_{dC} = 18-25-36-50 KA

To calculate the time cut short circuit breaker must calculate the maximum tolerable energy conductor.

The value of K is given by the copper conductor and the insulation of PVC and has a value of K=116.

(I_t^2)Ampacity driver=$K^2S^2=116^2 \cdot 300^2=1211 \cdot 10^6$

(I_t^2)shot I_A (Para I_N=630 A y P_{dC}= 25 KA)≈ 6·105
(From the tables of the manufacturer, Moeller)
(I_t^2)shot IA < (I_t^2) Ampacity driver; OK

Now check that it meets the overload condition:

· $I_B \leq I_N \leq I_Z$
564 ≤ 630 ≤ 615; Do not meet the requirements.

Therefore, as has the possibility of regulation, $I_r = 0.8\text{-}1 \cdot I_N$, is regulated to about 195 A to approximately satisfy the condition, obtaining a $I^r = 0.97 \cdot I_N$.
Now you have a main switch, with $I_N = 630 \cdot 0,97 = 611$ A

Features after the regulation:
$I_N = 611$ A
$I_r = 0.97 \cdot I_N$
$P_{dC} = 25$ KA
4-pole

7.4.2. RCD, Residual-current device

A residual-current device (RCD), or residual-current circuit breaker (RCCB) is an electrical wiring device that disconnects a circuit whenever it detects that the electric current is not balanced between the energized conductor and the return neutral conductor. Such an imbalance may indicate current leakage through the body of a person who is grounded and accidentally touching the energized part of the circuit. They are not intended to provide protection against overcurrent (overload) or all short-circuit conditions.

A circuit breaker is installed in the inverter output to protect individuals from referrals, thereby detect fault current is 30 mA.
In order to make a good sized, the differential is the same caliber as the breaker switch. I_N=630A, set at $I_N = 611$ A

7.4.3. Main switch border

Sizing is the same as that performed in the AC enclosure, but in this case was located in the general enclosure, and must be accessible to the distributor.

Features:

I_N=611 A
I_r=0,97· I_N
P_{dC}= 25 KA
4 poles

7.4.4. Differential switch

A circuit breaker is installed in the general enclosure, and must be accessible to distributor, It is intended to protect individuals from referrals, thereby detect fault current is 30 mA.

In order to make a good sized, the differential is the same caliber as the breaker switch. I_N=611A

7.4.5. AC Fuse

Is protected against overloads by fuses, wiring that connects the three phase junction box coils. These fuses are accessible to the company.

Details of the branch where the fuses are installed:

Maximum intensity: 564 A
Ampacity by conductor (buried cable, S = 150mm^2) I_Z = 615 A
First a caliber greater than current is selected, in this case 630 A, and the conditions are checked.
I_B =564 A;
I_Z = 615 A;
I_N = 630 A;
$I_B \leq I_N \leq I_Z$;564 ≤ 630 ≤ 615; Do not meet the requirements.

After sizing the line, the features are:
Maximum current: 564 A
Ampacity by conductor (buried cable, S = 185mm2) IZ = 730 A

I_Z = 730 A;
I_N = 630 A;
$I_2 \leq 1{,}45 \cdot I_Z$;
$I_2 \leq 1{,}6 \cdot I_N$;
$1{,}6 \cdot I_N \leq 1{,}45 \cdot I_Z$;
$I_N \leq 0{,}90625 \cdot I_Z$;
$I_N \leq 0{,}90625 \cdot 730$;
200 ≤ 650 ; OK

7.5. Surge arrester

To protect the installation against overvoltage a surge arrester is installed in the continuous part.

To size the discharger is required to know the value of higher nominal voltage of both the voltage and the maximum power vacuum. Although the maximum output voltage is the voltage at which predictably installation work is necessary to consider that can get to work in vacuum under some circumstances.

V_{SC_SIST}= 769.4 V;

V_{MPP_SIST} = 648 V;

The nominal voltage arresters: U_N = 1000V.

On the other hand it is necessary to determine the type of case and the values of Imax and In (discharge capacity) thereof. The most common solution in this type of facility is a shield with a value of Imax = 40 kA and In=20 kA, which are the recommended minimum policy level (UNE60364-5-534).

Finally will be installed an end-of-life indicators are associated with the internal disconnector and the external SCPD of the SPD to informs the user that the equipment is no longer protected against overvoltages of atmospheric origin.

8. GROUND WIRE SIZING

To size the grounding must perform several calculations, first the maximum allowable strength, then set the electrodes to be placed.

8.1. Resistance maximum allowed

According to ITC-BT-18, provides that local or driver setting, the limit is 24V, as in this case.

For protection by RCD, the following expression is used:

$$R_t \leq \frac{U_L}{I_S}$$

And the current expression is given by the discharge current of the RCD, which is 30 mA.

$$R_{t,max} \leq \frac{24}{0{,}03} = 800\Omega$$

8.2. Design of electrodes

The earth resistance is obtained as a function of soil resistivity and feature electrode, Table 7, so conversely, clearing the resistivity and assuming a length, you can get the number of cutting tools that are needed.

Electrode	Ground resistance
Input plate Vertical pike Horizontal underground driver	R=0,8ρ/P R=ρ/L R=2ρ/L
ρ ground resistance (Ω/m) P=perimeter plate (m) L= length from the pike to the driver (m)	

Table 8.1. Earth resistance depending on electrode ITC-BT-18

In this case the pike is placed vertically, so:

$$R_t = \frac{\rho}{L} \cdot N_{pikes}$$

Type of soil	Resistance average value (Ω/m)
Wet soil	50
Others	500
Dry soil	3000

Table 8.2. Ground resistance depending on the resistivity of the respective land ITC-BT-18

Whereas as a soil dry soil, the resistivity value is 500.

If the pikes to drop are 2 meters long, and buried at a depth of 0.5 meters, three meters separated from each other, we have:

$$R_t = \frac{500}{2} \cdot N_{pikes} \rightarrow R_t \leq R_{t,max} \rightarrow \frac{500}{2} \cdot N_{pikes} \leq 800 \rightarrow N_{pikes} \leq 3{,}2$$

So 3 pikes maximum therefore taken for valid configuration 2 electrode length of 2 meters, to a depth of 0.5 meters and 3 meters away from them, with this configuration needed is obtained:

$$R_t = \frac{500}{2} \cdot N_{pikes} = \frac{500}{2} \cdot 2 = 125\ \Omega$$

9. CALCULATION OF THE ANNUAL ELECTRICITY OUTPUT EXPECTED

The electricity production of photovoltaic modules for a year depends on parameters of the energy source, solar radiation in the area and the elements and factors of the PV system.

First an analysis of the variables or parameters that influence is performed, and then has to explain the method of calculation used for the annual production.

9.1. Production function estimation

The estimate of the production of a photovoltaic system connected to the transformer of the company can be done by the following method of calculation.

1. It starts from the time data of ambient temperature and incident solar irradiance in the plane of the PV generator of a typical meteorological year.

For each value of irradiance, G, and ambient temperature, T_a, the power at the maximum power point of an ideal PV generator, P_m, can be obtained from the value of the power at STC, Pm* , applying the following equations.

$$P_m = P_m^* \cdot \frac{G}{G^*}[1 - \delta(T_c - T_c^*)]$$

$$T_c = T_a + \frac{TONC - 20}{800} \cdot G$$

Where:

- G is the global irradiance incident on the surface of the photovoltaic module.
- T_c is the cell temperature.
- T_a is the ambient temperature.
- P_m is the power at the maximum power point of the PV generator.
- P_m* is the nominal power under standard conditions, STC.
- TONC is the nominal operating temperature.
- δ is the coefficient of variation with temperature of the power.
- G* is the irradiance at STC, G * = 1 kW / m².
- T_c* STC is the temperature, T_c* = 25 ° C.

G	800 W/m^2	Pm	199,16Wp	Tc*	25 ^oC
Tc	25^oC/45^oC	Pm*	270Wp	G*	1000 W/m^2
Ta	20^oC	TONC	47^oC		

Table 9.1

2. The power, Pm, obtained is applied to a general percentage of losses in the DC part of the installation (LDC) obtained as the product of the various losses, Li, DC, mismatch, LM; dust and dirt, LPS; angular and spectral, LAS; ohmic DC, Lohm, DC; and rated power, LPN). In this way is being obtained the power available at the output of the PV.

$$L_{DC} = 1 - \prod_i \left(1 - L_{i,DC}\right)$$

$$P_{DC} = P_m(1 - L_{DC})$$

3. An inverter is supposed to yield tracking maximum power point, η_{SMPP}, the particular inverter (also could be considered a yield curve based SMPP power), which has some associated energy losses, L_{SMPP}.

$$L_{SMPP} = 1 - \eta_{SMPP}$$

$$L_{SMPP} = 1 - 0{,}986 = 0{,}014kW$$

With this you can estimate the power available at the input to the inverter, $P_{DC,SPMP}$, as:

$$P_{DC,SMPP} = P_{DC}\ \eta_{SMPP} = P_{DC}(1 - L_{SMPP})$$

$$P_{DC,SMPP} = 500 \cdot 0{,}986 = 493kW$$

4. The AC power P_{AC}, the output of the inverter can be calculated considering the curve AC / DC inverter performance. In this case the expression of European performance is used.

$$P_{AC} = P_{DC,MPP}\ \eta_{inv}$$

$$P_{AC} = 500 \cdot 0{,}984 = 492kW$$

5. The power obtained in the previous section applies a percentage of losses in the AC, $L_{ohm,AC}$ wiring.

$$P_{Ohm,AC} = P_{AC}(1 - L_{Ohm,AC})$$

9.2. Array losses

Generally speaking, array losses can be defined as all events which penalize the available array output energy by respect to the PV-module nominal power as stated by the manufacturer for STC conditions. This is the philosophy stated by the JRC/Ispra European Centre recommendations, through the Normalized performance index and the Performance Ratio. Several of these loss sources are not directly measurable.

Starting with incident irradiation in the collector plane (after taking irradiation shading effects into account), one can imagine that an ideal PV-array should yield one kW/kWp under an irradiance (Ginc) of 1 kW. That is, assuming a linear response according to Ginc, the ideal array will produce one kWh energy under one kWh irradiance for each installed kWp (as defined at STC).
This ideal yield is diminished by the following losses:

- Shading losses (irradiance deficit and electrical effect). These are included in the official PR definition established by JRC/Ispra, as well as the IAM loss. It is not clear if the Horizon loss (far shadings) is included or not in the official PR.
- Incidence angle modifier (IAM), is an optical effect (reflexion loss) corresponding to the weakening of the irradiation really reaching the PV cells surface, with respect to irradiation under normal incidence.

- Irradiance Loss: the nominal efficiency is specified for the STC (1000 W/m²), but is decreasing with irradiance according to the PV standard model.

- Thermal behavior of the PV array. The standard test conditions are specified for a cell temperature of 25°C, but the modules are usually working at much higher temperatures. The thermal loss is calculated following the one-diode model. For crystalline silicon cells, the loss is about -0.4 %/°C at MPP. For fixed voltage operating conditions, the temperature mainly affects the I/V curve voltage, and effective losses are strongly dependent on the array overvoltage by respect to the operating voltage.

The parameters available to the user (thermal loss factor) involve the cell temperature determination by respect to given external conditions.

- Real module performances of the module by respect to the manufacturer specifications. PVSYST uses effective specification parameters to calculate the primary PV-array characteristics. The user may define a relative loss factor, which is related to the average effective module power at STC, and acts as a constant penalty during all simulation conditions.

- Mismatch losses of the PV modules, which can be evaluated by a special tool, but is only taken into account as a constant loss during simulation.

- Dirt on the PV-modules, may be defined in % of STC, yearly or in monthly values.

- Partial shading electrical effects, limiting each string current to the more shaded cell, are of course depending on the sun position. They are not explicitly calculated in PVsyst, but can only be roughly evaluated using the "Near shadings according to modules".

- MPP loss, i.e. the difference between the effective operation conditions and the maximum available power point. For MPP use (grid inverters) this loss is neglected in PVSYST. For fixed operating voltage, it can be quantified from the output simulation results (see EArrMPP, EArrUFix, MPPLoss).

- Ohmic wiring losses, as thermal effects, essentially result in a voltage drop of the I/V-array characteristics. The real effect is different whether the array operates at MPP or fixed voltage. At MPP operation, PVSYST applies the wiring loss before computing the MPP. At fixed voltage, the effective losses are strongly dependent on the array overvoltage by respect to the operating voltage.

- Regulation loss is the energy potentially available from the PV array, but which cannot be used by the system.

In MPP applications, this could be the array potential PV production outside the inverter input voltage limits, or during power overloads. This is usually accounted in "Inverter losses", that is in system losses.

In stand-alone systems, it corresponds to the excess energy which cannot be used when the battery is full.

In DC-grid installation, this is the potential current in excess by respect to the instantaneous load current.

In Normalized performance index, all these array losses are accounted for in the "Collection Losses" Lc, that is the difference between Yr (the ideal array yield at STC) and Ya (the effective yield as measured at the output of the array).

9.3. Loss factor influence

Losses for do not meet the requirements of the rated power or dispersion.
Scattering losses are given by the negative tolerance, in this case positive tolerance is therefore in this case, is not considered.

Mismatch losses or wiring.
Mismatch energy losses are usually in the range of 1% to 4% if the PV modules. In this case is considered to 2%.

Losses from dust and dirt.
The dust and dirt losses depend on the location of the facility and frequency of rainfall, can be estimated by visual inspection or by specific measures. Typical annual values are less than 4% for areas with a high degree of dirt. Therefore the installation located in an industrial area, with a high possibility of accumulating dirt is considered a 2%.

Angular and spectral losses.
The annual energy loss of angular and spectral effects is on the order of 3%, and this is the value that is selected.

Drops ohmic losses in the wiring.
We distinguish two, some in DC conditions, and other three-phase alternating current.
For DC:

$$P_{DC,Ohm} = \frac{I_{DC}^2 \cdot 2 \cdot L \cdot \rho}{S}$$

For AC:

$$P_{AC,Ohm} = \frac{(\sqrt{3} \cdot I_{AC})^2 \cdot L \cdot \rho}{S}$$

Where:
I_{AC}: three phase cable rated current (A)
I_{DC}: mono-phase cable rated current (A)
L: total cable length (m).
S: cable section (mm^2)
ρ: resistivity of copper (0.01725 · mm^2 / m)

The $P_{DC,Ohm}$ losses are:

DC	L (m)	S (mm$^{2)}$	Idc (A)	$P_{DC,Ohm}$	
L1	98	6	8,46	40,33	W
L2	2	35	90,945	16,3	W
Total				56,63	W

Table 9.2

The maximum power of the installation is 488 kW whence the % losses are:

Pmax	$P_{DC,Ohm}$
488000 W	0,011%

Table 9.3

From $P_{AC,Ohm}$ those are the losses:

AC	L (m)	S (mm$^{2)}$	Iac (A)	$P_{AC,Ohm}$	
L3	3	300	90,945	4,28	W
L4	25	240	90,945	44,59	W
Total				48,87	W

Table 9.4

Pmax	$P_{AC,Ohm}$
488000 W	0,01%

Table 9.5

Temperature losses.
To determine this parameter, the following information is required:
Temperature coefficient associated with power = -0.43 % / º C cell temperature under operating conditions = 47 º C

Month	Tª atm (ºC)	Tª cell (ºC)	Δ (25º)	LTEMP	(1-LTEMP)
January	0,4	43,18	23,18	0,1	0,9
February	2,7	44,24	24,24	0,1	0,9
March	7,7	46,54	26,54	0,11	0,89
April	13,3	49,12	29,12	0,12	0,88
May	18,3	51,42	31,42	0,13	0,87
June	21,4	52,84	32,84	0,15	0,85
July	23,3	53,72	33,72	0,16	0,84
August	23	53,58	33,58	0,16	0,84
September	19	51,74	31,74	0,15	0,85
October	13,1	49,03	29,03	0,13	0,87
November	6	45,76	25,76	0,11	0,89
December	2	43,92	23,92	0,1	0,9

Table 9.6

Losses by AC / DC inverter performance.
The inverter efficiency is given by the selected inverter, in this case, European performance is 98.6%
PV generator efficiency losses tracking the maximum power point.
Typical values are in the range of 96% on clear days to 94% on days with sunny spells. In Prague the days are use to be with sunny spells it will be take 94%.

Losses shading of the PV generator.

This type of loss is considered negligible, since there are no structures or buildings that may cast shadows on the cover of the warehouse, and also considered the minimum separation required by the specifications.

Another type of losses.

These losses are less specific, but as dependent on associated with maintenance, troubleshooting, performance degradation over time for values, etc., is assigned a 2%.

9.4. Estimated annual energy

In this section the steps in calculating the values assigned in the previous section are followed.

First we calculate the Performance Ratio:

$$PR = \left(1 - L_{Temp}\right) \cdot (1 - L_{DC}) \cdot (\eta_{SMPP}) \cdot (\eta_{INV}) \cdot \left(1 - L_{Ohm,AC}\right) \cdot (1 - L_{Shadow}) \cdot (L_{Others})$$

Losses arising from the temperature variation are:

Month	(1-L_{TEMP})
January	0,9
February	0,9
March	0,89
April	0,88
May	0,87
June	0,85
July	0,84
August	0,84
September	0,85
October	0,87
November	0,89
December	0,9

Table 9.7

Where the LCD is calculated as follows.

DC Losses Coefficient				
Ohm (%)	Mismatch	Dust and dirt (%)	Angular	PNOM (%)
0,011	2	2	3	0

Table 9.8

$$L_{DC} = (1 - 0{,}00011) \cdot (1 - 0{,}02) \cdot (1 - 0{,}02) \cdot (1 - 0{,}03) \cdot (1 - 0) = 0{,}93$$

$$PR = (1 - L_{Temp}) \cdot (1 - L_{DC}) \cdot (\eta_{SMPP}) \cdot (\eta_{INV}) \cdot (1 - L_{Ohm,AC}) \cdot (1 - L_{Shadow}) \cdot (L_{Others})$$

Month	(1-LTEMP)	(1-LDC)	nSMPP	nINV	(1-Lohm)	(1-Lothers)	PR
January	0,9						0,81
February	0,9						0,81
March	0,89						0,80
April	0,88						0,79
May	0,87						0,78
June	0,85	0,989	0,94	0,986	0,999	0,98	0,76
July	0,84						0,75
August	0,84						0,75
September	0,85						0,76
October	0,87						0,78
November	0,89						0,80
December	0,9						0,81

Table 9.9

$$E_{AC} = Hi \cdot Days \cdot PHS \cdot P_{Nom} \cdot PR$$

Month	SPH	Days	PSH/Month
January	0,93	31	28,83
February	1,63	28	45,64
March	2,64	31	81,84
April	3,8	30	114
May	4,85	31	150,35
June	4,6	30	138
July	4,97	31	154,07
August	4,31	31	133,61
September	3,04	30	91,2
October	1,87	31	57,97
November	0,915	30	27,45
December	0,7	31	21,7

Table 9.10

The rated power of the PV generator is:

P= 1809 modules 270 Wp /module = 488430 Wp

As a result, the energy obtained is calculated:

Month	PHS/Month		PR	Energy (Wh)	Energy (MWh)
January	28,83		0,81	11405963,89	11
February	47,27		0,81	18701349,74	19
March	81,84		0,8	31978488,96	32
April	114		0,79	43988005,8	44
May	150,35		0,78	57279651,39	57
June	138	488430	0,76	51226538,4	51
July	154,07		0,75	56439307,58	56
August	133,61		0,75	48944349,23	49
September	94,24		0,76	34982528,83	35
October	57,97		0,78	22085143,94	22
November	27,45		0,8	10725922,8	11
December	21,7		0,81	8585134,11	9
			TOTAL	**396.342.385**	

Table 9.11 Energy production

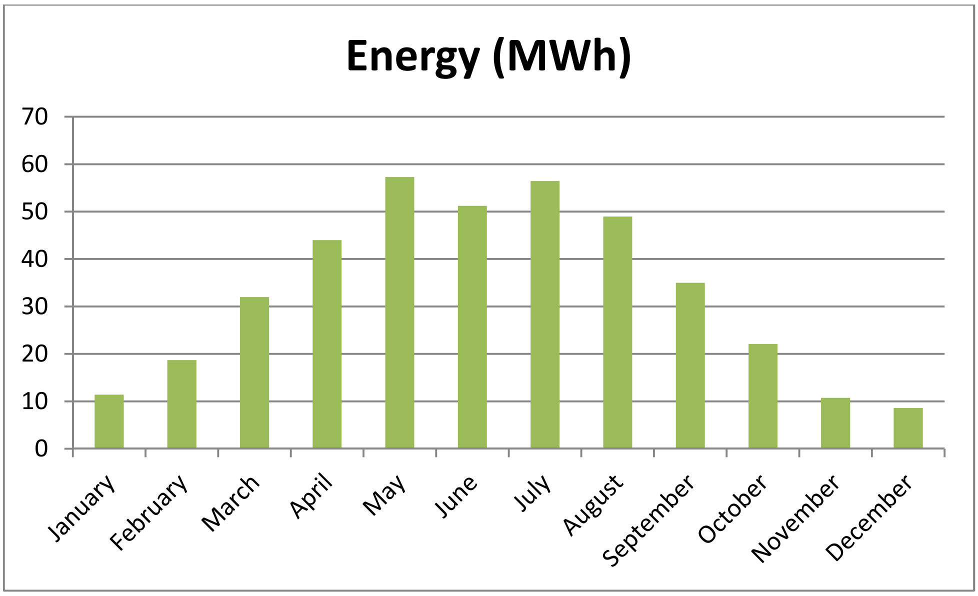


Figure 9.1

10. CALCULATION OF EMISSIONS REDUCTION

All kWh generated by a PV system equals energy savings generated by other sources of energy, in all likelihood dirty in terms of pollution, which leads to a reduction of emissions.

10.1. CO_2 Reduction

One of the most important sources of pollution is the greenhouse gases, and seriously affects the climate of the Earth. The most significant among these is gas CO2 generated in the combustion of any carbonaceous materials.
To calculate the CO2 savings obtained thanks to the clean energy production of a PV system, we can use the average emission per unit of electricity generated in the Czech Republic.

Power source	GWh	%
Solid fuels	35255	55,00%
Nuclear	20960,7	32,70%
Natural Gas	3076,8	4,80%
Renewable	4871,6	7,60%
TOTAL	64100	100%

Table 10.1

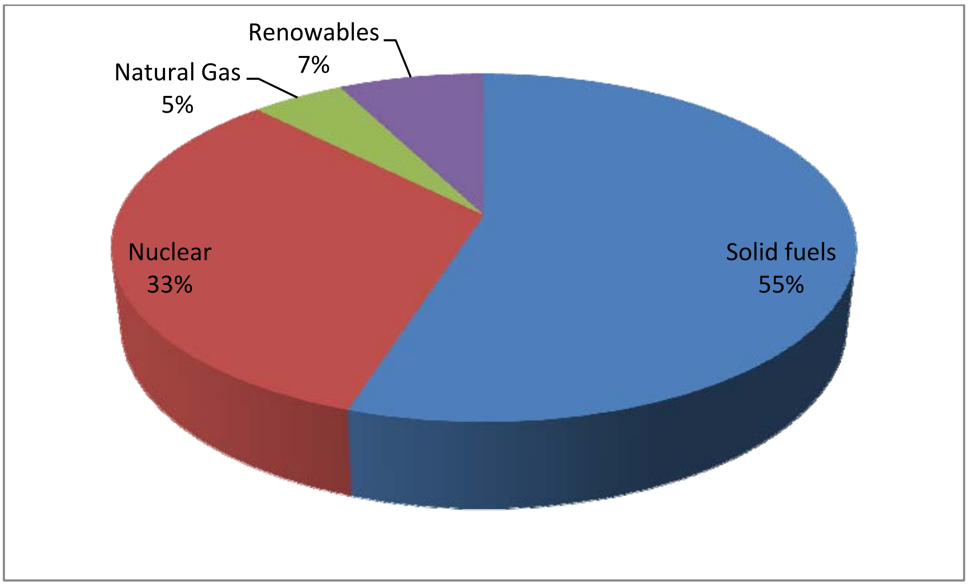


Table 10.2. Power production sources in Czech Republic in 2012

Measure emissions of CO_2 per kWh of energy produced in Czech Republic is 581g CO_2/KWh

Month	Energy (kWh)	CO2 (T)
January	12513	7,270
February	18041	10,482
March	36833	21,400
April	42394	24,631
May	58508	33,993
June	57713	33,531
July	55404	32,190
August	58120	33,768
September	41223	23,951
October	28973	16,833
November	15827	9,195
December	13676	7,946
	439.224,50	255,189

Table 10.3

With this installation is been saved 255,189 tons of CO_2 per year.

10.2. NO_x and SO_2 Reduction

The reduction of sulfur oxide and nitrogen, the emissions values are used:

SO_2	17,22 g/kWh
No_x	5,43 g/kWh

Table 10.4

Month	Energy (kWh)	SO2 (Kg)	NOx (Kg)
January	12513	215,465	67,943
February	18041	310,671	97,964
March	36833	634,259	200,001
April	42394	730,021	230,198
May	58508	1007,509	317,699
June	57713	993,813	313,380
July	55404	954,060	300,845
August	58120	1000,828	315,592
September	41223	709,866	223,843
October	28973	498,911	157,322
November	15827	272,533	85,938
December	13676	235,509	74,263
	439.224,50	7563,446	2384,989

Table 10.5

With this installation is been saved 7,563 tons of SO_2 and 2,38 tons of NO_x per year.

ANNEX II

WORKPLACE HEALTH AND SAFETY STUDY

Index

1. SCOPE AND PURPOSE

The next study is based on Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work and from Oregon Solar industries association.

The object of this Directive is to introduce measures to encourage improvements in the safety and health of workers at work.

To that end it contains general principles concerning the prevention of occupational risks, the protection of safety and health, the elimination of risk and accident factors, the informing, consultation, balanced participation in accordance with national laws and/or practices and training of workers and their representatives, as well as general guidelines for the implementation of the said principles.

This Directive shall be without prejudice to existing or future national and Community provisions which are more favorable to protection of the safety and health of workers at work.

Solar construction safety, like general construction safety, requires more than knowledge of safety rules; it requires the ability to evaluate unique situations to actively create safe work practices. This manual presents many common conditions found in typical solar work – both electrical and plumbing. These examples should be used as initial steps toward developing safe work habits for employees and to assist employers in developing appropriate safety policies.

Solar construction crews face many of the same conditions found in typical construction trades with notable exceptions that underscore the nature of both solar electric and solar hot water equipment: exposure to sunlight creates stored energy not present in other construction trades. Managing this energy safely is an important aspect of solar construction.

Use proactive safety policies, every employer have a legal obligation to provide and maintain a safe and healthful workplace for employees.

Taking risks is part of running a business. You take risks in product development, marketing, and advertising in order to stay competitive. But there are some risks that should never be taken. One of these risks is the safety and health of the employees in the company.

A proactive strategy means taking action to make sure accidents do not happen in the workplace. A proactive response to safety and health in the workplace must occur before an accident can be prevented.

The proactive improvement process first identifies a hazard and anticipates the possible injury. The hazard is analyzed, recommendations proposed, and corrective actions and system improvements are implemented. The proactive improvement process predicts in order to prevent. Proactive strategies look forward. By emphasizing accident prevention, management sends a message of caring to all employees. The safety professional attempts to identify and analyze hazardous conditions and unsafe behaviors in order to predict future accidents.

Proactive strategies are always less expensive than reactive strategies. Remember, proactive programs are implemented to prevent future injuries and illnesses.

Consider some of the costs associated with accidents and you will quickly find that having a proactive safety policy in place is a smart investment and better for everyone involved. Here are some potential costs associated with accidents:

Consider what one lost workday injury might cost your company in terms of:

- Production down-time.
- Productive time lost by an injured employee.
- Productive time lost by employees and supervisors helping the accident victim.
- Cleanup and start-up of operations interrupted by an accident.
- Time to hire or train a worker to replace the injured worker until they return to work.
- Time and cost for repair or replacement of damaged equipment or materials.
- Cost of continuing all or part of the employee's wages, plus compensation.
- Reduced morale among your employees and perhaps lower efficiency.
- Cost of completing paperwork generated by the accident.

2. GENERAL PREVENTION MEASUREMENTS

The previous section describes how to identify jobsite hazards using an example to evaluate potential risk areas for typical construction crew work. With that information, you can begin to develop a strategy to reduce the risks associated with construction crew work.

This section helps you develop strategies to either eliminate or control hazards. Since many construction hazards are difficult to eliminate altogether, most of the suggestions deal with controlling the hazard by developing safe work practices and habits. However, always be on the lookout for ways to eliminate hazards altogether.

The following actions were identified in the previous section:

- Action 1: Develop company personal protective equipment policy.
- Action 2: Eliminate extension cord hazards by using battery operated tools.
- Action 3: Develop procedures for using power tools and extension cords.
- Action 4: Develop proper lifting and carrying procedures for ladders.
- Action 5: Develop proper ladder use policies.
- Action 6: Reduce heat exhaustion risk hazards by working during cooler hours of the day.
- Action 7: Develop hydration and safe practices while working in hot weather conditions.
- Action 8: Eliminate hot collector hazards by covering the collector area with an opaque object.
- Action 9: Develop policies and procedures for working with solar hot water collectors.
- Action 10: Develop policies and procedures for working with solar electric PV panels.

Actions 2, 6, and 8 are self explanatory and the smartest way to avoid hazards – by eliminating them altogether.

This section deals with the following actions:

- Action 1: Develop a company personal protective equipment policy.
- Action 3: Develop procedures for using power tools and extension cords.
- Action 7: Develop hydration and safe practices while working in hot sun conditions.
- Action 9: Develop policies and procedures working with solar hot water collectors.
- Action 10: Develop policies and procedures for working with solar electric PV panels.

Develop procedures for using power tools and extension cords.
A power tool used on the job must be maintained in a safe working condition. Employers must designate one or more competent persons to oversee the proper use and maintenance of tools used on the job. In general, equipment, including electrical cords, must be inspected prior to use to ensure it is in safe condition.

Employees must be trained in the proper and safe use of all power tools they use. If maintenance is required, employees must be trained to safely perform that maintenance.

Ground Fault Circuit Interrupter rules apply to construction sites to 125-volt, single-phase, 15-, 20-, and 30-ampere receptacles that are not part of the permanent wiring of a building or structure; this includes use of extension cords. See rules and fact sheet noted below for more detailed information.

Develop hydration and safe practices while working in hot sun conditions. Working in hot conditions can contribute to dehydration, the excessive loss of water from your body. Fluid loss can become severe enough to be life threatening.

Develop policies and procedures for working with solar electric PV panels Solar electric panels produce electricity when exposed to sunlight. Even overcast days can present enough light to create an electric potential in solar panels. The only method of 'turning the panel off' is to remove the energy source: sunlight.

Caution should always be used when handling solar electric panels. Even a mild shock delivered at the wrong time can be dangerous.

Working smart

- **Remain aware while at work.**

Stay actively aware of your work surroundings. If you see unsafe conditions or people working in an unsafe manner; stop and correct the conditions before an accident happens.

- **Know the safety policies at large developments or jobsites.**

If you are working on a large construction site, such as a new development or large commercial job where the solar contractor is a sub-contractor, it is important to meet with the jobsite general contractor to check in and ask about safety policies in place.

- **Working with other contractors?**

Make sure you are fully aware of any work that other contractors are performing at your jobsite. Talk with them and identify any potential safety hazards created by their work.

- **Working in proximity to mobile equipment?**

If there is mobile equipment on the jobsite, make sure you know where the equipment is and when it is being used. For example, if you are working on a ladder and there is a forklift operating nearby, make sure the forklift operator is aware of your ladder location.

3. HAZARDS AND PREVENTIVE MEASURES

3.1. Lifting safety

3.1.1. Evaluate your lifting-related hazards

To establish safe lifting policies and procedures that reduce the risks associated with lifting, it's important to review your work tasks and identify where and how you move objects on the job. This section helps identify example action items that are addressed later in the section Procedures for lifting safely on page 30. You may come up with additional situations that need to be addressed. Use these common examples, but also analyze your unique situation thoroughly.

Typical lifting issues for solar contractors include:

- Carrying and moving heavy tools and equipment.
- Loading and unloading equipment and tools from truck.
- Lifting tools and equipment onto a roof.

After identifying where, when, and how you lift objects, determine what actions can reduce the hazards associated with lifting.

1. Carrying and moving tools and equipment.
   a) Working conditions include: carrying large equipment and tools around the jobsite.
   b) Hazards include: using improper lifting techniques or carrying awkward and heavy objects causing cumulative trauma or strains and sprains.

Action: Develop proper procedures for lifting and carrying.

2. Loading and unloading equipment and tools from the truck.
   a) Working conditions include: loading and unloading ladders, tools, solar equipment.
   b) Hazards include: using improper lifting techniques causing cumulative trauma or strains and sprains.

Action: Develop procedures for loading and unloading vehicles.

3. Lifting tools and equipment onto a roof.
   a) Working conditions include: lifting tools and equipment onto roofs.
   b) Hazards include: using improper lifting techniques causing cumulative trauma or strains and sprains.

Action: Eliminate lifting by using a crane to hoist equipment onto the roof.

Action: Develop safe lifting policies for moving items onto roofs.

3.1.2. Preventing back injuries

Since lifting puts your back at risk, it makes sense to use your back properly and take steps to protect it. Your spine has three natural curves that correspond to the upper curve (your neck area), mid curve, and lower curve.

These three curves form an "s" shape when you are in a correct standing or sitting position.

When you stand straight, your spinal curves are balanced and your weight is evenly distributed throughout your spine.

This is your strong back position. One of the keys to lifting properly is maintaining these curves throughout the entire lifting process (picking objects up, walking, and putting objects back down).

Practice finding your strong back position prior to lifting and get a sense of the correct posture. One method to learn the correct posture uses these easy steps:

1. Stand straight with your hands at your sides.
2. Imagine a string at the top of your head pulling gently up.

When you do these steps properly, your chin tucks slightly and you may stand a tiny bit taller.
That's all there is to it. You should not be standing ram-rod straight like a soldier at attention.

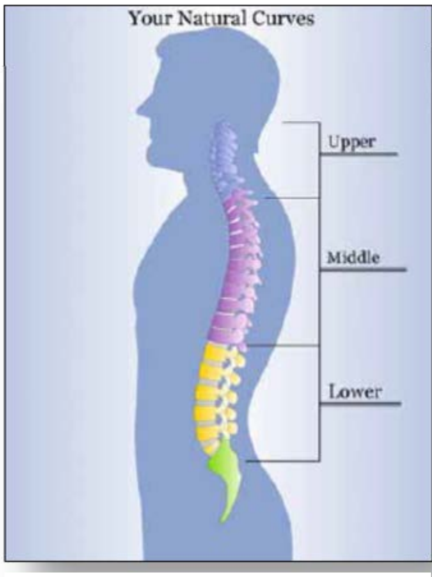


Figure 3.1 Parts of the back

Correct posture is a relaxed but strong posture; you feel the appropriate muscles engage slightly and you feel the proper back alignment that you need to maintain while lifting. This is a balanced position where your back is strongest.

3.2. Ladder safety

3.2.1. Evaluate your ladder hazards

Review the work day and identify where and how ladders are used. Then develop a safe ladder use policy and procedures to reduce the risks associated with ladders. The following example of a typical construction situation provides the starting place for evaluating unique risks in your work day. Use these common examples, but also analyze your own situation to identify additional risks in your job.

Ladder use in typical construction work situations can include:

- Using ladders for various tasks at the jobsite.
- Loading and unloading ladders and carrying ladders to work area.
- Climbing ladders to access roofs.
- Climbing ladders to work on wall-mounted equipment.
- Using ladders to rest or hang tools and equipment on.

After you evaluate your work situation related to ladder use, identify the hazards and risks associated with those situations. Then decide what action is needed to address the hazard.

1. Using ladders for various tasks at the jobsite.
   a) Working conditions include: accessing roofs, working on wall-mounted equipment, working on many different height levels.
   b) Hazards include: using an inappropriate ladder (fall hazard, shock hazard).

Action: Select the correct ladder for the job.

2. Loading and unloading ladders and carrying ladders to work area.
   a) Working conditions include: lifting onto truck and carrying ladders to the work area.
   b) Hazards include: lifting hazards from carrying ladders.

Action: Develop proper procedures for carrying ladders.

3. Climbing ladders to access roofs.
   a) Working conditions include: positioning ladders to reach rooftops, climbing up onto and down from roofs.
   b) Hazards include: setting up in unsafe areas, fall hazards from accidents on ladders, electrical hazards from contact with electrical power lines.

Action: Develop safe ladder use procedures for accessing the roof.

4. Climbing ladders to work on wall-mounted equipment.
   a) Working conditions include: setting up the ladder properly, climbing up and down safely.
   b) Hazards include: setting up in an unsafe area, setting up improperly, not securing the ladder properly, not climbing up or down properly, resulting in falls.

Action: Develop safe ladder practices for working from ladders.

5. Using ladders to rest or hang tools and equipment on.
   a) Working conditions include: working on ladders and resting tools on the top of step ladders or on the steps of any ladders.
   b) Hazards include: items falling from ladder resulting in impact-related injuries.

Action: Eliminate tool falling hazard by not using ladders to store your tools.
Action: Use a ladder or equipment specifically designed for tools.

3.2.2. Develop procedures to use ladders properly

This section will cover the issues noted below starting with the ladder inspection form.
Using ladders properly includes:

- Inspecting ladders prior to every use.
- Setting up and securing the ladder.
- Using ladders safely.

The inspection form on the following page is provided to print and use for your company.
This inspection form is derived from the Werner Ladder inspection form

3.2.3. Using the ladder safely

After the ladder is properly secured in place, it is ready for use. These practices make your time on the ladder more efficient and safe:

- Always face the ladder when climbing up or down.

- Never exceed the rated capacity of the ladder and use only as designed. (For example, never use a step ladder as a straight ladder). Consult the manufacturer's recommendations for more information.
- The areas near the bottom and top of the ladder must be kept clear to avoid tripping or falls.
- Never move, 'walk' or 'jog' a ladder while you are on it. Climb down first and then reposition the ladder.
- Ladders should not be used in windy conditions.
- Only one person should be on a ladder at one time.
- Maintain a 3-point contact when working from a ladder.
- Do not climb while holding something in your hands – use your tool belt to carry tools. If you need to move equipment to the roof that cannot be fastened or carried safely in a tool belt, tie off properly, using fall protection, and use a rope or hoist to raise and lower tools and other objects.

Whenever working on energized equipment or near power lines, use caution and fiberglass ladders. Never use metal or aluminum ladders near electricity – and remember, no one, for any reason, is allowed within 10 feet of an overhead power line.

- Raised ladders should never be left unattended. When your workday is finished, even if the total job isn't, take down and secure all ladders.
- Climb ladders with shoes that have slip-resistant soles.
- When working from the ladder, always work within an arm's reach from the ladder. While working, keep both feet on the rungs and use your belt buckle as a guide to keep your weight centered on the ladder during all times. With both feet on the rungs, your belt buckle should never stray outside of the side rails.

3.3. Fall protection and jobsite trip hazards

3.3.1. Evaluate your fall and trip hazards

The purpose of identifying fall hazards is to determine how to eliminate or control them before they cause injuries.

Fall prevention is more than just being safe on ladders and roof tops. Falls leading to serious injuries can happen anywhere, thus the jobsite evaluation needs to address potential falls wherever they may happen.

Trip hazards, such as debris or tools lying on the ground or on walking surfaces, can lead to injuries such as sprained ankles but can also increase the risk of falling. Trip hazards on rooftops create an unsafe environment that can lead to falls from the roof.

Following is an example of a typical scenario that construction crews may face. You may come up with additional areas in your job that need to be addressed. Use these common examples, but analyze your own situation as well. By reviewing your work day and identifying potential fall hazards, you can create a fall hazard risk-reduction strategy for your situation. Some typical fall and trip hazards include:

- Tripping on jobsite debris, cords, or equipment.
- Working with ladders.
- Working from heights.

1. General jobsite trip hazards
   a) Working conditions: clutter, equipment, and cords are trip hazards on the jobsite including the prep area at ground level and roof level.
   b) Hazards include: trip hazards resulting in fall-related injuries. These can occur on ground level or on roof tops.

Action: Eliminate trip hazards by removing the debris.

Action: Develop clean jobsite and work area practices.

2. Ladder and roof area fall hazards
   a. Working conditions include: climbing onto and off of rooftops and working on rooftops.
   b. Hazards include: falls from ladders or roofs resulting in fall-related injuries.

Action: Train employees on ladder safety practices

Action: Eliminate roof and ladder hazards for employees not required to be on roofs and ladders.

Action: Develop and train employees on fall-protection policies and procedures.

3.3.2. Develop clean jobsite and work area practices

Having a clean worksite makes sense from a safety standpoint and in presenting a positive image to your clients. From the job start to finish, having a cleaner worksite with no trip hazards lying around is safer. Below are several potential means of cleaning up a worksite.

You should develop policies that are adhered to and enforced.

- Maintain a clean and orderly jobsite. Do not allow construction debris to be randomly scattered at the jobsite. If debris is present, use a construction debris dumpster.
- Use proper tool boxes, tool belts, and storage devices to prevent tools from lying randomly throughout the jobsite.
- Put barriers around hazardous areas that physically block entrance to the hazard.

3.3.3. Working Smart

- **Cover holes.**

Simple and effective when they are properly installed, rigid covers prevent workers from falling through skylights or temporary openings and holes in walking/working surfaces.

- **Use fences and barricades.**

Fences and barricades are warning barriers, usually made from posts and wire or boards that keep people away from hazards such as wells, pits, and shafts.

- **Identify fall hazards that you *can* eliminate.**

Eliminating a fall hazard is the most effective fall-protection strategy. Ways to eliminate fall hazards include:

- Perform construction work on the ground before lifting or tilting it to an elevated position.
- Install permanent stairs early in the project so that workers don't need to use ladders between floors.
- Use tool extensions to perform work from the ground.

- **Identify fall hazards that you *can't* eliminate.**

If you can't eliminate fall hazards, you need to prevent falls or control them so that workers who might fall are not injured.

- Ways to prevent falls include covers, guardrails, handrails, perimeter safety cables, and personal fall-restraint systems.
- Ways to control falls include personal fall-arrest systems, positioning-device systems, and safety-net systems. Use these fall-protection systems only when you can't eliminate fall hazards or prevent falls from occurring.

- **Determine whether anchorages are necessary**

If workers use personal fall-arrest or restraint systems, they need secure anchorages for their lifelines or lanyards. Anchorages for personal fall-arrest systems must be able to support at least 5,000 kilograms per attached worker or be designed by an engineer with a safety factor of at least two—twice the impact force of a worker free-falling 6 meters.
Anchorages for personal fall-restraint systems must be able to support at least 3,000 kilograms per attached worker or be designed with a safety factor of at least two—twice the peak anticipated dynamic load.

- **Get professional training**

Training from a fall protection professional can be invaluable. Learning how personal fall protection gear should be used and when to use it is as important to your job as acquiring continuing education on the equipment you're installing. Like other gear, fall-protection equipment changes and improves over time. Make it a habit to stay current with fall protection training.

- **Use good tool bags to prevent trip hazards**

Use good organizers that will not spill on roof tops. Many of these bags can be tied off on steeper roofs if needed.

3.4. Solar electrical safety

3.4.1. Evaluate your electrical hazards

It's important to evaluate each specific situation to develop a list of hazards and potential injuries that could occur at your work site. Understanding hazards and potential injuries, along with knowing the likelihood of an accident occurring, enables you to set up a suitable safety policy for each specific job. This evaluation will help you set up policy and procedures to reduce the risks associated with electricity and energized equipment.

The following examples demonstrate work conditions that construction crews face while working with solar electric systems. You may come up with additional situations in your job that need to be addressed. You are encouraged to use these common examples but to analyze your own situation as well.

Electrical hazards in construction work situations can include:

- Using power tools and electric cords.
- Working with existing and new wiring and circuits.
- Working with solar electric PV panels, batteries, and equipment.

Once you've gone through your work situation related to electricity and energized equipment, you need to identify the hazards and risks associated with those situations. Then decide what action is needed to address the hazard.

1. Using power tools and electric cords.
a. Working conditions include: using power tools and extension cords.
b. Hazards include: using non-GFCI power cords, un-grounded power tools, and frayed or improperly spliced electric cords resulting in injuries associated with electric shock.

Action: Develop policies and procedures for using power tools and electric cords.

2. Working with existing and new wiring and circuits.
   a. Working conditions include: working on DC and AC wiring, connecting to utility.
   b. Hazards include: exposure to live electric circuits or energized equipment resulting in injuries associated with electric shock and arc-flash.

Action: Develop policies and procedures working with new and existing electric circuits.

3. Working with solar electric PV panels, batteries, and equipment.
   a. Working conditions include: wiring and connecting PV arrays, installing and removing batteries, and working with inverters and balance of system equipment.
   b. Hazards include: moving and installing PV panels, working with inverters and balance of system equipment resulting in injuries associated with electric shock and arc-flash.

Action: Develop safe practices for working with solar electric systems.

Action: Develop safe practices installing, handling, and disposing of batteries.

3.4.2. Working with power tools and electric cords

Companies working with power tools and electric cords must create clear safety policies for the maintenance and use of this equipment. Following are some areas to consider when setting power tool and electric cord safety practices and policies.

- Ground Fault Circuit Interrupters (GFCI or GFI) save lives.
    - Know and understand OSHA rules on GFCI devices. See Oregon OSHA information box on GFCI requirements.
    - Ensure all extension cords and equipment is protected by GFCI. Follow manufacturers testing procedures to insure the device is working properly.
    - Always use GFCI protected extension cords and equipment on the job.

- Construction equipment is used in rugged environments – equipment inspections can help ensure equipment is maintained in safe working condition.
    - Electric equipment and power cords should always be inspected after an accident or damage occurs.
    - Power cords with ground prongs missing should never be used.
    - Visually inspect electrical equipment prior to every use for electrical hazards such as missing prongs, frayed cords, cracked tool cases etc. Remove from service and apply a warning tag to any tools that are damaged.

3.4.3. Working with electrical circuits

Preventing electric shock by working on de-energized circuits is a key to electric safety. Following are some items to consider when working on electric circuits.

- Always de-energize circuits before beginning work on them.
    - You can't get shocked by a de-energized circuit. Unfortunately, many electric accidents have been caused by assumed 'dead' circuits. Working safely on circuits includes testing them for hazardous energy prior to working on them.
    - Use a meter or circuit test device such as a current clamp to ensure the circuit is dead prior to working on it. Implement circuit lock and tag out rules
    - Lock out the power on systems that are capable of being locked out. Remember that the lock out tag is not for the person that you are aware of and that knows you are working on the electrical circuit – it's for the person you don't know and that doesn't know you are working on the circuit. You must notify all affected persons.
    - Tag out all circuits that you're working on at points where that equipment or circuit can be energized.

3.4.4. Working with solar electric systems

Electricians are familiar with electricity coming from the utility side of the meter. With solar electric systems there are 2 sources of electricity: the utility and the solar electric system.

Turning off the main breaker doesn't stop a solar electric system from having the capacity to produce power. Electricians are used to isolating the 'load' from the power source (usually with a breaker or other disconnect switch) and then they proceed to work on that 'safe zero energy load'. With a solar electric system you work on the power source itself (the PV panels or associated wiring) – this is fundamentally different than working on a 'safe load' and you must keep this in mind. Even low light conditions can create a voltage potential that can lead to a shock or arc-flash. A surprise shock delivered at the wrong time could cause a fall from a roof or ladder.

Follow the procedures listed in the previous section on working with electrical systems

- Note that PV inverters may have significant capacitors that could hold a charge after the power source is removed – always follow manufacturer's directions and check the equipment you are working on for specific operation and safety information.

The only method of 'turning off' a solar array is removing the 'fuel' source – the sun. If needed, cover the array with an opaque cover that blocks sunlight to prevent a solar panel from generating electricity.

Small amounts of sunlight can produce a voltage potential and shock or arc-flash hazard

- Voltages can be present even in very low light conditions. While these voltages may not be enough to operate the inverter, the potential voltages are enough to produce a shock to an unsuspecting installer. Surprise shocks can cause injuries directly or cause a fall from a roof or ladder.
- Prior to working on a string of solar PV panels, if you're going to be connecting or disconnecting circuits, you should disrupt the current path by disconnecting the DC Disconnect switch. Tag and lock out the circuit using standard procedures discussed in the previous section.

Grid tied solar systems have 2 energy sources to consider

- Shutting off the main circuit breaker does not affect the potential output of a solar PV array – even if the inverter shuts off.

It's important to remember that opening (turning off) the main breaker does not shut off the power source from the solar array. Wires from the PV side of their low light conditions.

- Disconnect switches can isolate the solar PV array but they do not shut the power off.

Remember that if you open the DC disconnect switch, the line from the solar PV array can still have voltage potential on it. This is similar to the voltage potential present on the utility side of the line after the main breaker is opened. Treat the wiring coming from the solar PV array with the same caution you treat the utility power line. A residential PV array can have up to 600 VDC potential.

An electric arc-flash hazard exists while adding or removing a series of solar PV panels

- NEVER disconnect PV module connectors or other associated PV wiring under load!
- While adding or removing a series of solar PV panels, if a path for current is completed or the string was under load, an electrical arc can occur across the wire junction. The energy from the bright arc-flash can cause severe burns. Another hazard is the surprise arc blast causing you to lose balance and fall off a roof or ladder.
- Always open the DC Disconnect Switch prior to working on a solar PV system.
- Use a current clamp to check for hazardous energy prior to working on a PV array.

4. DUTIES OF PERSON CONDUCTING BUSINESS OR UNDERTAKING

4.1. Management of risks to health and safety

A person conducting a business or undertaking must manage risks associated with the carrying out of construction work.

1. Within the context of his responsibilities, the employer shall take the measures necessary for the safety and health protection of workers, including prevention of occupational risks and provision of information and training, as well as provision of the necessary organization and means.

The employer shall be alert to the need to adjust these measures to take account of changing circumstances and aim to improve existing situations.

2. The employer shall implement the measures referred to in the first subparagraph of paragraph 1 on the basis of the following general principles of prevention:

a) avoiding risks;

b) evaluating the risks which cannot be avoided:

c) combating the risks at source;

d) adapting the work to the individual, especially as regards the design of work places, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health.

e) adapting to technical progress;

f) replacing the dangerous by the non-dangerous or the less dangerous;

g) developing a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment;

h) giving collective protective measures priority over individual protective measures;

i) Giving appropriate instructions to the workers.

3. Without prejudice to the other provisions of this Directive, the employer shall, taking into account the nature of the activities of the enterprise and/or establishment:

a) Evaluate the risks to the safety and health of workers, inter alia in the choice of work equipment, the chemical substances or preparations used, and the fitting-out of work places.

Subsequent to this evaluation and as necessary, the preventive measures and the working and production methods implemented by the employer must:

- assure an improvement in the level of protection afforded to workers with regard to safety and health,

- be integrated into all the activities of the undertaking and/or establishment and at all hierarchical levels;

(b) Where he entrusts tasks to a worker, take into consideration the worker's capabilities as regards health and safety;

(c) Ensure that the planning and introduction of new technologies is the subject of consultation with the workers and/or their representatives, as regards the consequences of the choice of equipment, the working conditions and the working environment for the safety and health of workers;

(d) Take appropriate steps to ensure that only workers who have received adequate instructions may have access to areas where there is serious and specific danger.

4. Without prejudice to the other provisions of this Directive, where several undertakings share a work place, the employers shall cooperate in implementing the safety, health and occupational hygiene provisions and, taking into account the nature of the activities, shall coordinate their actions in matters of the protection and prevention of occupational risks, and shall inform one another and their respective workers and/or workers' representatives of these risks.

5. Measures related to safety, hygiene and health at work may in no circumstances involve the workers in financial cost.

4.2. Security of workplace

A person with management or control of a workplace at which construction work is carried out must ensure, so far as is reasonably practicable, that the workplace is secured from unauthorized access.

- The person must have regard to all relevant matters including risks to health and safety arising from unauthorized access to the workplace; and the likelihood of unauthorized access occurring;
    - *Example*: the proximity of the workplace to places frequented by children, including schools, parks and shopping precincts.

- To the extent that unauthorized access to the workplace cannot be prevented—how to isolate hazards within the workplace.

A person conducting a business or undertaking must ensure that relevant workers are provided with suitable and adequate information, training and instruction in relation to the following:

- The nature of all hazards relating to a confined space.
- The need for, and the appropriate use of, control measures to control risks to health and safety associated with those hazards.
- The selection, fit, use, wearing, testing, storage and maintenance of any personal protective equipment.
- The contents of any confined space entry permit that may be issued in relation to work carried out by the worker in a confined space.
- Emergency procedures.

5. SAFETY PLANNING CHECKLIST

While most construction jobs are within easy access to medical care, some construction jobs are in more remote areas. The following items should be considered when you develop procedures for responding to emergencies. Someone who is not on the jobsite should know the following:

□ How many people are on the jobsite?

□ Who knows they are on the jobsite?

□ Are they expected to return at a specific time?

□ Do they have access to phone service?

□ Are they expected to call in at a specific time?

□ Do employees have the proper safety training they need for the work they are doing?

□ Do employees have first-aid and CPR training?

□ Do they carry a first-aid kit?

□ Is there a nearby hospital or clinic?

□ Do employees have proper safety gear in good working condition (such as fall protection and other personal protective equipment)?

□ Is employee emergency-contact information such as phone number, person to contact, and any pertinent medical information up-to-date and accessible?

□ Does 911 work in the jobsite area? If not, do you have another number to call?

□ Is this a large construction site where employees must check in with the jobsite manager? What is their emergency plan?

6. SAFETY AND HEALTH POLICY

6.1. Developing an emergency-response plan

Effective plans don't need to be elaborate.
The plan should show that you've thought about how to eliminate and control hazards, and show workers how to respond promptly if something goes wrong.

Get others involved in planning.
When workers participate in developing the plan, they contribute valuable information, take the plan seriously, and are more likely to respond effectively during an emergency.
Key planning objectives include:

- Identify the emergencies that could affect your site.
- Establish procedures for responding to the emergencies.

Procedures are instructions for accomplishing specific tasks. Emergency procedures are important; they tell workers what to do to ensure their safety during an emergency. The emergency-response plan should include the following procedures—preferably in writing—that describe what people must know and do to ensure that an injured worker receives prompt attention:

- Reporting an emergency.
- Rescuing a worker.
- Providing first aid.

After an emergency, review your procedures; determine if they should be changed to prevent similar events, and revise them accordingly.

Identify critical resources and rescue equipment.
A prompt rescue won't happen without trained responders, appropriate medical supplies, and the right equipment for the emergency.

First-aid supplies: Every jobsite needs medical supplies for common injuries. Does your site have a first-aid kit for injuries that are likely to occur? Store the supplies in clearly marked, protective containers and make them available.

- Employers should have employees on hand who are trained in basic first aid and CPR even if a hospital or clinic is in near proximity.

- Adequate first aid supplies should be readily available.

- The contents of the first aid kit should be placed in a weatherproof container with individual sealed packages and should be checked weekly to ensure that missing items are replaced.

- In areas where 911 is not available, the telephone numbers of physicians, hospitals or ambulances must be known.

Rescue equipment: Identify on-site equipment that responders can use to rescue workers. Extension ladders and mobile lifts are useful. Determine where and how each type of equipment would be most effective during a rescue.

Train on-site responders.
Those who work at a remote site might need a higher level of emergency training than those who work near a trauma center or a fire department. It is important that someone on-site have training in first aid and CPR.

6.2. When an emergency occurs

Employee rescues.
Improperly prepared or trained rescuers can endanger themselves and those they are trying to rescue. Leave rescue work to trained professional responders who are equipped for emergency situations unless it is absolutely necessary to do otherwise.

Prompt rescue required.
“Prompt” means without delay. For example, if a worker is suspended in a personal fall arrest system, you must provide for a prompt response. A worker suspended in a harness after a fall can lose consciousness if the harness puts too much pressure on arteries. A worker suspended in a body harness must be rescued in time to prevent serious injury.

If a fall-related emergency could happen at your jobsite, have a plan for immediately responding. Workers who use personal fall-arrest systems must know how to promptly rescue themselves after a fall, or they must be promptly rescued.

What to do.

- Call 911. Tell the dispatcher the workplace location and the nature of the emergency. Know that most 911 responders are not trained to rescue a worker suspended in a personal fall-arrest system. Make sure only trained responders attempt a technical rescue.

- If you can reach the victim, administer proper first aid if required and you are trained.

If you are not trained, now is the time to get training before an accident happens.

- First responders should clear a path to the victim. Others should direct emergency personnel to the scene.
- Assist professional medical responders when they arrive.
- Inform the victim’s supervisor.

6.3. After an emergency

Report injuries requiring overnight hospitalization and medical treatment (other than first aid) to the insurance within 24 hours.

Identify equipment that may have contributed to the emergency and put it out of service.

Have a competent person examine the equipment. If the equipment is damaged, repair or replace it. If the equipment caused the accident, determine how and why.

- Document in detail the cause of the emergency.
- Review emergency procedures. Determine how the procedures could be changed to prevent similar events; revise the procedures accordingly.

7. SUSPENSION AND CANCELLATION OF HIGH RISK WORK LICENSE

1. The regulator may suspend or cancel a high risk work license if satisfied that:
   - the license holder has failed to take reasonable care to carry out the high risk work safely and competently;
   - the license holder has failed to comply with a condition of the license; or
   - the license holder, in the application for the grant or renewal of the license or on request by the regulator for additional information:
     - gave information that was false or misleading in a material particular;
     - failed to give any material information that should have been given in that application or on that request;
   - the license was granted or renewed on the basis of a certification that was obtained on the basis of the giving of false or misleading information by any person or body or that was obtained improperly through a breach of a condition of accreditation by the accredited assessor who conducted the competency assessment;
   - The license holder has failed to obtain a reassessment of the holder's competency directed under section 95.

2. If the regulator suspends or cancels a license, the regulator may disqualify the license holder from applying for:
   - a further high risk work license of the same class;
   - Another license under this regulation to carry out work which requires skills that are the same as or similar to those required for the work authorized by the license that has been suspended or cancelled.

3. If the regulator suspends a license, the regulator may vary the conditions of the license, including by imposing different or additional conditions.

4. A variation of conditions under subsection (3) takes effect when the suspension of the license ends.

ANNEX III

ENERGETIC STUDY

Index

1. DESCRIPTION OF THE PRODUCTION SYSTEM OF THE COMPANY AND ITS POWER CONSUMPTION

Glazura makes many different products, as it was said previously, with their respective production and control systems.

In the figure 1.2. is showing the production system diagram of the whole company.

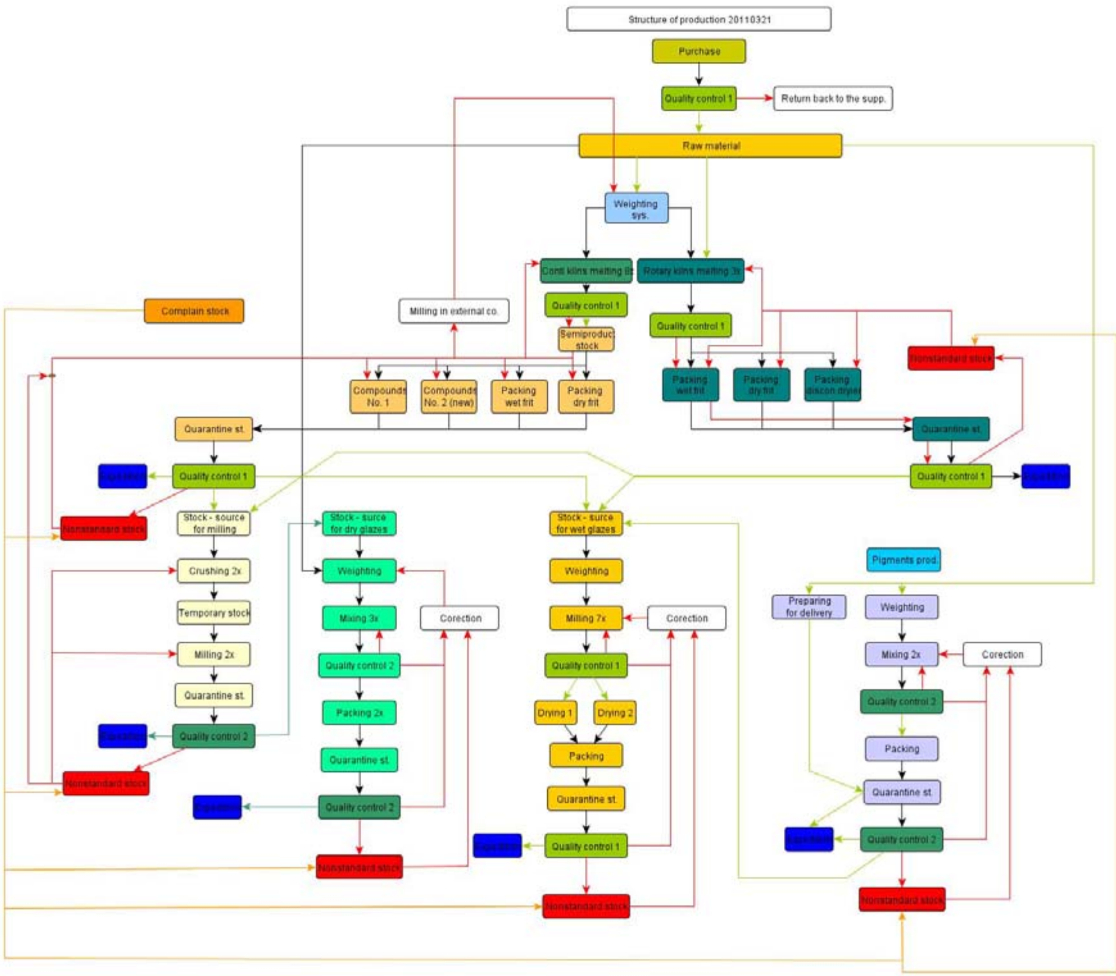


Figure 1.2 production system diagram

Now is going to be describe, analyzed the machinery and work time of each department:

<u>Frits</u>

First of all it goes to be explained the operation of the *frits* department. The one is a nonstop process. The company buys the raw material, the one before to be stock up has to pass a quality control, if it does not pass the control will be return back to the supplier but if it does, it will be stock up in the silos, figure 1.4.

Figure 1.3 Frits going out from the kiln

Figure 1.4 Truck filling up one silo

This department has 14 silos with 100 tons of capacity each and 6 more silos with 50 tons each. All of them have a pressure and weighting control system to avoid high pressure problems and watch the quantity of the raw material.

After that, depends on the material the company wants to make for the client, they are using different raw materials and quantities according to a formula. So they need to measure it before in a scale and then the combination of raw materials is going to the mixer throughout the air compressor to get the homogeneity of the combination. This air compressor works with a motor of 90 KW and the mixer with 60 KW. During the mixing process exists a dust extractor, the one has 75 KW, to keep the work environment clean. When the mixed material goes out from the mixer, it goes directly to the continue melting process.

Once melted, the melted material is going out of the kiln and is mix it with a cold flow of water where the materials is crashed due the sharp change of temperature making the regular frit. The temperature of the flow of water has to be check it all time due the size of the frit is related to.

Color frit

From another hand, to do a *color frit* the process will be very similar. After pass the quality control process the mix of raw materials according to the formula are mixed with colorants, made with different types of powder metal depends on the color that you want to get, this mixers are working with 77 KW. Then the mix is transported to the rotary kilns, figure 1.4. Unlike the continuous kilns this ones are working for batches. Each kiln can afford 100 kg of material. When the batch is done it is transported to a sieve to get the proper size of the frit. After that is introduced in a 15 KW dryer.

Figure 1.5 Rotary kiln

After that both types of frit have to pass a quality control, if it does not pass the control will be returned back to the kilns and if it does, it will be stock as a semi product. This semi product can be sell it to another company or can be use for the company to the compounds line.

Compounds line

In the *compounds line* works 16 hours per day from Monday to Friday. For this line is being taken the frit from the last process it was spoken about and then according to a formula is being mixed and packing it. This process is very automatic due has one of the last technologies on control systems. The crane is able to remember where each bag of the different materials is and put it up over the silos. After that according to the formula the new compound is made.

Figure 1.6 Compounds line

Dry milling

The *dry milling* process works 16 hours per day from Monday to Friday. In this process is being taken raw material and material from compounds line and frits. First of all this material has to be pre-crashed to get the material with a proper diameter, around 1-1,5mm, the crasher works with 110 KW. Then the crashed material is put it into the mill which is working with a motor of 110 KW of power. When material goes out from the dry milling process it is powder, the one will be packed to store it and then sell it or it can be mix it with other materials according to a formula to get a new type of glaze.

Figure 1.7 Dry miller

Wet milling

The *wet milling* process works 8 hours per day from Monday to Friday. The material for this process is being taken from raw material and material from compounds line and frits. These materials are weighting and then are putting into the mill, where it will be mill it with water, hence come wet milling process. These mill are smaller than the ones are using in the dry process these ones work with 49,5 KW. After that obtain the glazes are going to the dryers where they will be around 25 hours, these dryers need 20 KW. The end materials are packed and store it to later be sold.

Figure 1.8 Wet miller

Pigments production

Pigments production is working only 30 min per week. This process consists on mix the raw material with the pigments according to a formula to color the raw material or to create new colors and then sell it to the costumer. For this mixing process are being used 2 mixers of 500 Kg of capacity and a consumption of 40 KW and other of 50 Kg of capacity and 11KW for the small batches. After the mixing process, the materials is packed and stored to be ready to sell it.

Figure 1.9 Mixer

Pilot plant

The *pilot plant* is being used to simulate the client's production to test their own materials in the same conditions what the customer has in their factories to sell them the best product according to his technical characteristics.

The plant has in the first place an hydraulic pressure machine of 14,8 KW where it is apply a high pressure to compact the raw material to get a proper density to it and in this way is made the tile. Then the tile is going throughout an oven of 59 KW where is dried through a hot air flow to remove all the damp is in the tile.

After that depends on the test process the tile cans go to the rotocolor process or to the print process and the back to the second 133KW oven. After the oven, can be finished or it can be polished.

Figure 1.10 Pilot plant

2. ELECTRICAL INSTALLATION DESCRIPTION

The electrical installation of the plant on which the study is conducted is formed basically the elements shown in Figure 2.1. where it can be seen the Grid work entry ČEZ, a. s. of 22kV, which connect three elements.

In the electrical installation of the plant, there are three transformers, two connected in parallel and the other one in serie.

- The transformer one (T1) 22/0, 4 KV of 630 kVA which powers the dry grinding mill process and the dryers, the administration building, the compressors and illumination of the transformer station, the gas regulation station.
- Transformer two (T2) 22/0,4 KV of 630 kVA which powers the substations of the ovens (K5, K6, K7, K8), the dust extraction system, the old substation and the rotary kilns.
- Transformer three (T3) 22/0,4 KV of 630 kVA which powers the glazes substation, the composer and weighting facilities and the wet grinding mill process.

The **power installed** in the plant is, therefore, 1.890 kVA.

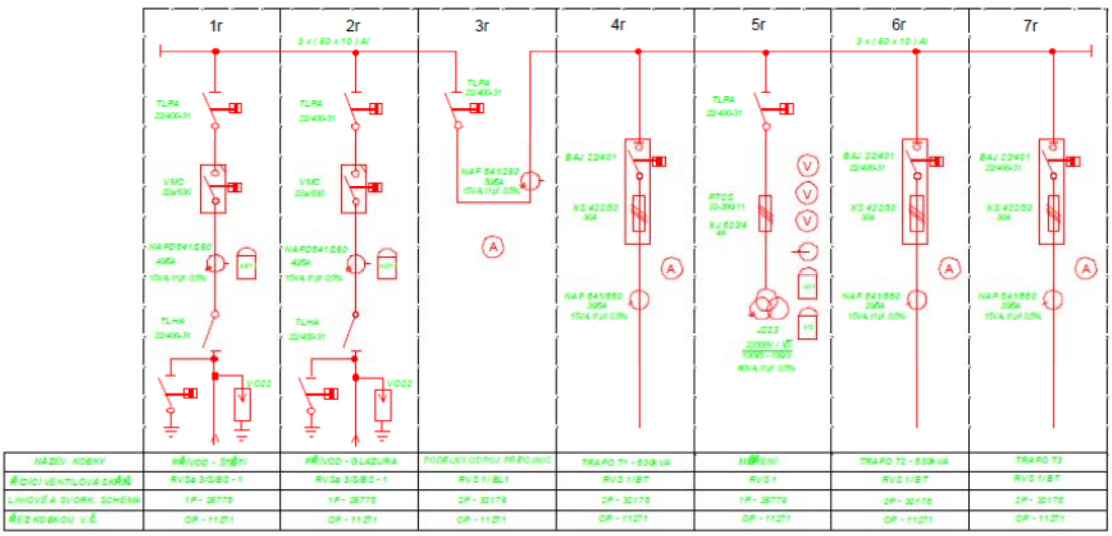


Figure 2.1 Wiring diagram of the company

Transformer	Power (KVA)
Total T1	630
Total T2	630
Total T3	630
Total power	1890

Table 2.1 Apparent power transformers installed in the plant.

In the table 6.2 you can see the distribution of the power among the three transformers, what are the equipments connected to each one, the power consumption as well as single consumption as total power of each transformer.

Substation NN	pole n.	Equipment	Power consumption kW	total power input kW	Concurrence
TRAFO 1	8	Garage RM1 (old generator room)	1,5	1118	783
	8	administration Building	63		
	11	Substation - lighting	1		
	11	Substation - Compressors	3		
	11	Gas regulation station	38		
	12	Dry grinding mill spirituous + dryer	1010		
TRAFO 2	1b	Substation NN care (K7-K8)	292	1957,8	1372
	1a	Dust extraction Tekneco, KP5 + KP6	160		
	1a	Substation NN Furnaces (K5-K6)	311		
	5	The old substation	860		
		Rotary kilns	334,8		
TRAFO 3	14	Substation glazes	539	794	556
	15	Lödige (Mixer)	75		
	18	Compressors - Weighing facilities	180		

Table 2.2 Transformer station

For another hand after to know what is connected to each transformer now is time to know deeply what is the consumption of each equipment over the ones it goes to work to save as much power as possible and with that obtain a reduction in the electric bill.

In the following tables we can check the consumption of each equipment or process in the table 2.3 about the T1, table 2.4 about T2 and in the table 2.5 about T3.

Figure 2.2 Transformer station

T 1				
Pole n.	**Terminal**	**Equipment**	**Power Equipment**	**Power sum**
8	Garage RM1 (old generator room)	lighting garages and warehouses	1,5	1,5
		chests of drawers		
8	administration Building	lighting, sockets, boiler	63	63
11	Substation	lighting	1	4
		compressors	3	
11	Gas regulation station	Lighting, heating	38	38
12	dry milling	Noll - mill	110	1010
		Noll - sucking	5,5	
		Předdrtič	6	
		Sahara	5	
		packaging Line	1,5	
		compressor 1	55	
		compressor 2	55	
		Lighting the building	18	
		Eirich	110	
		Předdrtič	17	
		AVA - hl.motor	132	
		AVA - clarifiers	16,5	
		Amixon	41	
		The Mixer	25	
		packing	1,5	
		Wet Glaze - mills 5x5, 5kW + 2x11kW	49,5	
		Wet Glaze - Elsa	90	
		Lihová ml. - Mills 12x1, 1kW	13,2	
		Lihová ml. - Drier SEC-N No.1	46,8	
		Lihová ml. - Drier SEC-N No.2	52	
		Lihová ml. - furnace	20	
		Lihová ml. - Exhaust + heating	32	
		Laboratory - furnace 5x11kW	55	
		Laboratory - furnace 15kW + 14kW 6,5 kW +	35,5	
		Laboratory - grinding stool 12x 0.5 kW + 3kW	9	
		Laboratory - Air Conditioning	4	
		Laboratory - heating	4	

total Power	1116,50 kW

Table 2.3 Equipment connected to transformer 1

T 2				
Pole n.	**Terminal**	**Equipment**	**Power Equipment**	**Power sum**
1b	Substation NN (K7, K8)	**Cabigrid kiln K7**	28	292
		Cabigrid kiln K8	28	
		Switchboards mixers Zippo	60	
		Dust extraction ILD	75	
		ATS - RM2 rack	0	
		Weighing facilities compressor No.3	90	
		Atlas Copco compressor distributor	11	
1a	Tecneco	**Dust extraction Tekneco**	160	160
1a	Substation NN (K5, K6)	**Switchboard CM5-6 (Weighing facilities control center)**	50	311
		distributor	10	
		Atlas Copco Compressor	22	
		Cabigrid RS1 (osvětl.hala, Tekneco, substations)	10	
		Cabigrid RM5 - pecč.5	28	
		Cabigrid RM6 - furnace No.6	28	
		Travel baskets K5	1,5	
		Travel baskets K6	1,5	
5	The old substation	**Listrovna**	110,4	859,4
		boiler room	13	
		Regeneration line	16	
		Pilot plant	5	
		V - mix	14,6	
		oven	37	
		centrifuge + generator	5,2	
		dryers	9,6	
		Fans	10	
		CEI + OTK	153,3	
		oven	133	
		mills	4,8	
		by X-ray	15,5	
		villa	34	
		OTS + pilot plant	281,7	
		Kemac	11	
		drying	86	
		compressor	14,8	
		glaz.linky	12	
		oven	59	
		rotocolor	8,4	
		grinding stool	4,5	
		boiler	4	
		drying SEC-N	52	
		mills	30	
		Substation K9 + K10 - suš.Elsa	120	

		Workshop - Maintenance	10	
		New barvičkárna	150	
7	Rotary kilns	compressors	16,8	334,8
		mixers 3x77	231	
		cranes	40	
		exhausts from ovens	4,5	
		powered furnaces	9	
		DM Lines	15	
		ILD fan	18,5	

total Power	1957,20 kW

Table 2.4 Equipment connected to transformer 2

T 3				
Pole n.	**terminal**	**equipment**	**Power Equipment**	**Power sum**
14	substation glazes	**line Torrecid**	90	539
		New compost	108	
		technology	90	
		conveyor	13	
		packer	5	
		line sandwiches	10	
		CM 1-2 dosing Furnace 2x22kW	44	
		CM 2-3 dosing Furnace 2x22kW	44	
		crane R5		
		RIS distributor warehouse of finished products	4	
		ATS + reservoir	94	
		chl.věže 11 + 7.5 +7.5	26	
		well pumps	5	
		reverse osmosis	3	
		Cabigrid Willo 2x30kW	60	
		Admin.budova furnaces	15	
		hall lighting	18	
		Continuity furnace K1-K4 (4x28)	112	
15	Lödige (Mixer)	**Lödige 1 + 2 (interlock) 2x 75 kW**	75	75
18	Weighing facilities compressors	**Weighing facilities compressors No.2 and No.3**	180	180

total Power	794,00 kW

Table 2.5 Equipment connected to transformer 3

It has to be mentioned as well that every transformer has its own capacitor battery

Capacitor banks are very useful equipment can reduce surcharges why generated reactive power, thereby obtaining a saving in electricity bill.

The use of a capacitor bank to correct AC power supply anomalies is typically found in heavy industrial environments that feature working loads made up of electric motors and transformers. This type of working load is problematic from a power supply perspective as electric motors and transformers represent inductive loads, which cause a phenomenon known as phase shift or power factor lag in the power supply. The presence of this undesirable phenomenon can cause serious losses in terms of overall system efficiency with an associated increase in the cost of supplying the power.

The use of a capacitor bank in the power supply system effectively cancels out or counteracts these phase shift issues, making the power supply far more efficient and cost effective. The installation of a capacitor bank is also one of the cheapest methods of correcting power lag problems and maintaining a power factor capacitor bank is simple and cost effective. One thing that should always be kept in mind when working with any capacitor or capacitor bank is the fact that the stored energy, if incorrectly discharged, can cause serious burns or electric shocks. The incorrect handling or disposal of capacitors may also lead to explosions, so care should always be exercised when dealing with capacitors of any sort.

In short, the benefits of having a capacitor is that it gets cheaper the electricity bill disappear and penalties, on the other hand, we can reduce the levels of load lines, optimizing the performance of the installation. For all this reasons the next pot to study is the reactive power compensation in the plant.

Figure 2.3 Capacitor's battery inside of the transformer

2.1. Reactive power compensation in the plant

This is one of the important aspects to consider if you want to reduce the cost of energy bills and improve the overall functioning of the electrical installation.

Most electricity consumption, due to its operation, grid work absorbs active and reactive power simultaneously. Reactive power is required for motors and transformers to create the magnetic field. Reactive power cannot be converted into useful work but, however, as the active energy must be generated and transported to consumption.

The transport of reactive power (cos phi ≠ 1) along the lines of the installation involves a number of problems:

- Increased losses by Joule effect:

Cos φ = 1 → $I=I_a$ → $P_j=3RI_a^2$

Cos φ ≠ 1 → $I=\sqrt{I_a^2+I_r^2}$ → $P_j=3R(I_a^2+I_r^2)$

- Increased voltage drop:

Cos φ = 1 → $I=I_a$ → $\Delta U=\sqrt{3}RI_L\,I_a$

Cos φ ≠ 1 → $I=\sqrt{I_a^2+I_r^2}$ → $\Delta U=\sqrt{3}(R_L\,I_a+X_L I_r)$

The data explained before also happen in transformers, where the copper losses and voltage drops increase.

Surprisingly according to the Czech legislation, it is not seeking to avoid this series of problems in the distribution lines, trying to force all consumers to be factors close to unity power as it happens in Spain. Thereby it is not penalizing factors below 0.90 and power, rewards the higher ones neither.

Anyway it has been done the calculation of the capacitors battery needed for the regular consumption oh the company and also it has been compared with the data obtained from the software and the results are very positives. As well as the transformer data how is showing below.

In this section, for each type of transformer plant parameters of its equivalent simplified schemes and their performance is compared with the ideal gain. It could be obtained the status of more efficient work from the point of view of energy or reactive energy consumption.

To find the equivalent circuit of each transformer, shown in Figure 3.8, you will need to know first its rated apparent power Sn, in kVA and V1n nominal primary voltage in V, from which it can obtain the primary current nominal I1n in a, although this value is also provided on the nameplate.

Take as the primary side of the transformer for which it is intended to obtain the equivalent circuit regardless of whether the high side or low voltage.

Furthermore, the magnitudes which provide vacuum testing circuit will be needed.

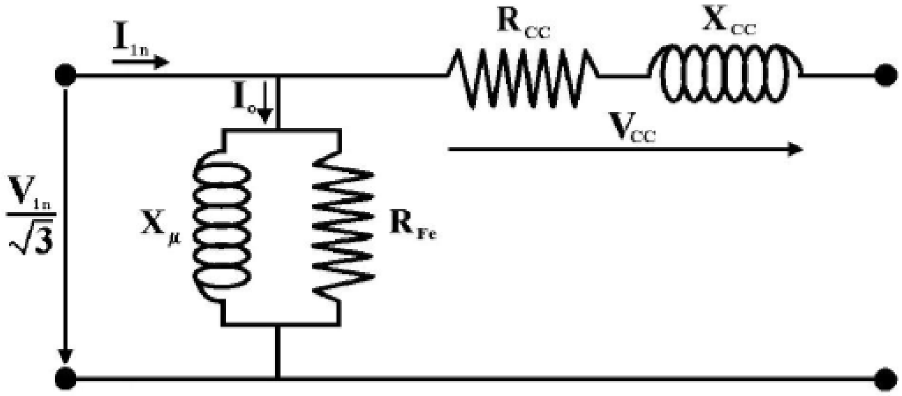


Figure 2.4 Equivalent circuit of a transformer

Although not necessary to obtain the equivalent scheme, the voltage and current as well as the secondary connection and control are also provided.

The vacuum test is obtained:

Po: load losses, in W.
Io: Intensity vacuum, in% of the rated current.
In the short-circuit test are obtained:
Pcc: Losses in short, in W.
εcc: Voltage drops in% of rated voltage.

For the parameters of the parallel branch of the scheme should be based on measurements of the load test. First you must obtain the load power factor, cosφ or, using the following equation:

$$P_o = 3 \cdot \frac{V_{1n}}{\sqrt{3}} \cdot I_o \cdot I_{1n} \cos \varphi_0$$

This value can be calculated the values of the two components of the vacuum intensity, and Iµ I_{FE} and Iµ in Amperes as:

$$I_{Fe} = I_o\, I_{1n} \cos\varphi_o$$

$$I_\mu = I_o\, I_{1n}\, sen\varphi_o$$

They allow finally get the R_{Fe} and Xµ parameters in Ω, of the parallel branch of the simplified scheme from the following equations:

$$R_{Fe} = \frac{V_{1n}}{\sqrt{3} \cdot I_{Fe}}$$

$$X_\mu = \frac{V_{1n}}{\sqrt{3} \cdot I_\mu}$$

In order to know the other two parameters must use the measurements obtained in the short-circuit test. As in the previous case also should begin to get the power factor, $\cos\varphi_{cc}$, by the following expression:

$$P_{cc} = 3 \cdot \frac{V_{cc}}{\sqrt{3}} \cdot I_{1n} \cdot \cos\varphi_{cc}$$

The above value can directly obtain the voltage drop in each of the elements of the series branch, in V as:

$$V_{Rcc} = \frac{V_{cc}}{\sqrt{3}} \cdot \cos\varphi_{cc}$$

$$V_{Xcc} = \frac{V_{cc}}{\sqrt{3}} \cdot sen\varphi_{cc}$$

These values allow finally obtain the parameters of the series branch of the simplified equivalent scheme Rcc and Xcc, in Ω, from the following equations:

$$R_{cc} = \frac{V_{Rcc}}{I_{1n}}$$

$$X_{cc} = \frac{V_{Xcc}}{I_{1n}}$$

After obtained the four parameters of the equivalent simplified scheme can be estimated losses or reactive energy consumed by each processor in the different working regimes.

Each regime is characterized by the demand which is subjected to each transformer or what is the same, the relationship between apparent power and nominal defendant. This value is known as load index calculation for each scheme will need to know its active power and power factor means then obtained:

$$C = \frac{P_{media}}{\cos\varphi \cdot S_n}$$

The losses of a transformer can be divided into load losses, which are fixed and can always get the transformer is connected to the network and load losses vary according to the load that the transformer is subjected.

$$Losses = Po + P_{LOAD}$$

Where:

$$P_{LOAD} = C^2 \cdot Pcc$$

Known losses can obtain the efficiency with which the transformer is working and will not be more than the ratio of the power transferred and absorbed power, which is the sum of the assigned and losses as shown in the following expression:

$$\eta = \frac{C \cdot S_n \cdot \cos\varphi}{C \cdot S_n \cdot \cos\varphi + P_o + C^2 P_{cc}}$$

As can be seen, for a particular transformer, with a loss of vacuum and particular circuit, the performance depends only on power factor and the load index. Obviously, the optimum power factor is one that is equal to unity. For this value, the maximum yield is obtained for a given load index, C_{opt}, which is obtained by differentiating the above expression with respect to C and equating to zero, resulting in:

$$P_0 = C_{opt}^2 \cdot P_{CC} \Rightarrow C_{opt} = \sqrt{\frac{P_0}{P_{CC}}}$$

Substituting $\cos\varphi$ by 1 and C by C_{opt} expression yield is obtained with maximum performance which can work with the transformer and compare the present to see how close the two are.

Finally, it is also interesting for this project to obtain the reactive power consumption of each processor, which, for each scheme will be, like losses, the sum of a corresponding vacuum term and another corresponding to load, which is get, from reactors previously found by the following expressions:

$$Q_{VOID}=3 \cdot I^2_{\mu} \cdot X_{\mu}$$

$$Q_{LOAD}=3 \cdot (C \cdot I_{In})^2 \cdot X_{cc}$$

The sum of these two terms in the reactive power consumed by the processor in a given system:

$$Q_{TOTAL} = Q_{VOID} + Q_{LOAD}$$

	Units	T3	T2	T1
S	KVA	630,00	630,00	630,00
V1	V	22000,00	22000,00	22000,00
I1	A	16,50	16,50	16,50
V2	V	400,00	400,00	400,00
I2	A	909,00	910,00	910,00
Po	W	929,00	1161,70	1512,00
Io	%	0,00	0,01	0,01
Pcc	W	6520,26	1785,10	8051,90
Ecc (U k)	%	0,06	0,06	0,06
Cos fi o		0,76	0,26	0,20
Sen fi o		0,65	0,96	0,98
I fe	A	0,02	0,03	0,04
I u	A	0,02	0,11	0,19
R Fe	Ohms	520990,31	416630,80	320105,82
X u	Ohms	604917,89	113352,02	65139,53
Cos fi cc		0,17	0,05	0,22
sen fi cc		0,99	1,00	0,98
V Rcc	V	131,72	36,06	162,66
V Xcc	V	786,50	742,17	736,74
Rcc	Ohms	7,98	2,19	9,86
Xcc	Ohms	47,67	44,98	44,65
P average	KW	556,00	1372,00	783,00
cos fi averag.		0,97	0,97	0,97
C		0,91	2,25	1,28
Pload	W	5408,72	9016,77	13246,53
Losses	W	6337,72	10178,47	14758,53
Efficiency	%	0,99	0,99	0,98
Copt		0,38	0,81	0,43
Effic. Max	%	0,96	0,99	0,96
Q void	VAr	800,11	4269,88	7430,20
Q load	VAr	32294,88	185566,20	59995,81
Q total	VAr	33094,99	189836,09	67426,01
	KVAr	33,09	189,84	67,43
Battery power	KVAr	506,40	3083,53	1004,30

Table 2.6 Capacitors battery calculation

From the software, as we can see in the figure 3.9, we obtained an average cos fi of 0,97 what it means the compensation of the reactive power is really well done, and the company is taking it into account even if they are not penalized for them.

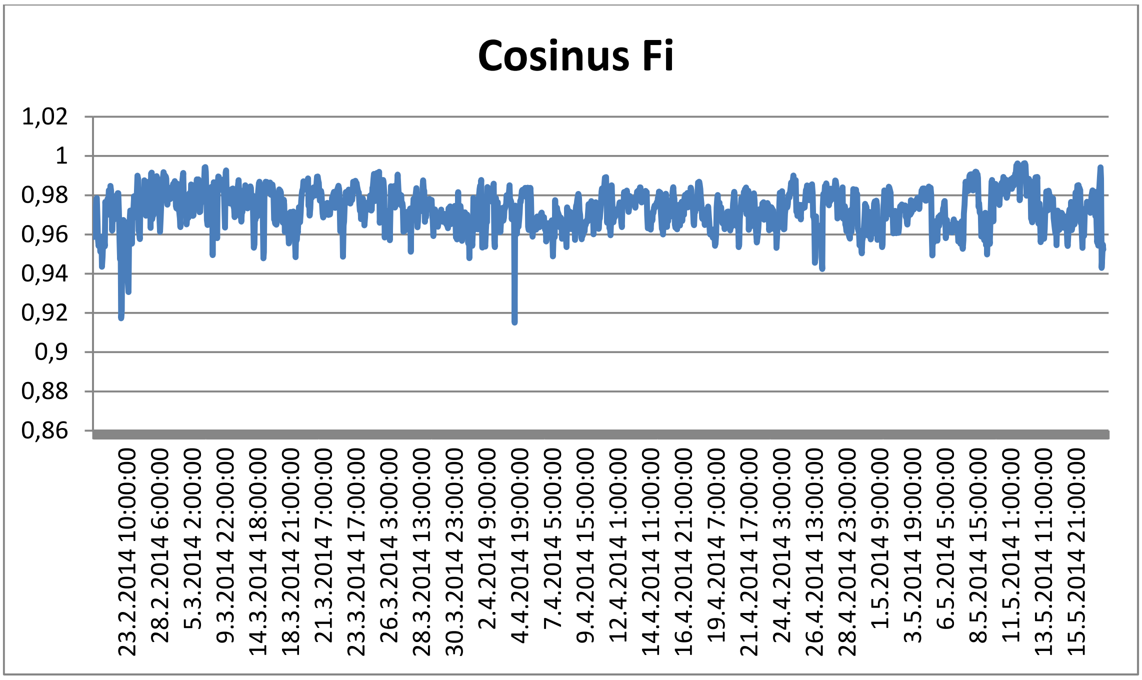


Figure 2.5 Cos fi data from the software

2.2. ECONOMIC AND ENERGETIC CONSUMPTION EVALUATION

2.3. Introduction

This section describes the tariff hired by the company and how much are they spending monthly, as it can be checked in the table 3.2

TARIFF HIRED		
WEEK DAY	60,57	€/MWh
WEEKEND DAY	32,86	€/MWh

Table 2.2.1 Tariff hired by the company

	KWh	€
January	426766	44.519,79 €
February	467224	48.672,93 €
March	494687	47.764,72 €
April	446409	43.883,87 €
May	385924	38.450,83 €
June	434743	42.532,73 €
July	357307	36.494,85 €
August	321907	32.793,47 €
September	374475	37.789,99 €
October	409481	40.168,46 €
November	439390	44.913,08 €
December	393991	40.243,12 €
TOTAL	4952304	498.227,84 €

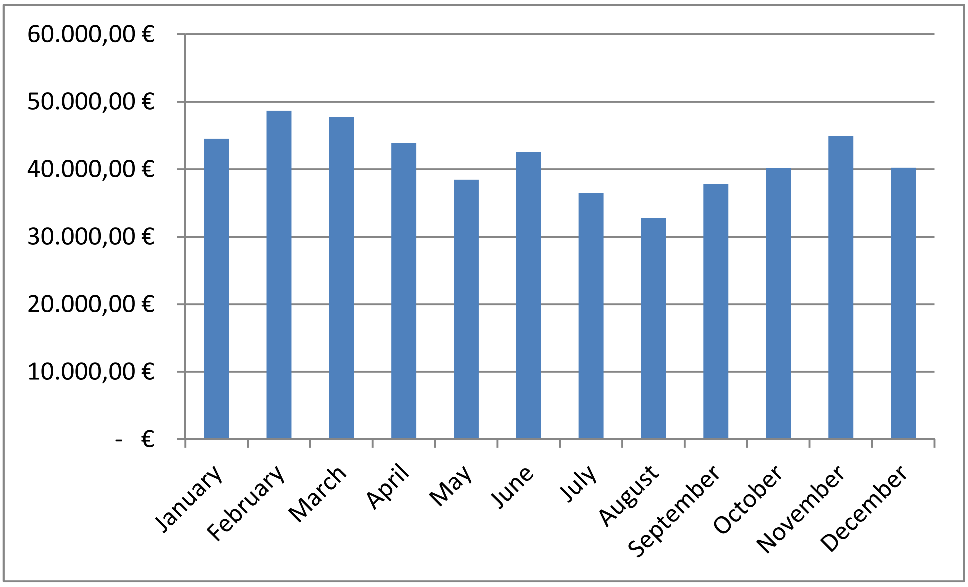


Table 2.2.2 Amount of electricity bills in 2013

As seen below, the term power is one of the most important in the electrical bills. To determine the cost, the factory has a maximeter installed by the electrical company, which records the maximum value of the active power demanded each month.

The maximeter is registering the active energy consumed during an interval of 15 minutes. At the end of that interval divided power between 15 minutes to obtain a power value. If the power value is greater than the peak demand was recorded in the previous period, the new value will be displayed by the maximeter, if not, the value of the previous period is retained.

This calculation method makes, for example, a motor starting point for one minute measured does not influences the maximeter directly due the maximeter is taken the average of the remaining 14 minutes interval calculation.

Always seek the power recorded by the maximeter is less than the contracted since otherwise it is severely penalized. Neither interested in hiring a very high power because it always has to pay a minimum and that minimum is a percentage of the contracted power.

For one hand, one of the objectives of the study will try to decrease the value of the power recorded by the maximeter, then allowing a reduction in the value of the contracted power. This objective can be achieved in two ways: reducing the power consumption itself or consuming the same, but better distributed in time, with fewer peaks.

The first is accomplished trying to optimize the consumption as many as possible, minimizing losses, while the second is achieved by reducing the peak power of each individual consumer as well as the total power curve, shifting consumption from the peaks to the valleys.

For the other hand, it will be necessary to do a comprehensive study of the general consumption of the plant and the each particularly consumption, which is going to do next. The study of consumption also will reduce energy consumption, thereby reducing this term, which also has a lot of weight in the amount of the electric bill.

To make the overall study of the plant and the use of each line, has been necessary the data from various sources.

This data is taken from 15 grid work analyzers located at the processing center, one at the entrance of each CT and the others connected to the beginning of each of the low voltage lines. Each analyzer can display the instantaneous values of the main electrical variables (simple and compound voltage, current, power factor, active power and reactive, apparent, reactive and active energy) and the recorded maximum and minimum for each of them.

All the electrometers from the beginning of February are connected to software called "Xenie Sofis" the one is receiving all the data from all the company and where it can be checked the historical of consumption or the instantaneous consumption of all the company or from each department. This software is going to be really useful to develop this project and to check all the consumptions and to study how they can be more efficient. (Figure 3.1)

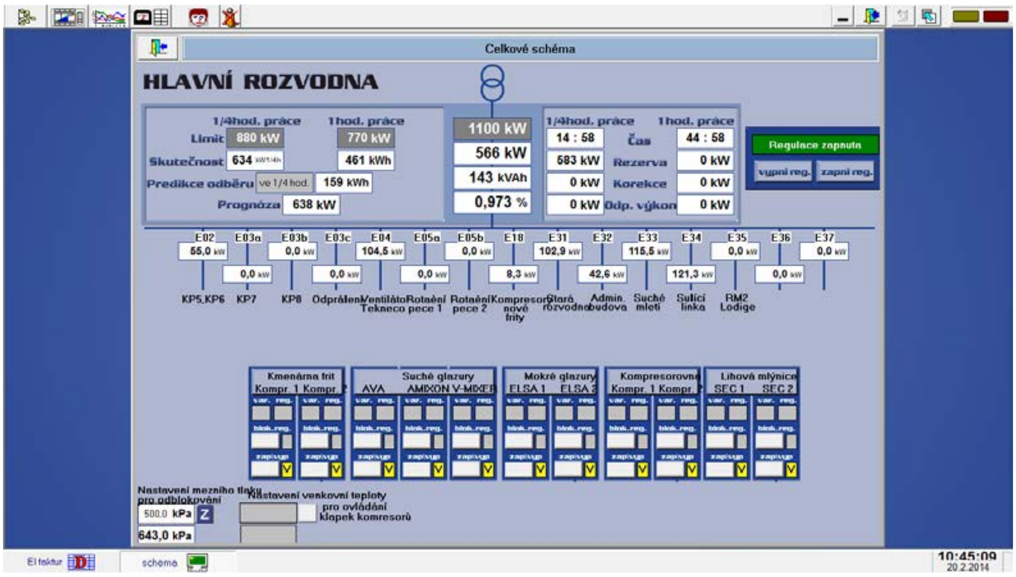


Figure 2.2.1 Software Xenie sofís

2.4. Energy evaluation

As it was commented lately the installed power is 1890 KVA nevertheless the power hired is lower due the concurrence consumption is 783 KW for T1, 1372 KW for T2 and 556 KW for T3.

To begin with the study it is interesting to know about the regular week and weekend consumption of each transformer as it can be checked in the following figures:

In the figure 3.2 can be checked the week day consumption of the transformer 1 where is connected the administration building (in black) and the dry milling process (in red).

For one hand consumption of the administration building is one of the lowest in the company due there is not any big powered machine connected to this line as well as it can be checked in the figure 3.3 the difference between a week day and a weekend is quite low.

To the other hand the consumption of the dry milling is one of the highest in the company due to this line is connected high powered machines like the pre-crashers, the mills and dryers. It has to be stand out this consumption is very balanced due the shift of work is 16 hours but only during the work days hence during the weekend the consumptions goes down so much as it can be checked on the figure 7.3.

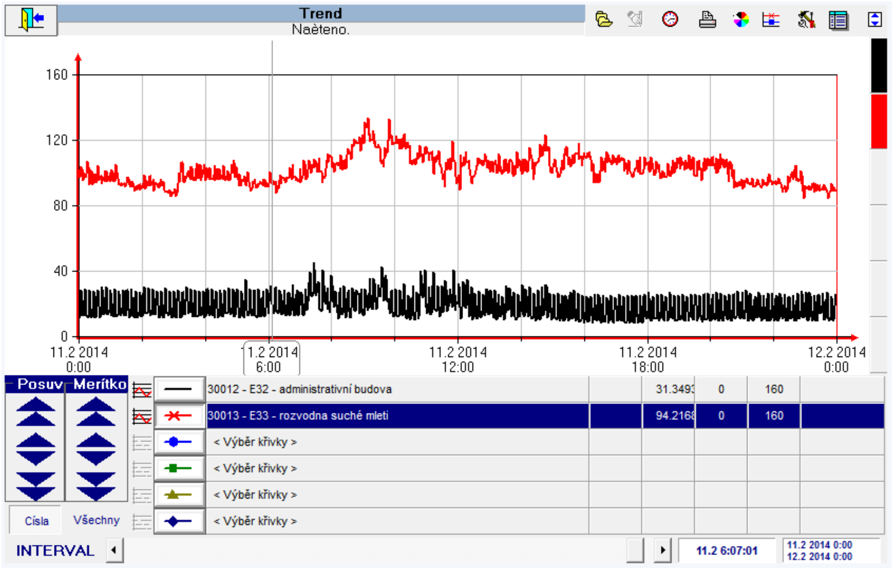


Figure 2.2.2 T1 Consumption of a week day

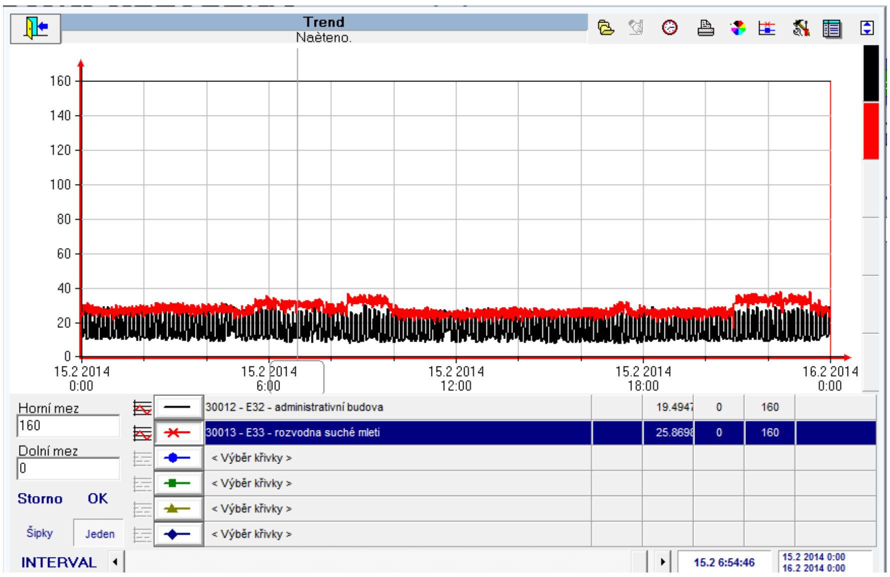


Figure 2.2.3 T1 Consumption of a weekend day

In the figure 3.4 can be checked the week day consumption of the transformer 2 where is connected the kilns number 7 and 8 in black a red respectively, the dust extraction system in blue, the kilns number 5 and 6 in green, the pilot plant in military green and finally the rotary kilns in dark blue.

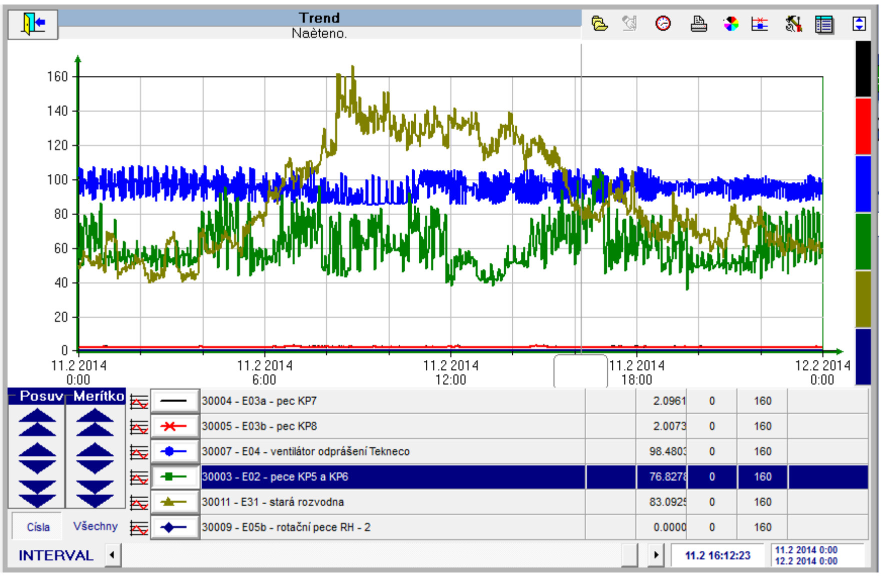


Figure 2.2.4 T2 Consumption of a week day

As can be esteem in the chart due a lower production nowadays the kilns number 7 and 8 are not working but kiln number 5 and 6 are working nonstop 24h per day, 7 days per week hence there is not any difference between the work days and the weekends. The dust extraction system is a complementary system to the kilns number 5 and 6 for this reason is working all time as well without difference between work days and weekends.

Where it can have a difference between work days and weekends is in the pilot plant due this department is only working throughout Monday to Friday and only time to time if they have to make up some work it is working on Saturday mornings too as it can be checked the peak on the chart.

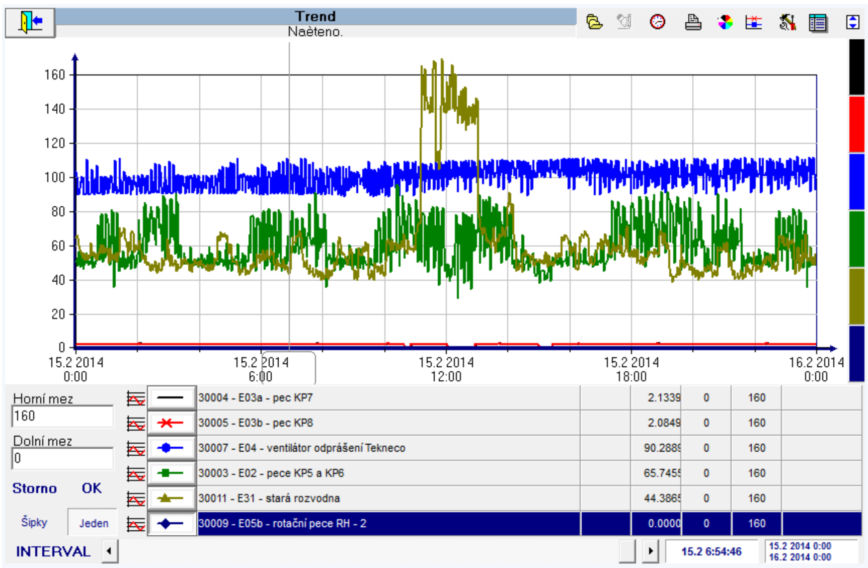


Figure 2.2.5 T2 Consumption of a weekend day

Has to be commented due an error in the electrometer the rotary kiln in dark blue on the chart, it seems like totally disconnected but it is no true. The rotary kiln has an irregular working hours, it just depends on the sets that they have every week. So it is one of the most flexible consumptions that it will be study to try to avoid the peaks in the energy consumption.

The consumption in the transformer 3 is the most balanced.

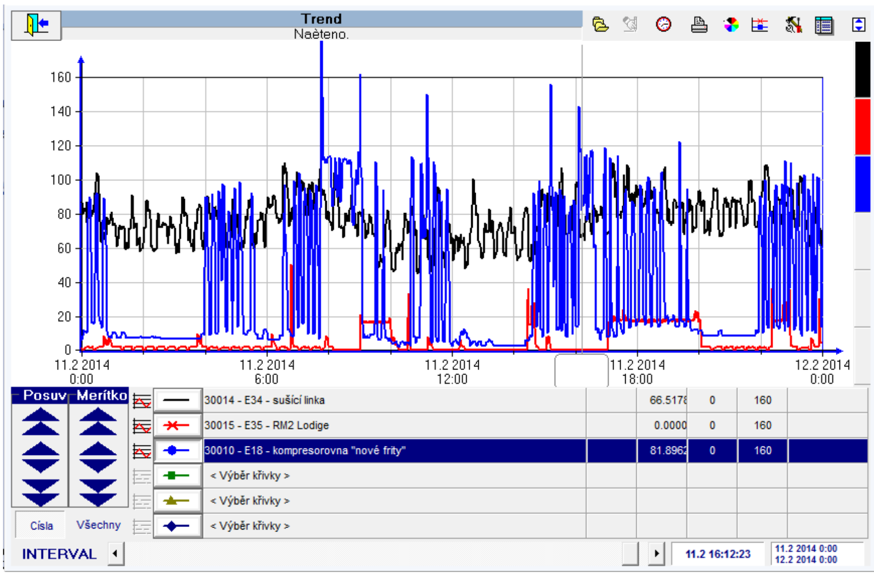
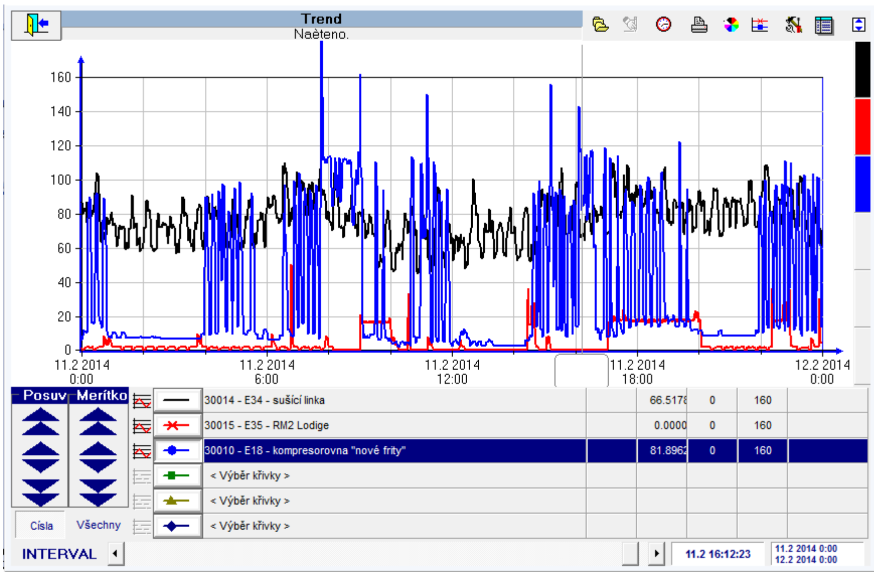


Figure 2.2.6 T3 Consumption of a week day



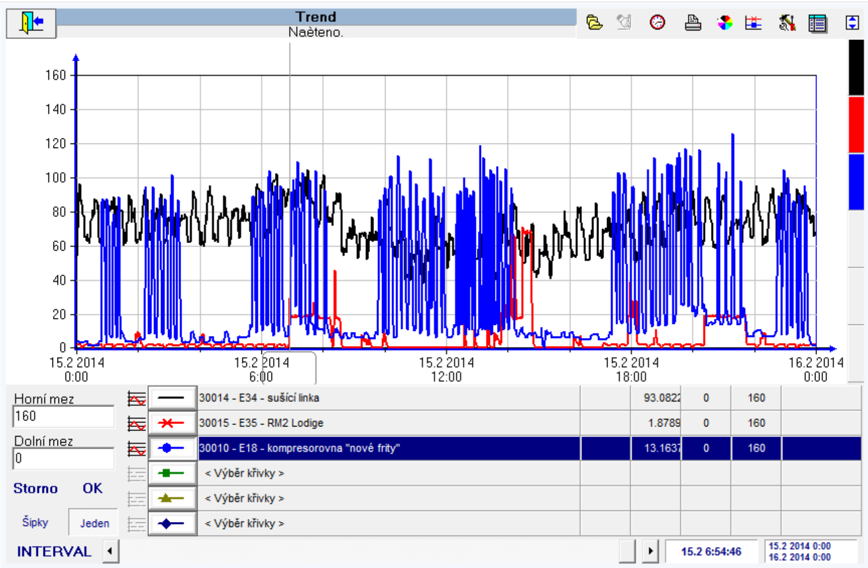


Figure 2.2.7 T3 Consumption of a weekend day

2.5. Compressors

The air compressor is a device that converts power from an electric motor into kinetic energy by compressing and pressurizing air, which, on command, can be released in quick bursts. These compressors have positive-displacement methods of air compression.

Figure 2.2.8

Positive-displacement air compressors work by forcing air into a chamber whose volume is decreased to compress the air. Piston-type air compressors use this principle by pumping air into an air chamber through the use of the constant motion of pistons. They use one-way valves to guide air into a chamber, where the air is compressed. Rotary screw compressors also use positive-displacement compression by matching two helical screws that, when turned, guide air into a chamber, whose volume is decreased as the screws turn. Vane compressors use a slotted rotor with varied blade placement to guide air into a chamber and compress the volume. It is a type of compressor that delivers a fixed volume of air at high pressure. Common types of positive displacement compressors include piston compressors and rotary screw compressors.

In Glazura s.r.o there are install two groups of compressors, the first one is in the dry milling department and it is compound by three compressors two of them of 55kW, those ones are working to its 100% of power alternately helping the third smaller compressor of 36kW installed with a frequency converter, this one is the main one, which is working all time.

The other group of compressor is installed in the compounds line, this group is made for 3 compressors with 90kW each, and follows the same technology as the other group, one of them has a frequency converter and is working all time and the other two are working alternately helping it.

The frequency converters are install due many fixed-speed motor load applications that are supplied direct from AC line power can save energy when they are operated at variable-speed, by means of VFD. Such energy cost savings are especially pronounced in variable-torque centrifugal fan and pump applications, where the loads' torque and power vary with the square and cube, respectively, of the speed. This change gives a large power reduction compared to fixed-speed operation for a relatively small reduction in speed. For example, at 63% speed a motor load consumes only 25% of its full speed power. This is in accordance with affinity laws that define the relationship between various centrifugal load variables.

Fixed-speed operated loads subject the motor to a high starting torque and to current surges that are up to eight times the full-load current. AC drives instead gradually ramp the motor up to operating speed to lessen mechanical and electrical stress, reducing maintenance and repair costs, and extending the life of the motor and the driven equipment.

Variable speed drives can also run a motor in specialized patterns to further minimize mechanical and electrical stress. For example, an S-curve pattern can be applied to a conveyor application for smoother deceleration and acceleration control, which reduces the backlash that can occur when a conveyor is accelerating or decelerating.

Besides all the compressors are connected to software, where it can be checked the work time of each one and the pressure.

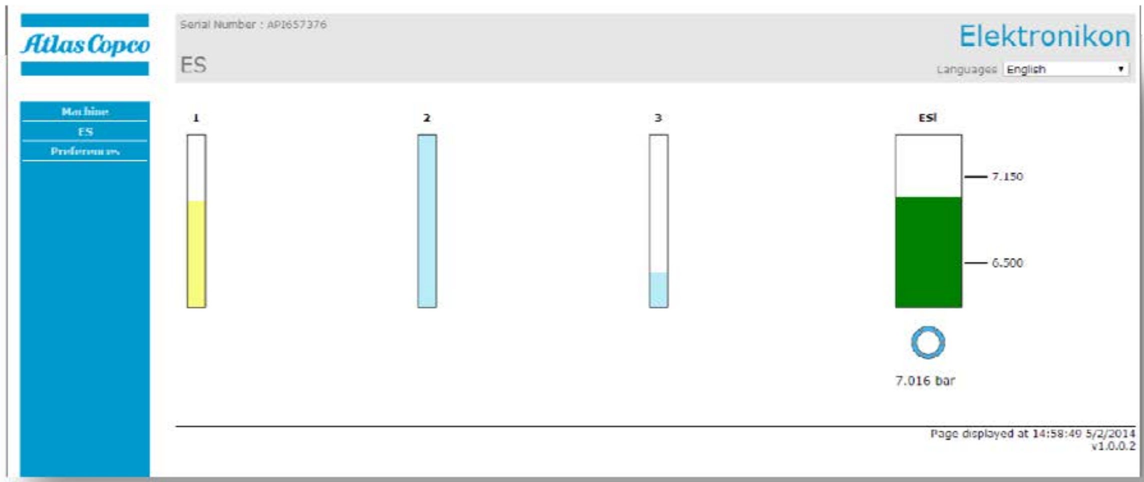


Figure 2.2.9 Software of the compressors

3. ANALYSIS RESULT

Once done the energetic study about the production of the company and all the technologies are involved in each process and check the consumption in its steps. Besides has been studied the hired tariff and their individual consumptions from the main energetic sources.

It is decided to pay special attention in the consumption energetic curve, taking advantage of the new software installed is able to show in instantaneous consumption of each source to avoid the consumption peaks and try to do the curve as flat as possible in order to save energy, money and possible penalties due to overconsumption.

Related with the reactive energy, it has to be highlighted; previously to the energetic study the company was very aware of the importance of the compensation of this energy. They have done a very good job installing the compensator batteries in the proper sites with the proper size, as it has been checked after the energetic study, getting an average of the cos fi near to 0,97.

Has to be underlined the installation of the compressors, where Gazura s.r.o. has installed the frequency converter in the smaller compressor and this one is been assisted for two bigger working alternately in order to save energy and extend the work life of the compressors.

As a conclusion of this energetic study is going to be modify the consumption curve to get an energetic demand as flat as possible. In addition is going to contemplate the possibility of the installation of a sun power panels over one of the roofs of the company with the aim of distribute the energetic consumption from the power station and the photovoltaic installation.

ANNEX IV

STRUCTURE CALCULATION

Index

1. SCOPE AND PURPOSE

The purpose of this study is to check that all elements of the structure verify compliance with the requirements of structural safety (stability and resistance) and release to (deformability) service established in the EN 1991: Actions on structures.

First you must know the characteristics of the building, the elements that compose it, the material and the disposal of each.

Then from the outer dimensions and morphology of industrial action on industrial construction will be obtained. These actions are permanent actions (weight of the structure and weight of the PV system) and variable actions (use overload, wind and snow).

Once you have the values for these actions are introduced into the structure calculation software "CypeCAD" where can be checked if the structure is valid to support the PV system on the roof.

2. LEGISLATION AND REFERENCES

2.1. Legislation and standard reviewed

EN 1991: Actions on structures

EN 1991 Eurocode 1 provides comprehensive information on all actions that should normally be considered in the design of buildings and other civil engineering works, including some geotechnical aspects.

It is in four main parts, the first part being divided into sub-parts that cover densities, self-weight and imposed loads; actions due to fire; snow; wind; thermal actions; loads during execution and accidental actions. The remaining three parts cover traffic loads on bridges, actions by cranes and machinery and actions in silos and tanks.

2.2. Bibliography

Background documents used to develop EN 1991, Part 1.1 [3] consist of national standards of CEN Member states, International Standard ISO 9194 [4], CIB Reports 115 and 116 [5, 6] (see also recent paper [7]). However, some principles, rules and numerical data provided in these documents are not entirely consistent. Moreover, available statistical data concerning densities, angles of repose and imposed loads are inconclusive [7]. Consequently, for properties of some materials and for some imposed loads intervals instead of distinct values are given in EN 1991, Part 1.1 [3].

2.3. Software

CypeCAD: It was brought about to carry out the analysis and design of reinforced concrete and steel structures, subject to horizontal and vertical forces, for houses, buildings and civil work projects.

3. LOADS ON THE STRUCTURE

Considering its variation in time and space, self-weight of a construction element is classified as permanent fixed action while imposed load as variable free action. However, if there is doubt about the permanency of a self-weight, then the load shall be treated as variable imposed load. Generally the imposed load is considered as static load, which may be increased by a dynamic magnification factor. If an imposed load causes significant acceleration of the structure or structural element, dynamic analysis should be applied in accordance with EN 1990.

Besides self-weight of a construction elements, in this study is going to be considered as a permanent load the weight of all the photovoltaic installation.

3.1. Permanent loads

It is called permanent actions to loads due to the weight of all structural elements and the enclosure.

3.2. Variable loads

3.2.1. Overloads

At this point you might not be constant loads on the structure because of its use throughout the life of this and not attributable to nature and other charges provided for in other scenarios (wind, earthquake or snow) is facing.

3.2.2. Wind loads

One of the main parameters in the determination of wind actions on structures is the characteristic peak velocity pressure up. This parameter is in fact the characteristic pressure due to the wind velocity of the undisturbed wind field. The peak wind velocity accounts for the mean wind velocity and a turbulence component. The characteristic peak velocity pressure up is influenced by the regional wind climate, local factors (e.g. terrain roughness and orography/terrain topography) and the height above terrain. This is used as provided in EN 1991-1-4 Wind Actions

3.2.3. Thermal actions

The exposure of a structure or of a roof to wind effects as well as the thermal transfer from a heated room through a non-insulated roof influences the accumulation of the snow. In order to take into account these effects prEN 1991-1-3 introduces the exposure coefficient Ce and the thermal coefficient Ct.

In general the exposure factor is chosen as Ce = 1,0. Only in case of exceptional circumstances where the roof is located either in open terrain or in surroundings which represent shelter the exposure factor should be adjusted. If the building is placed in open terrain the roof is denoted as "windswept" and the exposure coefficient may be reduced to Ce = 0,8. In case the building is sheltered due to dense vegetation or due to adjacent higher buildings the exposure factor should be enhanced to Ce = 1,2.

The thermal coefficient is also set to Ct = 1,0 for the normal situation. Only where roofs of heated buildings are not or poorly insulated (glass roofs / thermal transmittance > 1 W/m^2K) it is allowed to use a reduced factor Ct. It is planned to introduce recommendations for these reduction factors into the National Annexes.

3.2.4. Snow loads

These charges are due to the weight of snow that can accumulate on the structure due to snowfall in the area. His determination will linked to the geographical area in which the execution of the structure is projected mainly topographic height and the type of cover that is to be used, the roof slope and roughness.

3.3. Load and stress of the PV system determination

The load has being studied is the one produced by the PV modules plus the rest of the elements of the installation (wires, aluminum structure, anchorage…).

The weight of each modules is 20 kg and it occupied a surface of 1,8m2, so the load per square meter is around 20 kg, plus the weight of the rest of the elements that has being consider a load of 35 kg per square meter to be sure that the factory's structure can resist all the weight of the installation without problems.

3.4. Service load determination

In this study has been consider too the overload due the maintenance of the roof and the installation. The value of the overload is 0,4 kN/m^2 which is written in the EN 1991. This overload is independent to the snow and wind loads, basically because they are incompatible.

4. INDUSTRIAL BAY BACKGROUND

4.1. Description of the building

The factory where the PV plant is going to be installed is located at a remote place where no shadows are going to affect the panels. The factory presents a flat roof and its dimensions are the following:

- $Length_1$: 160 m
- $Light_1$: 50 m
- Total area: 8000m^2

Regarding the internal structure of the factory. It presents the following characteristics:

- Distance between frames: 5 meters.
- Height of columns: 10 meters.
- Ridge Height: 10 meters.
- Roof slope of 0% (0 °)

An important fact for the modules location is to know the orientation of the factory; in this case the longitudinal part is oriented to the south.

The building blocks that make up the industrial unit are described below.

Outdoor's porch.

The pillars are laminated profile HEB 160 and 180.
The beams are rolled section IPE 300.

Indoor's porch.

The pillars are laminated profile HEB 240.
The beams are rolled section IPE 330.

The Saltier profiles that formed steel braces 16mm diameter.

The cover material is sandwich panel consisting of two galvanized steel plates 40 mm thick and a core of rigid polyurethane foam and 30 mm thick.

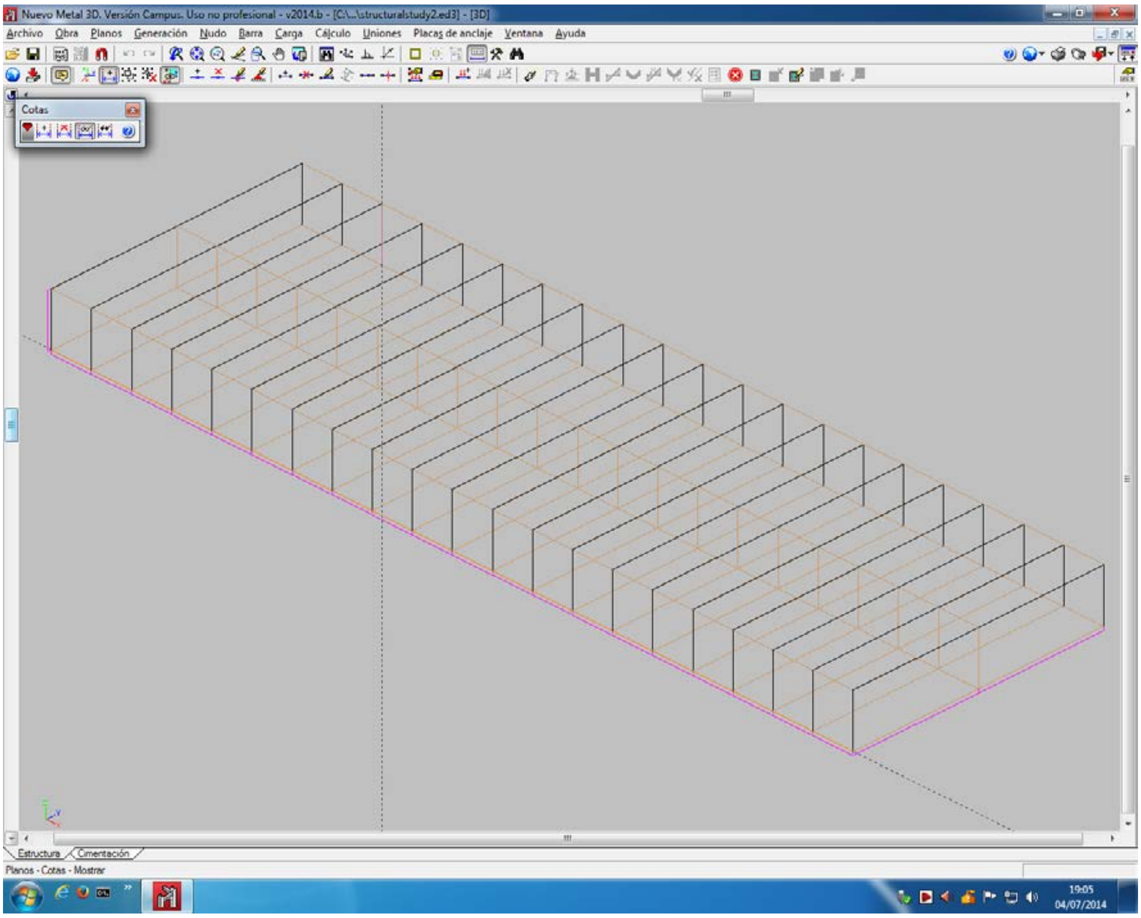


Figure 4.1 Factory's Structure

4.2. Load and stress of the PV system determination

The load has being studied is the one produced by the PV modules plus the rest of the elements of the installation (wires, aluminum structure, anchorage…).
The weight of each modules is 20 kg and it occupied a surface of 1,8m2, so the load per square meter is around 20 kg, plus the weight of the rest of the elements that has being consider a load of 35 kg per square meter to be sure that the factory's structure can resist all the weight of the installation without problems.

4.3. Service load determination

In this study has been consider too the overload due the maintenance of the roof and the installation. The value of the overload is 0,4 kN/m^2 which is written in the EN 1991. This overload is independent to the snow and wind loads, basically because they are incompatible.

As can be checked in the report of the CYPECAD software, attached in the end of this annex, the structure of the warehouse is well sized with a 40% of oversizing.

For this reason the PV installation can be installed without any kind of problem or restriction. The installation do not alter the structural safety (stability and resistance) and release to service (deformability), set in the EN 1991, the PV system can be installed on the factory.

5. ANALYSIS RESULT

First it can be checked that the structure of the building is well sized with a 40% of oversizing.

For this reason the PV installation can be installed without any kind of problem or restriction. The installation do not alter the structural safety (stability and resistance) and release to service (deformability), set in the EN 1991, the PV system can be installed on the factory.

CYPECAD REPORT

Datos de la obra

Separación entre pórticos: 5.00 m
Con cerramiento en cubierta
- Peso del cerramiento: 0.10 kN/m²
- Sobrecarga del cerramiento: 0.00 kN/m²
Sin cerramiento en laterales.

Normas y combinaciones

Perfiles conformados	CTE Cota de nieve: Altitud inferior o igual a 1000 m
Perfiles laminados	CTE Cota de nieve: Altitud inferior o igual a 1000 m
Desplazamientos	Acciones características

Datos de viento

Normativa: Eurocódigo 1 (UE)

Velocidad de referencia: 26.0 m/s
Sin coeficiente direccional
Categoría del terreno: Categoría III
Periodo de servicio (años): 50
Dirección transversal (X)
Tipo de terreno: Llano
Dirección longitudinal (Y)
Tipo de terreno: Llano
Profundidad nave industrial: 160.00 m

1 - V H1: Cubiertas aisladas
2 - V H2: Cubiertas aisladas

Datos de nieve

Normativa: Eurocódigo 1

Región climática: Centro este
Zona: 1
Topografía: Expuesta al viento
Altitud topográfica: 1490.00 m

Hipótesis aplicadas:

Situación persistente-transitoria

1 - N(EI): Nieve (estado inicial)
2 - N(R): Nieve (redistribución)

Aceros en perfiles

Tipo acero	Acero	Lim. elástico MPa	Módulo de elasticidad GPa
Acero laminado	S275	275	210

Datos de pórticos			
Pórtico	Tipo exterior	Geometría	Tipo interior
1	Dos aguas	Luz izquierda: 25.00 m Luz derecha: 25.00 m Alero izquierdo: 10.00 m Alero derecho: 10.00 m Altura cumbrera: 10.00 m	Pórtico rígido

Cargas en barras

Pórtico 1, Pórtico 33

Barra	Hipótesis	Tipo	Posición	Valor	Orientación
Cubierta	Carga permanente	Uniforme	---	0.76 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Uniforme	---	3.25 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	3.97 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	3.25 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	3.97 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	7.31 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Carga permanente	Uniforme	---	0.76 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Uniforme	---	3.25 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	3.97 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	3.25 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	3.97 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	7.31 kN/m	EG: (0.00, 0.00, -1.00)

Pórtico 2, Pórtico 3, Pórtico 31, Pórtico 32

Barra	Hipótesis	Tipo	Posición	Valor	Orientación
Cubierta	Carga permanente	Uniforme	---	1.53 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Uniforme	---	6.50 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	6.50 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	29.24 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Carga permanente	Uniforme	---	1.53 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Uniforme	---	6.50 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	6.50 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	29.24 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)

Pórtico 4, Pórtico 30

Barra	Hipótesis	Tipo	Posición	Valor	Orientación
Cubierta	Carga permanente	Uniforme	---	1.53 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	1.27 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	0.58 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	1.27 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Uniforme	---	4.42 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	6.15 kN/m	EXB: (0.00, 0.00, 1.00)

Barra	Hipótesis	Tipo	Posición	Valor	Orientación
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	29.24 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Carga permanente	Uniforme	---	1.53 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	1.27 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	0.58 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	1.27 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Uniforme	---	4.42 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	6.15 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	29.24 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)

Pórtico 5, Pórtico 29

Barra	Hipótesis	Tipo	Posición	Valor	Orientación
Cubierta	Carga permanente	Uniforme	---	1.53 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	3.89 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	1.77 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	3.89 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Uniforme	---	0.13 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	5.44 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	29.24 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Carga permanente	Uniforme	---	1.53 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	3.89 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	1.77 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	3.89 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Uniforme	---	0.13 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	5.44 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	29.24 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)

Pórtico 6, Pórtico 7, Pórtico 8, Pórtico 9, Pórtico 10, Pórtico 11, Pórtico 12, Pórtico 13, Pórtico 14, Pórtico 15, Pórtico 16, Pórtico 17, Pórtico 18, Pórtico 19, Pórtico 20, Pórtico 21, Pórtico 22, Pórtico 23, Pórtico 24, Pórtico 25, Pórtico 26, Pórtico 27, Pórtico 28

Barra	Hipótesis	Tipo	Posición	Valor	Orientación
Cubierta	Carga permanente	Uniforme	---	1.53 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	3.97 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	1.81 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	3.97 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	5.42 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	29.24 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)

Barra	Hipótesis	Tipo	Posición	Valor	Orientación
Cubierta	Carga permanente	Uniforme	---	1.53 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	3.97 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	1.81 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	3.97 kN/m	EXB: (0.00, 0.00, -1.00)
Cubierta	Cubiertas aisladas	Faja	0.00/0.10 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.10/0.90 (R)	5.42 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Cubiertas aisladas	Faja	0.90/1.00 (R)	7.94 kN/m	EXB: (0.00, 0.00, 1.00)
Cubierta	Nieve (estado inicial)	Uniforme	---	29.24 kN/m	EG: (0.00, 0.00, -1.00)
Cubierta	Nieve (redistribución)	Uniforme	---	14.62 kN/m	EG: (0.00, 0.00, -1.00)

Descripción de las abreviaturas:
R : Posición relativa a la longitud de la barra.
EG : Ejes de la carga coincidentes con los globales de la estructura.
EXB : Ejes de la carga en el plano de definición de la misma y con el eje X coincidente con la barra.

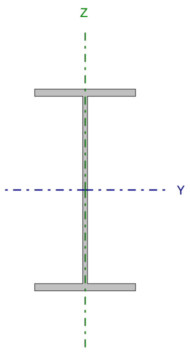
Datos de correas de cubierta	
Descripción de correas	Parámetros de cálculo
Tipo de perfil: IPE 300	Límite flecha: L / 250
Separación: 2.00 m	Número de vanos: Tres vanos
Tipo de Acero: S275	Tipo de fijación: Cubierta no colaborante

Comprobación de resistencia

Comprobación de resistencia
El perfil seleccionado cumple todas las comprobaciones.
Aprovechamiento: 61.04 %

Barra pésima en cubierta

Perfil: IPE 300
Material: S275



Nudos		Longitud (m)	Características mecánicas			
Inicial	Final		Área (cm²)	I_y [1] (cm4)	I_z [1] (cm4)	I_t [2] (cm4)
1.000, 155.000, 10.000	1.000, 150.000, 10.000	5.000	53.80	8356.00	603.80	20.12

Notas:
[1] Inercia respecto al eje indicado
[2] Momento de inercia a torsión uniforme

	Pandeo		Pandeo lateral	
	Plano XY	Plano XZ	Ala sup.	Ala inf.
β	1.00	1.00	1.00	1.00
L_K	5.000	5.000	5.000	5.000
C_m	1.000	1.000	1.300	1.300
C_1	-		1.000	

Notación:
b: Coeficiente de pandeo
L_K: Longitud de pandeo (m)
C_m: Coeficiente de momentos
C_1: Factor de modificación para el momento crítico

Barra	COMPROBACIONES (CTE DB SE-A)															Estado
	$\bar{\lambda}$	λ_w	N_t	N_c	M_Y	M_Z	V_Z	V_Y	M_YV_Z	M_ZV_Y	NM_YM_Z	$NM_YM_ZV_YV_Z$	M_t	M_tV_Z	M_tV_Y	
pésima en cubierta	N.P.[1]	$\lambda_w \le \lambda_{w,máx}$ Cumple	N_{Ed} = 0.00 N.P.[2]	N_{Ed} = 0.00 N.P.[3]	x: 0 m η = 61.0	M_{Ed} = 0.00 N.P.[4]	x: 0 m η = 16.1	V_{Ed} = 0.00 N.P.[5]	x: 0 m η < 0.1	N.P.[6]	N.P.[7]	N.P.[8]	M_{Ed} = 0.00 N.P.[9]	N.P.[10]	N.P.[10]	CUMPLE h = 61.0

Notación:
`l : Limitación de esbeltez
l_w: Abolladura del alma inducida por el ala comprimida
N_t: Resistencia a tracción
N_c: Resistencia a compresión
M_Y: Resistencia a flexión eje Y
M_Z: Resistencia a flexión eje Z
V_Z: Resistencia a corte Z
V_Y: Resistencia a corte Y
M_YV_Z: Resistencia a momento flector Y y fuerza cortante Z combinados
M_ZV_Y: Resistencia a momento flector Z y fuerza cortante Y combinados
NM_YM_Z: Resistencia a flexión y axil combinados
$NM_YM_ZV_YV_Z$: Resistencia a flexión, axil y cortante combinados
M_t: Resistencia a torsión
M_tV_Z: Resistencia a cortante Z y momento torsor combinados
M_tV_Y: Resistencia a cortante Y y momento torsor combinados
x: Distancia al origen de la barra
h: Coeficiente de aprovechamiento (%)
N.P.: No procede

Barra	COMPROBACIONES (CTE DB SE-A)																Estado
	$\overline{\lambda}$	λ_w	N_t	N_c	M_Y	M_Z	V_Z	V_Y	M_YV_Z	M_ZV_Y	NM_YM_Z	$NM_YM_ZV_YV_Z$	M_t	M_tV_Z	M_tV_Y		

Comprobaciones que no proceden (N.P.):
[1] La comprobación no procede, ya que no hay axil de compresión ni de tracción.
[2] La comprobación no procede, ya que no hay axil de tracción.
[3] La comprobación no procede, ya que no hay axil de compresión.
[4] La comprobación no procede, ya que no hay momento flector.
[5] La comprobación no procede, ya que no hay esfuerzo cortante.
[6] No hay interacción entre momento flector y esfuerzo cortante para ninguna combinación. Por lo tanto, la comprobación no procede.
[7] No hay interacción entre axil y momento flector ni entre momentos flectores en ambas direcciones para ninguna combinación. Por lo tanto, la comprobación no procede.
[8] No hay interacción entre momento flector, axil y cortante para ninguna combinación. Por lo tanto, la comprobación no procede.
[9] La comprobación no procede, ya que no hay momento torsor.
[10] No hay interacción entre momento torsor y esfuerzo cortante para ninguna combinación. Por lo tanto, la comprobación no procede.

Limitación de esbeltez (CTE DB SE-A, Artículos 6.3.1 y 6.3.2.1 - Tabla 6.3)

La comprobación no procede, ya que no hay axil de compresión ni de tracción.

Abolladura del alma inducida por el ala comprimida (Criterio de CYPE Ingenieros, basado en: Eurocódigo 3 EN 1993-1-5: 2006, Artículo 8)

Se debe satisfacer:

$$\frac{h_w}{t_w} \le k \frac{E}{f_{yf}} \sqrt{\frac{A_w}{A_{fc,ef}}}$$

39.24 £ 254.33 ✓

Donde:

h_w: Altura del alma.	h_w :	278.60	mm
t_w: Espesor del alma.	t_w :	7.10	mm
A_w: Área del alma.	A_w :	19.78	cm²
$A_{fc,ef}$: Área reducida del ala comprimida.	$A_{fc,ef}$:	16.05	cm²
k: Coeficiente que depende de la clase de la sección.	k :	0.30	
E: Módulo de elasticidad.	E :	210000	MPa
f_{yf}: Límite elástico del acero del ala comprimida.	f_{yf} :	275.00	MPa

Siendo:

$$f_{yf} = f_y$$

Resistencia a tracción (CTE DB SE-A, Artículo 6.2.3)

La comprobación no procede, ya que no hay axil de tracción.

Resistencia a compresión (CTE DB SE-A, Artículo 6.2.5)

La comprobación no procede, ya que no hay axil de compresión.

Resistencia a flexión eje Y (CTE DB SE-A, Artículo 6.2.6)

Se debe satisfacer:

$$\eta = \frac{M_{Ed}}{M_{c,Rd}} \le 1$$

h : 0.315 ✓

$$\eta = \frac{M_{Ed}}{M_{b,Rd}} \le 1$$

h : 0.610 ✓

Para flexión positiva:

M_{Ed}^{+}: Momento flector solicitante de cálculo pésimo. M_{Ed}^{+} : 0.00 kN·m

Para flexión negativa:

El esfuerzo solicitante de cálculo pésimo se produce en el nudo 1.000, 155.000, 10.000, para la combinación de acciones 1.35*G1 + 1.35*G2 + 1.50*N(EI) + 0.90*V H1.

M_{Ed}^-: Momento flector solicitante de cálculo pésimo. M_{Ed}^- : 51.77 kN·m

El momento flector resistente de cálculo $M_{c,Rd}$ viene dado por:

$$\mathbf{M_{c,Rd}} = W_{pl,y} \cdot f_{yd}$$ $M_{c,Rd}$: 164.58 kN·m

Donde:

Clase: Clase de la sección, según la capacidad de deformación y de desarrollo de la resistencia plástica de los elementos planos de una sección a flexión simple. Clase : 1

$W_{pl,y}$: Módulo resistente plástico correspondiente a la fibra con mayor tensión, para las secciones de clase 1 y 2. $W_{pl,y}$: 628.40 cm³

f_{yd}: Resistencia de cálculo del acero. f_{yd} : 261.90 MPa

$$\mathbf{f_{yd}} = f_y / \gamma_{M0}$$

Siendo:

f_y: Límite elástico. (CTE DB SE-A, Tabla 4.1) f_y : 275.00 MPa

g_{M0}: Coeficiente parcial de seguridad del material. g_{M0} : 1.05

Resistencia a pandeo lateral: (CTE DB SE-A, Artículo 6.3.3.2)

El momento flector resistente de cálculo $M_{b,Rd}$ viene dado por:

$$\mathbf{M_{b,Rd}} = \chi_{LT} \cdot W_{pl,y} \cdot f_{yd}$$ $M_{b,Rd}$: 84.81 kN·m

Donde:

$W_{pl,y}$: Módulo resistente plástico correspondiente a la fibra con mayor tensión, para las secciones de clase 1 y 2. $W_{pl,y}$: 628.40 cm³

f_{yd}: Resistencia de cálculo del acero. f_{yd} : 261.90 MPa

$$\mathbf{f_{yd}} = f_y / \gamma_{M1}$$

Siendo:

f_y: Límite elástico. (CTE DB SE-A, Tabla 4.1) f_y : 275.00 MPa

g_{M1}: Coeficiente parcial de seguridad del material. g_{M1} : 1.05

c_{LT}: Factor de reducción por pandeo lateral.

$$\boldsymbol{\chi_{LT}} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}} \leq 1$$ c_{LT} : 0.52

Siendo:

$$\mathbf{\Phi_{LT}} = 0.5 \cdot \left[1 + \alpha_{LT} \cdot \left(\bar{\lambda}_{LT} - 0.2\right) + \bar{\lambda}_{LT}^2\right]$$ f_{LT} : 1.36

a_{LT}: Coeficiente de imperfección elástica. a_{LT} : 0.21

$$\boldsymbol{\bar{\lambda}_{LT}} = \sqrt{\frac{W_{pl,y} \cdot f_y}{M_{cr}}}$$ `l_{LT} : 1.22

M_{cr}: Momento crítico elástico de pandeo lateral. M_{cr} : 115.43 kN·m

El momento crítico elástico de pandeo lateral M_{cr} se determina según la teoría de la elasticidad:

$$\mathbf{M_{cr}} = \sqrt{M_{LTv}^2 + M_{LTw}^2}$$

Siendo:

M_{LTv}: Componente que representa la resistencia por torsión uniforme de la barra.

$$\mathbf{M_{LTv}} = C_1 \cdot \frac{\pi}{L_c} \cdot \sqrt{G \cdot I_t \cdot E \cdot I_z}$$ M_{LTv} : 90.32 kN·m

M_{LTw}: Componente que representa la resistencia por torsión no uniforme de la barra.

$$\mathbf{M_{LTw}} = W_{el,y} \cdot \frac{\pi^2 \cdot E}{L_c^2} \cdot C_1 \cdot i_{f,z}^2$$

M_{LTw} : 71.87 kN·m

Siendo:

$W_{el,y}$: Módulo resistente elástico de la sección bruta, obtenido para la fibra más comprimida. $W_{el,y}$: 557.07 cm³

I_z: Momento de inercia de la sección bruta, respecto al eje Z. I_z : 603.80 cm4

I_t: Momento de inercia a torsión uniforme. I_t : 20.12 cm4

E: Módulo de elasticidad. E : 210000 MPa

G: Módulo de elasticidad transversal. G : 81000 MPa

L_c^+: Longitud efectiva de pandeo lateral del ala superior. L_c^+ : 5.000 m

L_c^-: Longitud efectiva de pandeo lateral del ala inferior. L_c^- : 5.000 m

C_1: Factor que depende de las condiciones de apoyo y de la forma de la ley de momentos flectores sobre la barra. C_1 : 1.00

$i_{f,z}$: Radio de giro, respecto al eje de menor inercia de la sección, del soporte formado por el ala comprimida y la tercera parte de la zona comprimida del alma adyacente al ala comprimida. $i_{f,z}^+$: 3.94 cm

$i_{f,z}^-$: 3.94 cm

Resistencia a flexión eje Z (CTE DB SE-A, Artículo 6.2.6)

La comprobación no procede, ya que no hay momento flector.

Resistencia a corte Z (CTE DB SE-A, Artículo 6.2.4)

Se debe satisfacer:

$$\eta = \frac{V_{Ed}}{V_{c,Rd}} \leq 1$$

h : 0.161 ✓

El esfuerzo solicitante de cálculo pésimo se produce en el nudo 1.000, 155.000, 10.000, para la combinación de acciones 1.35*G1 + 1.35*G2 + 1.50*N(EI) + 0.90*V H1.

V_{Ed}: Esfuerzo cortante solicitante de cálculo pésimo. V_{Ed} : 51.77 kN

El esfuerzo cortante resistente de cálculo $V_{c,Rd}$ viene dado por:

$$\mathbf{V_{c,Rd}} = A_V \cdot \frac{f_{yd}}{\sqrt{3}}$$

$V_{c,Rd}$: 322.08 kN

Donde:

A_v: Área transversal a cortante. A_v : 21.30 cm²

$$\mathbf{A_v} = h \cdot t_w$$

Siendo:

h: Canto de la sección. h : 300.00 mm

t_w: Espesor del alma. t_w : 7.10 mm

f_{yd}: Resistencia de cálculo del acero. f_{yd} : 261.90 MPa

$$\mathbf{f_{yd}} = f_y / \gamma_{M0}$$

Siendo:

f_y: Límite elástico. (CTE DB SE-A, Tabla 4.1) f_y : 275.00 MPa

g_{M0}: Coeficiente parcial de seguridad del material. g_{M0} : 1.05

Abolladura por cortante del alma: (CTE DB SE-A, Artículo 6.3.3.4)

Aunque no se han dispuesto rigidizadores transversales, no es necesario comprobar la resistencia a la abolladura del alma, puesto que se cumple:

$$\frac{\mathbf{d}}{\mathbf{t_w}} < 70 \cdot \varepsilon$$

39.24 < 64.71 ✓

Donde:

l_w: Esbeltez del alma. l_w : 39.24

$$\lambda_w = \frac{d}{t_w}$$

$l_{máx}$: Esbeltez máxima. $l_{máx}$: 64.71

$$\lambda_{max} = 70 \cdot \varepsilon$$

e: Factor de reducción. e : 0.92

$$\varepsilon = \sqrt{\frac{f_{ref}}{f_y}}$$

Siendo:

f_{ref}: Límite elástico de referencia. f_{ref} : 235.00 MPa

f_y: Límite elástico. (CTE DB SE-A, Tabla 4.1) f_y : 275.00 MPa

Resistencia a corte Y (CTE DB SE-A, Artículo 6.2.4)

La comprobación no procede, ya que no hay esfuerzo cortante.

Resistencia a momento flector Y y fuerza cortante Z combinados (CTE DB SE-A, Artículo 6.2.8)

No es necesario reducir la resistencia de cálculo a flexión, ya que el esfuerzo cortante solicitante de cálculo pésimo V_{Ed} no es superior al 50% de la resistencia de cálculo a cortante $V_{c,Rd}$.

$$V_{Ed} \le \frac{V_{c,Rd}}{2}$$

51.77 kN ≤ 161.04 kN ✓

Los esfuerzos solicitantes de cálculo pésimos se producen en el nudo 1.000, 155.000, 10.000, para la combinación de acciones 1.35*G1 + 1.35*G2 + 1.50*N(EI) + 0.90*V H1.

V_{Ed}: Esfuerzo cortante solicitante de cálculo pésimo. V_{Ed} : *51.77* kN

$V_{c,Rd}$: Esfuerzo cortante resistente de cálculo. $V_{c,Rd}$: *322.08* kN

Resistencia a momento flector Z y fuerza cortante Y combinados (CTE DB SE-A, Artículo 6.2.8)

No hay interacción entre momento flector y esfuerzo cortante para ninguna combinación. Por lo tanto, la comprobación no procede.

Resistencia a flexión y axil combinados (CTE DB SE-A, Artículo 6.2.8)

No hay interacción entre axil y momento flector ni entre momentos flectores en ambas direcciones para ninguna combinación. Por lo tanto, la comprobación no procede.

Resistencia a flexión, axil y cortante combinados (CTE DB SE-A, Artículo 6.2.8)

No hay interacción entre momento flector, axil y cortante para ninguna combinación. Por lo tanto, la comprobación no procede.

Resistencia a torsión (CTE DB SE-A, Artículo 6.2.7)

La comprobación no procede, ya que no hay momento torsor.

Resistencia a cortante Z y momento torsor combinados (CTE DB SE-A, Artículo 6.2.8)

No hay interacción entre momento torsor y esfuerzo cortante para ninguna combinación. Por lo tanto, la comprobación no procede.

Resistencia a cortante Y y momento torsor combinados (CTE DB SE-A, Artículo 6.2.8)

No hay interacción entre momento torsor y esfuerzo cortante para ninguna combinación. Por lo tanto, la comprobación no procede.

Comprobación de flecha

Comprobación de flecha
El perfil seleccionado cumple todas las comprobaciones.
Porcentajes de aprovechamiento:
- Flecha: 17.97 %

Coordenadas del nudo inicial: 1.000, 160.000, 10.000
Coordenadas del nudo final: 1.000, 155.000, 10.000
El aprovechamiento pésimo se produce para la combinación de hipótesis 1.00*G1 + 1.00*G2 + 1.00*Q + 1.00*N(EI) + 1.00*V H1 a una distancia 2.500 m del origen en el primer vano de la correa.
(Iy = 8356 cm4) (Iz = 604 cm4)

Medición de correas			
Tipo de correas	Nº de correas	Peso lineal kg/m	Peso superficial kN/m²
Correas de cubierta	26	1098.06	0.22

ANNEX V

CATALOGUES

Index

GS POWER

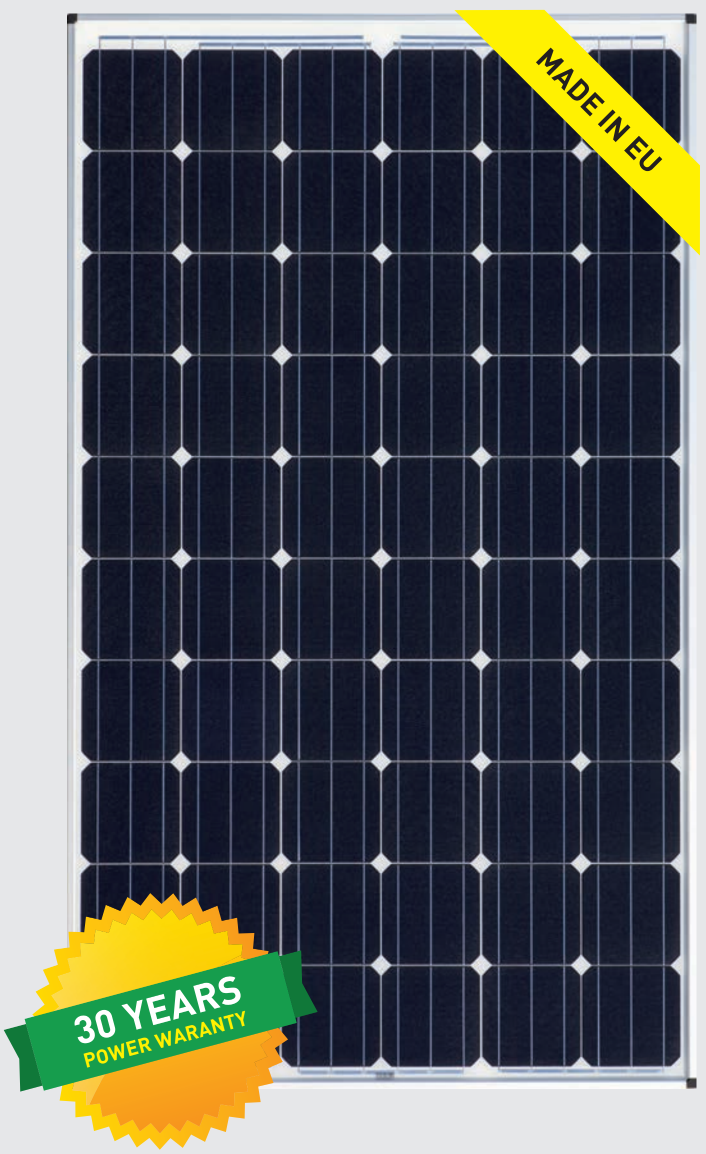
HIGH PERFORMANCE AND RELIABILITY
MADE IN EU

GS POWER 255–270 Wp MONO

30 YEARS POWER WARRANTY

The performance of photovoltaic power plants at the beginning and throughout their lifetime is mainly affected by the performance and reliability of photovoltaic panels.

Thanks to their thoughtful design, quality materials and quality control, the GS POWER panels guarantee not only high performance but also excellent energy yields. The range of guarantees and long-term reliability are the basis for safe investment for all solar power plant owners.



Advantages of GS POWER modules

EXTENSIVE WARRANTIES

GS POWER provides:
12 year workmanship warranty,*
12 year power warranty at 92% nominal power,*
30 year warranty at 80% nominal power.*

GUARANTEED POWER

High efficiency cells 156 x 156 mm, with 3-BUS technology and a plus classification (0.0 W / + 4.9 W) ensure high performance of GS POWER panels.

HIGH STANDARD YIELDS

Sophisticated construction of GS POWER panels and the method of the circuitry of the cells reduce energy losses significantly. The ingenious solution, high efficient cells and high-tech materials are the basis for high standard energy yield.

QUALITY MATERIALS AND EXCELLENT PROCESSING

Only high quality and certified materials from reputable suppliers are used for the production of GS POWER panels. Our stable level of technological processes, skilled staff and permanent control in all stages of production are a guarantee of long-term reliability.

Electroluminescent test
Each module is undergoing electroluminescent test before leaving production line to determine long term quality and module efficiency.

CETECOM™ ein Unternehmen der RWTÜV Gruppe MCS CE

GS Energy Europe Distribution s.r.o.

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T: +420 283 101 360, M: +420 725 565 932
E: info@gsenergy.eu

www.gsenergy.eu

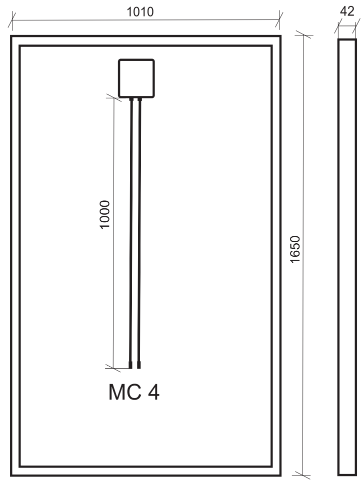
*) According to current guaranty conditions of GS POWER.

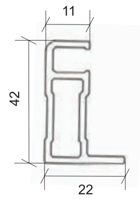
GS POWER 255–270 Wp MONO

Performance under standard test condions (STC) STC: 1 000 W/m², 25 °C, AM 1,5					
Maximum power	P_{max}	**255 Wp**	**260 Wp**	**265 Wp**	**270 Wp**
Maximum power voltage	U_{mpp}	30.77 V	31.38 V	31.90 V	32.40 V
Maximum power current	I_{mpp}	8.36 A	8.40 A	8.42 A	8.46 A
Open circuit voltage	U_{oc}	37.70 V	37.78 V	37.90 V	38.47 V
Short circuit current	I_{sc}	9.06 A	9.13 A	9.22 A	9.26 A
Module Efficiency		15.3 %	15.6 %	15.9 %	16.2 %

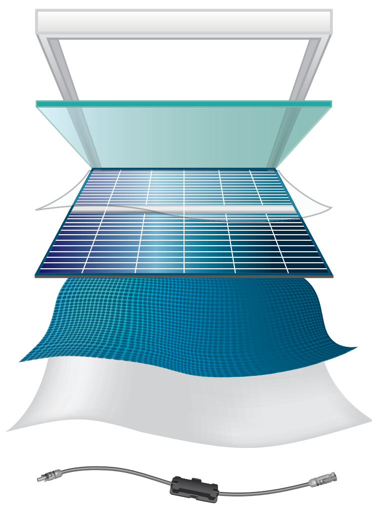
Minor reduc on in efficiency under par al load condi ons at 25 °C:
at 200 W/m², 95 % (+/-103 %) of the STC efficiency (1 000 W/m²) is achieved.

Performance under normal opera ng cell temperature NOCT NOCT: 800 W/m², 47 °C, AM 1,5					
Maximum power	P_{max}	188.10 Wp	191.78 Wp	195.47 Wp	199.16 Wp
Maximum power voltage	U_{mpp}	29.15 V	29.22 V	29.28 V	29.74 V
Maximum power current	I_{mpp}	6.49 A	6.57 A	6.70 A	6.74 A
Open circuit voltage	U_{oc}	35.31 V	35.46 V	35.59 V	36.12 V
Short circuit current	I_{sc}	6.91 A	7.02 A	7.13 A	7.17 A





Used material	
Panel	Glass sheets Laminate
Glass	tempered solar glass 3.2 mm
Encapsulation	EVA
Back sheet material	PET – Polyester sheet multiply
Solar cells	60 cells 156 x 156, polycrystalline, Connection lengthwise 6 x 10 cells
Junction box	IP 65, 3 Bypass diodes
Junction cable	2 2x 1.00 m, 4 mm , MC 4 connector
Frame	Aluminous box profile, anodised
Connection material	Silicone
Dimensions	1 650 x 1 010 x 42 mm (H x B x T)
Weight	19 kg
Mechanical loading	Loading pressure tested up to 5.4 kN/m²



1. Frame – Czech Republic
2. Glass – Belgium
3. Cells – Taiwan
4. Ribbons – Germany
5. EVA – Germany
6. Backsheet – Germany
7. Junction box, cabels, connectors – Germany

Thermal characteristics	
Outdoor temperature	- 45 °C to + 45 °C
Operating temperature	- 45 °C to + 80 °C
Temperature coefficient PN	- 0.43 % / K
TK V_{oc}	- 0.35 % / K
TK I_{sc}	0.05 % / K
NOCT	47 °C

LOGISTIC PARAMETERS

18 pcs per pallet
828 pcs (46 pallet) per truck

Pallet dimmensions:
170 x 80 x 120 cm, weight 390 kg

Dealer

System integration parameters	
System integration	Max. system voltage 1 000 V
Reverse current	max. External power < Uoc
Reverse current protection	string protec on max. I < 16 A
Panel protection	IP 65
Applica on classification	IEC 61215 2nd ED, IEC 61730

Inversores solares

Inversores centrales ABB PVS800 100 kW a 630 kW

Los inversores solares centrales ABB elevan la fiabilidad, eficiencia y facilidad de instalación hasta un nuevo nivel. Estos inversores están dirigidos a integradores de sistemas y usuarios finales que precisen inversores solares de alto rendimiento para plantas de energía fotovoltaica de gran superficie y para edificios industriales y comerciales. Los inversores, disponibles con potencias de entre 100 y 630 kW, están optimizados para centrales eléctricas rentables de varios megavatios.

Plataforma de inversor lider del mercado

Los inversores solares ABB han sido desarrollados sobre la base de décadas de experiencia en la industria y una probada plataforma tecnológica. La experiencia práctica incomparable de nuestra empresa, líder tecnológico y del mercado mundial en convertidores de CA y CC de velocidad variable, es el sello de la nueva gama de inversores solares.

Los inversores, basados en la exitosa plataforma de convertidores industriales de ABB – los convertidores industriales más utilizados en el mercado – son la forma más eficiente y rentable de convertir la corriente continua generada por los módulos solares en corriente alterna de alta calidad, sin generación de CO_2 y lista para ser inyectada en la red.

Inversores solares de ABB

Los inversores centrales ABB son idóneos para instalaciones fotovoltaicas a gran escala y centrales eléctricas de tamaño medio instaladas en edificios comerciales o industriales. Gracias a su alto rendimiento, componentes contrastados, un diseño compacto y modular y un conjunto de servicios durante todo el ciclo de vida del producto, los inversores centrales ABB garantizan un retorno rápido de la inversión.

Principales características

- Alta eficiencia y elevada vida útil
- Diseño modular y compacto
- Amplia protección de los lados de CC y CA
- Compensación del factor de potencia como estándar
- Instalación rápida y sencilla
- Gama completa de opciones para la transmisión de datos de tipo industrial, incluida la monitorización remota
- Servicio durante el ciclo de vida del producto a través de la amplia red de servicio global de ABB

Inversores centrales ABB

Máxima energía e ingresos por inyección a la red

Los inversores centrales ABB hacen gala de un alto rendimiento. Con un control optimizado y preciso del sistema y un algoritmo de seguimiento del punto de potencia máxima (MPPT), se asegura que los módulos solares entreguen la máxima cantidad de energía a la red eléctrica. Esto hace que los usuarios finales obtengan los máximos ingresos posibles por la inyección subvencionada a red, una posibilidad que ofrecen ya muchos países.

Componentes ABB contrastados

Los inversores están provistos de componentes ABB contrastados, con un expediente intachable por su excelente rendimiento en aplicaciones exigentes y entornos duros. Estos inversores, dotados de una amplia protección eléctrica y mecánica, se han diseñado para proporcionar una vida útil prolongada y fiable durante un mínimo de 20 años.

Diseño compacto y modular

Los inversores se han diseñado pensando en una instalación rápida y sencilla. El diseño industrial y la plataforma modular ofrecen una amplia gama de opciones, como la monitorización remota, la conexión del bus de campo y los armarios de CC integrados. Los tiempos de entrega de los inversores, fabricados a medida y configurados conforme a las necesidades de los usuarios, son reducidos.

Conectividad efectiva

Los inversores centrales ABB forman parte de una gama de inversores solares sin transformador que permite a los integradores de sistemas diseñar la central eléctrica combinando inversores de distintos tamaños y la conexión adecuada a la red.

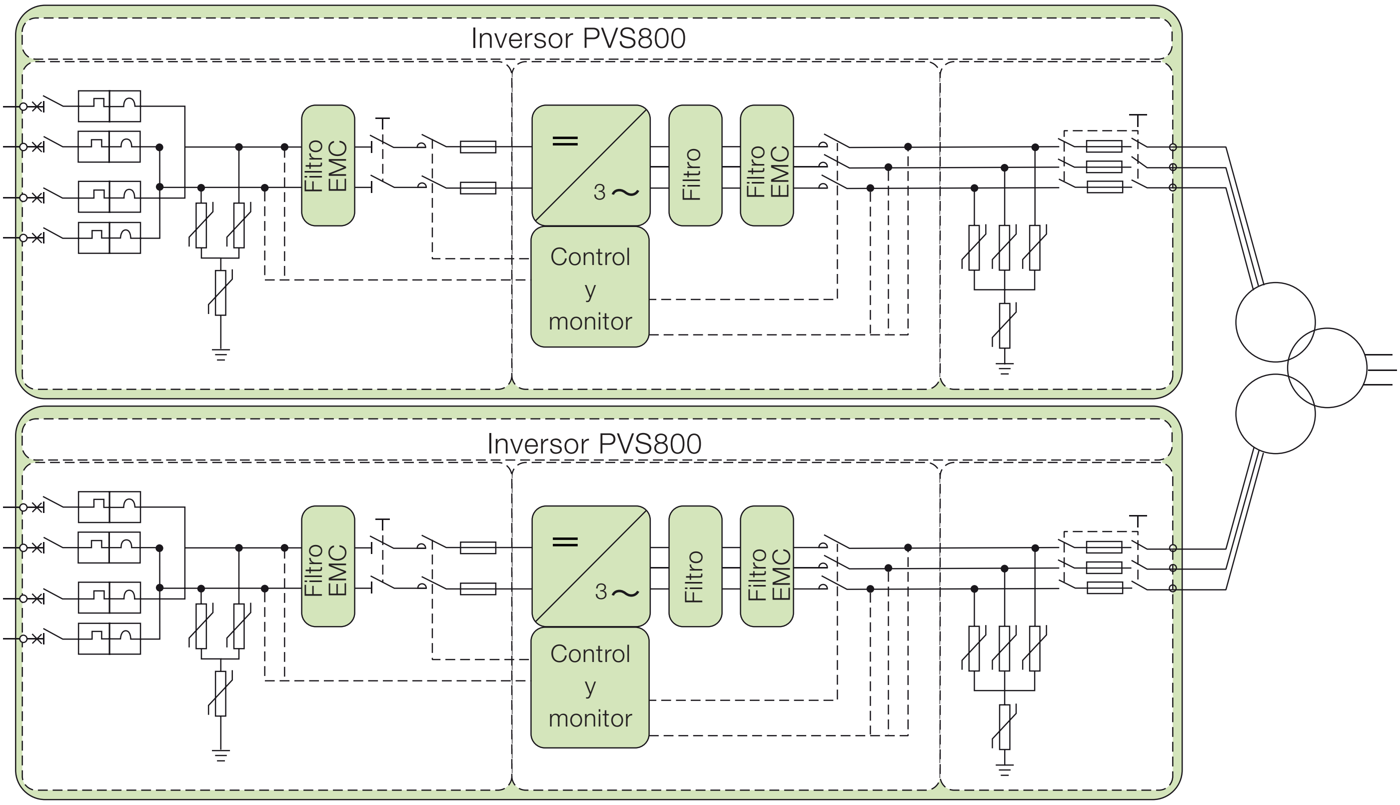
En ciertas condiciones, la topología de los inversores centrales ABB permiten una conexión directa en paralelo en el lado CA, permitiendo que la energía eléctrica sea suministrada a la red a través de un solo transformador. Esto evita la necesidad de que cada inversor deba de tener su propio transformador, ahorrándose así en costes y espacio. Sin embargo, en sistemas donde deba conectarse a tierra el lado CC, se requiere siempre un transformador o un devanado del secundario dedicados para cada inversor.

Datos técnicos y tipos

Código de tipo	PVS800 -57-0100kW-A	PVS800 -57-0250kW-A	PVS800 -57-0315kW-B	PVS800 -57-0500kW-A	PVS800 -57-0630kW-B
	100 kW	**250 kW**	**315 kW**	**500 kW**	**630 kW**
Entrada (CC)					
Potencia FV máx. recomendada ($P_{FV, max}$)[1]	120 kW_p	300 kW_p	378 kW_p	600 kW_p	756 kW_p
Rango de tensión CC, mpp (U_{CC})	450 a 825 V	450 a 825 V	525 a 825 V	450 a 825 V	525 a 825 V
Tensión CC máx. ($U_{CC, max}$)	1000 V	1000 V	1000 V	1000 V	1000 V
Intensidad CC máx. ($I_{CC, max}$)	245 A	600 A	615 A	1145 A	1240 A
Rizado de tensión	< 3%	< 3%	< 3%	< 3%	< 3%
Número de entradas CC protegidas (paralelo)	1 (+/-) /4 [2]	2, 4, 8 (+/-)/8 [2]	2, 4, 8 (+/-)	4, 8, 12 (+/-)/16 [2]	4, 8, 12 (+/-)
Salida (CA)					
Potencia de salida CA nominal ($P_{CA,nom}$)	100 kW	250 kW	315 kW [3]	500 kW	630 kW [3]
Intensidad nominal CA ($I_{CA, nom}$)	195 A	485 A	520 A	965 A	1040 A
Tensión nominal ($U_{CA,nom}$) [4]	300 V	300 V	350 V	300 V	350 V
Frecuencia de salida (f_{CA})	50/60 Hz	50/60 Hz	50/60 Hz	50/60 Hz	50/60 Hz
Distorsión armónica de la intensidad de red [5]	< 3%	< 3%	< 3%	< 3%	< 3%
Compensación del factor de potencia (cosfii)	Sí	Sí	Sí	Sí	Sí
Estructura de la red [6]	TN e IT	TN e IT	TN e IT	TN e IT	TN e IT
Rendimiento					
Rendimiento máx. [7]	98,0%	98,0%	98,6%	98,6%	98,6%
Euro-eta [7]	97,5%	97,6%	98,3%	98,2%	98,4%
Consumo de energía					
Consumo propio en funcionamiento	< 350 W	< 350 W	< 350 W	< 550 W	< 550 W
Consumo en modo de espera	60 W	60 W	60 W	70 W	70 W
Tensión auxiliar externa [8]	230 V, 50 Hz	230 V, 50 Hz	230 V, 50 Hz	230 V, 50 Hz	230 V, 50 Hz
Dimensiones y peso					
Anchura/Altura/Profundidad, mm (An/Al / P	1030/2130/646 [9]	1830/2130/646 [9]	1830/2130/646 [9]	2630/2130/646 [9]	2630/2130/646 [9]
Peso aprox. [9]	550 kg	1100 kg	1100 kg	1800 kg	1800 kg

[1] El inversor limita la potencia a un valor seguro
[2] Entradas MCB de 80 A opcionales
[3] Hasta un 10% de capacidad de sobrecarga a bajas temperaturas. Máximo 110% a 25 ºC. Para más detalles consulte el manual del usuario.
[4] Tensión de red (+/- 10%)
[5] A potencia nominal
[6] En el lado del inversor es necesaria red tipo IT
[7] Rendimiento sin consumo auxiliar a min U_{CC}
[8] Opcional a 115 V y 60 Hz
[9] Para el caso del mínimo número de entradas de CC posibles. Para más detalles consulte el manual del usuario

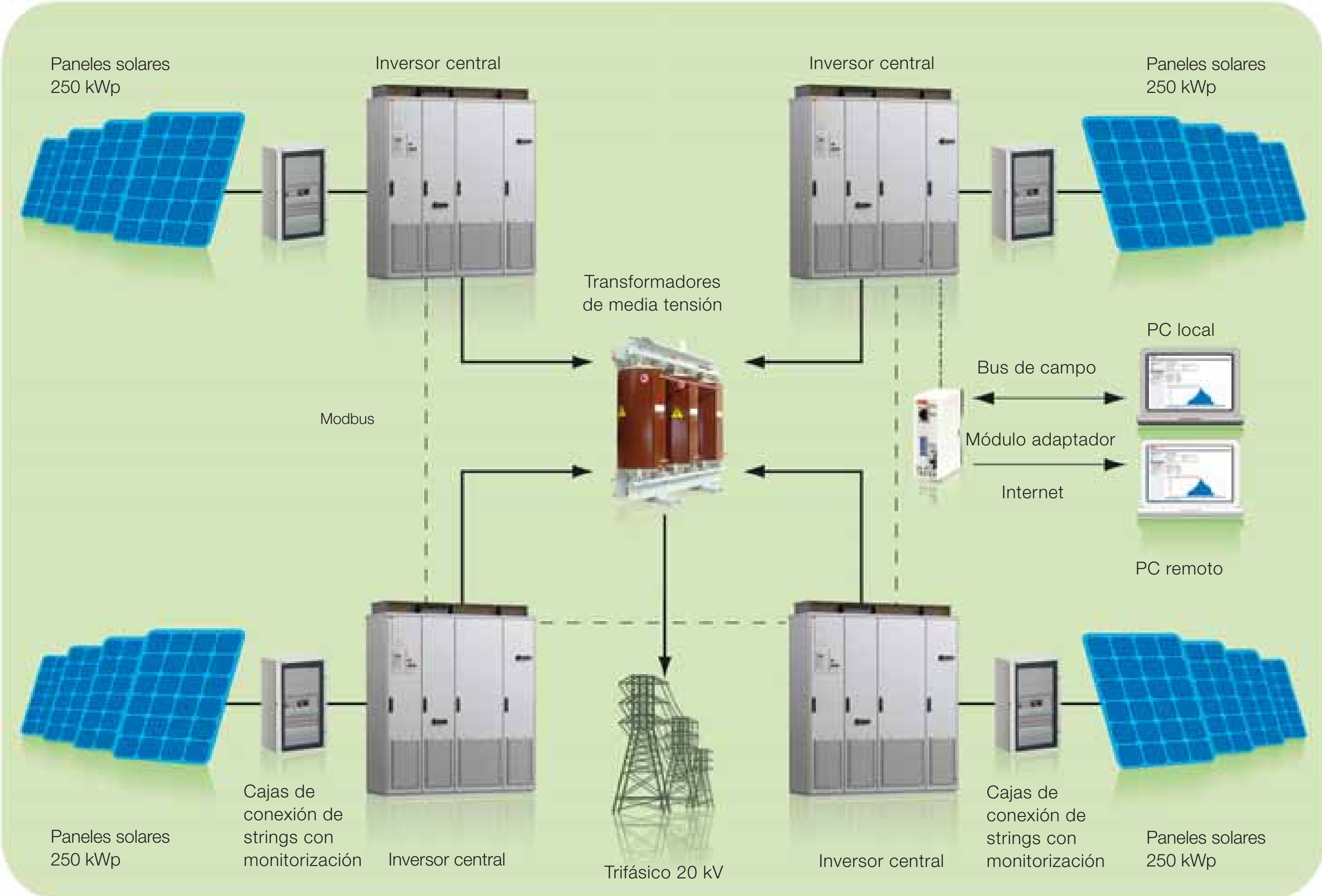
Diseño y conexión a la red del inversor central ABB



Código de tipo	PVS800 -57-0100kW-A	PVS800 -57-0250kW-A	PVS800 -57-0315kW-B	PVS800 -57-0500kW-A	PVS800 -57-0630kW-B
	100 kW	**250 kW**	**315 kW**	**500 kW**	**630 kW**
Límites ambientales					
Categoría de protección	IP42	IP42	IP42	IP42	IP42
Rango de temperatura ambiente (potencia nominal) [10]	-15 °C a +40 °C	-15 °C a +40 °C	-15 °C a +45 °C	-15 °C a +40 °C	-15 °C a +45 °C
Temperatura ambiente máxima [11]	+50 °C	+50 °C	+55 °C	+50 °C	+55 °C
Humedad relativa (sin condensación)	15% a 95%	15% a 95%	15% a 95%	15% a 95%	15% a 95%
Altitud máxima sobre el nivel del mar [12]	2000 m	2000 m	2000 m	2000 m	2000 m
Nivel máximo de ruido	75 dBA	75 dBA [13]	75 dBA [13]	75 dBA [13]	75 dBA [13]
Máximo flujo de aire de la sección del inversor	1100 m³/h	1680 m³/h	1680 m³/h	3360 m³/h	3360 m³/h
Protección					
Monitorización contra defecto a tierra [14]	Sí	Sí	Sí	Sí	Sí
Monitorización de red	Sí	Sí	Sí	Sí	Sí
Protección anti-isla	Sí	Sí	Sí	Sí	Sí
Polaridad inversa de CC	Sí	Sí	Sí	Sí	Sí
Protección contra cortocircuito y sobreintensidad de CC y CA	Sí	Sí	Sí	Sí	Sí
Protección contra sobretensión y sobretemperatura de CC y CA	Sí	Sí	Sí	Sí	Sí
Interfaz de usuario y comunicaciones					
Interfaz local de usuario	Panel de control local ABB				
Entradas/Salidas analógicas	1/2	1/2	1/2	1/2	1/2
Entradas Digitales/Relé de salida	3/1	3/1	3/1	3/1	3/1
Conectividad de bus de campo	Modbus, PROFIBUS, Ethernet				
Cumplimiento de normativas del producto					
Seguridad y CEM	Conformidad CE de acuerdo con las Directivas de Baja Tensión y de CEM				
Certificaciones	VDE,CEI,UNE,RD,EDF, Golden Sun, BDEW				
Soporte de red	Compensación de la potencia reactiva, reducción de potencia, ajuste frente a huecos de tensión				

[10] No se permite escarcha. Puede requerirse calefacción del armario.
[11] Derrateo de potencia por encima de los 40 °C/45 °C
[12] Derrateo de potencia por encima de los 1000 m. Por encima de 2000 m es necesario requisitos especiales
[13] A potencia parcial tipicamente <70 dBA
[14] Opcional

Esquema de transmisión de datos del inversor central ABB



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Accesorios
- Cajas de conexión de strings con monitorización
- Soluciones para la monitorización remota
- Ampliaciones de garantía
- Contrato de Servicio de mantenimiento

Opciones
- Solución flexible para la extensión de entradas de CC mediante armarios integrados
- Calefacción de los armarios
- Ampliaciones de E/S
- Conexión a tierra del polo positivo o negativo del generador de CC
- Conexión Fieldbus y Ethernet

Asistencia y servicio
ABB presta asistencia a sus clientes con una red de servicio específica en más de 60 países y ofrece una amplia gama de servicios para el ciclo completo de vida del producto, desde la instalación y la puesta en marcha al mantenimiento preventivo, los recambios, las reparaciones y el reciclado.

Para obtener más información póngase en contacto con su representante ABB local o visite la webb:

www.abb.com/solar
www.abb.es

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