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**20kWp PHOTOVOLTAICS APPLICATION AND ELECTRIC CAR CHARGING STATION AT BITOLA**

**CALCULATIONS**

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**CALCULATIONS**

# Introduction

This paper is the computational part for the study of the application of photovoltaic (PV) systems of 20 kWp and electric car charging station.

The calculations concern both the energy (power generation) and the electromechanical part (cables, boards, high current switching) of the Renewable Energy facility and the charging station.

The power generation was obtained using the tmy PVGIS database (https://ec.europa.eu/jrc/en/pvgis) and took into account the location of the installation, the type of the PV panels, the type of the inverters, the slope and the orientation, potential shading caused by nearby buildings and the losses of the cables.

In the E/M section the necessary cross sections and the voltage drop of the AC wiring were calculated, the switches were dimensioned and their selective protection was checked.

# Strong Current Installation Calculations

## General

This study refers to the electrical installations of the above project.

## Regulations

The electrical installations will be planned in accordance with the regulations of the country.

## Technical aids

In order to draft the study the following technical aids were used:

• Planning and Installing Photovoltaic Systems: A Guide for Installers, Architects and Engineers, German Solar Energy Society (DGS).

• P. Dokopoulos "Internal Electrical Installations".

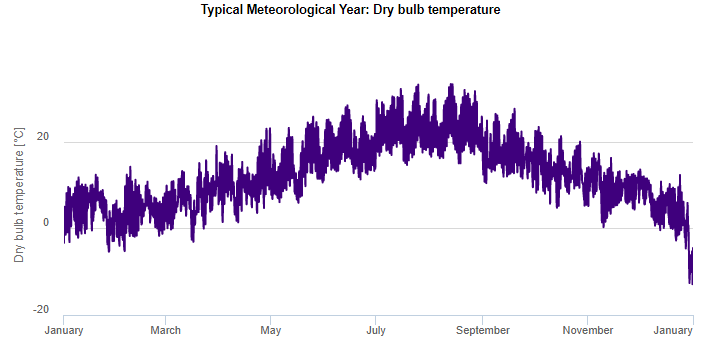
• Siemens, "Electrical Installations Handbook", Wiley, 3rd Edition 2000.

## Energy Calculation Parameters

### Climatic Data

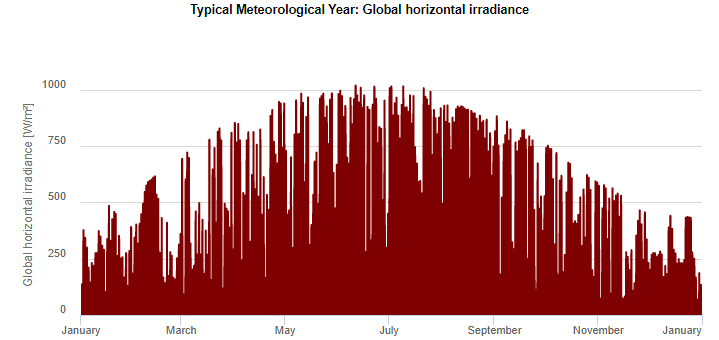
The climate data of the region as obtained from the tmy PVGIS database (https://re.jrc.ec.europa.eu/pvgis/) were used to calculate the energy consumption of the PV System.

The chart below shows the annual temperature in Bitola. Its average value is 12.33˚C.

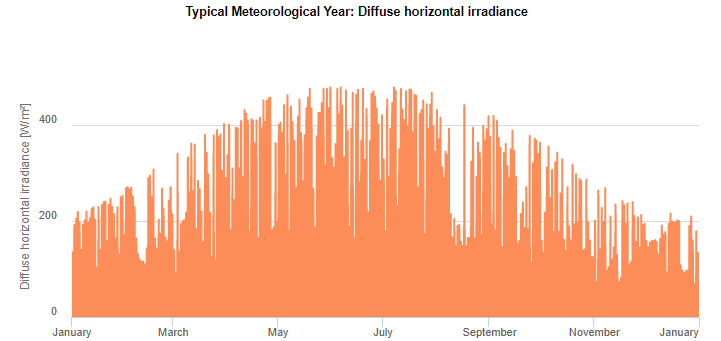


**Εικόνα 2.1** Annual Temperature at Bitola

The figures below show the annual global horizontal radiation and the diffuse horizontal radiation.



**Εικόνα 2.2** Annual Global Horizontal Irradiance at Bitola



**Εικόνα 2.3** Annual Diffuse Horizontal Irradiance at Bitola

### Electrical Energy Consumption

The initial design of the PV system was made on the assumption that each car (Nissan Leaf and Nissan e-NV200 EVALIA) would be fully charged once a day. The battery capacity of each vehicle is 40kWh. Therefore, the annual energy demand is 14600kWh for each vehicle and 29200kWh in total. According to the tmy PVGIS database, having frame slope of 25˚ and azimuth 45˚, the annual output will reach 25636.28 kWh. Therefore it is assumed that there will be 320 charges per year for each car.

## Basic Calculation Rules

### Number of Strings per Inverter

#### Temperature Parameters

The number of in-line and parallel frames in each inverter is determined by the inverter's maximum input voltage, the inverter's maximum input current, and the minimum possible detection voltage of the Maximum Power Point. As the electrical characteristics of the frames vary according to the climatic conditions (temperature, radiation) their extreme values are set for operating temperatures between -10 ° C and 70 ° C.

#### Correlation of the inverter voltage and the PV panels’ voltage

The maximum permissible input voltage of the inverter selected for this study is Vmaxinverter = 1000V. Correspondingly, the detection range of the inverter maximum power point is between Vinverter-mpp = 320-800Volt. The open circuit voltage (Voc) of PV modules at -10 ° C (worst inverter temperature at winter) will be:

The open circuit voltage of the panels at -10 ° C will be **51.15V**.

The voltage at the MPP (maximum power point) of the PV panels at 70 ° C will be equal to:

The voltage at the MPP (maximum power point) of the PV panels at 70°C will be **32,58V**.

Therefore, the maximum number of PV panels allowed to be connected in series to the inverter shall be:

The minimum number of PV panels allowed to be connected in series to the inverter shall be:

#### Correlation of the inverter current and the PV panels’ current

The maximum current the inverter can receive at each input is equal to 33A. Given that the PV modules can develop the maximum current at high temperatures and at error state (short circuit current Isc) the design should be such that the inverter operation is not compromised. Thus the true current of the frames in the worst case (Short circuit error in summer) will be equal to:

Therefore, the maximum number of parallel PV strings for the inverter is:

For inverter input A:

For inverter input B:

#### Electrical Installation Connection

According to the analysis above the electrical connection of all PV modules should verify the mathematical inequalities:

All circuit calculations were made taking into account the following:

### Pipelines - Routes

#### Calculations of the Dimensions of metal rails

The ducts and cables as referred to in the technical specification are routed within metal galvanized cable grates. The dimensions of the grate are selected based on the number and diameter of the cables that will be installed. According to the diameter of the cables, the dimensions are chosen as follows:

where:

D: the area of the required grate

α: the percentage (%) as a provision for empty space on the grate

S: the sum of the area of all cables

di: the diameter of each cable

The side height (H) and width (B) of the grate are calculated by the equation: B x H ≥ D

It should be noted that for these grates the provision for vacant space was 30% to ensure adequate ventilation of the cables and to cover future installation needs.

#### Cables

To reduce losses in DC circuits between inverters and PV panels, a fixed cross section of H1Z2Z2-K wiring equal to 6.0mm² was obtained to ensure voltage drop and energy loss below 1%. The table below summarizes the results for the various strings.

Πίνακας 3. DC Losses

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| String Operating Voltage | String Operating Current | Number of Strings | Average Current per String | Average Wiring Length (Single Run) | Voltage Drop | Energy Losses |
| Vmpp  (Volt) | Impp  (A) | n | Impp  (A) | L  (m) | (%) | (%) |
| 437 | 147 | 16 | 9,19 | 55,00 | 0,72 | 0,67 |
| 466 | 28 | 3 | 9,33 | 55,00 | 0,68 | 0,69 |
| 437 | 110 | 12 | 9,17 | 55,00 | 0,72 | 0,67 |
| 525 | 73 | 8 | 9,13 | 55,00 | 0,60 | 0,66 |
| 583 | 110 | 12 | 9,17 | 55,00 | 0,54 | 0,67 |

The AC cables are FG7OR-type ethylpropylene insulated flexible copper ducts for better resistance to high temperatures. The cross-section of the cables depends on the rated current flowing through them and on the total length.

The calculations were carried out with ambient temperature at 45 ° C and maximum permissible voltage drop of 1.2%.

The following parameters are taken into account when selecting the cross section:

The maximum continuous permissible current for off-ground cables shall be equal to:

|  |  |
| --- | --- |
| Ιο: | is the reference current that flows continuously across the conductors, i.e. the charge coefficient is m = 1, given in Table A (1,2) below and applies to the following scenario  - ambient temperature 30 ° C  - PVC insulation  - single-phase or three-phase system |
| fθ: | Temperature dependent factor, given at Table B. |
| fn: | Factor dependent on the number of adjacent circuits, given at Table C |

The following table A(1,2) gives the value Io, that is the maximum continuous current (in Ampere) of a low voltage cable installed on the ground. The cable insulation is made of PVC, the conductor from copper and the current is 50Hz frequency.

Table Α.1: Cable charge limits for 1-phase or 3-phase systems inside or on walls

|  |  |  |  |
| --- | --- | --- | --- |
| **Cable Cross section (mm²)** | **Insulation** | | |
| **PVC** | | |
| **For XLPE or EPR insulation the values are multiplied by 1.19** | | |
| **Three-pole cable in tube in insulated wall** | **System of 3 insulated cables in tube or three-pole cable in insulated wall** | **Three-pole cable in tube on or in building materials** |
| 1,5 | 13 | 13,5 | 14,5 |
| 2,5 | 17,5 | 18 | 19,5 |
| 4 | 23 | 24 | 26 |
| 6 | 29 | 31 | 34 |
| 10 | 39 | 42 | 46 |
| 16 | 52 | 56 | 61 |
| 25 | 68 | 73 | 80 |
| 35 | 83 | 89 | 99 |
| 50 | 99 | 108 | 118 |
| 70 | 125 | 136 | 149 |
| 95 | 150 | 164 | 179 |
| 120 | 172 | 188 | 206 |
| 150 | 196 | 216 | 240 |
| 185 | 223 | 245 | 273 |
| 240 | 261 | 286 | 321 |
| 300 | 298 | 328 | 367 |

Table Α.2: Charging limits for multipolar and single polar low voltage cables

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Cable Cross section (mm²)** | **Insulation** | | | | |
| **PVC** | | | | |
| **For XLPE or EPR insulation the values are multiplied by 1.19** | | | | |
| **Multipolar cables** | | **Single polar cables** | | |
|  | 3 ducts | 2 ducts | In contact | < 0,3d | > 0,3d |
| 1,5 | 18,5 | 22 | - | - | - |
| 2,5 | 25 | 30 | - | - | - |
| 4 | 34 | 40 | - | - | - |
| 6 | 43 | 51 | - | - | - |
| 10 | 60 | 70 | - | - | - |
| 16 | 80 | 94 | - | - | - |
| 25 | 101 | 119 | 110 | 130 | 141 |
| 35 | 126 | 148 | 137 | 162 | 176 |
| 50 | 153 | 180 | 167 | 196 | 216 |
| 70 | 196 | 232 | 216 | 251 | 279 |
| 95 | 238 | 282 | 264 | 304 | 341 |
| 120 | 276 | 328 | 308 | 352 | 396 |
| 150 | 319 | 379 | 356 | 406 | 456 |
| 185 | 364 | 434 | 409 | 463 | 521 |
| 240 | 430 | 514 | 485 | 546 | 615 |
| 300 | 497 | 593 | 561 | 629 | 709 |

Table Β: Correction factor fθ for ambient temperature other than 30 ° C.

|  |  |  |
| --- | --- | --- |
| **Ground temperature (°C)** | **Insulation** | |
| **PVC** | **EPR or XLPE** |
| 10 | 1,22 | 1,15 |
| 15 | 1,17 | 1,12 |
| 20 | 1,12 | 1,08 |
| 25 | 1,06 | 1,04 |
| 35 | 0,94 | 0,96 |
| 40 | 0,87 | 0,91 |
| 45 | 0,79 | 0,87 |
| 50 | 0,71 | 0,82 |
| 55 | 0,61 | 0,76 |
| 60 | 0,50 | 0,71 |
| 65 | - | 0,65 |
| 70 | - | 0,58 |
| 75 | - | 0,50 |

Table C: Correction factor fn for grouping more than one circuit or more than one multipolar cables in contact or short distance between them.

|  |  |  |  |
| --- | --- | --- | --- |
| **Number of Circuits** | **Free in the air or**  **on the surface of construction material or**  **on wall bare in a pipe or**  **in a wall bare or in pipe** | **In a simple layer, in contact with wall or**  **floor or**  **on a solid cable carrier** | **In a simple layer mounted directly under the roof** |
| **1** | **1,00** | **1,00** | **0,95** |
| **2** | **0,80** | **0,85** | **0,81** |
| **3** | **0,70** | **0,79** | **0,72** |
| **4** | **0,65** | **0,75** | **0,68** |
| **5** | **0,60** | **0,73** | **0,66** |
| **6** | **0,57** | **0,72** | **0,64** |
| **7** | **0,54** | **0,71** | **0,63** |
| **8** | **0,52** | **0,70** | **0,62** |
| **9** | **0,50** | **0,70** | **0,61** |
| **12** | **0,45** | **0,70** | **0,61** |
| **16** | **0,41** | **0,70** | **0,61** |
| **20** | **0,38** | **0,70** | **0,61** |

### Voltage Drop

#### Voltage drop calculation on a simple line with a load and a supply

The voltage drop ΔU is usually calculated at the rated voltage based on the resistor R' and the reactance X' per length unit, the power Π and the power factor cosφ.

For single-phase circuit is (U = phase voltage):

For three-phase circuit is (U = polar voltage):

΄

Ψ' is the equivalent resistance per unit of length, which is a function of the line and angle φ of the power factor. The following apply:

The symbol memo for this paragraph is:

l = length (m)

P = power (W)

U = voltage (V)

I = current (Α)

cosφ = power factor

R', X' = resistance, reactance per unit of length (Ω/m)

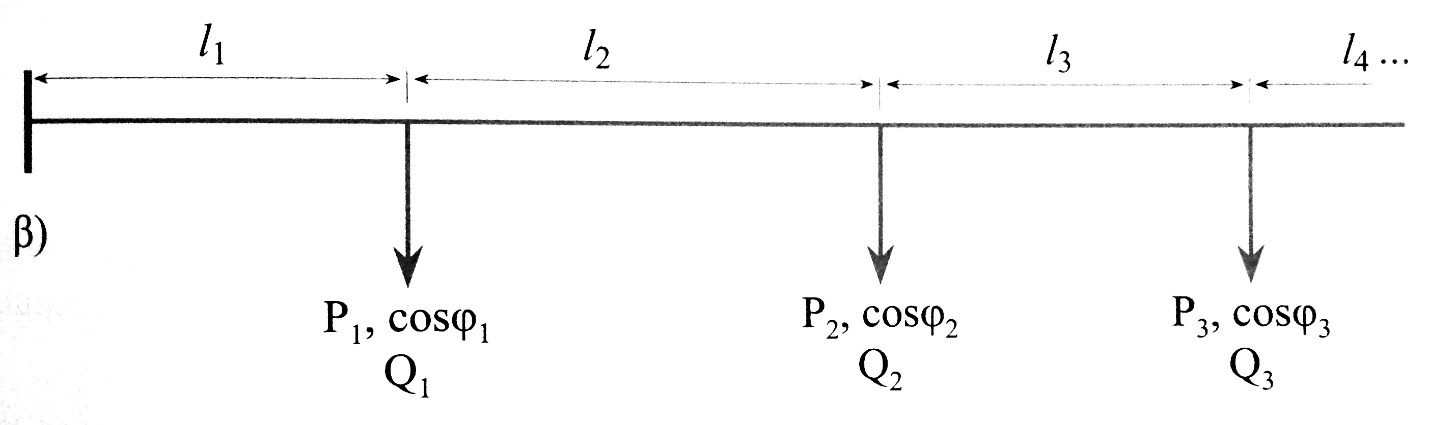
κ = conductivity (Ω-1∙m∙mm-2), at operating temperature

Α = cross section (mm²)

For low voltage and cross sections Α≤16mm² applies Ψ'=R'.

#### Voltage drop in line with multiple load

On distribution lines with loads P1, P2, P3 with space l1, l2, l3 between each other as in the following figure:



For single-phase circuit is (U = phase voltage):

These calculations are made taking into account not the actual loads P1, P2, P3 but total notional loads P1', P2', P3'and Q1', Q2 ', Q3' corresponding to the lengths l1, l2, l3.

**P1'= P1+P2+P3+..., Q1'= Q1+Q2+Q3+...**

**P2'= P2+P3+P4+..., Q2'= Q2+Q3+Q4+...**

**P3'= P3+P4+P5+..., Q3'= Q3+Q4+Q5+...**

Ψ1 ', Ψ2', Ψ3' are the resistances corresponding to the loads (P1', Q1'), (P2', Q2'), (P3', Q3') and the lengths l1, l2, l3. If the line has a fixed cross-section it can be assumed to the above formulas that

Ψ1 '= Ψ2' = Ψ3'= Ψm' , where Ψm' is the equivalent resistance.

The following also applies:

where φm is the angle of an average power factor.

For the angle φm applies: