Procedure of the design of photovoltaic systems applied to ornamental lighting

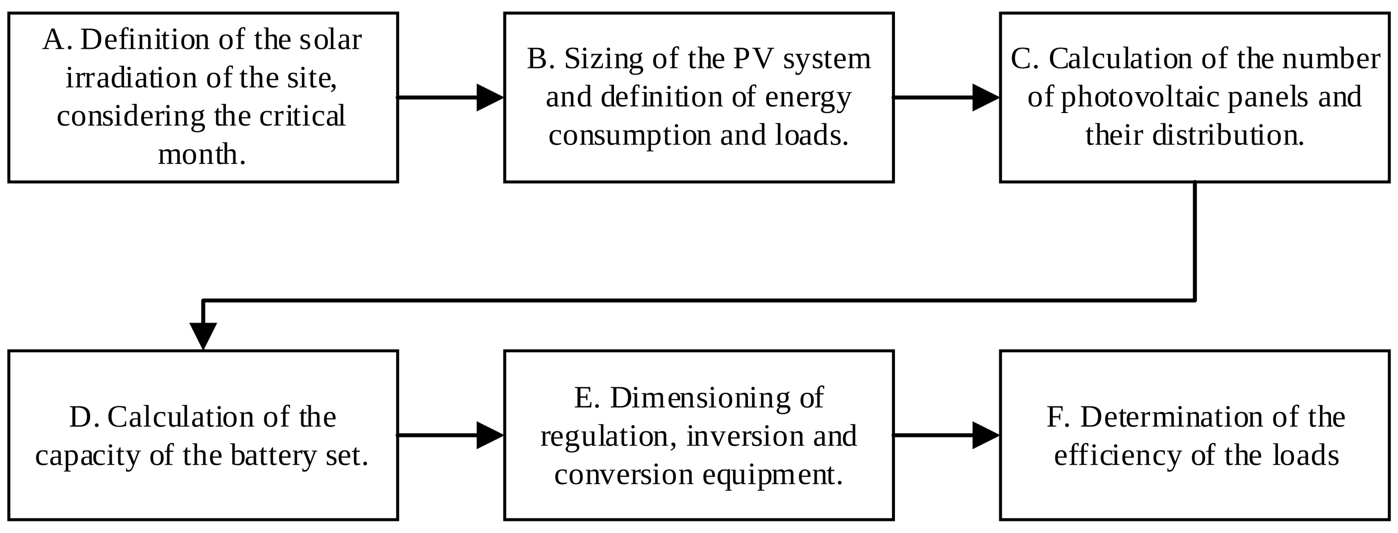
X. Serrano-Guerrero (1), C. Ochoa-Malhaber (1), I. Ortega-Romero (1)
(1) Universidad Politécnica Salesiana, Cuenca, Ecuador.
+593984843054, e-mail: jserranog@ups.edu.ec

1. Introduction - Photovoltaic (PV) systems are clean electricity generation technologies that reduce CO_2 emissions. The low energy consumption of the new ornamental lighting (OL) technologies allows powering them by off-grid PV systems.

Public, ornamental, residential and commercial lighting are the four sectors where lighting has the highest energy consumption in Ecuador. OL includes the lighting of parks and gardens, where there is commonly a high consumption due to the low level of luminous efficacy. In Cuenca, OL systems use conventional electricity from the grid, which often represents considerable costs when extending the distribution network.

This study presents a procedure for the design of PV systems applied to OL in order to reduce costs, starting from obtaining adjusted values of solar irradiance, based on real measured data in Cuenca, Ecuador and estimated solar irradiance in tilted plane data from NASA. In addition, a boost converter is developed to increase the voltage coming from the set of batteries and to feed the LED luminaires.

2. Methodology – The procedure for the design of photovoltaic systems applied to lighting:



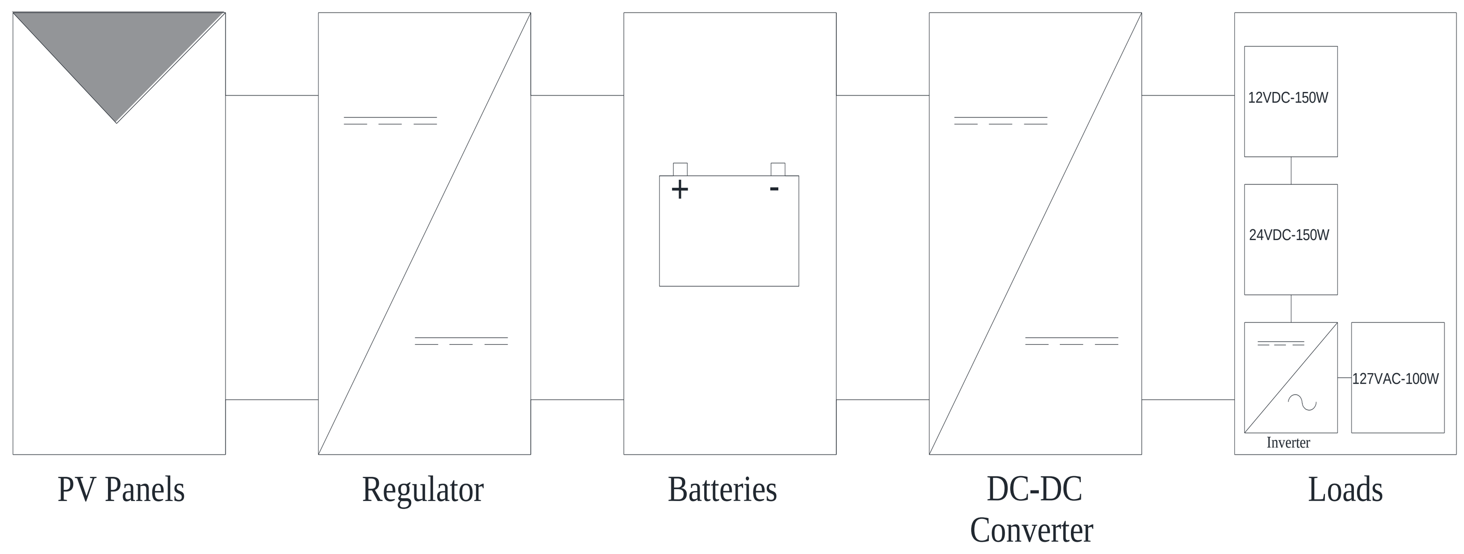
2.A. Definition of the solar irradiation of the site, considering the critical month.

We propose to adjust the real data measured in the horizontal plane. The global irradiance real-data measured on the horizontal plane, are collected. Then, the solar irradiance values according to month and tilt angle are obtained from the NASA database. A coefficient is calculated between the different tilt angles. For this purpose, the average irradiance for each month of the tilt angles of 15, 30 and 45° is divided for the irradiance at an angle of 0°. Then each coefficient is multiplied by the actual value of global irradiance measured in the horizontal plane. Table I presents the adjusted global irradiance data at different tilt angles.

Adjusted global irradiance data $[kWh/m^2]$				
Month	**0° Tilt**	**15° Tilt**	**30° Tilt**	**45° Tilt**
January	5,09	5,25	5,03	4,58
February	4,99	5,02	5,16	5,31
March	4,29	4,23	5,09	4,92
April	4,29	4,11	5,11	5,13
May	4,22	3,92	5,15	5,34
June	3,91	3,76	5,28	5,25
July	3,85	3,92	5,13	5,10
August	4,16	3,93	5,13	5,22
September	4,68	4,57	5,10	5,01
October	4,74	4,76	5,06	4,79
November	5,45	5,60	5,02	4,59
December	5,04	5,25	5,02	4,52

Then, we identify the critical month as the one with the lowest solar irradiation and highest energy demand. In the study case, energy consumption is constant around the year. Then, the slope corresponding to the highest energy collection for that month is selected. In this case study it corresponds to the month of June with a value of 3,76 kWh/m² and a 15° tilt angle.

2.B Sizing of the PV system and definition of energy consumption and loads.



Loads	Voltage [V]	Power [W]	Time of use [h]	Daily energy [kWh/day]	Monthly energy [kWh/month]
LED luminaire in DC	12	200	12	2,4	72
LED luminaire in DC	24	200	12	2,4	72
LED luminaire in AC	127	100	12	1,2	36
Total				**6**	**180**

2.C. Number of PV Panels of 270W: 9

The number of panels is calculated through Equation:

$$N_T = \frac{E_{T_{PVP}} \cdot 1000}{P_{PV} \cdot G_{dm} \cdot P_R} = 9$$

2.D. Capacity of the battery set: 2540 Ah a 12V

- **Daily rated capacity**

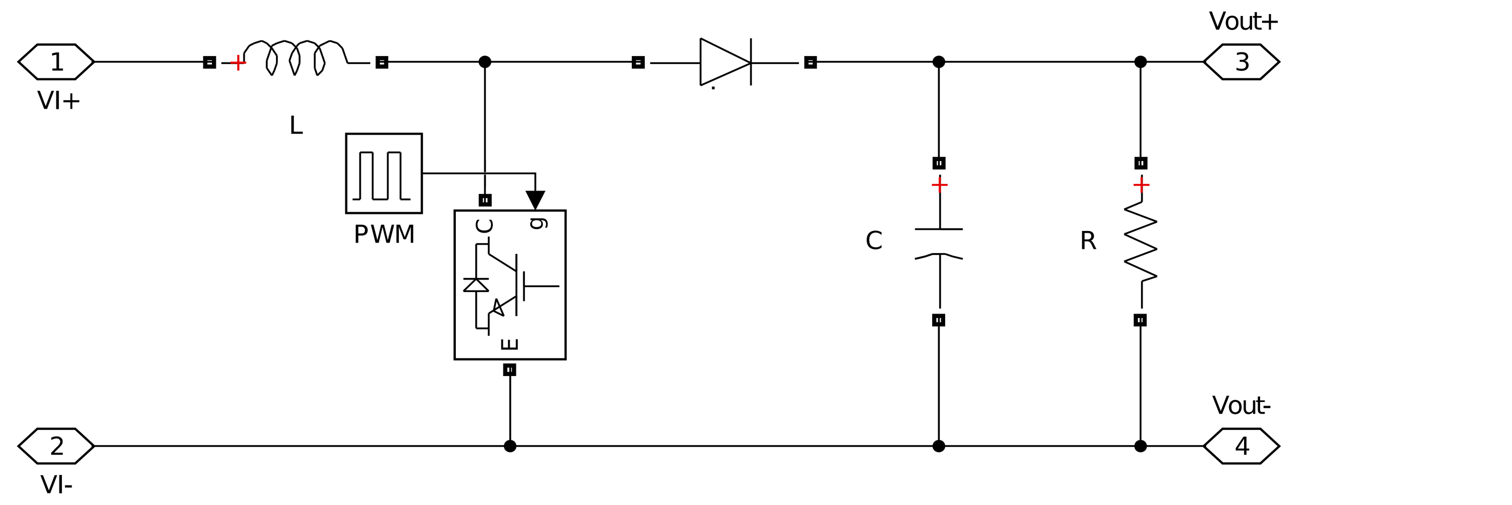
$$B_C = \frac{E_D \cdot D_A}{V_S \cdot DP} = 1975.31Ah$$

Where B_c is the battery capacity [Ah], $E_D$is the energy demand [Wh/day], D_A is the number of autonomy days, V_S is the system voltage [V] and B_c DP the depth of discharge.

- **Seasonal rated capacity**

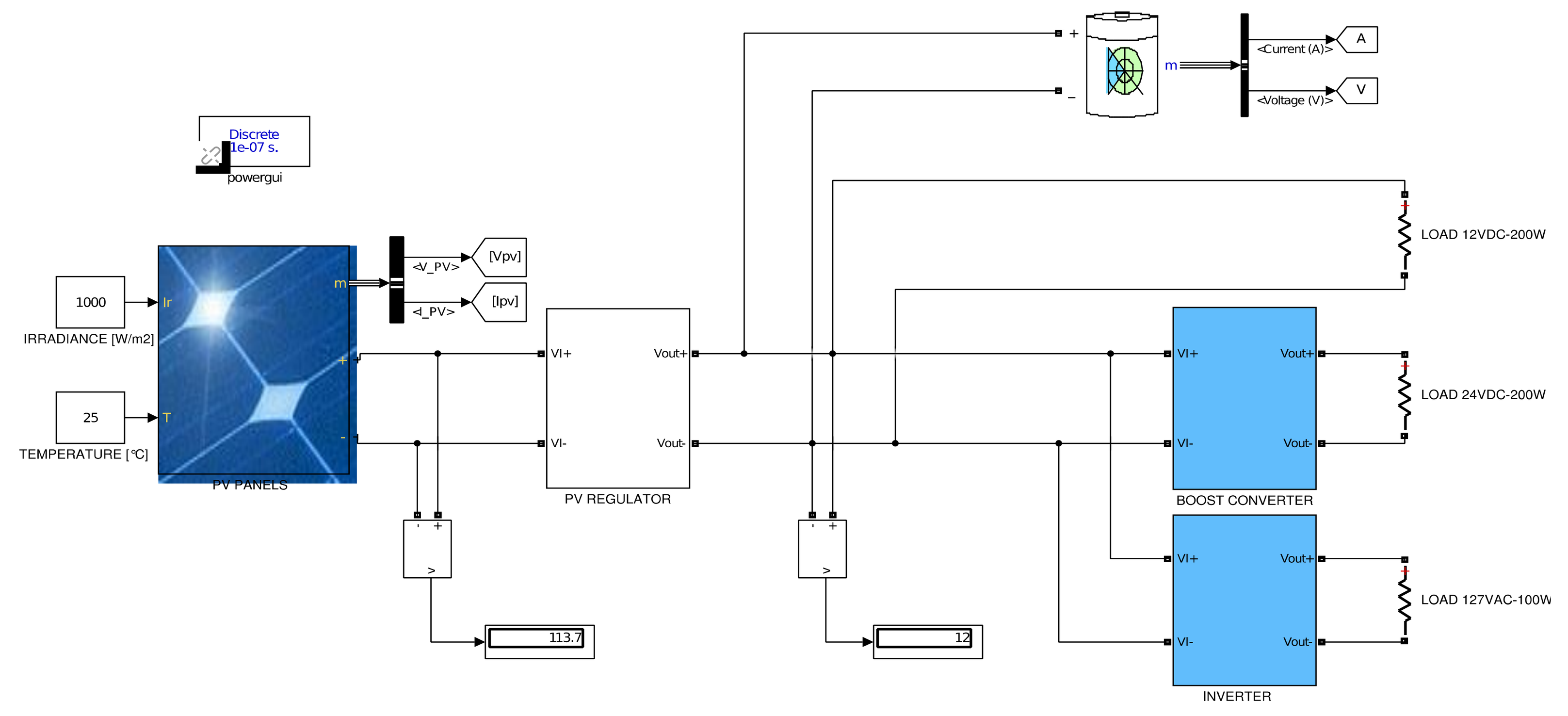
The same equation is used with a depth of discharge of 70% and 3 days of autonomy. The result is $B_C = 2539.68\ Ah$

2.E Dimensioning of boost converter



$$D = 1 - \frac{V_{in}}{V_{out}} = 0{,}5,\ R = 2{,}88\ \Omega,\ L = 27\ uH,\ C = 347\ uf$$

3. Results and Discussion -



4. Conclusions – It is feasible to design a boost converter in case the required output voltage is not so high compared to its input voltage. For example, if a system needs to feed a load of 110 Vdc and has an input voltage of 12 Vdc, the most advisable is to perform a process of inversion, boost and power rectification. This is due to the complexity that exists when working with high DC voltages and loads.

The impact of photovoltaic systems on the environment is minimal compared to other non-renewable energy sources such as thermal and nuclear power plants. This has greatly benefited the reduction of progressive environmental impacts and the problems they generate. Regarding the economic return of a photovoltaic system, it will be profitable as long as the payback time is less than the useful life of the system components.

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