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Photovoltaic system at UTNC

Sistema fotovoltaico aislado en la UTNC

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Abstract

This article represents the work and research carried out for the implementation of a photovoltaic system at the Universidad Tecnológica del Norte de Coahuila. Setting the objective of avoiding high consumption of electrical energy caused by metallic additive-type luminaires in exterior corridors. The change to LED technology luminaires is proposed and these in turn are energized by a solar panel. It begins with the execution of a theoretical and practical study in order to find out what refers to a photovoltaic solar energy system in isolated mode, to evaluate the conditions in which it will work when carrying out this project. The area to be illuminated, the necessary light intensity, the type of LED reflector to be used, the terrain was dimensioned and the distance between each LED reflector was decided. For the proposal, a plan was prepared in AutoCAD and with the use of the DIALux program, the simulation of the lighting system was carried out, obtaining measurements in lux, in order to have a more precise result prior to authorization. Finally, when carrying out the implementation, the objective was met, so it will be sought to replicate it in other areas.

DIALux, Implementation, Off-grid PV system

Resumen

El presente artículo representa el trabajo e investigación realizado para la implementación de un sistema fotovoltaico en la Universidad Tecnológica del Norte de Coahuila. Marcando como objetivo el evitar consumos altos de energía eléctrica, ocasionados por luminarias del tipo aditivo metálico en pasillos exteriores. Se propone el cambio a luminarias de tecnología LED y estas a su vez sean energizadas por un panel solar. Se inicia por la ejecución de un estudio teórico y práctico con el fin de conocer lo referente a un sistema de energía solar fotovoltaica en modalidad aislada, para evaluar las condiciones en las que se trabajará al realizar este proyecto. Se determinó la zona a iluminar, la intensidad de luz necesaria, tipo de reflector LED a utilizar, se dimensionó el terreno y decidió la distancia entre cada reflector LED. Para la propuesta, se elaboró un plano en AutoCAD y con la utilización del programa DIALux se realizó la simulación del sistema de iluminación, obteniendo mediciones en lux, para tener un resultado más preciso previo a la autorización. Finalmente, al realizar la implementación se cumplió con el objetivo, por lo que se buscará replicar en otras áreas.

DIALux, implementación, Sistema fotovoltaico aislado

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Introduction

This project covers from the determination of the area, through the design of the circuit to its implementation in the area. An isolated photovoltaic system for the lighting of the back corridor of the library building of the Universidad Tecnológica del Norte de Coahuila (UTNC), seeking to achieve significant savings in electrical energy consumed by outdoor luminaires, without neglecting the proper lighting of the area. The metal additive lamps for exterior corridors in the University are widely used, however the use of this type of luminaire generates high consumption of electricity by the simple fact of what this technology represents, not having illuminated the corridors can cause accidents to students and teachers while passing through them in the evening shift, which ends at 21:30 pm, so removing the lights is not an option, however replace them with LED technology luminaires would lead to energy savings. Finally, it is intended that this will be replicated in the other corridors of the University once its effectiveness is demonstrated. The methodology section covers the review of information on photovoltaic systems, calculations and design, and the two-stage implementation of the system. The results section reports on both stages of implementation, while the discussion and conclusions sections address recommendations and analyze the fulfillment of the project's purpose.

Methodology

Literature review

Photovoltaic systems are divided into two types, one is isolated and the other is interconnected. Isolated PV systems are suitable for meeting specific energy needs, especially in remote or difficult to access locations (indisect, 2020).

A stand-alone system consists of a solar panel, charge controller, inverter, solar batteries (ecofener, 2019).

Solar panels exist in different capacities, i.e., there are some that are capable of producing from a small amount of energy to large amounts such as 810W (pv magazine, 2020). It should be considered that solar panels are designed to work together as well as individually, so depending on the user's need, the number and type of panels should be adjusted.

The charge regulators are designed under two different technologies, one of them is the PWM, which is the most economical, is more widely distributed, however, depending on the efficiency that is sought to achieve with the system, you can opt for the economic or the other type of technology that compared to the above is not as easy to achieve or as economical. The MPPT regulator allows an increase in energy productivity of up to 30% compared to other regulators (Sanz, 2021).

A power inverter's sole purpose is to receive the battery voltage and provide an output of 110-220 volts with which to power a load.

If there are different battery technologies, the recommended technology for use in photovoltaic systems is deep cycle technology. These are designed to be almost fully discharged and regularly lose between 50% and 80% of their capacity (ledsolar, 2020).

Applicable regulations

According to the Secretaría de Salud (2015):

Mexican Official Standards (NOM) are technical regulations of mandatory observance issued by the competent agencies, whose purpose is to establish the characteristics that processes or services must meet when they may constitute a risk to people's safety or harm human health; as well as those related to terminology and those that refer to their compliance and application.

Identifying applicable standards, one of them NOM-025-STPS-2008 Condiciones de iluminación en los centros de trabajo", la Secretaría del Trabajo y Previsión Social (2008) mentions that the minimum lighting levels that should affect the plane to move around walking should be 20 lux.

Current situation

The chosen corridor has a 400W metal additive type lamp with a luminous flux of 36,000 lumens; it has auxiliary equipment consisting of a 400W ballast and a 120-240V photoelectric switch, which sometimes does not turn on, as shown in Figure 1.

Figure 1 Area to be illuminated on the right side
Source: Own elaboration

Once the corridor was chosen, measurements were taken of the area to be illuminated, obtaining measurements of 10 meters wide and 38 meters long, as shown in Figure 2.

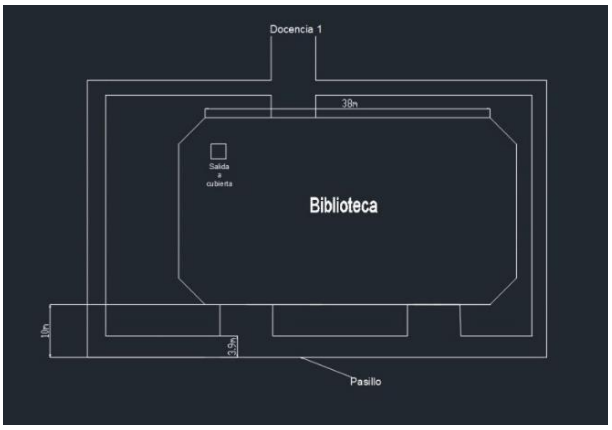

Figure 2 Plan of the area
Source: Own elaboration

Dimensioning of the system

Based on NOM-031-ENER-2012, "Eficiencia energética para luminarios con diodos emisores de luz (leds) destinados a vialidades y áreas exteriores públicas" (Energy efficiency for luminaires with light emitting diodes (leds) intended for roads and public outdoor areas), we seek to perform the necessary calculations to determine the appropriate materials for the project.

The first point is to determine where the luminaires will be installed, see Table 1.

Luminaire for to be installed in	Minimum luminous efficacy [lm/W]	Percentage of luminous flux in the zone, of total luminous flux
Wall	52	No more than 48% to the front in the zone of 60 and 80° (FH)
		No more than 3% forward in the 80 and 90° zone (FVH). 90° (FVH)
		0% in the 90 and 100° zone (UL) and in the above 100° zone (UH). above 100° (UH)
Post	70	At least 30% forward and backward in the 60 and 80° zone (FH + BH). 60 and 80° zone (FH + BH)
		No more than 20% above 80° (FVH + BVH + UL + UH)

Table 1 Minimum luminous efficacy and total luminous flux
Source: Secretaría de Energía (2012)

Since the lamps will be recessed in the building, the Secretaría de Energía (2012) suggests taking 52 lm/W as the minimum luminous efficacy. In order to replace the current lamp with an equivalent LED lamp, a 50W lamp was found, equivalent to a 500W lamp, with a luminous flux of 3500 lm, color temperature of 6000K and a luminous efficacy of 70 lm/W, thus complying with the minimum luminous efficacy specifications.

With the understanding that one lux is equivalent to one lumen per square meter (krealo, 2014), and for this project, for the moment only the dimensions of the space to be illuminated are known, as well as the minimum illumination levels, we proceed to calculate the lumens needed to cover that area, in equation (1).

$$\text{Lumens} = (20\ lx) * (380\ m2) = 7600\ lm \qquad (1)$$

By dividing the total lumens required by the luminous efficacy we obtain the electrical power required in equation (2)

$$\text{Electrical power} = (7600\ \text{lm})/(70\ \text{lm/W}) = 108\text{W} \qquad (2)$$

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To know the number of lamps required, the total electrical power must be divided by the power offered by the lamp, as shown in equation (3).

$$\text{Number of lamps} = (108\ \text{W})/(50\ \text{W}) = 2.16 \quad (3)$$

For the calculation of the battery bank, we initially consider an energy consumption of the lamps of approximately 10 hours per day, time controlled by a photoelectric switch, and we take for calculation purposes a 30% of total losses by connections and conductors according to Alvarado and Cruz (2016). Equation (4) will indicate the required capacity.

$$\text{Battery} = ((100\ \text{W} * 10\ \text{h}) * 1.3)/12\ \text{V} = 108.3\ \text{Ah} \quad (4)$$

The battery that meets these 108.3 Ah, is the 115Ah, however, it would be performing almost total discharges, which is not recommended, as it decreases the life of the battery, so it is proposed the use of a timer to control the on time of the lamps to only 4 hours.

$$\text{Battery} = ((100\ \text{W} * 4\ \text{h}) * 1.3)\ /\ 12\ \text{V} = 43.3\ \text{Ah} \quad (5)$$

$$\text{Download} = \left(\frac{43.3\ \text{Ah}}{115\ \text{Ah}}\right) * 100 = 37.68\% \quad (6)$$

As shown in equation (6), the suggested action of controlling the ignition by means of a timer allows making good use of the battery, since it is possible to discharge the battery only 37% of its capacity, preserving its useful life.

To identify the panel capacity required for the system, the solar irradiation received by Piedras Negras is considered, this city obtains an annual average of 4.5 kWh/m2 per day according to Conermex (2016), so the photovoltaic power (PFV) required for the system is calculated as shown in equation (7).

$$\text{PFV} = ((100\text{W} * 4\ \text{h}) * 1.3)\ /\ 4.5 = 115.5\text{W} \quad (7)$$

Therefore, a panel providing a value higher than 115W is required.

In the case of the controller, it must support higher currents than the maximum currents generated by the panel. Similarly, the inverter must be higher than the loads fed by it.

Simulation of the project in DIALux

The location of the luminaires was made considering that the trees could block the passage of light.

With this type of simulation it is possible to observe by means of the false color technique, the representation of the illumination in lux, as shown in the color table under the design, in this way it is possible to visualize that the minimum of 20 lux is largely complied with.

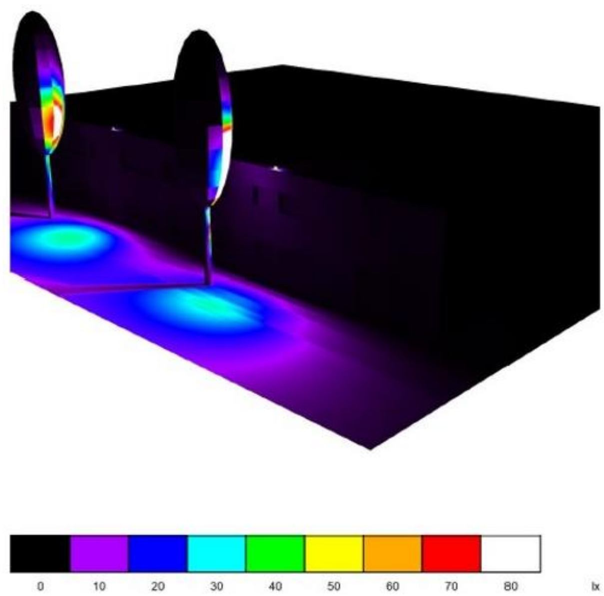

Figure 3 Simulation of the area to be illuminated with false color technique
Source: Own elaboration

Request for materials

The project was presented as a proposal to the University, which provided support with the purchase of materials necessary for the implementation.

Implementation stage one

The tools and materials available for the first stage were those indicated in Table 2.

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Tools and materials needed		
Solar panel (270W)	Deep cycle battery (115 Ah)	2 LED spotlights
14 gauge wire	Charge controller (30 Amp)	Inverter (300W)
Pipe mt of 3 meters	3 meter metal angle	Welding
Drill	Clamps	Tube bender
Segueta	3/8" brush	Sockets
Nuts	Sanding Machine	Screws
Luxmeter	Battery terminals	Multimeter
Electric tongs	Timer	Insulating tape

Table 2 Tools and materials used in the implementation
Source: Own elaboration

Once the panel arrived at the University, measurements were taken to design a support as shown in Figure 4.

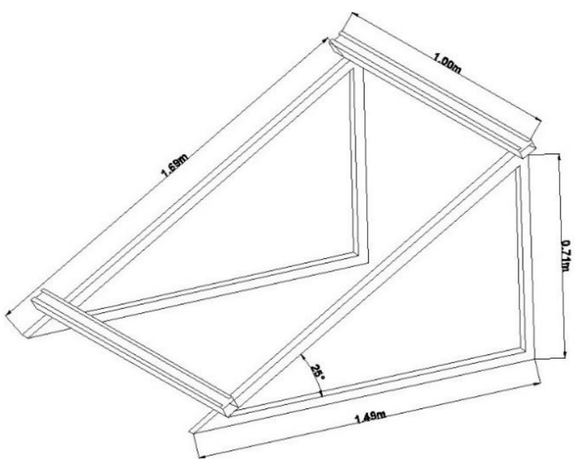

Figure 4 Solar panel support design
Source: Own elaboration

A height of 20 cm. was placed so that the panel does not touch the ground and to anchor the support to a safe part, as shown in Figure 5.

Figure 5 Panel with anchored support
Source: Own elaboration

The installation for this system consisted of connecting the solar panel to the charge controller with 14 gauge cable, the deep cycle battery to the charge controller to regulate the battery voltage and protect it from overload, then the charge inverter to the battery, to feed 110VAC to the reflectors, between the reflectors and the inverter was placed the timer already configured, all this embedded in a wooden base as shown in Figure 6.

Figure 6 Controller connected
Source: Own elaboration

Stage two implementation

After a few quarters of testing, it was considered viable to decrease the operation time of the lamps from 4 hours to only 2 hours, but increasing the lighting quality with 2 more lamps, to cover a little more area and the operation schedule was established from 8pm to 10pm, so the total consumption will remain the same as calculated in the first stage.

In terms of regulations for this time, NOM-031-ENER-2012, "Eficiencia energética para luminarios con diodos emisores de luz (leds) destinados a vialidades y áreas exteriores públicas" was cancelled and replaced by NOM-031-ENER-2019, but as the project was worked to comply with the standard, The new regulation, in which the Secretaría de Energía (2021) established the minimum required value at 75 lm/W, the initial calculations of the project were 70 lm/W, a result not too far off, however, this minimum must be covered in the other corridors of the university.

Results

Measurements were taken with the luxmeter in stage one, obtaining values ranging from 41 lux to 6 lux in the corridor area, so work continues on finding the degrees of inclination for the luminaires and their optimal use (see figures 7, 8, 9, 10).

In stage two, the lamps were rearranged, since now with 4 lamps they had to be distributed at a shorter distance between them, resulting in a distance of 3 meters between each one (see figure 11).

Figure 7 Front illuminated area of stage one
Source: Own elaboration

Figure 8 Illuminated area on the right side of stage one
Source: Own elaboration

Figure 9 Stage one high luxmeter reading
Source: Own elaboration

Figure 10 Low stage one luxmeter reading
Source: Own elaboration

Figure 11 Illuminated area on the left side of stage two
Source: Own elaboration

Discussion

Following the recommendation of Haro and Ocampo (2019) to avoid voltage drops, short lengths were sought in the connections between battery-inverter, regulator-battery and as far as possible a short distance from the panel to the regulator; considering that although the panel is at the top of the building and the battery along with inverter-regulator are located inside.

Also, Haro and Ocampo (2019) suggest a discharge regime of 30%, to prolong the life of the battery, an issue that in the present project was considered and a discharge period of 37.68% was achieved.

Something that was also observed during the planning of the project, was mentioned by Haro and Ocampo (2019) where it mentions that it should be verified that the luminaires to be used are on the market, contributing to the previous comment, there is also the option of adapting a design to the simulation from standard lamps, modifying the properties of the lamp, with what can be obtained in the local market (as long as there is certainty of its technical data).

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Conclusions

The Universidad Tecnológica del Norte de Coahuila is an institution committed to the environment; among its actions is the recycling of PET containers coordinated by students of Industrial Processes, the planting of trees directed by the Ecological Club and, among others, it also supports improvement projects, such as the one described in this publication, that have an impact on the conservation of the environment and generate awareness in students and society.

The use of clean energy is in growing demand, due to the great savings in economic terms that it represents at the time of making the payment of the electric energy service, so it is a developing field of work and for which the student must be prepared.

During stage one, considering an identical operating time for the two types of lamps (4 hours), a single lamp of the metallic additive type that the school has to illuminate its corridors that communicate one building with another, has a consumption of 1600W per day, while 2 LED technology lamps consume only 25%, i.e. 400W; besides being an option with much less consumption, it is a load that is powered by a solar panel, so it can be concluded that 1600W per day will be subtracted from the CFE bill.

During stage two, considering an identical operating time for the two types of lamps (2 hours), a single lamp of the metallic additive type that the school has to illuminate its corridors that communicate one building with another, has a consumption of 800W per day, while 2 LED technology lamps consume only 50%, i.e. 400W; besides being an option with much less consumption, it is a load that is powered by a solar panel, so it can be concluded that 800W per day will be subtracted from the CFE bill.

It should also be taken into account that the photoelectric switches, which are the ones used in the institution until before this project, are sometimes activated in cloudy conditions, so sometimes energy is being consumed when it is not necessary, instead a timer tends to be a better option (taking into account that there are different models with higher or lower quality).

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