DESIGN OF A LOW-COST SYSTEM FOR THE MONITORING AND CONTROL OF PUBLIC LIGHTING

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Abstract. The public lighting poles are part of the public lighting system, so its operation is important and is offered as a welfare mechanism for citizens, it has the disadvantage of the high cost of operation because it is in operation all night for 365 days of the year, in this work a low-cost system is designed to be able to supply power to the public lighting poles, based on a solar panel system and with sensors to be able to measure luminosity, voltages and current, this system sends the information to a base station using the XBEE protocol and viewed using LABVIEW software.

1. Introduction

Currently, solar radiation is one of the virtually inexhaustible sources of ecological energy [2], it can be transformed into electrical energy through photovoltaic panels whose efficient application can meet the demand for electricity supply in public lighting in urban and rural areas.

This research is focused on the development of a remote monitoring system that will be applied to public lighting poles with photovoltaic panels added with a one degree of freedom solar tracking system. The system will be remotely monitored by obtaining information from sensors, which allow adjustments to be made in the control of the system, improving performance in its operation.

2. Materials and Methods

A design based on a 30W LED lantern will be made, therefore, we will use a 65Ah 12V deep cycle dry battery, a 150W photovoltaic panel that will have a solar tracking sensor that will allow us to position with the highest intensity of radiation from the sun having at the base a linear electric articulator allowing a 1 GL movement. The photovoltaic panel also has a motion sensor, an accelerometer with which we will determine its position in time.

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A 20A solar regulator and charger will be used, which has a voltage and charge current control. The design of a custom controller based on a PIC18F4550 microcontroller and an XBEE transmitter will be carried out, which will help us to carry out an autonomous control of the system and send the information from the sensors to a data reception stage that can be processed and visualized in a graphical interface in LabView.

2.1. System Diagrams

Our diagram of public lighting with monitoring based on solar panels is represented in figure 1, representatively indicates the characteristics of its composition.

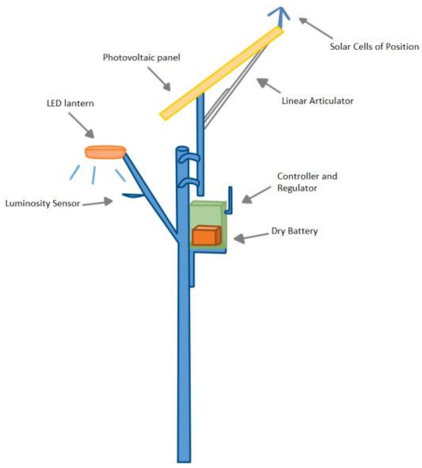

Figure 1: General System Diagram.

In figure 2 we represent the solar charger regulator the respective connections and the sensor to be used for monitoring.

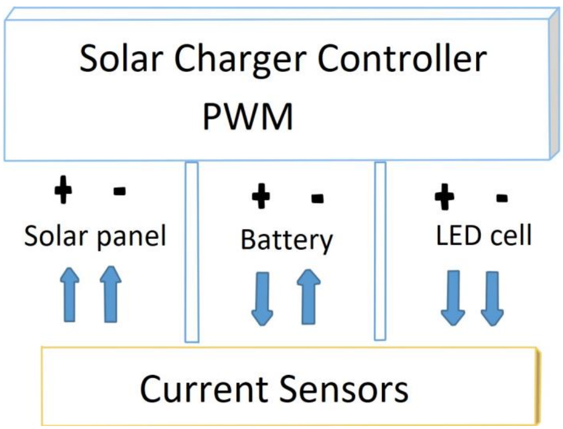

Figure 2: Solar Charger Regulator Diagram.

In figure 3 we represent the block diagram of the custom controller, using a microcontroller that allows us to govern the sensors, the transmitter and power drives that control the light intensity of the LED lanterns and the speed with which the linear actuator is going to operate.

Figure 3: Custom Controller Block Diagram.

2.2. Process Control

The orientation of the panel will be activated by a linear actuator which has a power stage, which will allow speed control, which will be continuously monitored by a motion sensor, which in turn will be the feedback element for the system. closed loop.

The intensity of the LED lantern is carried out through a second power stage, which allows the brightness to be varied according to the requirement, being monitored by a lumen depression sensor over time. Thus, the process is more efficient. Below is a block diagram for process control in figure 4.

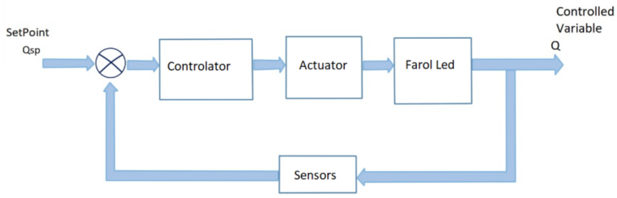

Figure 4: Block Diagram for Process Control.

2.3. System Design

2.3.1. Estimation of Energy Consumption

For our prototype of public lighting based on solar panels, the following DC charges are taken into account according to the figure 5.

Units	Loads (DC)	Unitary Power (Watt)	Hours of Operation per Day (Horas)	Total Energy (Wh)	Total Energy (WH) x 20% Safety Margin
01	LED Lantern	3W	12 Hours	360 Wh	432 Wh
01	Linear actuator	18W	01 Hour	18 Wh	21.6 Wh
01	Others (Sensors, C.I. and Power)	3W	24 Hours	72 Wh	86.4 Wh
				450 Wh/Day	540 Wh/Day

Figure 5: Energy Consumption.

After calculating the average consumption, it is applied as a safety mechanism approximately between 20 to 25%, due to the cause by effect of the performance and wear of the battery, a battery performance between 95% is considered and the drivers ideally with 100% [4].

Calculation of average daily consumption (Lmd) we consider the following expression.

$$Lmd = \frac{Lmd.DC + \frac{Lmd.AC}{Ninv}}{nbat * ncon}$$

Being (Lmd) the average daily energy consumption, ($Lmd.DC$) the average daily energy consumption of continuous loads and ($Lmd.AC$) the one of the loads in alternating (In our design it does not have alternating loads $Lmd.Ac$= 0).

$$Lmd = \ 568.42\ Wh/día$$

$$Lmd = \frac{Lmd.DC + \frac{Lmd.AC}{ninv}}{nbat * ncon} = \frac{540 + \frac{0}{0.90}}{0.95 * 1}$$

Calculation of the average energy consumption in Ah / day:

$$QAH = \frac{Lmd}{Vbat} = 47.37\ AH\ /\ dia$$

In the calculation, it was determined that the average consumption is greater than the nominal; therefore the safety margin to be considered is 20%.

Calculation of total annual consumption (LT) and a half yearly (Lma):

$$LT = Lmd * 365\ días = 207473.3\ Wh/año$$

$$Lma = \frac{LT}{365} = 568.42\ Wh/día$$

In this case the average annual consumption (Lma) coincides with the Average daily consumption (Lmd), since the consumption that has been estimated is constant throughout the year.

For purposes of design calculations Considering the location of the Parcona District with the coordinates Latitude -14.055 and Longitude -75.7, we obtain the solar radiation for each month according to the clean energy management software "RETScreen" developed by the Government of Canada in collaboration with NASA's Langley Research Center which collects scientific data from Earth. [3].

	Unit	Climate data location
Latitude	N	-14.055
Longitude	E	-75.7
Elevation	m	1460
Heating design temperatura	C	11.39
Cooling design temperatura	C	22.91
Earth temperature amplitude	C	13.86
Frost days at size	day	0

Figure 6: Entering the Coordinates of the Parcona District.

Month	Air temperature	Relative humidity	Daily solar radiation	Atmospheric pressure	Wind speed	Earth temperature
	C	%	kWh/m2/d	kPs	m/s	C
January	17.7	793%	6.69	85.9	3.5	20.9
February	18.2	800%	6.70	85.9	3.4	21.0
March	18.3	786%	6.64	85.8	3.3	21.1
April	18.2	724%	5.92	85.8	3.4	21.2
May	17.8	586%	5.12	85.9	3.6	20.8
June	16.8	516%	4.32	86.0	3.8	19.5
July	16.4	477%	4.29	86.0	4.0	19.1
21.6August	16.9	470%	4.78	86.0	3.9	20.2
September	17.3	490%	5.79	86.0	3.9	21.6
October	17.6	534%	6.59	85.9	3.7	22.7
November	17.4	623%	6.92	85.9	3.7	22.2
December	17.6	712%	7.00	85.9	3.6	21.7
Anual	17.5	626%	1.90	85.9	3.6	21.9
Measured at(m)					10.0	0.0

Figure 7: Solar Radiation Table.

The minimum solar radiation in the month of July of 4.29 kW h / m2 and maximum in the month of December of kW h / m2 is appreciated.

Solar Panel Sizing

Calculation of the total number of solar panels needed:

$$Nt = \frac{Lmdcrit}{PMPP * HPScrit * PR}$$

Where:

- ($Lmdcrit$) It is the average daily monthly consumption for the critical month (in this case, it is always the same [568.42 Wh/dia], since daily consumption is constant all year round)
- ($PMPP$) The peak power of the module under standard conditions, we are using a 150W peak power high efficiency monocrystalline panel.

- ($HPScrit$) They are the peak sun hours of the critical month calculated from the "Radiation Table", that is: Irradiation of the critical month (July) = 4.29 HPS
- (PR) the global factor of operation that varies between 0.65 and 0.90. We will use 0.90 by default.

$$Nt = \frac{Lmdcrit}{PMPP * HPScrit * PR} = \frac{568.42}{150 * 4.29 * 0.90}$$

$$Nt = 0.98147 = 1$$

Calculation of the number of photovoltaic panels in series and parallel (Considering the maximum panel voltage):

$$Vmax = 18.90\ V$$

$$Nserie = \frac{Vbat}{Vmax} = \frac{12}{18.90} = 0.635 = 1$$

$$Nparalelo = \frac{Nt}{Nserie} = 1$$

Considering the above formulas, to cover the required energy [568.42 Wh / day] a high efficiency 150W 12 volt monocrystalline photovoltaic panel is needed. The TS150M Panel is chosen for our design.

2.4. Battery Sizing

For our sizing, the nominal capacity of the battery is considered based on the maximum seasonal discharge.

$$Cne = \frac{Lmd * N}{Pdmax.e * Fct}$$

Where:

- ($Pdmax.e$) Maximum Seasonal Discharge Depth of 70%.
- (N) Autonomy days numbers.
- (Lmd) Average daily energy consumption.
- (Fct) Temperature Correction Factor.

$$Cne(Wh) = \frac{Lmd * N}{Pdmax.e * Fct} = \frac{568.42 * 1}{0.7 * 1} = 812.029\ Wh$$

Expressing Nominal Capacity in Ah:

$$Cne(Ah) = \frac{Cne\ (Wh)}{VDAT} = \frac{812.029}{12} = 67.67\ Ah = 65\ Ah$$

For the choice of our energy accumulator we will consider a commercial value of the battery capacity of 65 Ah, that next lower value is chosen since it is considered margins of oversizing in all calculations and this will be compensated with the efficiency of the monitoring solar. For our design, the YUASA NP65-12 Battery is chosen, which supports deep discharges.

2.5. Regulator Sizing

The maximum current that the regulator must withstand, at its input and output, will be calculated.

Input current:

$$Ientrada = 1.25 * IMOD.CC * Np$$

Where:

- (IMOD.CC) It is the unit current of the photovoltaic module in short-circuit conditions which will be found to avoid losses in performance is 8.45 Amps.
- (Np) Number of photovoltaic panels in parallel.
- (1.25) It is the safety factor to avoid occasional damage to the regulator.

$$Ientrada = 1.25 * IMOD.CC * Np = 1.25 * 8.45 * 1 = 10.56\ A$$

Output current:

$$Isalida = \frac{1.25 * PDC}{VBAT}$$

Where:

- (PDC) Power of continuous loads.
- (VBAT) Battery Voltage.

$$Isalida = \frac{1.25 * PDC}{VBAT} = \frac{1.25 * 51}{12} = 5.31\ A$$

The regulator should withstand a current of at least 10.56 At its input and 5.31 A at its output. For our design we use the commercial value of 20 A and 12V, the model CMTP02 MPPT solar charger charger is chosen, this MPPT type solar charger regulator can increase efficiency by 10% - 30%.

2.6. Sizing of the LED Lantern

For our design of public lighting we will use a 30W 12VDC LED lantern which must have a degree of protection IP65 (Strong protection against dust and water jets). For this design we will use Model FH-LD30W LED Lantern.

2.7. Sizing of the Solar Tracking System

Our public lighting design will implement a solar tracking of one degree of freedom, because the maximum variation between Sun and panel occurs in azimuth of the earth, the variation in elevation is neglected as it is considered of little impact in terms of energy and is more expensive. implementation costs. However, the elevation is done manually every 6 months for each winter and summer season, or can be set in the middle, for both seasons. We will have a sensor that will tell us which is the brightest point in the sky to be aimed at.

Figure 8: Umbrella Detector.

An umbrella type light sensor is chosen, which is composed of two Epoxy silicon cells on a stainless steel metal structure allowing to adjust the steering angle and calibrate the orientation, a metal structure. Using an Electric linear actuator allows us to position our solar panel where the sensor indicates.

Figure 9: Electric Linear Actuator.

System Controller Design

A custom controller design is made based on the PIC18F4550 microcontroller, which will carry out an autonomous control of the system and send the information from the solar cells, current sensors, lumen depreciation sensors and motion sensor to a reception stage which can be processed and viewed in a graphical interface.

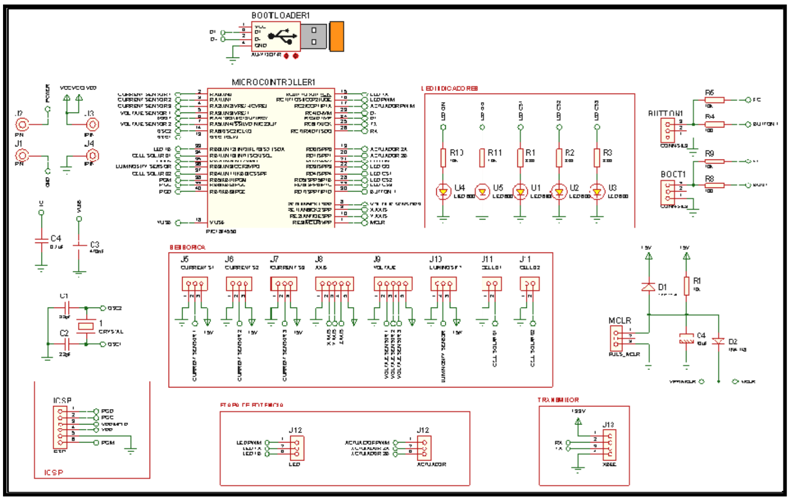

Figure 10: Controller Layout with PIC18F4550.

This design will control two power stages, the first being the LED lantern which, through the generation of PWM, we can vary the light intensity according to the needs and the second the electric linear actuator that we will vary the speed of the motor, managing to position our panel. with the greatest precision that we request.
The PIC18F4550 microcontroller allows us to implement a bootloader through the USB port [1], facilitating the download of programming, making the adjustments that carry the calibration quickly and efficiently.

2.8. *Design of the Graphical Interface*

A monitoring interface is designed in LabView, which is a platform and development environment to design systems, with a graphic visual programming language (G language).

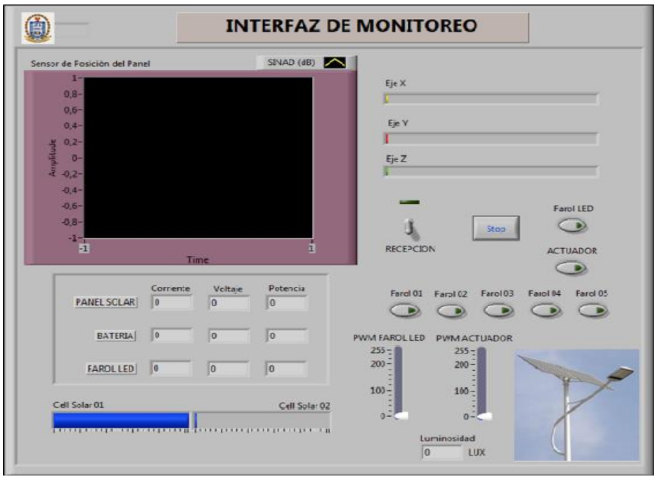

Figure 11: Monitoring Interface.

In our monitoring interface, all the sensors of our public lighting design are displayed, such as the motion sensor that allows us to visualize the position of the solar panel and the disturbances that could appear from gusts of winds. With the current sensors we obtain readings of the panel, battery and the LED lamp in real time. We can vary the intensity of the lantern and the speed of the actuator motor. The light intensity is visualized by means of a luminosity sensor and finally the lantern to be evaluated is selected.

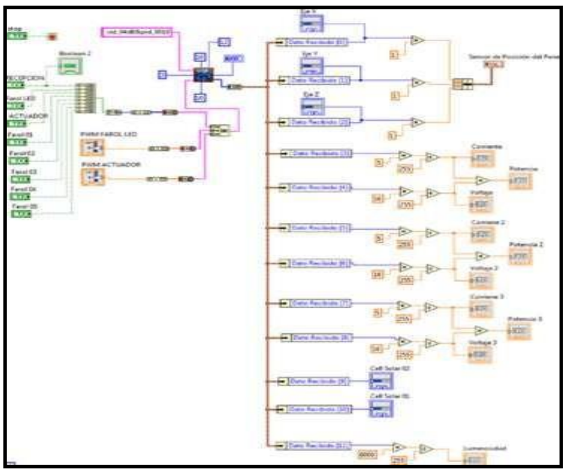

Figure 12: Programming the Monitoring Interface.

In the programming of the monitoring interface, the reception of 10 Bytes is visualized to visualize the readings of the sensors and he sent 3 Bytes which are for control and selection.

2.9. SIMULATION IN LABVIEW

Our prototype of public lighting in the day the solar panel provides the necessary energy to charge our battery obtaining voltage readings and charging currents. We can regulate the speed of the actuator by fine-tuning the solar panel position degrees.

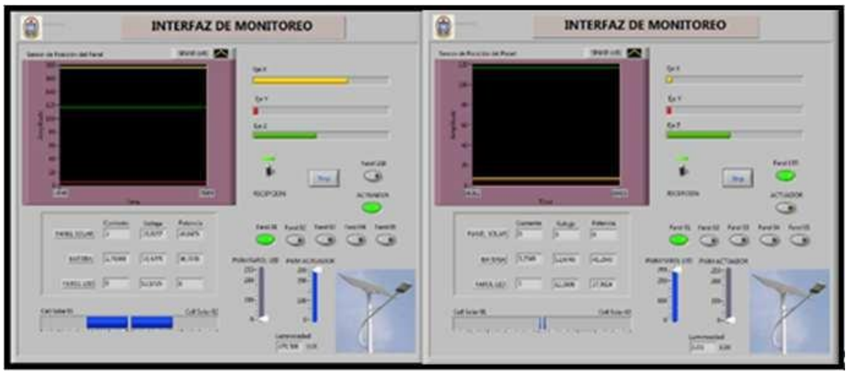

Figure 13: Day - Night Operation.

It can be seen that the bars of the position solar cells are homogeneous, this indicating that it is pointing to the greatest amount of radiation, if these bars vary, our actuator will be activated and positioned on the panel to obtain the values of the cells again equal.
When the sun sets, the LED lantern is turned on, we obtain current and operating voltage readings, we can vary the intensity of light if required at the time.

3. Results

The results obtained in our research carried out in the real-time simulation of the PIC18F4550 controller with the Proteus ISIS software with the monitoring interface carried out in LabVIEW. The result of the daytime control module, which measures the storage system and the nighttime module that registers the lighting system, allows working in an optimal way as designed.

In image 13, you can see a comparison between the proposal presented, with commercial solutions, related to cost and application.

Commercial team	Development presented
limited development	Lets scale
high price	Low cost
defined application	Multiple applications

Figure 14: Comparative chart

4. Conclusions

- It is concluded that we can obtain enough solar energy in the Parcona district throughout the year to power an LED lantern for 12 hours of daily operation.
- Through the sensor, the capture and energy consumption can be monitored, in which the readings are interpreted that will allow us to make the necessary adjustments to obtain the maximum efficiency of the system.
- The ideal panels to implement the system are monocrystalline type panels, due to their symmetrical arrangement, allowing greater efficiency between 15% and 18%.
- It is recommended to increase the number of days of battery life according to the maximum seasonal discharge if required.
- Make speed adjustments of the linear actuator to obtain desired degrees of position of the panel with respect to the Sun, consider manufacturing a rigid structure with the ability to resist winds of up to 140 km / h.
- When choosing the solar panels to be used in the project, it must be taken into account that these must be the largest, since with these a greater efficiency is obtained than with a smaller one.

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