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Design &simulation of solar-powered Automatic Street lighting for Adigrat University

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Abstract— The main purpose of this project is the design and simulation of a solar-powered generation system of automatic Street lighting for Adigrat University campus which means that switch ON/OFF street lights without manual operation. By using this system energy consumption is reduced. The work was begun by investigating solar power generators from different sources and analyzing it using a software tool. A stand-alone solar-powered street or area lighting system is designed and operated completely independently of the power grid. The solar power (PV) has been given in the form of solar radiation plots for the panels. According to the results obtained through the analysis, the campus has abundant solar energy and strictly controlled the Street light. The design of a standalone PV power generating system has proceeded based on the promising findings of this renewable energy resource. The simulations and design has been carried out using Proteus based micro C for PIC and the cost analysis by Homer software. By running the software, the simulation results have been generated automatic street lights.

Index Terms— solar panel, PV sizing, Battery sizing, Automatic Street light, Proteus, and homer Software.

1 Introduction

Solar Street lights are raised light source which is powered by photovoltaic panels mounted on the lighting structure. the photovoltaic panels charge a rechargeable battery, which powers LDR during the night. The idea of designing a new system for the streetlight that do not consume a huge amount of electricity and illuminate large areas with the highest intensity of light is concerning each engineer working in this field. Providing street lighting is one of the most important and expensive responsibilities of a rural electrification, village, and campus. Automatic streetlight needs no manual operation of switching ON and OFF. The system itself detects whether there is a need for light or not. When darkness rises to a certain level then automatically streetlight is switched ON and when there is another source of light, the streetlight switches OFF.

This is done by a sensor called light-dependent resistor (LDR) which senses the light actually like our eyes. This vital use of light gives rise to the idea of using solar energy to power street lights as an alternative to electricity. These solar-powered street lights can then be used for the provision of illumination on roads at night to enhance security and prevent accidents that may otherwise occur due to poor visibility.

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1.1 Background of the study

Adigrat University is one of the universities located at North region of the Tigray Region which established in 1997 as Adigrat institute of technology, offering degree-level education in technology fields and it is located in the Misraqawi Zone at **longitude** and **latitude** 14°16′N 39°27′E Coordinates: 14°16′N 39°27′E, with an **elevation** of 2,457 meters (8,061 ft) above sea level and below a high ridge to the west.

The campus is growing in the student population as well as the geographical territory. It is obvious to have had a proportional utility resource increment as campus expansion in terms of territory and student numbers, such as water, electric power, etc. One of these very essential utility is the electrical power for the automatic street lighting system. Not only the scarcity of the power but also the utilization is flexible and the using method is not smart and satisfactory.

1.2 Problem statement

In Adigrat campus, there is no sufficient street lightning system required reliability and standard form of installation. The main aim of this project is to reduce the cost & loss of energy as well as manpower to manually turn off street light.

1.3 Project objectives

The general objective of this project is to supply electric power for street lighting systems using solar energy and making the system ON/OFF automatically and Providing fully automatic street light regulation that certainly affects humanity. It will have a cost-effective public lighting system; it will help to minimize crime, and it will have less impact on the environment.

ISSN 2229-5518

2 LITERATURE REVIEW

Table 2.1 below outlines the comparison of the various methods that were applied previously. For this analysis different papers written by different authors were analyzed and compared for tabular form taking into account the methods used, the merits, and the demerits.

Table 2.1 Comparisons of different techniques

Paper	Technique	Merits	Demerits
Solar Lighting System	Solar Panel, Passive Solar Technology	1. Operation n cost is minimum 2.Less maintenance 3.Non-polluting source	1. Initial investment is higher 2. Cost of equipment is high 3. Climatic condition may be affected.
GSM Based Street Light System	GSM modem, circuitry system, client server mechanism	1. Low cost 2 Easy deployment 2. Highly scalable	1.No appropriate Communication Protocol 2.Not defined in Semantic point of view.
Street Light System Control With Single Chip Microcomputer	Photo resistor & Fixed resistor. Photo sensitive Technique.	1.Compact in structure 2.Low cost	Maintains must be done regularly.
Wireless self Localizing System	Wireless retrofitting lamps	1.Installation flexibility 2.lower cost	Limited coverage
Zigbee Based System	Zigbee communication Protocol	1.Reduced the manual work 2.Save more energy	Complexity in design

Gong Siliang defines a remote streetlight monitoring system based on a network of wireless sensors that means this device is operating in an automatic mode. In this, the streetlight regulation was performed based on the sunlight intensity along with the Sunrise and Sunset Algorithm. This system not only tracks the real-time streetlight but also the ambient temperature and humidity. Through operating like this the device incorporates a wireless temperature-humidity sensor[1].

A. C. Kalaiarasandeals about solar-based street light with auto-tracking device for optimizing solar power production is desirable to increase performance. As such it needs a way of monitoring the sun. It has been calculated that, instead of using a stationary array, the yield from solar panels can be increased by 30 percent - 60 percent if we use a monitoring device in solar panels[2]

2.1 Solar energy in Ethiopia

For a solar system to be a feasible and appropriate choice, the first requirement is the availability of the fuel for the system, i.e. good solar insulation. Since Ethiopia is geographically located within the tropics between 30N to 150N latitude above the equator, it is endowed with abundant solar energy resources. The yearly average daily radiation reaching the ground is about 5.4Kw h/m². The daily and monthly variation of the insulation level is narrow enough for the efficient utilization of photovoltaic systems anywhere in the country at any period of the year. If such a considerable resource is there, the use of photovoltaic could be matchless.

As Adigrat has plenty of solar intensity and long sunny hours it is so beneficial and most likely to be efficient and effective. PV system is a type of technology that has been tested in so many conditions and turned out to be a success in most cases.

Photovoltaic systems have the following advantages;

- Operate with renewable energy resources and is environmentally friendly.
- If the system is utilized properly, it can operate for at least 20 years.
- Less initial investment cost as compared to hydroelectric power and grid extension.
- The technology is simple for installation, maintenance, and operation since there are no rotating parts such as motors in a photovoltaic.
- The main fuel for solar-powered systems is the sun, which is available all around the world as a free resource.
- The environment effect is no harmful byproducts[3].

3 SPECIFICATION

3.1 Solar panel

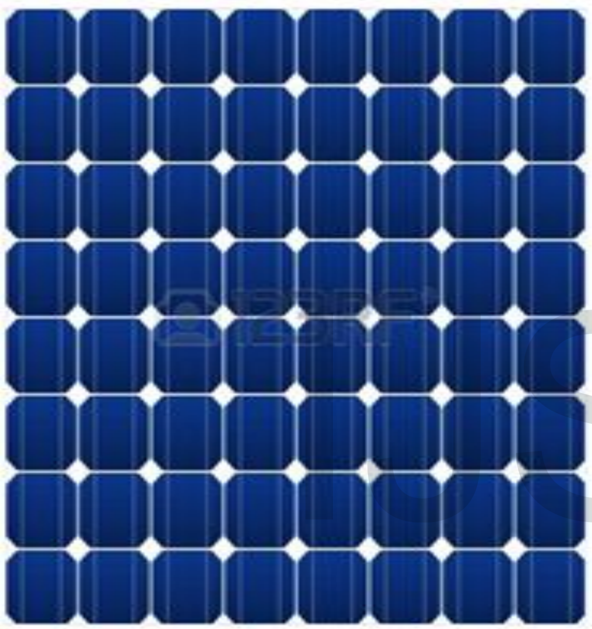
The solar panel is one of the most important parts of solar street lights, as the solar panels generate free power from the sun by converting sunlight to electricity with no moving parts, zero emissions, and no maintenance. The solar panel, the first component of an electric solar power system, is a collection of individual silicon cells that generate electricity from sunlight. The photons (light particles) produce an electrical current as they strike the surface of the thin silicon wafers. A single solar cell produces only about 1/2 (.5) of a volt. However, a typical 12-volt panel about 25 inches by 54 inches will contain 36 cells wired in series to produce about 17 volts' peak output. If the solar panel can be configured for 24-volt output, there will be 72 cells so the two 12 volt groups of 36 each can be wired in series, usually with a jumper, allowing the solar panel to output 24 volts. Multiple solar panels can be wired in parallel to increase current capacity (more power) and wired in series to increase voltage for 24, 48, or even higher voltage systems. The advantage of using a higher voltage output at the solar panels is that smaller wire sizes can be used to transfer the electric power from the solar panel array to the charge controller & batteries. Since copper has gone up considerably in the last few years, purchasing large copper wiring and cables is quite

ISSN 2229-5518

expensive[4]

The solar panel is comprised of one or more solar cells that produce electricity or power. People put solar panels on their homes to turn solar energy into electricity. It serves as a power supply to the circuit. It receives light from the sun and converts this to energy. The photovoltaic cell is an unusual power source whereas most sources of electrical power are constant voltage sources, such as a battery, a PV to a limiting voltage where the current collapses. For an ideal PV module, the voltage where the current collapses would be at the open-circuit voltage, V oc[5]

Fig: 3.1 picture of BP SX 150S PV MODULE[4]



3.2 Solar Charger Controller

The controller is also very important for the solar street light. A controller will usually decide to switch on /off charging and lighting. Some modern controllers are programmable so that the user can decide the appropriate chance of charging, lighting, and dimming.

A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life. The terms “charge controller” or “charge regulator” may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or battery recharger.

In solar applications, charge controllers may also be called solar regulators. Without charge control, the current from the module will flow into a battery proportional to the irradiance, whether the battery needs to be charging or not. If the battery is fully charged, unregulated charging will cause the battery voltage to reach exceedingly high levels, causing severe gassing, electrolyte loss, internal heating, and accelerated grid corrosion. The charge controller maintains the health and extends the lifetime of the battery.

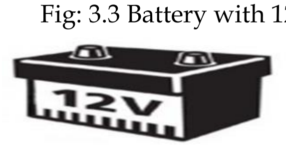
Fig: 3.2 outback MX60 charge controller[4]

3.3 Rechargeable Battery

The battery will store the electricity from the solar panel during the day and provide energy to the LDR lamp at night. The battery stores the solar power that has been generated by panels and discharges the power as needed. A typical battery bank consists of one or more deep cycle type batteries. Typically, battery efficiency is 85 Percent requiring a battery bank capacity getter than what is needed. Batteries periodically need servicing and have the highest potential of faults in a solar PV system. Battery condition and the corresponding state of charge that we gathered from a reading of formerly used batteries for the solar system is used to measure the PWM states. It is crucial to follow the ratings in our design so that it may work well with batteries from any organization.

Car batteries discharge a large current for a very short time to start your car and are then immediately recharged as you drive PV batteries generally have to discharge a smaller current for a longer period (such as all night) while being charged during the day. The most commonly used deep –cycle batteries are lead-acid batteries (both sealed and vented) and nickel-cadmium batteries. Nickel-cadmium batteries are more expensive, but last longer and can be discharged more completely without harm. Even deep-cycle lead-acid batteries can’t be discharged 100% without seriously shortening battery life, and generally, PV systems are designed to discharge lead-acid batteries no more than 40%or 50%.

Fig: 3.3 Battery with 12v



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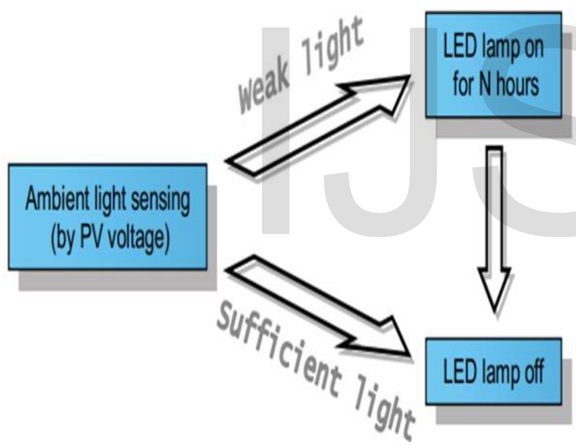
3.4 Load (LED Lamp)

A simple LED light bulb that can fits standard E40 bulb holders can be applied for a solar-powered street light system that is independent of power mains. The high power LEDs of the last generation and technology offer a considerable alternative to conventional street lighting with energy savings of up to 75 % and an important reduction in carbon emissions[4].

The photometric properties of high power LED street lights adding to their bright, natural light color, give a uniform rectangular beam pattern that is 50% brighter and 50% larger than the oval beam pattern produced by a conventional lamp. This highly focused beam pattern allows LED lights to be spaced at much wider intervals than sodium and CFL lights. [12]. During night time, normally the ambient light is weak, the LED lamp lights for N hours. The determined light-on duration (N hours) can be set by selecting a switch. The controller turns on/off the LED lamp to automatically correspond to the ambient light[6].

Figure 3.4 illustrates how the controller turns on the LED lamp. The switch also provides a test mode to test the LED lamp.

Fig: 3.4 LED lamp driving scheme



3.5 Pole

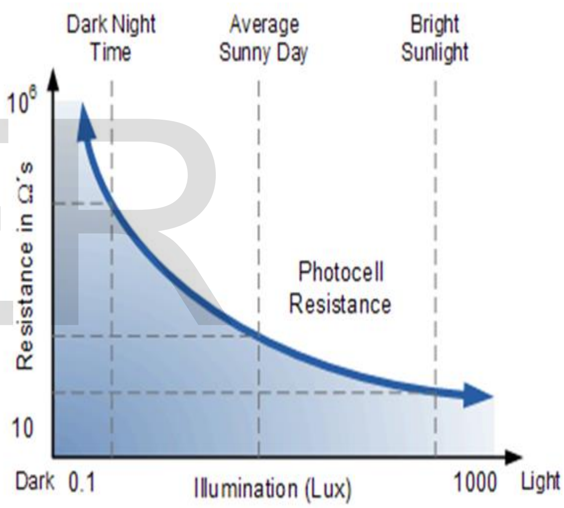
Strong Poles are necessary to all street lights, especially to solar street lights as there are often components mounted on the top of the pole: fixtures, panels, and sometimes batteries. However, in some newer designs, the PV panels and all electronics are integrated into the pole itself, and Wind resistance is also a factor to be considering when choosing a pole. Then from the different types of poles by the factor of the above reason, we select still pole type.

3.6 Light Sensor (LDR)

A photoresistor (or light-dependent resistor, LDR, or photocell) is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. A photoresistor can be applied in light-sensitive detector circuits, and light- and dark-activated switching circuits. A photoelectric device can be either intrinsic or extrinsic. An intrinsic semiconductor has its charge carriers and is not an efficient semiconductor, for example, silicon. In intrinsic devices, the only available electrons are in the valence band, and hence the photon must have enough energy to excite the electron across the entire bandgap. Extrinsic devices have impurities, also called dopants, and added whose ground state energy is closer to the conduction band; since the electrons do not have as far to jump, lower energy photons (that is, longer wavelengths and lower frequencies) are sufficient to trigger the device. If a sample of silicon has some of its atoms replaced by phosphorus atoms (impurities), there will be extra electrons available for conduction.

When the light level decreases, the resistance of the LDR increases. As this resistance increases with the other Resistor, which has a fixed resistance, it causes the voltage dropped across the LDR to also increase. When this voltage is large enough (0.7V for a typical NPN Transistor), it will cause the transistor to turn on.

Fig: 3.5 Variation of light intensity versus resistance



3.7 PIC 16F876A Microcontroller

The semiconductor division of General Instruments Inc originally developed the PIC (Programmable Interface Controller) line of microcontrollers. The first PIC"s was a major improvement over existing microcontrollers because they were programmable, high output current, input/output controller built around RISC (Reduced Instruction Set Code) architecture. The first PICs ran efficiently at one instruction per internal clock cycle, and the clock cycle was derived from the oscillator divided by 4. Early PICs could run with a high oscillator frequency of 20 MHz. This made them relatively fast for an 8-bit microcontroller, but their main feature was 20 mA of source and sink current capability on each I/O (Input/output) pin. Typical micros of the time were advertising high I/O currents of only 1-milliampere (mA) source and 1.6 mA sink.

The microcontroller (MCU) provides a real-time system monitoring for the controller, including:

❖ Error detection/protection for solar module of automatic

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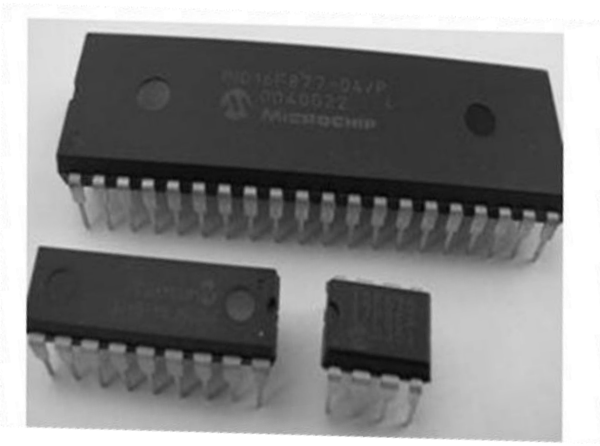
street light, battery voltage(VBAT), LED lamp voltage(VLED)
- Temperature detection for the operating temperature of the battery, NPN and LED lamp
- System self-recovery[7]

Fig: 3.6 Types of PIC Microcontroller[8]



3.8 Bipolar Junction Transistor

BJT or Bipolar Transistor is an active semiconductor device formed by two P-N junctions whose function is an amplification of an electric current. Bipolar transistors are made from 3 sections of semiconductor material (alternating P-type and N-type), with 2 resulting P-N junctions.

A transistor is a semiconductor device used to amplify and switch electronic signals and electrical power. It is composed of semiconductor material with at least three terminals for connection to an external circuit. NPN and PNP transistors are bipolar junction transistors, and it is a basic electrical and electronic component that is used to build many electrical and electronic projects. The operation of these transistors involves both electrons and holes. The PNP and NPN transistors allow current amplification. These transistors are used as switches, amplifiers or oscillators. Bipolar junction transistors can be found either as large numbers as parts of integrated circuits or in discrete components. In PNP transistors, majority charge carriers are holes, whereas, in NPN transistors, electrons are the majority charge carriers. But, field-effect transistors have only one type of charge carrier[9].

Fig: 3.7 a) structure of NPN transistor

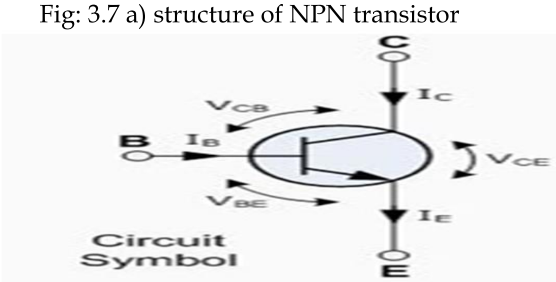
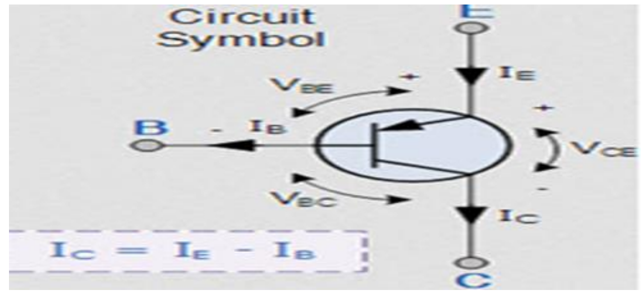


Fig: 3.7 b) structure of PNP transistor



4 METHDOLOGY

To work this project, the following methodology has been adopted:

- Data collection this includes average maximum temperature, average minimum temperature, average sunshine duration, Topography of location.
- Analysis PV sizing, PV module, Battery size and Pole load calculation
- Design of power generation based on data collected peak load and load demand
- Analysis of the output by simulating with microprocessor (protous.8) software and for cost estimation we use HOMER software.

4.1 Data Collection of solar radiation

Table 4.1 the annual data of dolar radiation

No_	2020	2021	2022	2023	2024	2025	2026	2027
January	6.12	9.00	8.20	8.36	7.68	9.21	9.31	8.38
February	7.78	9.98	8.95	6.25	9.45	10.66	9.8	6.742
March	9.01	10.72	8.72	6.09	7.86	9.23	8.63	8.18
April	8.47	9.48	9.26	6.69	8.9	7.88	8.47	8.46
May	8.72	8.70	9.79	6.95	7.70	8.71	8.32	8.32
June	6.25	8.60	9.09	7.85	8.52	7.22	5.89	8.43
July	533	6.48	5.85	6.75	6.91	5.27	5.51	6.62
August	7.08	672	6.46	738	6.79	5.35	5.49	5.81
September	6.84	6.85	7.71	7.27	7.45	6.73	7.39	6.38
October	8.95	7.74	7.35	8.61	9.29	9.41	7.76	7.48
November	8.79	7.90	9.93	9.22	6.77	9.70	8.84	8.38
December	10.23	9.38	6.63	7.70	9.91	9.35	9.68	9.25

Design Month: August

5 SIMULATION AND RESULT

Fig: 5.1 circuit diagram of automatic control of street lights

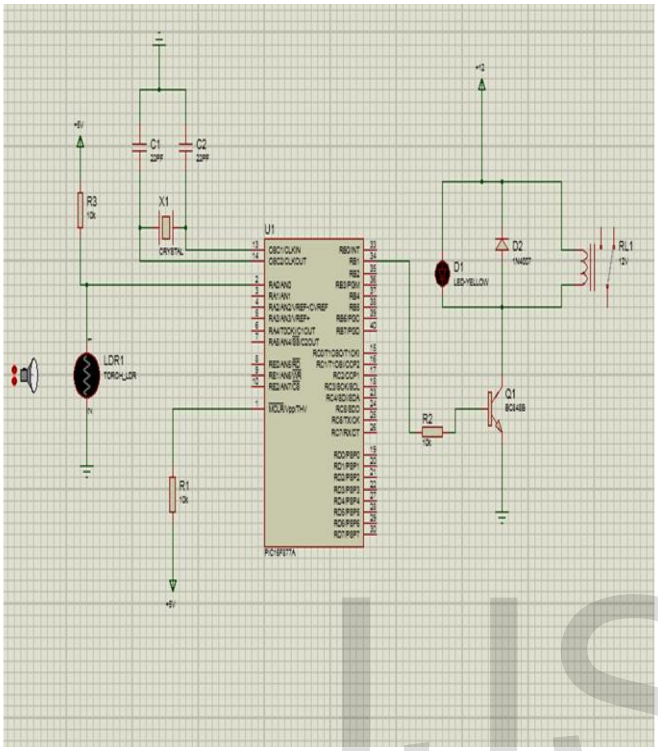


Fig: 5.2 circuit diagram of automatic control of street lights on the night time

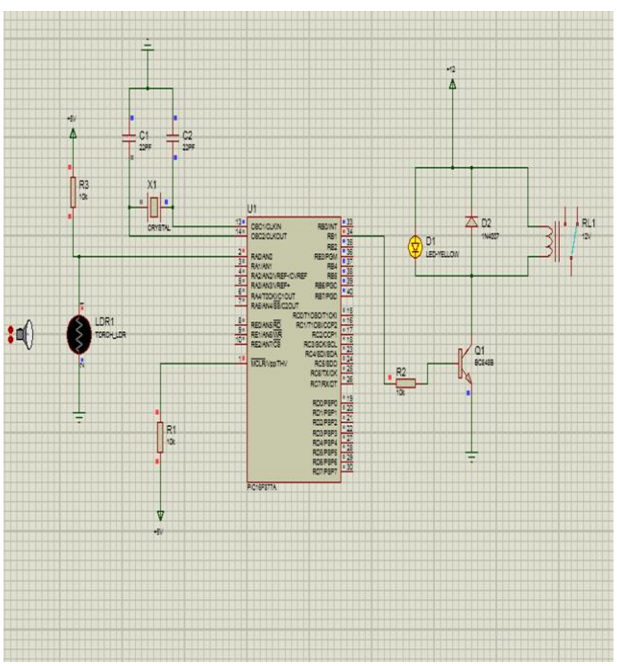
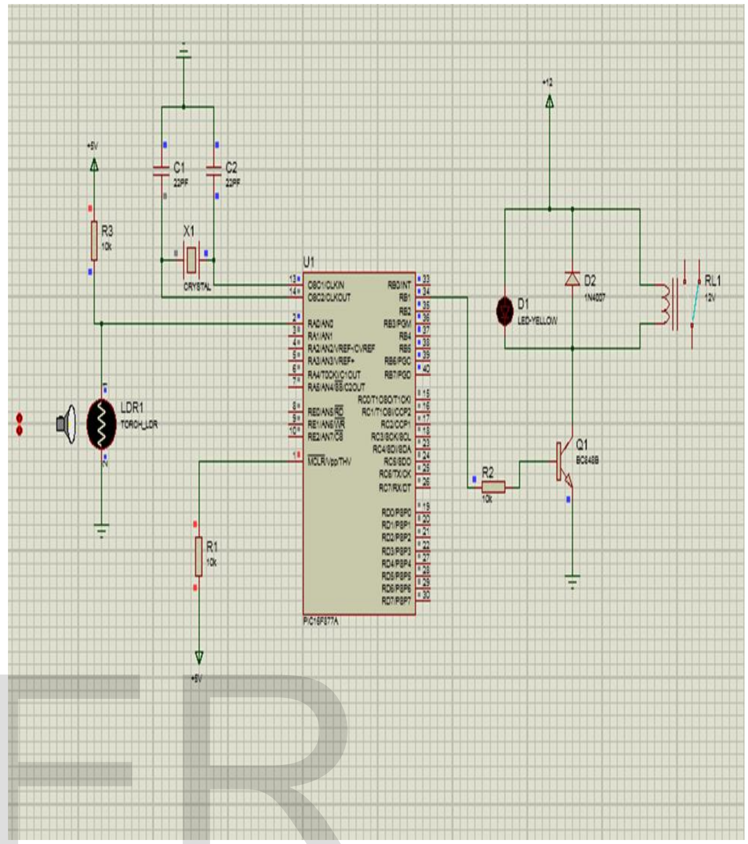


Fig: 5.3 circuit diagram of automatic control of street lights of the day time



5.1 Cost summary analysis using homer software

HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations. HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares different demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system. For the systems that include batteries, and PV. HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries. After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by net present cost (sometimes called lifecycle cost), that you can use to compare system design options.

Fig: 5.4 Solar source input 1

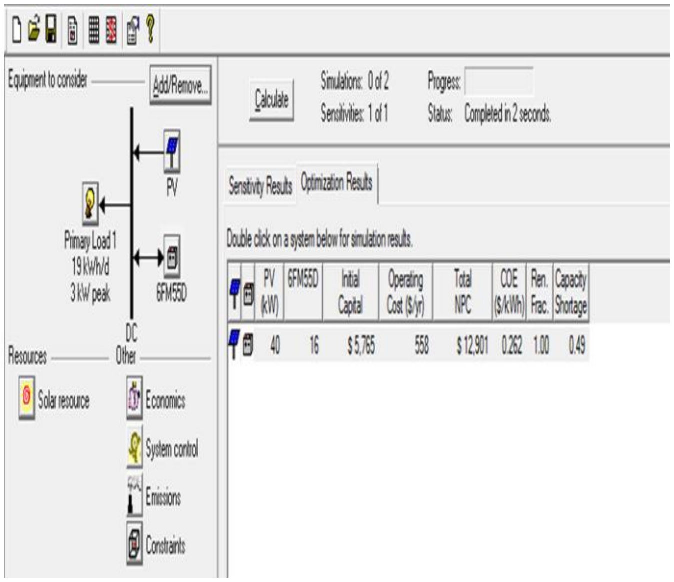


Fig: 5.6 Cash Flow Summary (by component type)

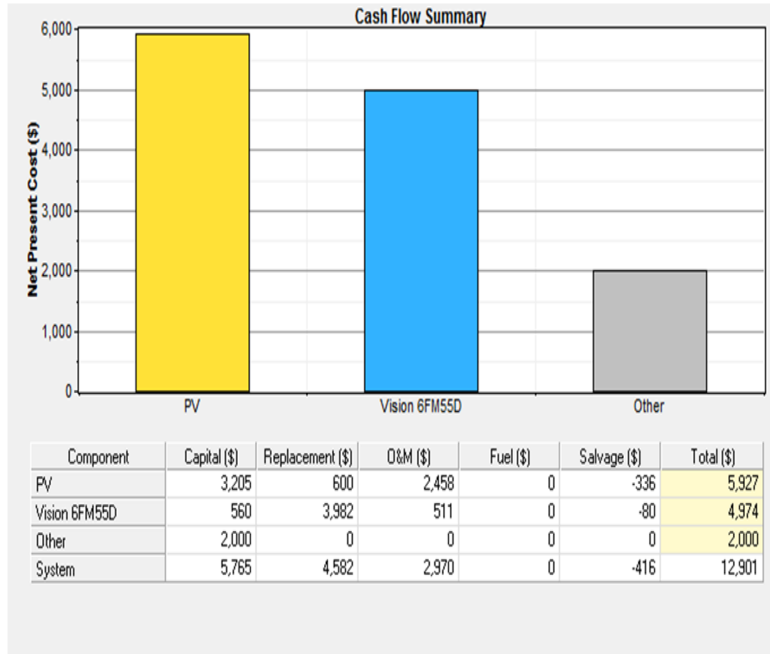


Fig: 5.5 Solar source input 2

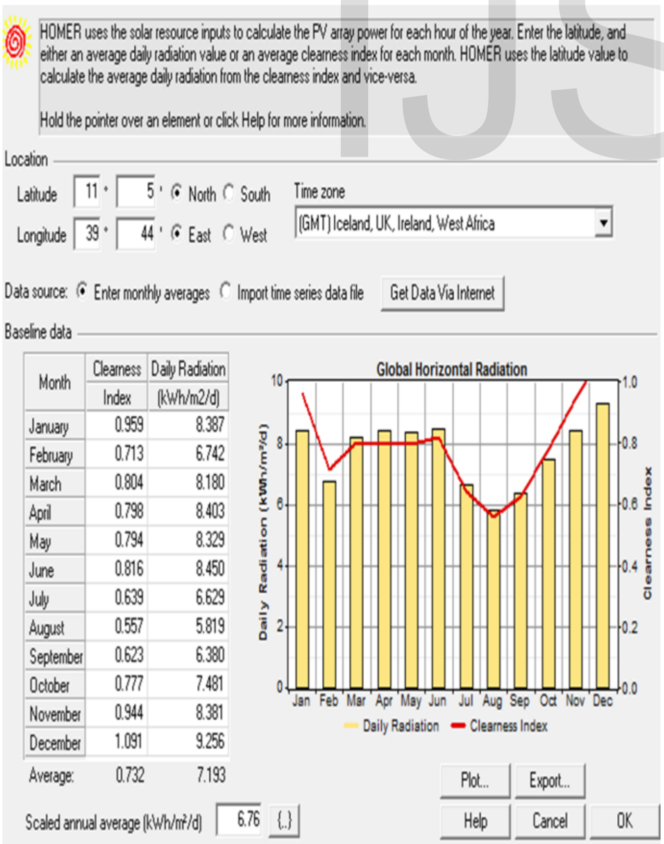


Fig: 5.7 Cash Flow Summary (by Cost Type)

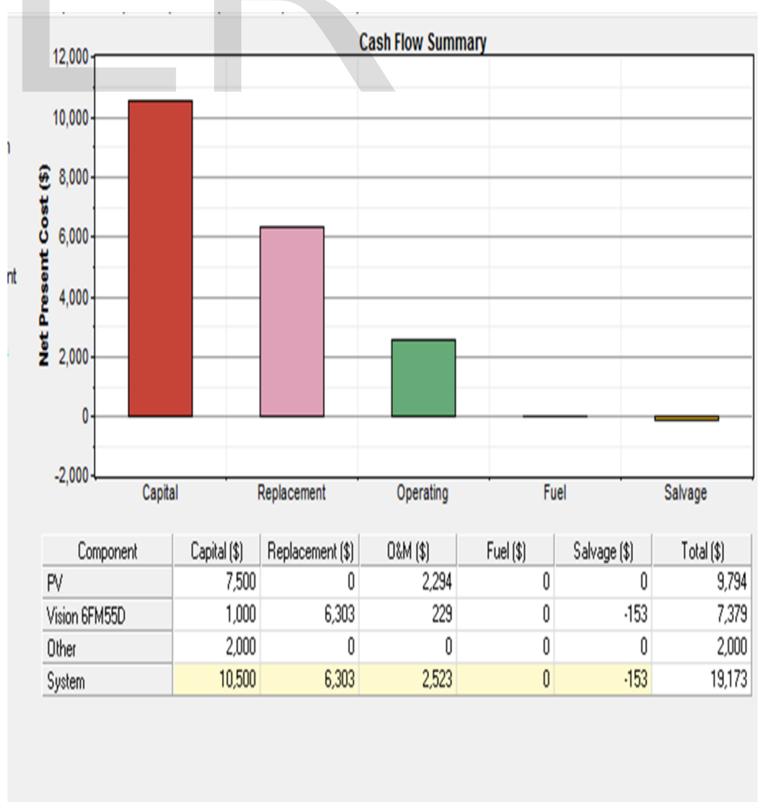


Fig: 5.8 Cash Flow for the System

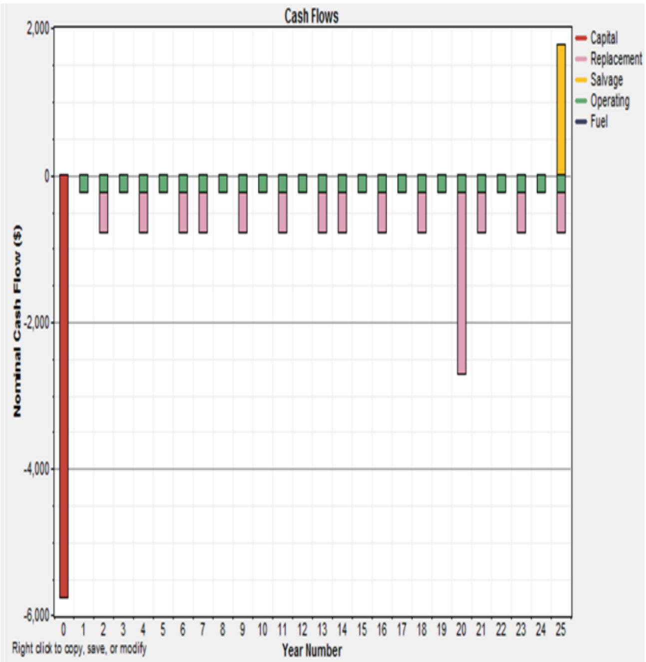


Fig: 5.9 Electrical output

Production	kWh/yr	%
PV array	80,246	100
Total	80,246	100

Consumption	kWh/yr	%
DC primary load	3,848	100
Total	3,848	100

Quantity	kWh/yr	%
Excess electricity	75,878	94.6
Unmet electric load	3,050	44.2
Capacity shortage	3,388	49.1

Quantity	Value
Renewable fraction	1.00

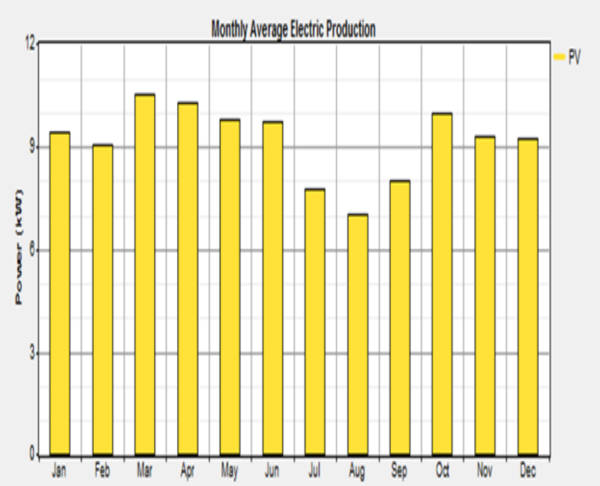
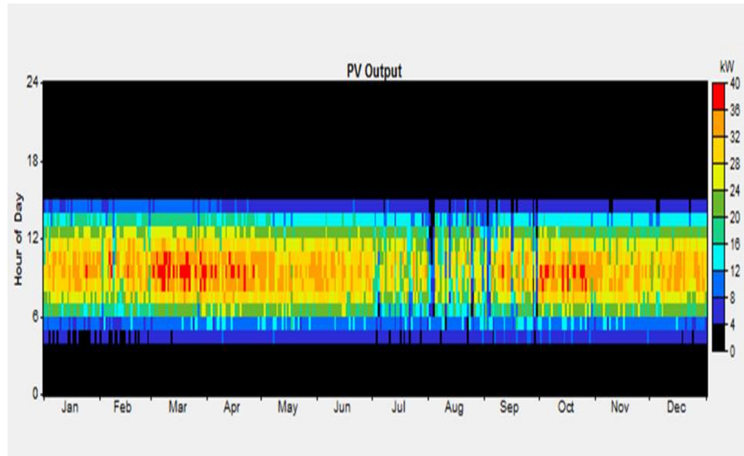


Fig: 5.10 PV Output Distribution versus Hour of the day (Monthly)



6 CONCLUSION

In the current situation of the weather's unexpected behavior and shortage of rain, it is becoming a challenge to get the required amount of water in the reservoirs of the hydroelectric power plants. Including the society's ever-growing demand for electrical energy, it is difficult to satisfy this by the hydroelectric plants only. The oil use option to get electric energy also getting worse than ever as the cost has been climbing higher and higher. But there is still another better choice especially for medium-level generation of electrical energy. Especially, PV has a powerful attraction because it produces electrical energy from free in an exhaustible source, the sun, using no moving parts, consuming no fossil fuels, and creating no pollution or greenhouse gases during the power generation. And also design circuit and construction of the Automatic Street light control system. The circuit works properly to turn street lamp ON/OFF automatically by LDR Sensor which detects the light intensity of the environmental condition. Together with decreasing PV module costs and increasing efficiency, PV is getting to choose able than ever. So it is easy using this project to save your electricity and in return your money. In countries where load shedding is a big issue due to the short fall in electricity and less in resources to generate electricity. In these countries, load shedding issue can be resolved to some extent by saving as much as you can. By using automatic control of street lights, we can save the maximum amount of energy which is useful for your nation and also beneficial for you. Because it will reduce your electricity bill and in return save your money.

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APPENDIX

Battery rating calculation:
The normal power rating of LED=1W
The maximum energy required by the LEDs for 12 hours in a day is 12x25W =300Wh
For 3 days, the required amount of energy is 900 Wh.
Therefore, for a 12V battery, the Ah needed is 900/12 = 75 Ah.
Considering 45% depth of discharge battery capacity required =75Ah/0.45 = 166 Ah

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