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Automatic Control Street Lighting System based on Solar Photovoltaic Energy as an Alternative Source of Electrical Energy in Bangladesh

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Abstract- *As the fossil fuels are quickly depleting and have some detrimental effect on environment renewable energy based power generation scheme is a better option for Bangladesh. With all the perils of typical commercial energy based system, a solar photovoltaic system can be a good choice. Street lights in Bangladesh receive electrical energy from national grid. This paper discusses the use of solar photovoltaic power as an alternative source of electrical energy for street lighting system. Instead of typical sodium light super bright LED light is used that receive energy from lead-acid batteries, charged by solar panels. Automatic switching of turn-on and turn-off is done by light sensitive switch using light dependent resistor. Design is made as stand alone type. Reasonable days of autonomy are considered for cost effective design. It is found that the proposed system provide higher efficiency as all power stages are implemented in DC. The system resulted in low power consumption and extended lighting period. In comparative cost analysis it is found that though the initial cost is higher but the cost is justified in longer operating period, system performance and life cycle cost in present worth and environment friendliness.*

Keywords: Photovoltaic lighting, Solar Street light, Battery Charging, Energy Saving, Maximum Power Point Tracking.

1. INTRODUCTION

Energy security is a key ingredient to progress the country's future and prerequisite for the country's progress is the electricity supply compatible with demand, in a dependable manner and at a reasonable price. Bangladesh is facing continuous challenge in this field after its independence in 1971 and various reform programs are taken and different policies are made throughout the time. The major focus is now on renewable energy and proper utilization of the energy resources and reduction of system loss [1].

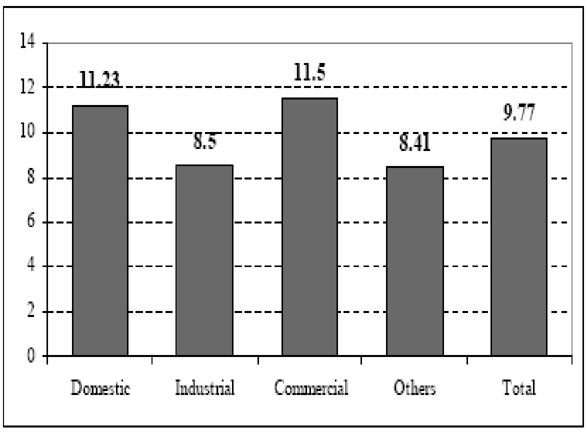

Fig. 1: Annual Rates of Growth (%) of Power Consumption by Sector, 2000-07[2]

Figure 1 depicts the annual rate if growth of power consumption by sectors and it shows that the average growth is very fast. So to meet up the demand of electricity with they present amount of supply, efficient energy use is the best possible solution till now. Hence energy saving has become a prime priority for machines working round the clock to provide us various comforts and necessities [3].

Use of naturally gifted energy resources, energy saving equipments and devices and automatic control of systems can be a good step to meet the present challenges. Keeping these issues in mind a system is designed for efficient street lighting. Twenty percent (20%) of world energy is consumed in lighting and it can be reduced to four percent (4%) using energy saving lighting system [4]. Street light in Bangladesh receive energy from national grid and use commonly High Pressure Sodium, Metal Halide, Mercury Vapor, Sodium Vapor, Fluorescent and Incandescent lamp. And in most of the cases the control is manual. This can be replaced by a system comprised of sun i.e. solar energy as the energy source, automatic control for on and off to ensure proper use of daylight and super bright LED light for saving energy and longer lifetime.

2. MODELING of THE SYSTEM

The design of the system includes solar panel, battery charge controller, rechargeable battery bank, switching circuit for light on-off control and the LED light panel.

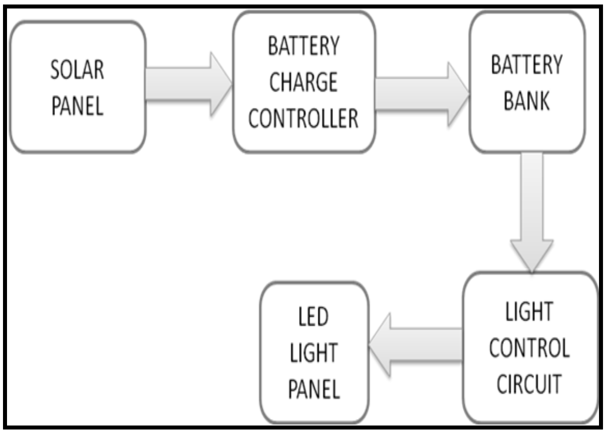

Fig. 2: The proposed system.

Figure 2 above shows the block diagram of proposed system. Energy from the sun is stored in the battery bank as the energy is being used at night. For efficient charging and discharging battery charge controller is included. Deep discharge battery is used for getting maximum charge from the battery bank with depth of discharge (DOD) around eighty percent (80%). All the stages are implanted in DC, so no inverter is used.

Solar panel used to charge the battery during sunshine period. A light dependent resistor (LDR) is used as sensor in the switching circuit to sense the light intensity. The brightness of the LED lights is higher than the commonly used lamps such as mercury, sodium or fluorescent lamp. The LDR is placed at a position as such it is exposed to light from atmosphere. The LDR senses light and differentiates daytime from night time, and then the sensor circuit triggers the switching circuit. A regulator is used in the charge controlling circuit to sense the charging voltage of the battery so as to prevent it from overcharging.

3. SYSTEM DESIGN

As per model, the system is designed. The entire components are bought from the local markets with regular available prices. The system is experimented in circuit board and before that the system is simulated.

3.1 Charge Controller Circuit

When battery is fully charged charging circuit reduces the charging current and this mode is called trickle charging mode [5]. It keeps battery fully charged without over charging it. This circuit protects the battery bank from over charging and over drawn and also the flow of charges. It is a lead acid battery charger circuit using IC LM 317.The IC here provides the correct charging voltage for the battery. A battery must be charged with 1/10 its Ah value. This charging circuit is designed based on this fact. The charging current for the battery is controlled by Q1, R1, R4 and R5. Potentiometer R5 can be used to set the charging current.

As the battery gets charged the current through R1 increases .This changes the conduction of Q1. Since collector of Q1 is connected to adjust pin of IC LM 317 the voltage at the output of LM 317 increases. Figure 3 shows the chare controller circuit.

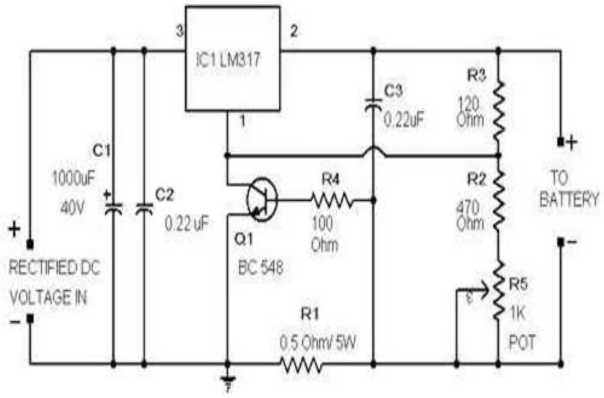

Fig. 3: Charge Controller Circuit

3.2 Switching Circuit

The switching circuit consists of LDR as light sensor, operational amplifier, switching element, 12V (DC) street light system. In bright light the resistance of the photocell can be as low as 200 ohm and at 50-lux (darkness) the resistance increases to over 1M ohm. The 1M control should provide a wide range for light intensities.

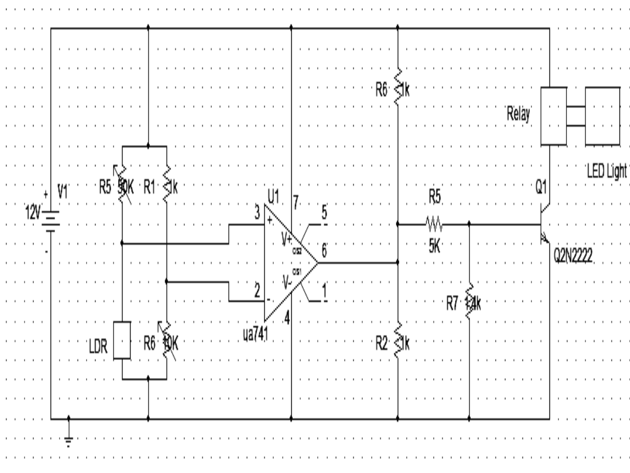

Fig. 4: The switching circuit.

The op-amp senses the voltage difference between pins 2 and 3. Triggers pin 2 high which biases the base of Q1 via pin 6 and R5 and in turn activates the relay. The control R3 is adjusted so that the relay is off, the output of the op-amp will be around 2 Volts at light condition. When it is dark, the resistance of the photocell increases and the difference in input voltage is amplified by the op-amp, the output will swing towards full supply voltage (12.08V) and drive the transistor and relay.

3.3 Technical and Economical Parameters

The system components costs are listed in table 1. The listed components are for one unit system. For larger system, the components can be multiplied by as with the number of increased system.

Table 1: List of Equipments for Implementation of the System, their Model/Value and Prices in TK (BD)

Equipment	Model	Quantity	Cost in Taka (BD)
Solar Panel	18 Watt	1	2500/-
Charge Controller Circuit			
1. IC	LM317	1	30/-
2. Transistor	BC-548	1	20/-
3. Resistors	0.5Ω/5W	1	10/-
	470Ω	1	
	120Ω	1	
	100Ω	1	
	1K	1	
4. Capacitors	1000µF/40V	1	10/-
	C2- 0.22µF	1	
	C3-0.22µF	1	
		Total	70/-
Battery	12V, 6AH	2	1000/-
Switching Circuit			
1. Light		1	5/-
2.Electromag	SPDT type	1	20/-
4. Transistor	2N2219A	1	30/-
5. Resistors	1KΩ	2	15/-
	50KΩ	1	
	5KΩ	1	
	10KΩ	1	
	1.4KΩ	1	
			90/-
LED Light		1	2000/-
Total Cost of single unit			**5660/-**

4. SIMULATION and RESULT

Overall system setup is shown in figure 5. The system worked reliably over the test period. Energy loss was greatly reduced due to automatic control and using of LED light. The luminous intensity of the street lights is measured with luxmeter at night 11.00PM at the date of April 14, 2011. These data are shown in table 2. From the table it is seen that maximum available intensity found from the existing fluorescent street lamp of Chittagong University of Engineering & Technology is 14 LUX whereas luminous intensity found from the LED lamps is 35 LUX just under the light. The value is 26 LUX and 17 LUX from one meter and two meter far away from the LED light respectively, thus ensuring much higher brightness than the existing system.

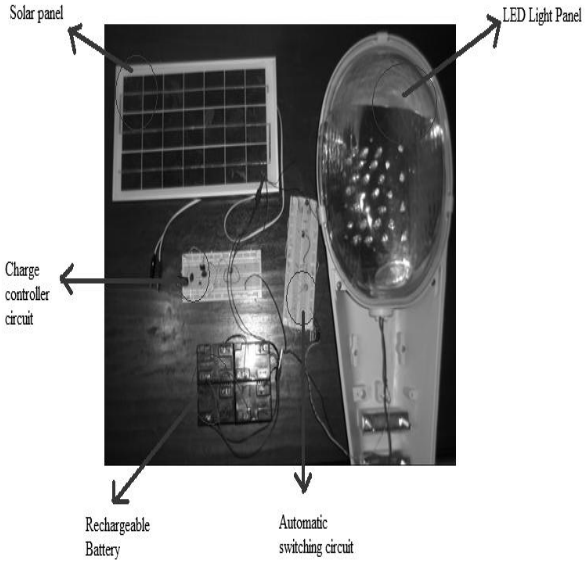

Fig. 5: Overall System Setup

Table 2: Luminous intensity of street lights of Chittagong University if Engineering & Technology

Light Post No.	Observed data (LUX)
1	7
2	12
3	10
4	14
5	8
6	6
7	7
8	7
9	7
10	5
11	4
12	7
13	5
14	5
15	5
16	5

In simulation result in dark condition it is seen that At dark condition LDR (R7) shows high resistance approximately 500 mega ohm, which leads output of the OPAMP high. It provides enough voltage to turn on the transistor as well as relay & the street light will be on. On figure 7 it is seen that the voltage is found 812.44mV which is sufficient to turn on the transistor Q1and hence turn on the relay and lit the LED light.

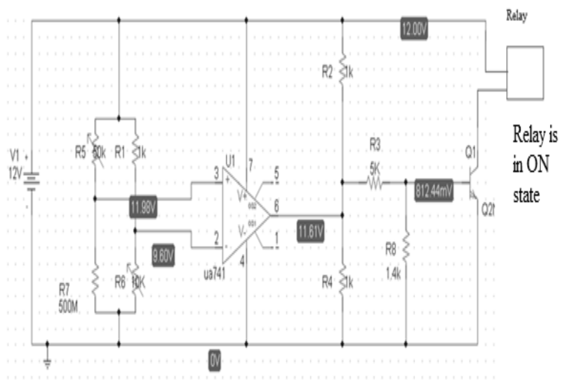

Fig. 6: Simulation result at dark condition

Figure 7 shows the system state at daylight condition. At lightened condition LDR (R7) shows low resistance approximately 50 ohm, which leads output of the OPAMP low. The voltage to the transistor is 84.49mV. This voltage is not sufficient enough to turn on the transistor as well as relay and the street light will turn off.

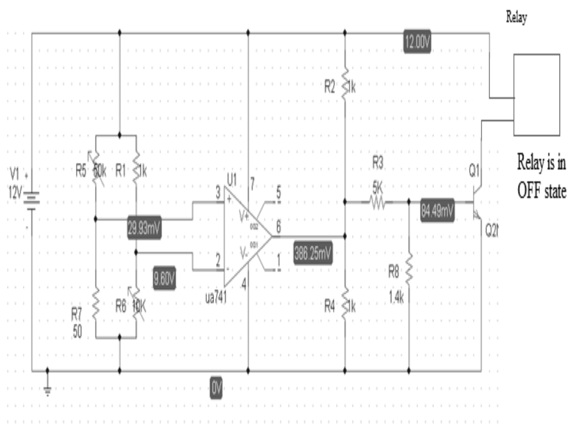

Fig.7: Simulation result at daylight condition

In comparative cost analysis of the designed solar photovoltaic (PV) energy based system with the existing grid connected system that use conventional fossil fuel, it is found that the life cycle cost of the designed system is higher. In terms of Net Present Cost (NPC) the newly designed system will charge higher, but a 324,000 KWh of energy is being saved.

Figure 8 shows the cash flow summary in terms of Net Present Cost (NPC). Table 3 shows the emission of pollutants from existing grid connected system as well as solar energy based system. It is seen that the solar energy based system has zero amount of pollutant.

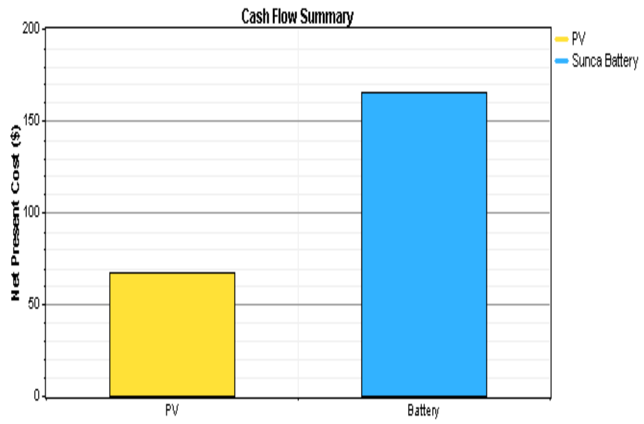

Fig. 8: Cash flow summary in Terms of Net Present Cost.

Table 3: Comparison of Emission

Pollutant	Emissions for grid connected system (kg/yr).	Emissions for PV system (kg/yr)
Carbon dioxide	108	0
Carbon monoxide	0	0
Unburned hydrocarbons	0	0
Sulfur dioxide	0.12	0
Nitrogen oxides	0.296	0

5. CONCLUTIONS

A unit street lighting system is designed with automatic control of turn on and off of with a solar panel of 18 Watt peak. The system provides reliable street lighting with higher light intensity. Large amount of energy is saved due to the use of super bright LED lights and longer lifetime can be assured. As all the power stages are DC, much higher efficiency is achieved. The system requires no fuel cost, so the only operating cost is negligible and replacement cost involved is only of battery.

The system requires higher initial cost due to high solar PV panel cost, but it is justified in terms of longer lifetime and smooth operation. And considering the detrimental effects of pollutants from the grid power, the new system provides reliable power with no harmful effect to the environment. There are further scopes of research and as the price of solar panel is gradually decreasing, the system cost will presume to reduce. The system is of stand alone type, so better suited for distributed generation in remote location.

7. REFERENCES

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