PERFORMANCE OF A SOLAR LANTERN

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Abstract The sun radiates vast quantity of energy from its surface. The solar energy reaching the earth in one hour if fully tapped is sufficient to meet all human energy needs for the whole year. The purpose of the work is to study operational performance of a solar lantern. In this device solar energy is converted to electrical energy and stored in the battery. The high efficient inverter converts the DC voltage to high frequency AC voltage that makes the compact fluorescent lamp to give the light output. The system has been designed to operate four hours daily. The PV array is selected for operating in average weather conditions of solar radiation.

INTRODUCTION

Bangladesh is experiencing an increasing demand of energy use. At present, limited fossil fuels and biomass sources are supplying the total energy requirement of the country.

Besides, for electricity generation by conventional sources (natural gas, oil etc) release incredible amount of pollutants (CO_2, Sulfur oxide, Nitrogen oxide etc). To combat this pollution, alternative and environment friendly energy sources need consideration. In this respect, solar PV technology stands to be one of the prospective devices.

The application of Photovoltaic in lightening is increasing everyday with tens of thousand of units installed worldwide. They are mainly used to provide light for domestic or community buildings, such as schools, or health centers. PV lighting is being used increasingly for security, street and tunnel lighting.

ENERGY SCENARIO IN BANGLADESH

Bangladesh is a country (147,570 km^2) of 125 million people with a per capita income of around US$ 337. About 85% of the population lives in rural areas in 15.61 million households spread over more than 68,000 villages.

The consumption of energy is reasonably a reliable indicator of the state of the economy of a country. Bangladesh, one of the world's least developed countries, has per capita consumption of energy of 4.2 GJ compared to 344.6 GJ in the USA. Limited conventional energy sources in Bangladesh are out of reach to the rural people, so traditional energy sources are the only way for their survival. The energy requirement of the country is met from different sources such as biomass, natural gas, kerosene, petrol, diesel, and hydropower, coal and other sources of renewable energy.

PROSPECT OF SOLAR ENERGY IN BANGLADESH

The geographical location of Bangladesh facilitates for tapping solar energy effectively. Solar energy utilization is being accepted day by day. Bangladesh is at $20.3^0 – 26.38^0$ N and $88.04^0 – 92.44^0$ E, indicating an attractive location for effective solar energy (Daily average solar radiation is about 3.5 ~ 5.0 KWh/m^2).

SYSTEM DESCRIPTION

A Photovoltaic solar lantern consists of PV module, charge control unit, battery, inverter, switching circuit, and a compact fluorescent lamp.

Specification of solar lantern

Module Module Type: TBP 1210
Power = $10^{+0.5}_{-0}$ Watts
AT 16.4 Volts
Data at STC 25^0 C and 100 mW/cm^2

Lamp TNDO ASIAN
Ecolite S/E 7W/65

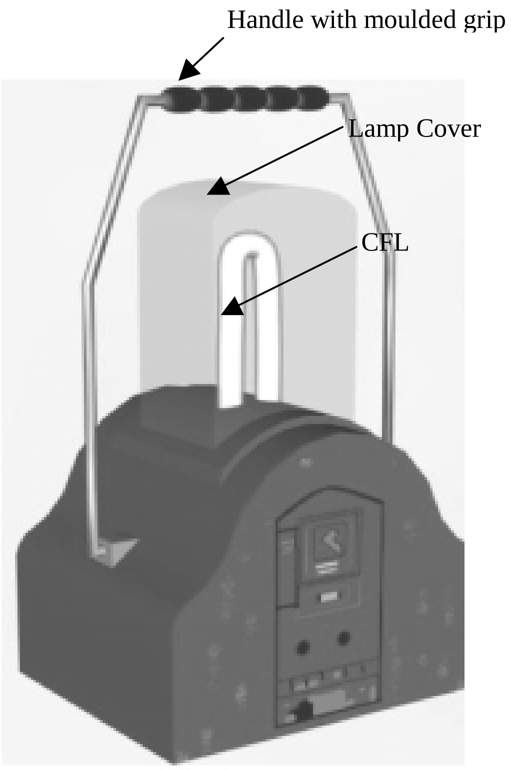

Fig. 1 Solar lantern

Battery VOLTA VT1207 (12V 7Ah, 20HR)

Input 12V DC

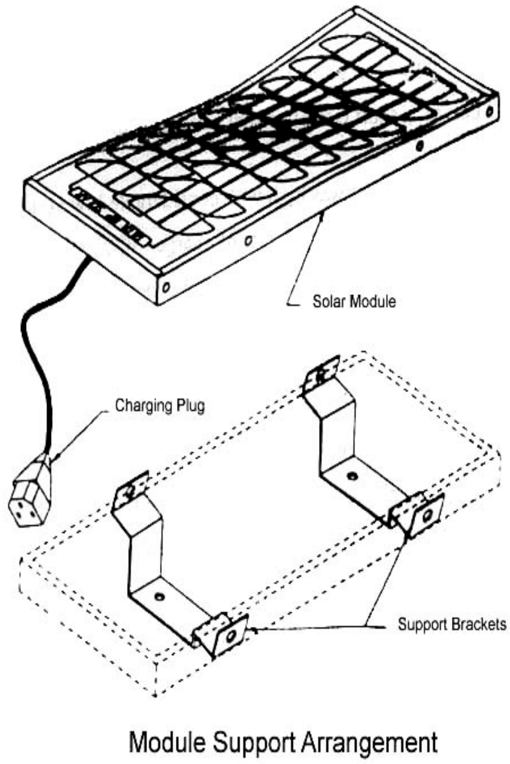

Fig. 2 Module and support arrangement

Other electric components

Blocking diode It is made of silicon. It acts as a switch that conducts current in only one direction.

Zener diode It is a silicon diode that the manufacturer has optimized for operation in the breakdown region. The Zener diode is the backbone of voltage regulators, circuits that hold the load voltage almost constant despite large changes in the line voltage and load resistance.

Transistor T_1 & T_2 (2N 2222) are PNP Germanium transistor.

T_3 & T_4 (BE1961) are NPN Germanium transistor.

Inverter Bistable oscillator/Multi vibrator

Transformer Ferrite core (To reduce hysteresis loss)

Step up (12V to 300V)

LANTERN ELECTRONIC WORKING PRICIPLE

The 12V DC is converted to high frequency sine wave AC by self-oscillating inverter. The open circuit voltage of about 300V is generated which is clamped to 37V at the lamp and the remaining voltage is dropped in the series choke provided at the secondary of the inverter. Initially before the lamp strikes the current through the lamp filaments provides preheating. This helps the lamp not to strike with cold filaments resulting in sputtering of filaments.

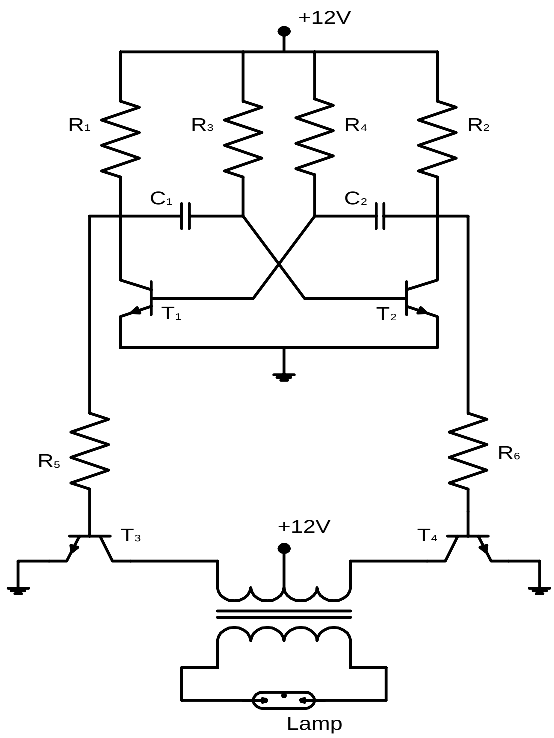

Fig. 3 Working principle

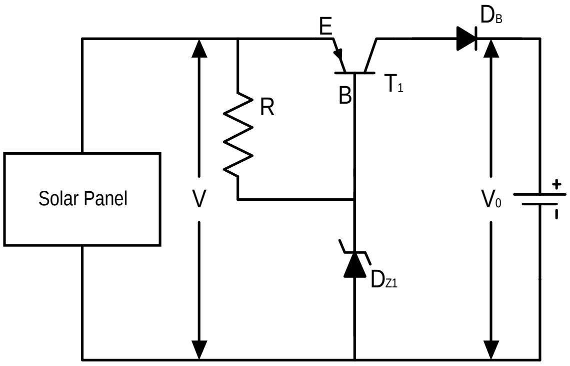

Fig. 4 Charging circuit

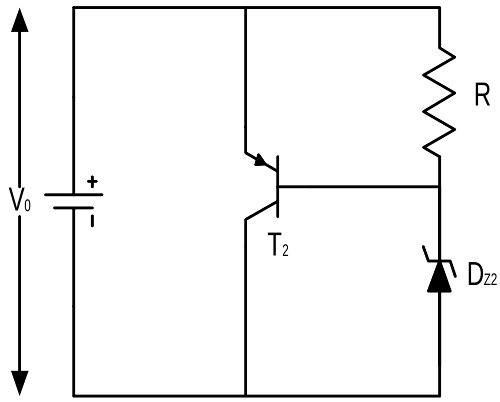

Fig. 6 Overcharging protection circuit

Charging and discharging of the battery

The solar module produces an open circuit voltage of 17V this is connected to the battery through a blocking diode. The battery starts getting charged and the voltage of the battery gradually rises. When the battery voltage reaches 14.4V, the transistor connected across the module is turned ON. This shunts the module and prevents the over-charging of the battery. The blocking diode prevents the battery from this shunting and also discharge of the battery through the module in the night. The control electronics also turns OFF the inverter-switching transistor when the battery attains the lower cut-off voltage preventing the deep discharge.

Drop across Zener diode is fixed, i.e. $V_z = 14$ V

$V_{EB} = 0.4$ V to turn ON

So, $V = V_z + V_{EB}$

$= (14 + 0.4)$ V

$= 14.4$ V

So, now $V_o = V - 0.7$

$= (14.4 - 0.7)$ V

$= 13.7$ V

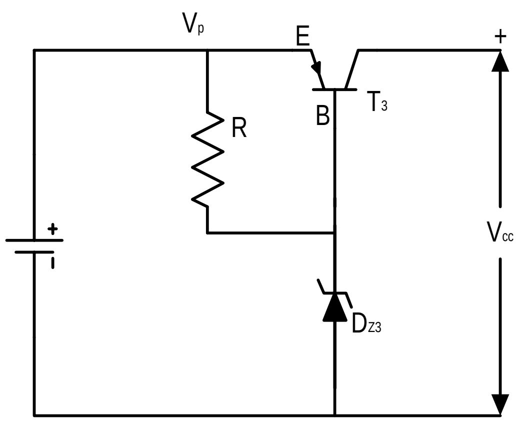

Fig. 5 Deep discharge prevention circuit

Zener diode voltage, $V_{z3} = 11$V

$V_p = V_{z3} + 0.4$

$= (11 + 0.4)$ V

$= 11.4$ V

If $V_p < 11.4$ V, the T_3 is OFF.

Battery over charge

If the battery is over charged, then the voltage will rise, grassing will begin, electrolyte will be lost, internal heating will occur and battery life will be reduced and causes permanently damage and the load will fail. Clearly regulator prevents excessive charging.

For overcharging prevention, $V_0 \leq 14.4$ V

To turn T_2 ON, $V_0 = V_{z2} + 0.4$

$= (14 + 0.4)$ V

$= 14.4$ V

MODULE CHARACTERISTICS

I-V Characteristics

Fig. 7 is the sample curve obtained from the experimental data for the PV module. In figure the open circuit voltage is 16 V which is the maximum voltage corresponding to zero current. The maximum short circuit current is 0.65 A. It is found that the output current increases from minimum to maximum value when the voltage drop across the load is decreased from maximum to minimum value.

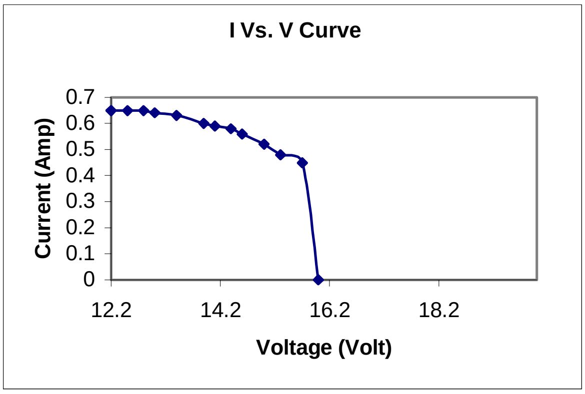

Fig. 7 Current vs. Voltage (17th April, 2001)

P-V Characteristics

Fig. 8 is sample curve obtained from the experimental data for the PV module. The maximum power is determined from figure is 8.576 W and the corresponding maximum power point voltage and current are recorded as 13.4 V and 0.63 A respectively.

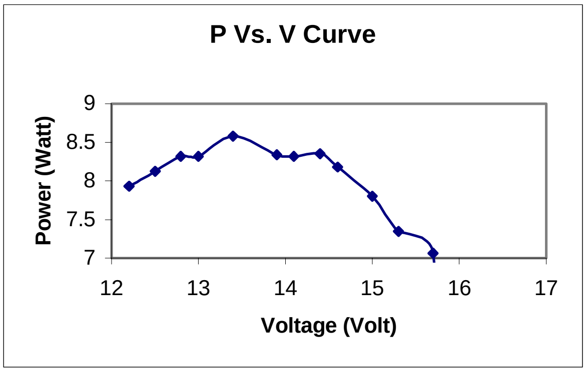

Fig. 8 Power vs. Voltage (17th April, 2001)

Insolation vs. Time curve

Fig. 9 shows the generated data for the month of April 2001. The readings of solar insolation are taken at one hour interval. The graph shows that the maximum and minimum solar insolation is 678.95 W/m^2 and 252.63 W/m^2 respectively. The total time taken for battery charging is 15 hours.

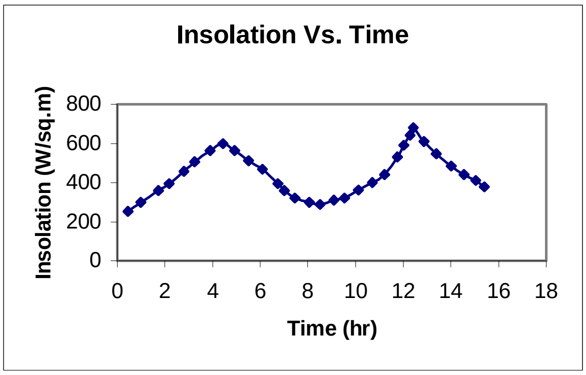

Fig. 9 Insolation vs. Time (17th & 18th April, 2001)

Illumination vs. Distance Curve

From experimental data fig. 10 shows that a downward sloping curve. Since illumination varies inversely with distance. For that reason lux decreases with increasing the distance. This curve shows a 6th order polynomial.

Illumination (lux), $Y = 4 \times 10^{-9} X^6 - 2 \times 10^{-6} X^5 + 0.0006 X^4 - 0.0701 X^3 + 4.6726 X^2 - 164.31 X + 2512.6$

Where, X = Distance (cm)

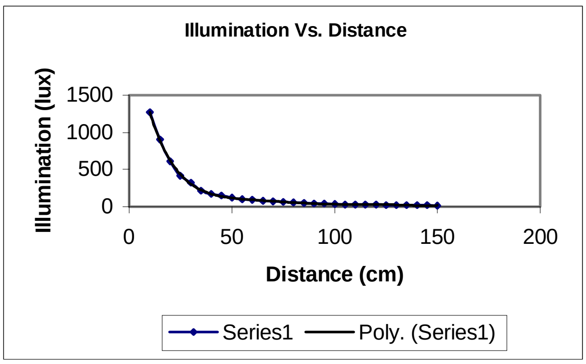

Fig. 10 Illumination vs. Distance (18th April, 2001)

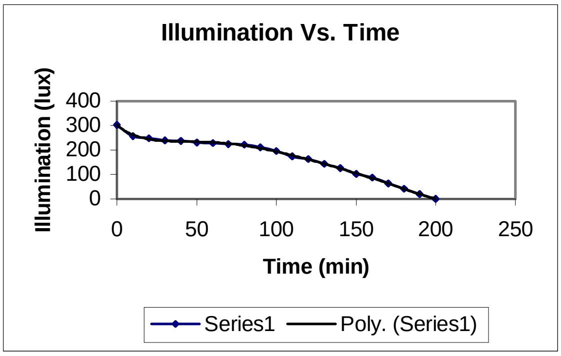

Fig. 11 Illumination vs. Time (18th April, 2001)

Illumination vs. Time curve

The fig. 11 shows the illumination vs. time curve and it's a downward sloping curve, because of passing time, the illumination will be reduced and finally it will be zero. This curve shows a 6th order polynomial.

Illumination (lux), $Y = 8 \times 10^{-11} X^6 - 6 \times 10^{-8} X^5 + 2 \times 10^{-5} X^4 - 0.0023 X^3 + 0.1599 X^2 - 5.2449 X + 301.17$

Where, X = Time (min)

TROUBLE SHOOTING

Symptom	Possible cause	Action
1. Lamp not turning ON	1. Lamp defective 2. Loose wiring 3. Defective electronics	The lamp power portion will appear dark: replace lamp. Check the wiring as per diagram. Change PCB
2. Lamp not turning ON and RED indicator is ON	1. Battery low 2. Battery not getting charged	Allow the battery to be fully charged, till the GREEN indicator flickers. a) Cloudy weather causing slow charging: Allow longer duration for charging before use. b) Check if any shadow is falling on the module, shift if required. c) Check if dust

		is formed on the module surface and clean as routine maintenance.
3. Lamp does not work for specified duration	1. Battery not fully charged 2. No adequate sunshine 3. Battery not retaining charge	Allow the battery to be fully charged. Wait for few days till the battery gets fully charged. Replace the battery.
4. Load OFF & charging LED's flicker alternatively	1. Fuse blown 2. Battery terminal loose	Replace the fuse. Check the battery terminal connection.
5. Charging LED doesn't glow	1. Battery not getting charged 2. No sufficient sunshine	Check the wiring at the solar module and the connector end. Wait for good sunshine.

MAINTENANCE AND PARTS REPLACEMENT

Battery replacement
Battery is of maintenance free type, hence no maintenance is required.

Lamp replacement
For replacement of lamp, remove the lamp cover and then the lamp from the holder and fit the new lamp back to its position.

PCB replacement
Replacement of the PCB as it fails to operate.

CONCLUSIONS

There appears to be no single or simple answer to the energy dilemma of developing countries. It is likely to be a mixture of mutually supporting technical, institutional and development approaches.

The main consumers of solar PV systems in Bangladesh are the rural people, who have very limited purchasing capacity. These people are mostly uneducated and do not have any idea about the technology behind the solar PV systems. For this reason, the design of the components like DC lamps should be rugged, highly reliable and low cost. At the same time, durability is also of great importance as any sort of maintenance is quite difficult in rural villages. Hence, proper care should be taken to test the lamps properly before delivering it to the customers. Data generation and subsequent analysis may evaluate the performance of the PV light system, specially the locally manufactured components such as batteries, charge control units, inverters, tube lights etc.

The depth of discharge of the battery and the period after discharge before charging commencement are critical in PV application for system reliability.

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