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Critical Design of SPV AC Lighting Systems – A Case Study at Energy Park, BEC[A], BGK

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Abstract— This paper presents design of energy efficient SPV based lighting system. The proposed system consists of photovoltaic array, 12V battery, charge controller, and inverter. The experimental setup is built in Energy Park, Basaveshwar engineering college [A], Bagalkot, India. Inverter gets the DC supply from the 12V battery charged by photovoltaic arrays. Charge controller employed to prevent battery from overcharging. Assessment of lighting load in watts is carried for energy park requirements. Based on the load required, capacity of the inverter and capacity of the batteries is identified. Further, the designed lighting scheme is implemented and tested for its performance. Inverter efficiency, solar radiation and inverter output are experimentally obtained and tabulated. Results revealed that designed system is capable of providing power to adequate loads at least 3 to 4 hours. Maximum efficiency of inverter is obtained at highest solar radiation of 1162 (W/m^2). Employment of proposed concept for selecting the lighting schemes is energy efficient and cost effective.

Index Terms— Solar photovoltaic system, Radiation, Inverter, Battery, Charge Controller.

1 Introduction

SPV based lighting system is gaining its important due to freely available solar energy, eco friendly and for being economic option. Solar lighting system is designed for outdoor application in un-electrified remote rural areas. This system is an ideal application for campus and village street lighting. Even in urban areas people prefer solar lighting as an alternative during power cuts. SPV based lighting system requires inverter, battery and charge controller.

Energy Park situated in the Basaveshwara Engineering College campus has solar panel of 3.2KW. The output of this solar panel is used for irrigation purpose. This power is being used to run 1hp, 2hp, 0.5hp motors as the application of irrigation pumps. Remaining unused power from the solar panel is used for lighting the energy park. Existing System in the energy park already consist of solar panels directly coupled to DC lamps. In this system DC supply from the solar panel is directly fed to DC loads. From the literature it is proved that LED lighting consumes less power producing high efficiency. In this regard, critical design of AC lighting system for Energy Park requirements is taken up and presented in this paper.

2 Methodology

2.1 Wattage Assessment of Exterior Lighting System

Load assessment of exterior lighting system is carried out in three steps: Selection of bulb/wattage, Inverter sizing and identification of optimum battery size for required load.

Lighting requirements of Energy Park is carried out by determining luminance intensity of different bulbs by Lux meter. Luminous intensity is the intensity of light falling at a given place on a lighted surface. Hence, with the help of finding luminance intensity of different bulbs, suitable type of bulb is identified. Based on the luminance intensity number of blub required for lighting energy park is obtained.

TABLE.1. Lumens of different lamps

Light source	Load (W)	Illumination (Lux)
Incandescent	40	82
CFL	7	15
CFL	11	30
CFL	15	73
LED	9	120
LED	14	180

Lighting Calculation: Area of Energy Park is 130 Sq-m (13mX10m) and number of bulbs required for lighting is assessed. Comparative analysis of bulbs from Table.1, LED bulb of 14 W is considered for calculation. Lumen output of Philips LED 14W bulb is 1400 lumen. Total number of lumens required on the working place is given by (1):

$$\text{Luminous flux} = \frac{\text{Illumination} \times \text{Area}}{\text{U.F} \times \text{M.F}} \quad (1)$$

Utilization factor (U.F) is 0.7 for LED bulbs; Maintenance factor (M.F) value is about 0.8.

$$\text{Lumious flux} = 5714.2 \text{ lumens.}$$

Number of lamps required is calculated by (2)

$$\text{No of lamps} = \frac{\text{Luminous flux}}{\text{Total lumen of the lamp}} \quad (2)$$

$$\text{No of lamps} = 25 \text{ lamps.}$$

Total load (Watts) is assessed by (3):

$$\text{Total Wattage} = \text{No of lamps} \times \text{Wattage of bulb} \quad (3)$$

$$\text{Total Wattage} = 350\text{W}$$

2.2 Inverter Sizing

Rating of the inverter is decided based on the load and it is assessed by (4):

$$\text{Inverter Capacity} = \frac{\text{Power in VA} + (1 + \text{aging factor})}{\text{Power factor}} \quad (4)$$

$$\text{Inverter Capacity} = 542.1\ \text{V} = 0.5\text{KVA}$$

Where, Power is given by the ratio of total wattage and efficiency of inverter.

2.3 Proposed Block Diagram

Block diagram of solar lighting system is shown in Fig.1. One of the objectives is to design a model for 0.5 kVA inverter for lighting system. It includes SPV array, battery, charge controller, Inverter & AC lighting. Setup consists of 75 W SPV panel. For the performance testing solar radiation data are collected from Automatic Weather station.

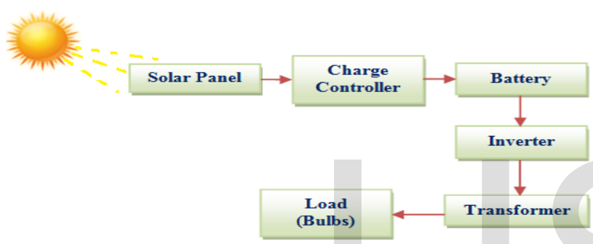

Fig.1 Proposed block diagram of inverter

Fig.2 Solar panel installed in the energy park

Table.2.Specifications of the solar panel used in this project

Power rating of a panel	75 W
Open circuit voltage (V)	22 V
Short circuit current (A)	4.45 A
Maximum voltage (V)	18.2 V
Maximum current (A)	4.13 A
Solar Radiation	1000 W/m²

2.4 Working Principle

The operation of converting DC signal to AC signal is carried out in three stages oscillating or pulsating stage, amplify stage, transformer stage. Two heat sinks are used on both side of the MOSFET to treat the heat. 12V output from the battery is input for the inverter. 12V DC from the battery is supplied to PWM ICSG3524 through voltage regulator. ICSG3524 is employed to generate pulses. These PWM signals of 10 KHz which are calculated by CT & RT. Two transistors amplify signal generated by oscillator stage after it goes to RC network. The RC network consists of three capacitor and resistors. In this RC network capacitor charges and discharges, and square is slowly converted into sine wave. This PWM signal goes to gate of MOSFET.

2.5 Components Used in Circuit

Oscillator: The oscillator section generates 50HZ frequency. Supply from battery is connected to IC SG3524 through the electrical converter ON/OFF switch. In generator stage signals generated are coupled to flip flop section of IC1. Incoming signals are signals of opposite polarity. First signal is positive and second signal is negative. This method is perennial for 50 times per second. Hence alternating signal of 50HZ frequency is generated within the flip flop section of IC. This alternating signal of 50Hz is associated at out pin 11 and 14and these signals are known as PWM signals or MOS drive signals.

Center tapped transformer: The transformer used with inverter is centre tap, and the transformer ratio is 1:8. Centre tapped electrical device separates the secondary winding. The MOSFET switches S1 and S2 connects the first winding ends of the electrical device to the negative terminal of the battery. Switch S1 and S2 opens and closes or else the present flow through the first winding, the electromotive force is lead in to secondary. As a results of modification in electrical flux within the primary develops magnetic filed within the primary. The sine wave output is created from the secondary at frequency of 50Hz.

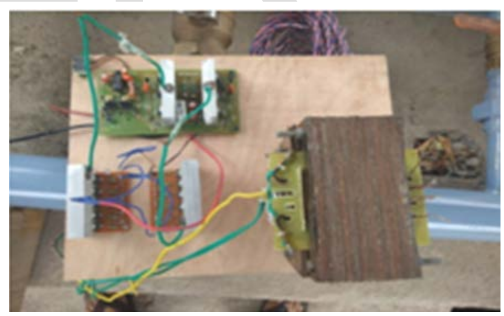

Fig.3 Center tap transformer used in the project

2.6 Battery Sizing

In PV System batteries are used to store energy during non shine hours. The stored energy is delivered to inverter. Converter delivers a continuing output power and thus delivers constant output voltage to the load. Because the battery voltage decreases, the battery current will increase to maintain constant output voltage and thus constant output power. The output of the battery is fed to the electrical converter. Most ordinarily used batteries within the PV systems are lead acid batteries, nickel metal batteries. Lithium and nickel are batteries are used, however lesser extent. The most effective storage is lead acid batteries.

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Number of cells in the battery is assessed by (5):

$$\text{No of cells} = \frac{\text{Maximum system voltage on DC side}}{\text{Cell Voltage}} \quad (5)$$

$$\text{No of cells} = 6$$

Energy (VA) during autonomy time is given (7):

$$E_d = E_t(1 + K_g) \times (1 + K_C) \quad (7)$$

Et = design energy growth
Kg = Contingency for future load growth (10%)
Kc = design contingency (10%)

$$\text{Therefore, } E_d = 423.5 \text{ VA}$$

Current on DC side is assessed by (8):

$$\text{Current on DC side} = \frac{\text{Design energy}}{\text{Battery volatge}} \quad (9)$$

$$\text{Current on DC side} = 35 \text{ A}$$

Ah capacity of the battery is given by (10):

$$\text{Battery Capacity} = \frac{\text{DC current X Discarge time}}{\text{Battery ageing factor}} \quad (10)$$

$$K_a = \text{Battery ageing factor std factor is } 1.25$$

Therefore, capacity of the battery at discharge of 3hrs is

$$\textit{Capacity of the battery} = 84Ah$$

3 Result and Discussion

The proposed converter circuit is coupled between the SPV array and the battery. With increase in solar radiation inverter efficiency also increases. Detailed performance analysis of SPV powered AC lighting is carried out and readings are tabulated.

TABLE.3. Performance analysis of the inverter for lighting load in the month of May

Solar radiation (w/m2)	V_{in}	I_{in}	P_{in}	V_{out}	I_{out}	P_{out}	η (%)
953	14	3.7	52.1	176.1	0.21	36.9	71.1
983	15.1	3.9	59.2	178.3	0.22	43.5	73.5
1001	15.3	3.9	59.8	182.5	0.24	45.6	76.2
1010	15.7	3.9	60.7	183.1	0.25	47.1	77.5
1015	15.8	4.0	62.8	188.1	0.26	49.2	78.3
1023	16.2	4.6	63.7	188.6	0.27	52.2	81.3
1031	16.5	4.6	65.8	195.2	0.28	55.6	84.4
1042	16.5	4.7	67.1	196.7	0.30	60.1	89.5
1053	16.7	4.7	70.3	197.2	0.30	60.5	91.1

The tests are conducted during the Feb to May months. The test data were analyzed rigorously. Battery starts charging during peak hours. With increase in solar radiation total power stroked on to the SPV panels will also increase, which in turn lead to improved efficiency of the inverter. With the increase in the solar radiation inverter efficiency and power output of the inverter increases.

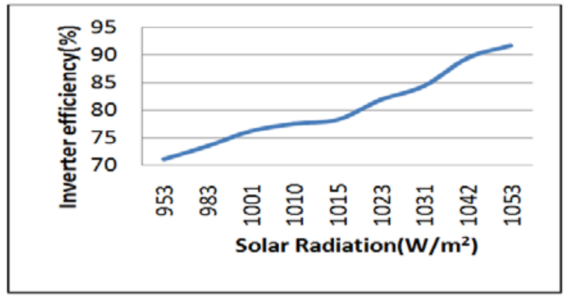

Fig. 4 Variation of inverter output with change in solar radiation

From Fig.4, inverter efficiency increase with increase in solar radiation. It is observed that efficiency of inverter is high at maximum solar radiation of 1053W/m2 and efficiency of inverter is low at minimum solar radiation of 953W/m2. Battery stores the energy during peak hours and the stored energy is used for lighting. AC lighting system runs for 3 to 4 hours. AC lighting system proves to be much cost effective and reliable option. The readings are noted for a period of one month for various conditions.

4 Conclusion

Solar lighting system is developed successfully for the energy park in the campus. The proposed system is installed and tested in Energy Park, Basaveshwar Engineering College [A], Bagalkot. Detailed performance of the systems with varying solar radiations is monitored and tabulated. It was observed that lighting system operated effectively. Further, lighting calculation and illumination study revealed that AC lighting system through LED units is much cost effective and yields brighter illumination.

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