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Performance analysis of a proposed model of lantern with LED and CFL

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Abstract

To meet the lighting demand at night various technologies have been developed which utilizes various renewable energy sources such as solar, biomass, wind etc. Among the various renewable sources solar energy is abundantly available and published literatures show that the use of solar energy assisted products for lighting are increasing in the remote villages. Solar lanterns have got various advantages such as quality of illumination, durability and versatility of use over to the other options of lighting as hurricane lamp, candles and petro-max.

In this paper a model has been proposed to increase the performance of lighting systems. Performance analysis has been done on the basis of available lighting loads. A square wave inverter is used for analyzing the behavior of the proposed model with LED and CFLs. Batteries can be charged by using solar panels.

"I. Introduction"

Solar lantern was made as a viable alternative to the hurricane lantern for use in the remote areas of India, where conventional electric power was not available. Compact Fluorescent Lamps are gas discharge tubes and therefore require high voltages, of the order of hundreds of volts, to start glowing.

A. Light dimmers: Dimmers are devices used to vary the brightness of a light. By decreasing or increasing the RMS voltage and, hence, the mean power to the lamp, it is possible to vary the intensity of the light output. Although variable-voltage devices are used for various purposes, the term dimmer is generally reserved for those intended to control light output from resistive incandescent, halogen, and (more recently) compact fluorescent lights (CFLs) and light-emitting diodes (LEDs). More specialized equipment is needed to dim fluorescent, mercury vapor, solid state and other arc lighting.

B. Inverter: Inverter converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical component in a photovoltaic system, allowing the use of ordinary commercial appliance.

The inverter is an important part when it comes to supply the ac load. As inverter is a unit which converts Direct current to an alternating current output as mostly the household appliances are manufactured to operate on ac. The converted ac can be taken at any level of desired voltage and frequency by using appropriate transformers, switching and control circuits. The inverters perform the opposite function of a rectifier.

The output of a modified sine wave inverter is similar to a square wave output except that the output goes to zero volts for a time before switching positive or negative. It is simple and low cost and is compatible with most electronic devices, except for sensitive or specialized equipment, for example certain laser printers, audio equipment.

"II. Inverter Circuit Design and fabrication"

The schematic of Inverter is shown in figure 1. The working operation is discussed below. Frequency is varied of pulses through the value of variable resistor R. The equation 3.2 is used for calculation of the frequency

A. Working of DC to AC Inverter: The inverter circuit is built around IC CD4047 which is wired as astable multivibrator. The operating frequency of astable multivibrator is set to 50Hz. The power MOSFETs IRFZ44 are directly driven by the Q and Q' output of CD4047. Thus an AC voltage is transferred to the primary of transformer; it is stepped up to 230V.

The transformer used here is an ordinary step down transformer which is connected in inverted manner. That is, the primary of a 230V to 12V-0-12V step down transformer. Suitable heat sinks are used for MOSFETs.

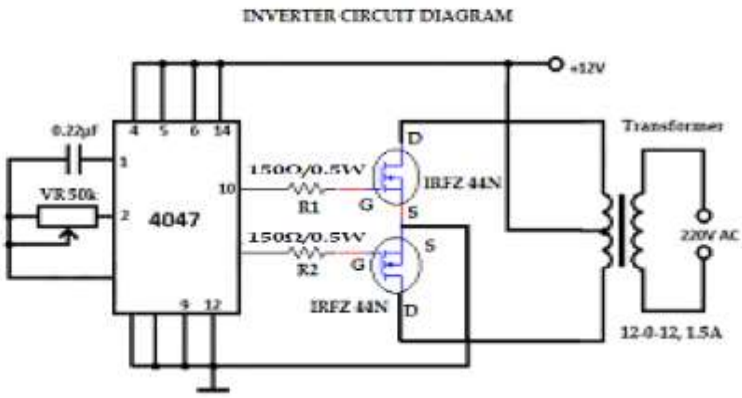

Figure 1. Inverter circuit diagram

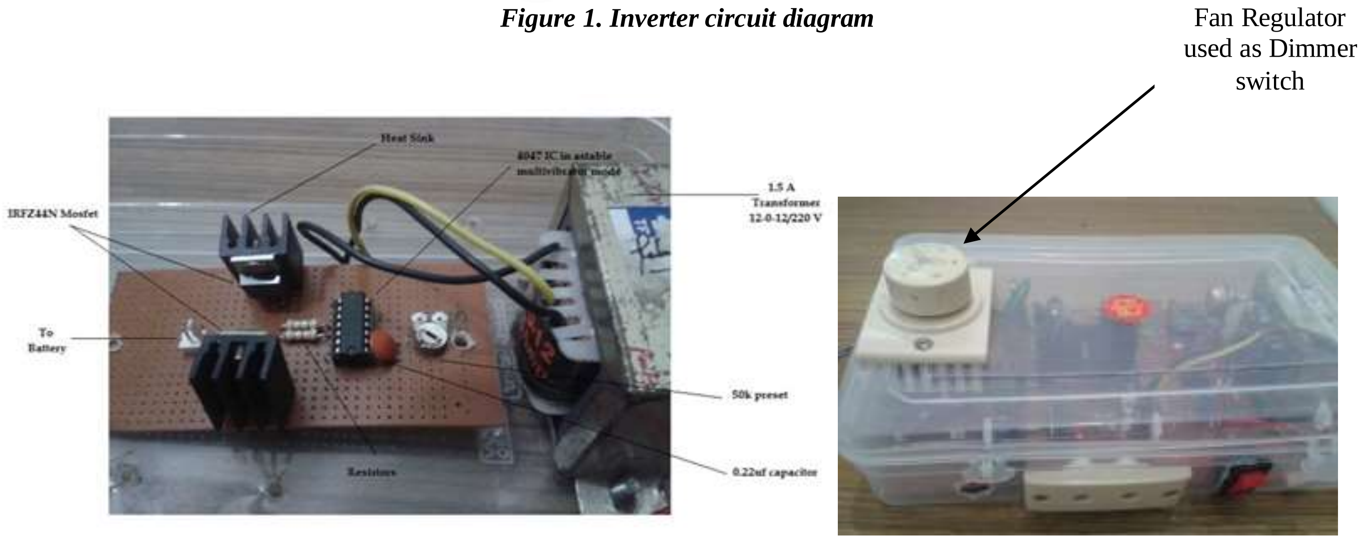

Figure 2. PCB fabrication of Inverter circuit and dimmer switch used

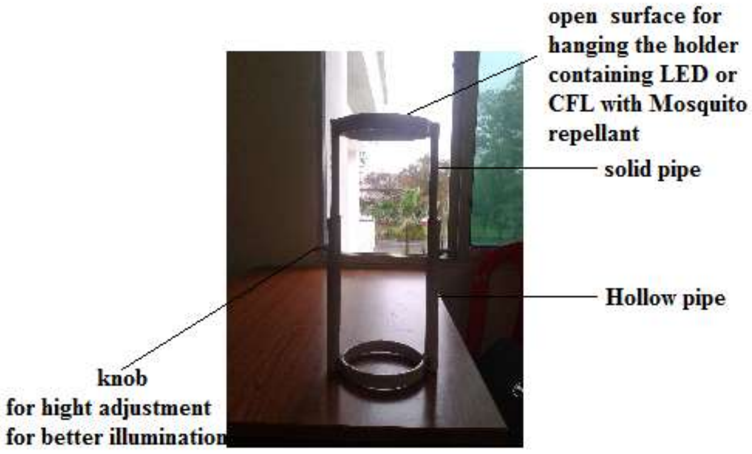

Figure 3. Proposed model design (replacement of the closed casings present in the market)

Table 1. Average energy delivered in a short period of time

Solar Lantern Performance (Table. 1)							
Dimmer Switch position	Operation	Input Voltage/ Battery Voltage, Vb (Volts)	Input current from battery, Ib (Amps)	Power Delivered Pd (Watts) Pd=Vb X Ib	Operation Time (Min)	Energy Delivered to Load, Ed (Watt-hr)	Average Energy Delivered, Ed (Watt-hr)
1	LED Bulb without Repellent	11.55	0.41	4.74	5	0.39	0.395
		11.55	0.41	4.74	5	0.39	
		11.55	0.41	4.74	5	0.39	
3		11.55	0.45	5.20	5	0.43	0.433
		11.55	0.45	5.20	5	0.43	
		11.55	0.45	5.20	5	0.43	
5		11.54	0.49	5.65	5	0.47	0.471
		11.54	0.49	5.65	5	0.47	
		11.53	0.49	5.65	5	0.47	
1	LED Bulb with Repellent (Normal Mode)	11.44	0.82	9.38	5	0.78	0.782
		11.44	0.82	9.38	5	0.78	
		11.44	0.82	9.38	5	0.78	
3		11.44	0.84	9.61	5	0.80	0.801
		11.44	0.84	9.61	5	0.80	
		11.44	0.84	9.61	5	0.80	
5		11.41	0.86	9.81	5	0.82	0.818
		11.41	0.86	9.81	5	0.82	
		11.41	0.86	9.81	5	0.82	
1	CFL without Repellent	11.61	0.54	6.2694	5	0.52	0.522
		11.61	0.54	6.2694	5	0.52	
		11.61	0.54	6.2694	5	0.52	
3		11.58	0.57	6.6006	5	0.55	0.550
		11.58	0.57	6.6006	5	0.55	
		11.57	0.57	6.5949	5	0.55	
5		11.56	0.59	6.8204	5	0.57	0.568
		11.56	0.59	6.8204	5	0.57	
		11.56	0.59	6.8204	5	0.57	
1	CFL with Repellent (Normal Mode)	11.36	0.84	9.5424	5	0.80	0.795
		11.36	0.84	9.5424	5	0.80	
		11.35	0.84	9.534	5	0.79	
3		11.33	0.9	10.197	5	0.85	0.850
		11.33	0.9	10.197	5	0.85	
		11.33	0.9	10.197	5	0.85	
5		11.30	0.95	10.735	5	0.89	0.895
		11.30	0.95	10.735	5	0.89	
		11.30	0.95	10.735	5	0.89	

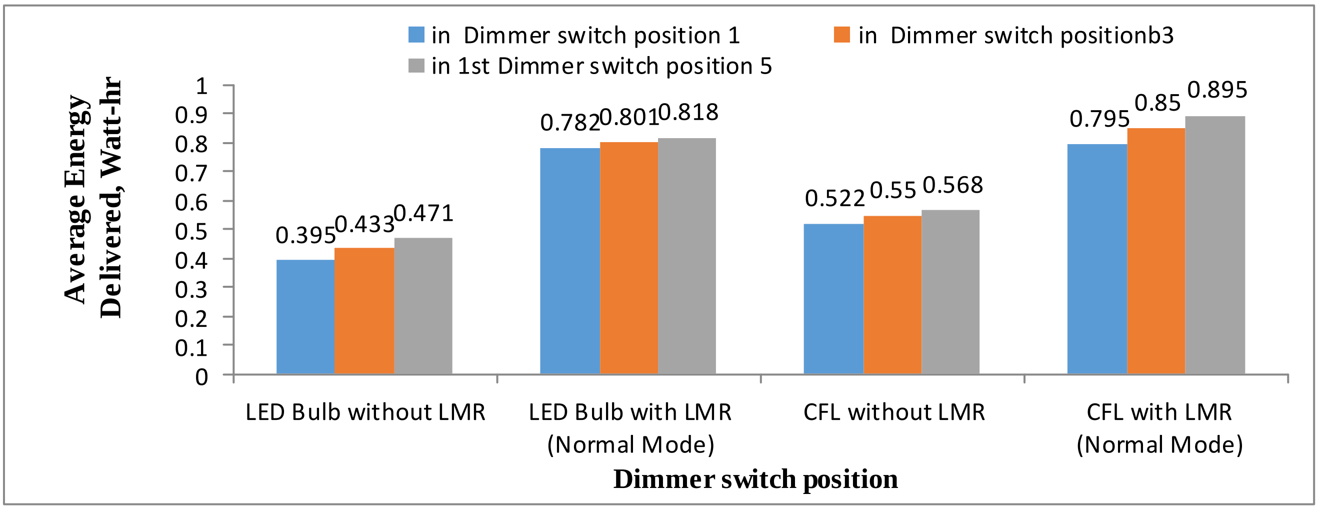

Figure 4. Comparison in average energy delivered in 5 min to the load in three different dimmer switch positions during all the operations

"III. Solar lantern performance tests"

A. Average energy delivered in a short period of time

The average energy delivered from battery is calculated in Table 1 for a short duration of 5 minutes. The summary of Figure 4 is given below (plot from the readings of the Table 1)

Summary of the Average energy delivered testing:

1. As from above table and its graphs it is clearly observed that the Average energy delivered having difference with dimmer positions 1, 3 and 5. As it is calculated for 5 minutes the difference is significant in the three with respect to operating time. When solar lantern is operated for long periods that difference will be higher and much significant.
2. The backup time or the operating hours will increase as with the dimmer positions. With less dimming the higher will be the energy conservation so it will increase the backup time or the operating hours.
3. Here the dimmer is used not for the scarification with the comfort. As it is putting here just to use the light intensity according to your need. Means if with less intensity a task or deed can be performed with comfort.

B. Average energy conserved in a short duration of time:

Average energy conserved is calculated in Table 5.3 by considering the Average energy delivered values from Table 5.2 for a short period of 5 minutes. The Figure 5.7 is the plot in between the values of average energy conserved with respect to the dimmer switch positions. The dimmer is used without losing the comfort in lighting. It is used if less light intensity is needed. The conclusions are discussed below.

Table 2. Average energy conserved in a short period of time

operation	Average Energy Delivered, E_d(W-h)			Average Energy conserved, E_c (W-h)		
	E_{d1}	E_{d3}	E_{d5}	$E_{c1}=E_{d3}-E_{d1}$	$E_{c2}=E_{d5}-E_{d1}$	$E_{c3}=E_{d5}-E_{d3}$
LED Bulb without LMR	0.395	0.433	0.471	0.038	0.076	0.038
LED Bulb with NLMR	0.782	0.801	0.808	0.019	0.026	0.007
CFL without LMR	0.522	0.55	0.568	0.028	0.046	0.018
CFL with NLMR	0.795	0.85	0.895	0.055	0.1	0.045

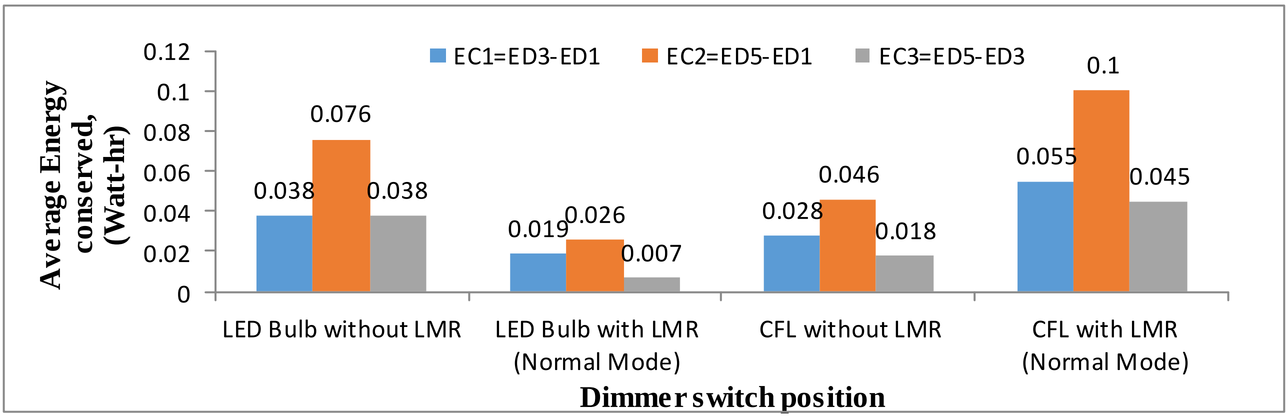

Figure 5. Comparison in average energy conserved in 5 min in three different dimmer switch positions during all the operations

Summary of Energy Conserved Testing:

1. The plot showing a small energy is conserved in a short duration of 5 minutes by using dimmer. The conservation of energy will be higher for long period's operation.

2. The objective of energy conserved is not losing the comfort level. There should be less dimming if the activity can be performed on that level of illumination of solar lantern.

C. Comparison of Light Intensity with power Delivered for CFL and LED based Lantern without mosquito Repellent operation:

The Light Intensity comparisons with respect to the unit power are investigated for CFL and LED based Lanterns in Table 3. The plot is also showing for the Light intensity per unit power delivered in Figure 5.8. The conclusions are discussed below.

Operation	Dimmer switch position	Battery Voltage (V_b) (Volt)		Current input to Load (I_b) (Amp)		Power Delivered (P_d)* (Watt)=V_b x I_b		Distance from the lantern in open holder design		Light Intensity (Lux)		Light Intensity (Lux)/Watt	
		LED Bulb	CFL	LED Bulb	CFL	LED Bulb	CFL	LED Bulb	CFL	LED Bulb	CFL	LED Bulb	CFL
CFL/LED Bulb Solar lantern without mosquito repellent	1	11.89	11.81	0.53	0.57	6.30	6.73	8"	8"	62	37	9.84	5.50
	2	11.88	11.86	0.57	0.58	6.77	6.88	8"	8"	69	38	10.19	5.52
	3	11.81	11.86	0.58	0.58	6.85	6.88	8"	8"	72	40	10.51	5.81
	4	11.81	11.86	0.6	0.58	7.09	6.88	8"	8"	74	40	10.44	5.81
	5	11.86	11.86	0.65	0.59	7.70	6.99	8"	8"	84	42	10.90	6.00

Table 3. Comparison of illumination with power Delivered for CFL and LED based Lantern without mosquito Repellent

Experiment Results:

1. From above plot it is clear that solar lantern under LED Bulb lighting illuminates more in compare to the CFL lighting.

2. Advantage can be taken of lighting for studying by increasing the number of students sitting under that lantern in compare to the CFL lantern lighting. As the level of light intensity is higher for LED Bulb lantern.

D. Battery Backup Calculation

Battery specification

Nominal Voltage: 12 Volt
Charge capacity: 7.2 AH

The safe voltage limit (minimum voltage where battery is considered fully discharged and protected): 10.5 Volt (usually considered for Lead-Acid Batteries).
The safe voltage limit (maximum voltage where battery is considered fully charged and protected): 14.5 Volt (usually considered for Lead-Acid Batteries or depend on the manufacturers specifications for the particular battery)
As here the battery rating for cycle use is given as: 14.4-15.0 Volt. Simply the calculation for backup hours or time of operation for the solar lantern can be done by using following formula

$$\text{Back up hours} = \frac{\text{Charge capacity of the battery}}{\text{average current flowing to the lantern}}$$

Full charging means battery stands with 7.2 AH charge capacity, the back-ups under different operations and dimmer switches will be as follows:

From Table 5.7 to 5.10 calculation of operating hours or backup hours has been done by considering the average current flowing from the battery in 1, 3 and 5 dimmer switch position. Conclusions are given below.

Table 4. Backup calculation in LED Bulb without LMR operation

Dimmer Switch position	Mode of operation of solar lantern	I_b (Amp)	charge capacity of the battery	Operating hours/backup hours
1	LED Bulb without LMR	0.41 Amp	7.2 AH	17.56 Hrs
3		0.45 Amp	7.2 AH	16 Hrs
5		0.49 Amp	7.2 AH	14.69 Hrs

Table 5. Backup calculation in LED Bulb with NLMR operation and dimmer switch positions

Dimmer Switch position	Mode of operation of solar lantern	I_b (Amp)	charge capacity of the battery	Operating hours/backup hours
1	LED Bulb with NLMR	0.72 Amp	7.2 AH	10 Hrs
3		0.75 Amp	7.2 AH	9.6 Hrs
5		0.77 Amp	7.2 AH	9.35 Hrs

Table 6. Backup calculation in CFL without LMR operation and dimmer switch positions

Dimmer Switch position	Mode of operation of solar lantern	I_b (Amp)	charge capacity of the battery	Operating hours/backup hours
1	CFL without LMR	0.54 Amp	7.2 AH	13.33 Hrs
3		0.57 Amp	7.2 AH	12.63 Hrs
5		0.59 Amp	7.2 AH	12.2 Hrs

Table 7. Backup calculation in CFL with NLMR operation and dimmer switch positions

Dimmer Switch position	Mode of operation of solar lantern	I_b (Amp)	charge capacity of the battery	Operating hours/backup hours
1	CFL with NLMR	0.84 Amp	7.2 AH	8.57 Hrs
3		0.9 Amp	7.2 AH	8 Hrs
5		0.95 Amp	7.2 AH	7.57 Hrs

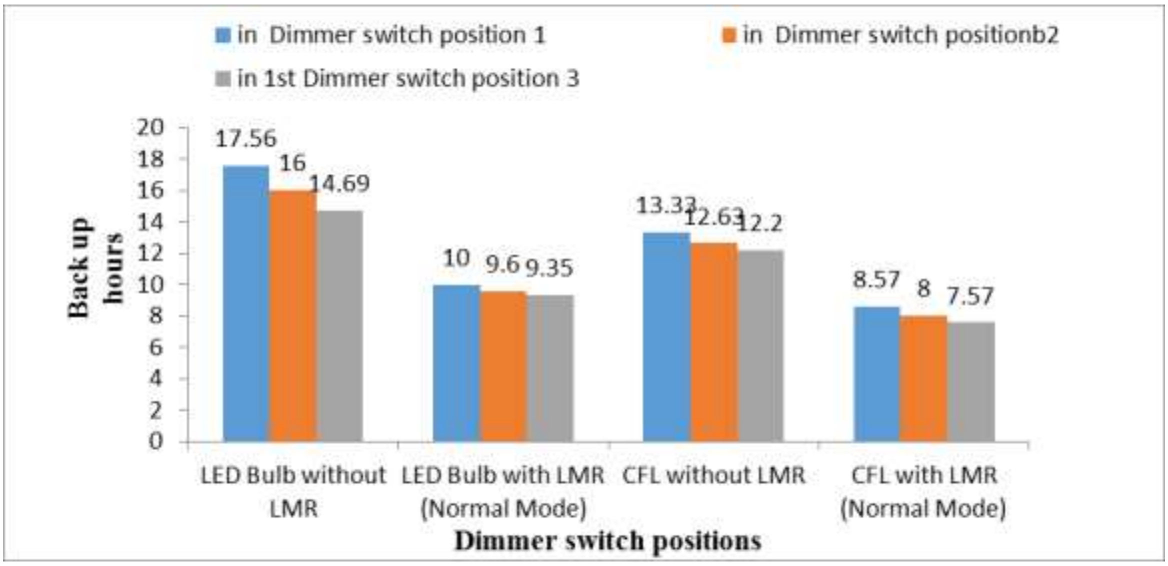

Figure 6. Battery Backup with different loads at three different dimmer switch positions

Experiment Results:

1. By using light dimmer switch in the operations it is clear that the backup hours will be increased

2. It is clear from the tables that in without LMR operation the solar lantern stands for long periods in both the lighting loads.
3. Ultimately the aim of energy conservation is to increase the backup hours. From the Figure 5.10 it is clearly observed that in all the operations the peaks in 1st dimmer switch position is higher from 3rd and 5th dimmer switch position.

These small systems can empower the lives of our poor villagers. As up to now many of the villages are away from the quality of lives due to poor lighting availability in

"IV. Novelty of the proposed model"

It is very unique and different from the existing models of lanterns or the lighting devices in the market. It is a lighting system which comprises discussion on several issues related to energy, power, space, cost and lighting. Firstly in system designing main preference is given to cost after that other issues are taken into consideration and try to compensate up to a level. By using light dimmers the energy can be conserved here in the system a small fan regulator is used as a light dimmer

form of Kerosene lamps, candles, petromaxes. It can be used as table lamp or hanging lamp.

- In India till now the concept of using Light dimmer switches is very rare. In solar lanterns this concept is not being implemented in India till now.
- Dimmer switch is not being used to loss the comfort in light; it is basically used when the activity can be performed by dimming the light.
- Not consider the provision for extra utility attachment in the projected inverter design; it is only designed for this system because any extra utility provision will increase the burden over the transformer size. 1.5 A transformer is used here which makes inverter efficient. Any extra utility provision makes inverter costly and less efficient.
- Designed inverter provides optimization in space, cost over to extra utility provision inverter with this design.
- Testing with LED Bulb and with same power rated CFL, as it is obvious with the general system of lighting that LED Bulbs are brighter than CFLs but with this particular design which one would be effective and how much level it would be effective that is the objective of this particular testing.
- Conventional inverter requires higher number of components for designing as these are sinusoidal wave generator but for small sizes inverter a square wave generator can also be used. Designed for higher power rating as 1kw, 2kw etc for solar power system applications. Companies are not interested to manufacture smaller sizes of inverter (as this objective requires only 10.3 Watt inverter) due to profit.
- Preferring these high power market available inverters for so small power application is useless due to inefficiency of the inverter for low power application as these used higher rated components which takes more voltage drop when current will be passed that makes high power loss.
- Highly cost effective, in 150 rs. It is designed due to very less expensive components has been used by considering the power requirement is very small only 10.3 watt for getting project objective

"V. Conclusions"

In the present work an emphasis has been given to develop a solar energy assisted device for lighting with a provision for mosquito protection unit. Performance of the device was tested in terms of level of illumination by using two different lights viz. LED and CFL. Effectiveness of mosquito protection unit at different altitude and power consumption at different dimmer position was also investigated. Based on the current investigation the project arrived at the following conclusions,

- With increase in dimmer regulator positions the inverter performance decreases more rapidly with LMR operations in comparison to without LMR operation. The efficiency of the inverter is observed very high 80% for all 5 positions of dimmer with LED bulb without LMR connection.

- The performance of a LED based solar lantern is much appreciable in compare to the CFL based solar lantern. The light intensity per watt from LED based solar lantern is around 80% more in all the dimmer switch positions in comparison to the CFL based solar lantern.

- The open holder design is preferable over the closed lantern design. The light intensity in open holder design with LED Bulb is 3.5 times higher than closed lantern design in without mosquito protection unit. With mosquito protection unit in normal mode in closed lantern design light intensity is negligible in comparison to the open holder design for a same distance.

- For operation of solar lantern in long periods the preferable operation is without the LMR. The backup is more than 17 Hours with LED bulb in 1st dimmer position in comparison to CFL having 13 hours backup with 1st dimmer position.

- The light dimmer switch is used to conserve the energy without losing the comfort to increase the backup periods or operating hours of the solar lantern. The backup will be increased by 10% using dimmer position 1st over 3rd and 20% by using dimmer position 1st over 5th in case of LED based solar lantern without using mosquito protection unit.
- Backup will be increased by 5% using dimmer position 1st over 3rd and 10% by using dimmer position 1st over 5th in case of LED based solar lantern using mosquito protection in normal mode.

Snaps Taken during Experiments:

LED Bulb Based lantern pictures during all the operations on open holder design of the solar lantern

CFL Based lantern pictures during all the operations on open holder design of the solar lantern in minimum height setting

CFL Based lantern pictures during all the operations on open holder design of the solar lantern with maximum height adjustment

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