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Development of a novel solar energy assisted lighting device

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Abstract

In India more than 70% of the people lived in villages are cutoff from the conventional electric grid system due to its various technical and economic reasons. Hurricane lamps fueled by kerosene are widely used for lighting in the remote villages. 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. 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.

Based on the importance and demand in the present work a modified solar lantern with liquid mosquito repellant has been developed and tested at different operating conditions. The different tests were performed for comparing Compact fluorescent lamps with light emitting diode bulb based solar lanterns. The solar lantern design provides an optimum performance in terms of Illumination.

Keywords: solar Lantern, light dimmers, Liquid mosquito repellant, system designing

1. 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. Since sunlight is freely and abundantly available at all places, not covered with clouds, it can be easily converted into electricity by solar cells, a string of such cells make a solar panel. This Electricity can then be stored in suitable batteries, normally lead acid maintenance free type, to be used when needed.

1.1 Solar PV Panel: A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic Module is a packaged, connected assembly of solar cells. The solar module can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications.

1.2 Battery: A rechargeable battery or storage battery is a type of electrical battery. It comprises one or more electrochemical cells, and is a type of energy accumulator.

To carry out the objective it is necessary to convert solar energy into the electrical form to a suitable level of output. The load in the present configuration is operated on alternating current (AC).

1.3 Battery charge/ Discharge controller: The charge controller ensures that the battery is not overcharged or discharged below a certain limit, and thus prevents the battery from being damaged.

1.4 Inverter: A solar inverter or PV 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 appliances.

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.

2. Objective of the present work:

2.1 Development of a novel solar energy assisted device for lighting with a provision for mosquito protection Unit.

2.2 Performance testing of illumination and effectiveness of mosquito protection unit at different altitude.

3. Methodology

To carry out the objective it is necessary to convert solar energy into the electrical form to a suitable level

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of output. The load in the present configuration is operated on alternating current (AC). In order to operate the unit under AC mode the different components have to be selected appropriately at different stages of fabrication process. In the present chapter, selection of different stages and their circuit diagrams with appropriate working operations, components used and methodology are discussed.

3.1 Selection of stages

It is very important to know about the system behavior. The selection of the stages depends on the necessity and the type of the system. As here it is a solar powered lighting system coupled with mosquito repellent. Firstly all the stage are defined here as to achieve the objective of a solar powered lantern coupled with mosquito repellent. The methodology used for designing the solar lantern is presented in the Fig.3.1.

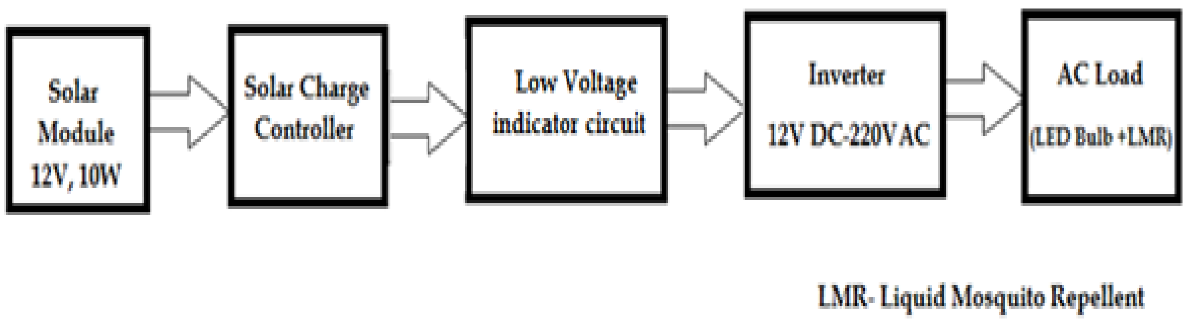

Fig. 3.1: Methodology used for designing the solar lantern

So a solar powered lighting system coupled with mosquito repellent have the following parts/stages:

- Solar module
- Solar charge controller
- Low voltage indicator circuit
- Inverter
- Appropriate design of the lantern for maximum effectiveness

3.2 Inverter selection

Circuit diagram of DC to AC Inverter Circuit

The schematic of Inverter is shown in figure 3.6. The working operation is discussed below. Frequency is varied of pulses through the value of variable resistor R.

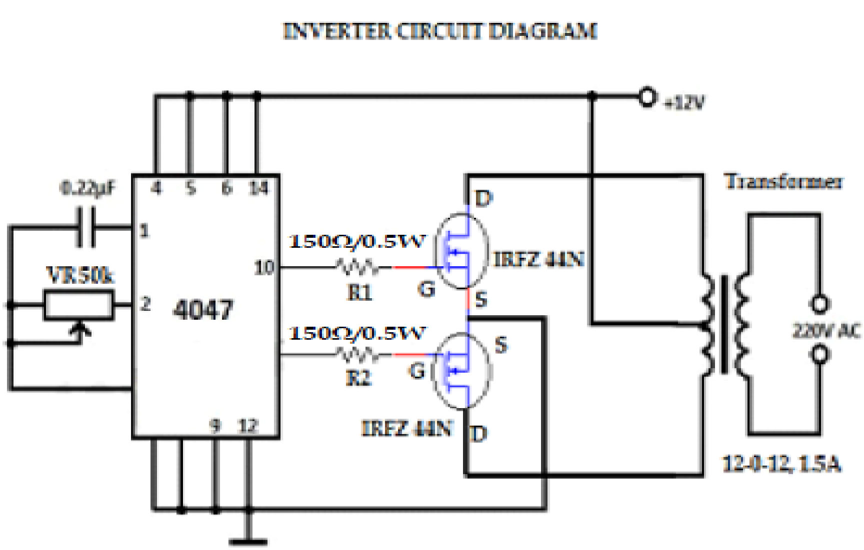

Fig 3.1: Schematic of a square wave inverter by using CD 4047 IC

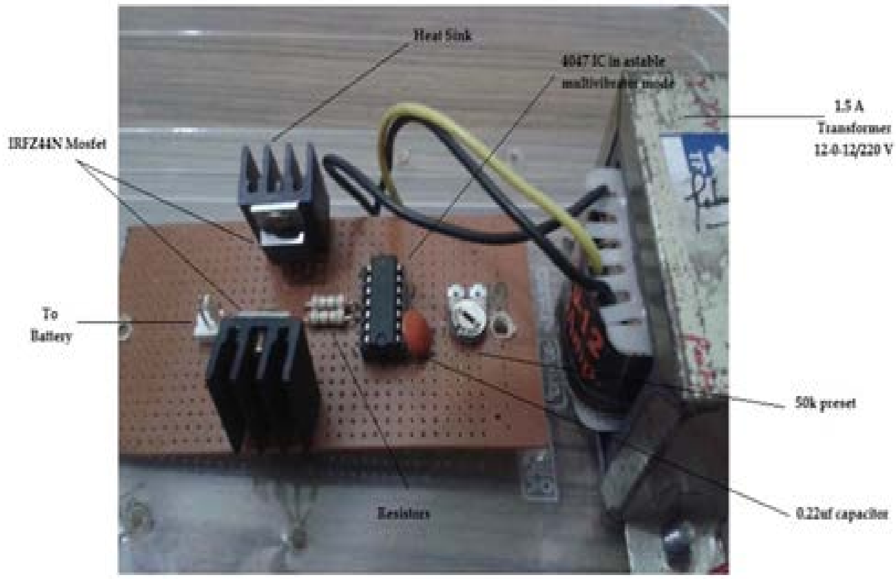

Fig 3.2: Perforated printed circuit board design of Inverter

Fig 3.3: Closed and open holder (novel) design of solar lantern

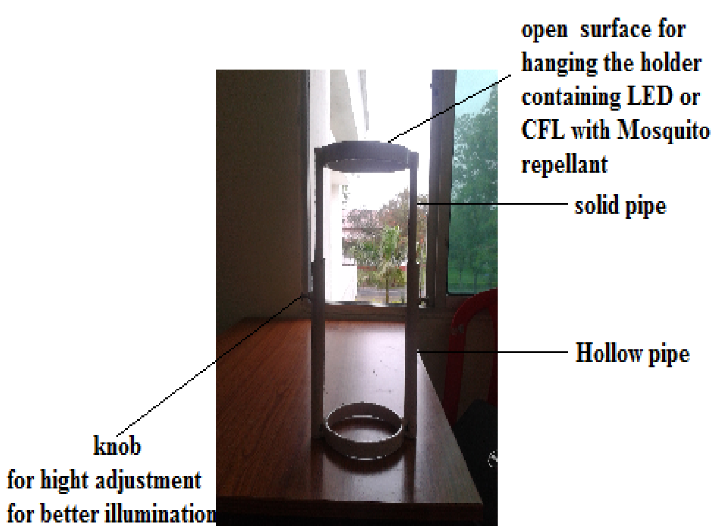

Fig 3.4: Novel designed (open holder) casing for placing Lighting Loads

Fig. 3.5: Height adjustment flexibility demonstration through the knob

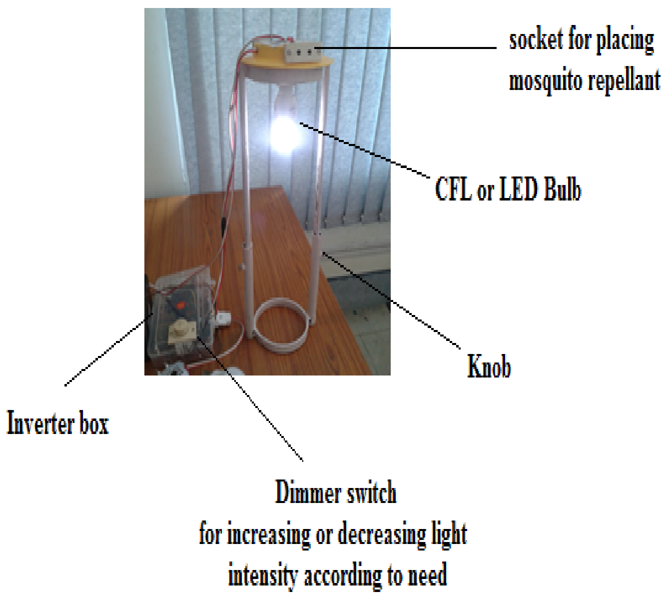

Fig 3.6: Demonstration after placing lighting load and inverter circuit with the assembly

4. Solar lantern performance Tests

4.1 Simulation results of conventional Inverter

Fabrication of the IC Based Inverter is simpler in compare to the conventional Inverter. Firstly to show the simplification in designing of an inverter with a timer IC the conventional inverter design is simulated in Fig.4.1 and the Simulink outputs are shown below in Fig.4.2

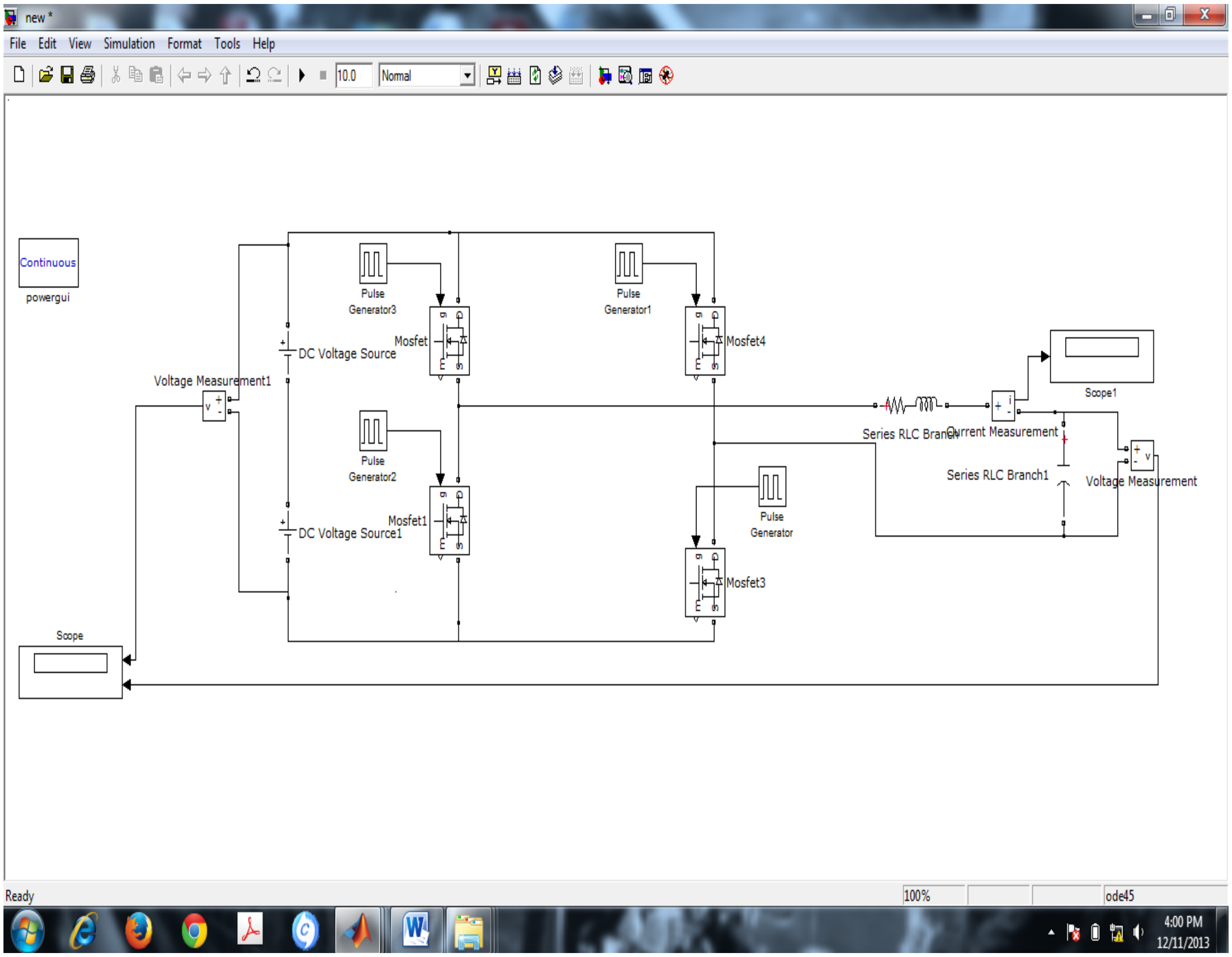

Fig. 4.1 Simulated circuit of a conventional full bridge inverter using MOSFET

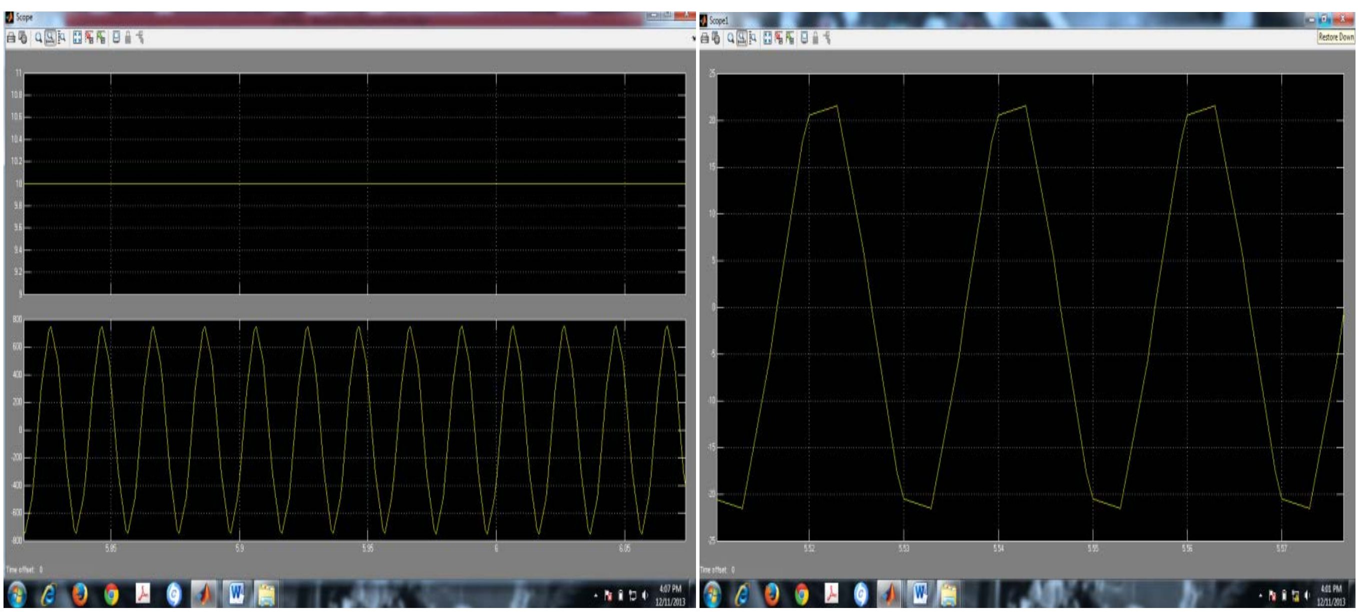

Fig. 4.2 Voltage and current output waveforms of the above full bridge inverter

Summary of the simulation Results: The conventional inverter is complex to design having number of components required for fabrication. Whereas IC based inverter is easy to design as present in figure 3.2

4.2 Inverter performance testing

Comparisons of Inverter performance of solar lantern with LED bulb and CFL attached with liquid mosquito repellant and without liquid mosquito repellant (LMR) are shown in the table 5.1. The table 5.1 presents the inverter performance at different dimmer switch positions under these operations.

Table 4.1: Inverter performance testing

Inverter Performance									
Dimmer switch Position	Operation	V_b (Volt)	I_b(Amp)	$P_d=V_b x\ I_b$ (Watt)	V_o, (Volts) (V_{rms})	I_o (mA) (I_{rms})	P_c (Watt) $=V_o \times I_o$	f (Hz)	%η
1	LED Bulb without LMR	11.71	0.41	4.80	163.6	24.2	3.96	50	82.46
2		11.71	0.44	5.15	159.5	26.9	4.29	50	83.27
3		11.71	0.45	5.27	157.7	27.9	4.40	50	83.50
4		11.71	0.47	5.50	157.7	29.0	4.57	50	83.10
5		11.71	0.52	6.09	152.7	33.0	5.04	50	82.75
1	LED Bulb with NLMR	12.12	0.78	9.45	84.8	67.7	5.74	50	60.73
2		12.09	0.81	9.79	84.7	68	5.76	50	58.81
3		12.09	0.81	9.79	85	68	5.78	50	59.02
4		12.09	0.82	9.91	85.5	68.2	5.83	50	58.82
5		12.06	0.85	10.25	85.7	69.8	5.98	50	58.35
1	LED Bulb with ALMR	12.01	0.84	10.09	66.1	74.8	4.94	50	49.01
2		12.01	0.86	10.33	65.4	74.9	4.90	50	47.43
3		12.01	0.9	10.81	64.3	75.1	4.83	50	44.68
4		12.01	0.92	11.05	63.7	75.3	4.80	50	43.41
5		12.01	0.94	11.29	62.7	76	4.77	50	42.21

Summary of the inverter performance testing

1. The inverter efficiency is less for both operations of LMR (Normal and Active Mode) in comparison to without LMR operation. This is due to square wave prevailing in the inverter.
2. So from above conclusions it is recommended that this solar lantern will be performed well under without LMR operation with LED Bulb and under LMR operation it is good with LED Bulb in Normal Mode.
3. From above table 5.1 it is also concluded that in dimmer positions 2, 3 and 4 the power delivered is not having much variation under all the operations. So for energy conservation calculation the 1, 3 and 5 dimmer switch positions will be considered.

By using Inverter performance the solar lantern is now tested for optimum output. After including the conclusions of inverter performance the solar lantern is tested under the predefined operations for finding best combination of placing, illumination with energy conservation.

4.3 Solar lantern performance testing with height and distance adjustment by using open holder design for LED based solar lantern.

In Table 4.2 the testing of solar lantern is done by adjusting the heights of the open holder stand in minimum and maximum position h_1 and h_2 respectively for finding optimum illumination. The figure 5.9 shows the placing arrangements of lantern in both the cases against the lantern and middle of the table positions.

Table 4.2: Solar lantern performance testing with height and distance by using open holder design for LED solar lantern design

operation	Dimmer switch setting	Position of lantern	Distances and heights from table					Light Intensity at these distances in h1 and h2 heights (Lux)											
								in h_1				in h_2				in h_1		in h_2	
			a_1,a_2, a_3,a_4	b	c	h_1	h_2	a_1	a_2	a_3	a_4	a_1	a_2	a_3	a_4	b	c	b	c
LED Bulb without mosquito Repellent	1	Upper Middle & Side upper middle (with bulbs are in downward position)	1 Feet	8"	8"	10"	17"	25	21	24	29	28	24	24	25	59	52	41	35
	3		1 Feet	8"	8"	10"	17"	29	25	29	34	32	29	28	30	66	59	47	41
	5		1 Feet	8"	8"	10"	17"	35	30	34	40	38	34	34	35	80	70	55	48
LED Bulb with mosquito Repellent (Normal Mode)	1		1 Feet	8"	8"	10"	17"	7	5	7	8	8	8	9	7	25	18	18	14
	3		1 Feet	8"	8"	10"	17"	5	3	4	6	6	6	5	4	20	15	13	10
	5		1 Feet	8"	8"	10"	17"	3	1	3	4	4	4	3	3	17	12	12	8

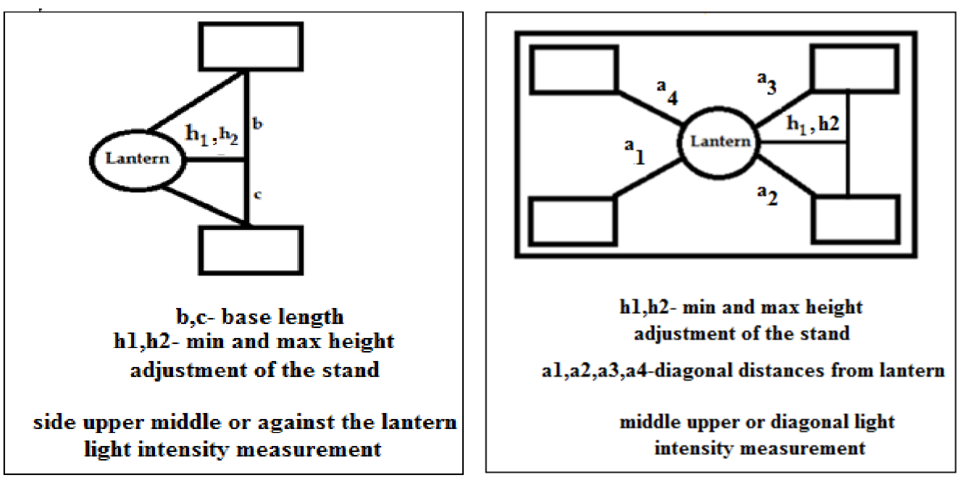

Fig.4.3 Light intensity mesurement in open holder design in two different adjustments of height

In Table 4.2the testing of solar lantern is done by adjusting the heights of the open holder stand in minimum and maximum position h_1 and h_2 respectively for finding optimum illumination. The figure 4.3 shows the placing arrangements of lantern in both the cases against the lantern and middle of the table positions. Conclusions are given below

Note: By considering the Table.1 dimmer positions and data for finding illumination levels at a Wooden Table size of length (62") x width (34") at different diagonal lengths of wooden Table

Results from the experiment:

1. From the above table it can be concluded that the open holder design is suitable with height adjustment according to the need or to increase the light intensity.
2. The side upper middle or against the lantern is suitable with minimum height adjustment as the light intensity is higher with this case.
3. But in case of diagonal placing of solar lantern the maximum height adjustment will be preferable to get highe illumination. It is clear from the above table.

4.4 Comparison in the effectiveness of closed casing and open holder design of solar lantern

The effectiveness of both the designs of solar lantern has been compared on the basis of Light Intensity at the same instance. Table 5.6 is showing the experiment results by keeping the distance constant as 10" for both the cases.

Table 5.6 comparison in the effectiveness of closed casing and open holder design

Operation	Dimmer switch position	Distance from lantern	Light Intensity (Lux)		
			Closed casing design	Open holder design	
				Min Height adj. (h_1)	Max Height adj. (h_2)
LED Bulb without Repellant	1	10"	13	48	35
	3	10"	17	56	42
	5	10"	20	66	49
LED Bulb with NLMR	1	10"	2	26	17
	3	10"	3	28	18
	5	10"	4	34	21

Results of the above experiment:

1. From table it is concluded that the open holder design is highly advantageous in terms of light intensity.
2. The height adjustment is taken in minimum and maximum height setting of the stand of open holder. It is showing that in minimum height setting it has higher light intensity in compare to the maximum height setting of the stand. as these results are taken against the solar lantern design. As it has also been concluded in the previous test.
3. This open holder design is suggested in compare to the closed casing design for students or to do the activities in idle situation of the la

4. 5. Conclusions

In this paper 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,

- 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 side upper middle is suitable with minimum height adjustment as the light intensity is higher with this case in comparison to the maximum height adjustment. Light intensity is aroung 40% higher with minimum height adjustment. The performance is investigated for both the adjustments in with LED based open holder solar lantern.
- 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.

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