Optimization of Solar (PV) Home lighting in Literacy House with integration of LEDs and Social Impact in Indian Rural Society

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Abstract - Solar photovoltaic are extensively used as an alternative power source in gridless low grid electrified places for home lighting system such as portable lantern lighting, street lighting and home/community house lighting applications. Presently Sodium vapour(SV) lamps or CFL lamps are being used in these houses. With the advent of LED lamps which give lumen efficiencies as high as 110-140 lumen/W, the solidstate lighting is becoming a competitve technology to the conventional SV /CFL technology. The penentration of LED technology is through downsizing of the lamp size, low power requirement as compared to conventional lighting system. Besides reducing the cost of the LED lamps, major reduction in solar(PV) module cost is achieved through this downsized replacement option. Investigation study reveals that the optimization of lighting with solar powered LED lamps are feasible to meet lighting requirement in houses as well as in community placs due tto its low power consumption Thus it is concluded after investigation that solar powered LED lamps can be cost effective due to low sizing of solar pannel as compared with large sizing of conventional lamps. The study also reveals that ilts impact on indian rural society may provide potential youths an opportunity to become literate in vocational trades.

Keywords – Solar photovoltaic cell, lighting, LEDs, CFL etc.

1 INTRODUCTION

Lighting load which is consumed by almost every urban and rural masses in our country accounting for nearly 18% of the total electrical energy amounting to approximately 150 billion kWh/year during evening hours. But nearly 40% of the rural households are still using kerosene/ petromax lighting systems as they are not connected by the utility supply. Solid state, opto- semiconductors LEDs are the lighting of the 21st century [1-3] and in conjunction with solar PV source have the potential for wiping off the dependence on kerosene lanterns from the country. It is a continually evolving technology and is an ideal energy saving solution in the lighting sector as a standalone or as an integrated technology with on line /off line grid power[4]. It is an ideal solution for minimization of the grid power consumption during peak hour arises due to lighting loads. The building lighting load and street lighting load when using LED systems would be of much lower electric rating and can also be controlled with ease. The major area of applications of LED lighting is the portable lanterns [2] used mostly in electrified houses with provision to charge either from solar or utility power or from both in sharing mode. This market has already developed well and likely to grow in the near future. One of the top priorities is to phase out the usage of 70 million kerosene based lighting which provides only around 10-20 lumen/lamp. The kerosene consumption varies between 70 to 280ml/ household/night for a 4-6 hour period. The average value is around 150 ml/household/night. The annual consumption is around 60litres/household/year. Kerosene is an unhealthy, unsafe, polluting source which become the root cause of many diseases like tuberculosis, asthama etc. The replacement of CFLs by LEDs has already penetrated into the Indian market in the form of portable lamps and table lamps in grid electrified houses. In this project study, an attempt has been made to investigate the cost effectiveness of lighting systems among conventional such as CFL/SVs and proposed LEDs and its integration with solar power source for lighting application in rural houses.

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2 TECHNOLOGY : INTEGRATION OF SOLAR PV POWER SOURCES WITH LEDS FOR LIGHTING APPLICATION

Solar(PV)-LED lamps integration is becoming more popular in rural houses. A 5W PV powered LED can be a preliminary substitute for a kerosene lamp with much better distribution of luminance across the room or place of working. With better focusing arrangement, the lighting level can be upgraded or enhanced to higher level also.

2.1 LED Devices : The low-power, smaller-sized light emitting diode (LED) device produces high brightness and are based on silicon carbide (SiC) product technology. These new devices consume 50% power and represent a cost savings over the current standard and high brightness blue and green LEDs. These devices are available in large production quantities and are currently shipping into high volume consumer applications. Target applications for these new devices include home lighting, cellular phones, high-resolution video boards and segmented LED displays.

2.2 Solar Modules : Photovoltaic (PV) systems involve the direct conversion of sunlight into electricity with no intervening heat engine PV devices are solid state; therefore, they are rugged and simple in design and require very little maintenance. PV systems produce no emissions of hazardous gases like CO2, CO and SO2 etc, are reliable, and require minimal maintenance to operate. They can produce electricity from microwatts to few megawatts. The technology involved for generation of electricity is shown in Figure 1. Sun light (photons) falls on the surface of solar plate consisting of P-N semiconductor material generate electron hole pair and accumulate charges on opposite plate resulting in generation of electricity while connected across the load. The efficiency of mono crystalline solar PV panelsis shown in Table 1

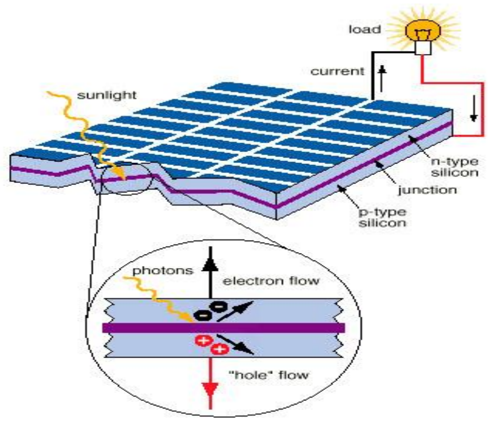

Fig.1 Solar Electricity generation

TABLE 1
ENERGY EFFICIENCY OF TYPICAL MONO CRYSTAL- LINE SOLAR PV PANELS

Sl. No.	Particulars	Units	Typical Value
1	Energy input (solar radiation)	kWh/m^2/day	5.65
2	Energy output (Electrical power) Sun hour-6.2 hour	kWh/m^2/day	0.88
3	Overall efficiency	%	15.58

Table 2 gives the typical panel capacity for LED lanterns of 3 W, 5W and 10 W. It is seen that choice of the individual solar panel capacity ranges from 9W/11W for home lighting and for other high power load upto 300W requirement in multiple of 25W/37W is commonly used. The light energy converted into electricity by PV module is stored in Battery unit which feed power to LEDs through inverter.

TABLE 2
TYPICAL PANEL CAPACITY FOR LED PORTABLE HOME LANTERNS OF 3W, 5W AND 10W.

Sl. No.	Particulars (Unit)	Light Emitting Diode		
		3W	5W	10W
1	Lamp capacity(W)	3	5	10
2	Panel capacity (input energy) (Wp)	37	75	125
3	No of hours of operation/day (Hr)	4	4	4
4	Lamp Energy requirement per day (4hours) (Wh/day)	12	20	40
5	Energy input (solar radiation)(Wh/day)	200	600	800
6	Energy output (electrical)(Wh/day)	40	80	100
7	No of days of autonomy (days)	2	3	2

2.3 Solar Power Converter

The block diagram of solar (PV) power supply for home lighting system is shown in Fig. 2.

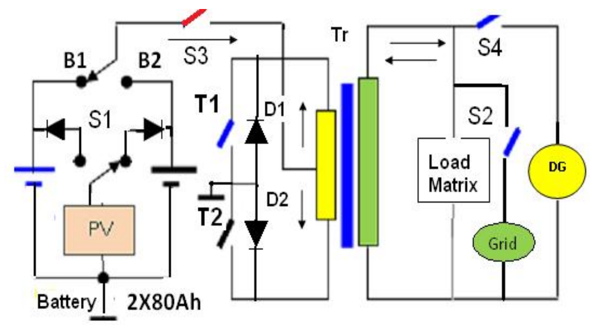

Fig.2 : Proposed power circuit model of a solar (PV) Home lighting power supply

The solar power supply system [5] makes use of the solar (PV) module to produce DC electricity and subsequently convert it into AC power as required for home lighting The dual battery system of PV unit controlled through DPDT switch S1 as shown in Fig.2 feed power to load from one of battery (i.e. B1/or B2) bank while other bank of battery (i.e. B2/or B1) store energy from PV source and thus could be able to deliver power for 24 hours in a day. The bi-directional converter (inverter cum charger) converts DC power from the 12V battery to SPWM AC power 220V +/- 20%, 50Hz for the load. The base drive pulses generated by controller using IC oscillator circuits CD 4047 switch on and off the transistor devices T1 and T2 alternatively for 10ms and thus produces 50Hz AC voltage waveform across load due to centre tap transformer (Tr) action. The battery (B1/or B2) will supply power to load to its maximum discharge level 10.4V. In case of low sun radiation or deep discharge level (below 10.4V) of battery, it may be charged from auxiliary standby sources such as grid or DG through switch S2/S4.

2.3 Solar self powered LEDs based portable intelligent lamp : Fig 3 shows an inbuilt self powered intelligent solar lamp that can be used for multipurpose applications inside and outside houses.

Fig 3: Solar powered portable multipurpose intelligent LEDs Lamp

The rechargeable battery (dual) unit of lamp gets its from PV module fitted on the base plate. The LEDs array gets its power from one battery unit while other remain under charge. Switching action takes place which depend on sun light intensity available in room. The load (i.e 15 LEDs) has been arranged in such a way that the connectivity of LEDs follows the series in terms of 2^n (i.e 1 2 4 8...). The provision has also been made to charge the battery unit from main solar power source or auxiliary sources.

3 Solar PV Lighting Systems Cost: Economy Analysis and Results

The solar PV sizing considerations are quite different for ballasted lamps like CFLs, TFLs and sodium vapor lamps (SVLs). The ballasted lamps require high power for start up and generally have a higher storage to overcome the steady state losses in the lamp and its associated circuit. Thus, LED lamps would involve lower solar PV area requirement. Apart from this, from the commercial point of view, an industry accepted equivalence has been established for replacement of ballasted lamps with LEDs. A typical equivalence is given as follows in Table 3. This equivalence is not based on lumen or lux equivalence because the energy efficiency of LEDs is around 110 lumen/W whereas that of CFLs is also 110-130 lumen/W. Since there is reduction in both lamp power as well as reduced margin to handle lamp start up and lamp circuit losses, there will be drastic reduction in solar PV panel and battery size which brings down the cost of the lighting system.
The cost of PV panels is in the range of Rs. 100-120/W. The cost of the balance of solar PV plant is around Rs. 30-40/W. The cost of CFLs is around Rs.15/W whereas the present cost of LEDs is Rs. 300/W. The high cost of the LEDs is overcome by the lower cost of the PV panels. Typical cost comparison for applications is given as follows in Tables 3-5.

Case I : Portable home lighting system

Table 3 : Cost comparison CFL and LEDs

	Solar-CFL	Solar LED
Size of lamp(W)	7W	3W
Cost of power supply	Rs 2,300	570
Cost of lamp	105	900
Total System Cost	**Rs 2,405**	**Rs 1,470**

Case II : Street lighting system

Table 4 : Cost comparison SVL and LEDs

	Solar-SVL	**Solar LED**
Size of lamp(W)	250W	100W
Cost of power supply	Rs 82,500	19,000
Cost of lamp	3,650	30,000
Total System Cost	**Rs 86,150**	**Rs 49,200**

Case III : Home lighting system

Table 5 : Cost comparison SVL and LEDs

	Solar-SVL	**Solar LED**
Size of lamp(W)	11W	5W
Cost of power supply	Rs 3,600	960
Cost of lamp	155	1500
Total System Cost	**Rs 3,755**	**Rs 2,460**

It can be seen from the above tables that

- Solar PV based LED lighting systems are most cost economical than the solar PV-CFL/ PV-SVL lighting systems and thus resulting in cost effective optimal case of home lighting system .
- It has an added advantage that it is light in weight and low voltage operating device.
- The life of this device is more as compared to conventional CFL .
- The array of LEDs can partially be repaired and hence maintenance cost is low as compared to CFL.
- It is also anticipated that the R&D work going on around the whole world that may reduce the manufacturing cost of LEDs with reduce size with more intensity of light in near future.
- The lenses can be fitted on front side of LEDs to make the light coherent.
- The fiber optics cable can also be used to divert or transmit light to a place as per the need in room.
- The long life of LEDs ensure the reliabily of lighting system

4 Lighting Applications

Principal Function	Lighting Application
Area Illumination	Parks and recreation areas/clubs
	Parking plots/places
	Residential street lighting
	Pedestrian and bike paths
	Bus Terminal/Bus stops and shelters
	Security/warning lighting and remote illumination
	Storage yards portable lighting systems
Sign Board illumination	Highway information on Display Board
	Billboards
Flashing and signaling devices	Navigational aids
	Highway warming road signals
	Traffic and railway signals
	Transmission and mobile antenna tower warming lights
	Work area protection devices including flashing arrow boards and barricades etc
	Signaling systems bridges and other general hazards
Consumer products	Low-level pathway and landscape lighting
	Rechargeable flashlights
	Portable home lanterns
Solar home systems	Rural/urban residential/community houses , Panchayat bhawan lighting ,
Street/Common Places	Street Hawkers /community places village Hatt market) /Dhaba (Restaurant) / /Road side Fish / Vegetable market/Road side automobile garage /Literacy training centres /Boats/hospitals/Clinics

5 Socio - Economic Impact of Lighting in Rural Society : A Case Study

A solar powered LEDs lighting provided in rural *vocational literacy houses* (Fig.5-11) have been adopted to study the impact of LEDs powered home lighting system made available to these literacy houses. The study revealed that although a few houses were connected with grid supply source but availability of power in these were observed as very poor. During its frequent failure or load shedding period, petromax and kerosene oil lamps were being used for lighting in these houses which were causing inconvenience to potential youth and women clientele group trainee/ learners, continuing their study/training leading to unsafe environment. This could become possible with the use of solar integrated power home lighting system . The use of LEDs and its impact could be able to bring many benefits and upliftment in rural society in the field of literacy such as **:**

a) Approximately 30-40% potential youth were trained in income generating vocational skill formation courses in solar powered lighting schools.
b) Female illiterate and neo-literate beneficiary specially belonging to socially and economically backward society were trained in cottage industry products (candle, agarbatti, masala, pickle, jam-jelly and papad making etc), agro-based products like vermi compost and mushroom, garment/bag making, jute product items, handicraft items, jute bag item, photo frames, interior home decorative items, soft toys making etc. They could start the production of these products in their houses.
c) School dropout children, along with their mother started going to literacy schools and thus literacy rate could be increased from 30% to 60
d) Villagers could be able to engage themselves in production of cottage industry products during evening hours. Thus economic status increased by 30%.

Fig 5: Author(right)'s visit to solar powered Jute product literacy classes

Fig 6 : Cottage Industry(candle) production demonstration class under solar LEDs light

Fig 7: Dress designing literacy classes in solar electrified aganbadi centre

Fig 8 : Mushroom production in village house under solar light

Fig 9 : Solar Home Lighting system in a village house

Fig 10 : Maintenance of solar charger by author

Fig 11 : Villagers watching solar powered TV

6 CONCLUSIONS

Solar PV- LED lighting systems are more compatible than the solar PV-CFL based systems. Both are solid state devices and their start up characteristics are good. Investigation study in this project revealed that solar PV-LED lighting systems are more cost economical than solar PV-CFL systems. The market for solar PV-LED lighting technology in India has three segments - kerosene lamp replacement, portable LEDs in electrified areas and controllable LEDs through integration into smart grid structures. The kerosene lamps in the rural as well as in urban sector can be replaced by solar PV-LED of 5W or higher rating. Portable LEDs lanterns chargeable through solar as well as grid power(optional) for localized lighting include table lamps, portable lamps, etc .and has a major market in India. This is a popular technology and is likely to penetrate higher with reduction in costs of reliable systems. Integration of LEDs lighting systems into street lighting systems and building lighting systems with intelligence and controllable features has a fair share of potential as a substitute for fluorescent and ballasted technology.

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