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Utility Interfaced Solar Electrification and Indian Rural Society : A Case Study

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Abstract

This paper presents a PV- grid/ DG hybrid energy system for a remote village in Jharkhand, a state in India. The hybrid system designed for rural home for 1kW load power sharing between PV-grid/ DG sources and optimize the cost of electricity against maximum household loads of 2000Wh/day. An PV inverter has been designed to supplement the load power to reduce the quantum of power to be drawn from grid sources. A prototype module has resulted in an optimal yield leading to an average monthly power sharing of 50% by PV with grid/DG over a period of one year. The objective is to meet the critical power requirement of household as a primary power source from PV and to draw power from the grid /diesel fueled-engine generator for a short period of time during peak load to achieve the optimum point of operation as well as to get the sustainable power for 24x7 days .

Keywords : *PV photovoltaic, Inverter, Intelligent Controller etc*

1. Introduction

Electricity is the basic need of every rural home in our country. The economic growth of country increases with its productivity which depend on availability of Electricity. The rural houses and the workplaces located in villages or its surrounding area are powered by grid (utility) sources. The raw material of these conventional sources i.e., fossil fuel (petrol, diesel, coal etc) is depleting day by day and is expected to be exhausted in near future. As a result the expansion of these grid sources has become almost standstill. On the other hand, the demand of electricity is increasing due to random growth of population. This has compelled our Scientist and Engineers to look for alternative non Conventional Energy Sources such as Solar, Wind, Biomass, Tidal, Fuel cell etc. Among all these renewable sources, Solar Energy is gaining more popularity due to involvement of simple technology of conversion from solar into electricity. The raw material i.e sun radiation of solar energy source is free , abundant in nature and is easily available everywhere. The Electricity produced by these sources generate green pollution free electricity. The only drawback of the PV sources is that it is well suitable for small loads as a standby power source but become a costly affair for large load. Thus need of integration of PV sources with grid sources is felt necessary.

In this research project, a 1kW PV-grid/DG hybrid system has been proposed to meet the additional load power demand of a typical Rural home. Attempt has been made to develop a low cost sustainable power system with simple technology, acceptable to rural masses.

2. Solar Electrification

2.1 PV 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 CO_2, CO and SO_2 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 DC power while connected across the load. The power thus obtained through cell are low and hence series and parallel connection of these cells are required to be done to get the desired voltage and current . The power is converted from solar radiation during the sun hour (i.e 8A.M - 4 P.M) only. The installation of these module require large space and hence roof of houses or open land is used to install them . The problem faces by these PV modules are low radiation during cloudy weather or rainy season and hence efficiency automatically goes down under these circumstances.

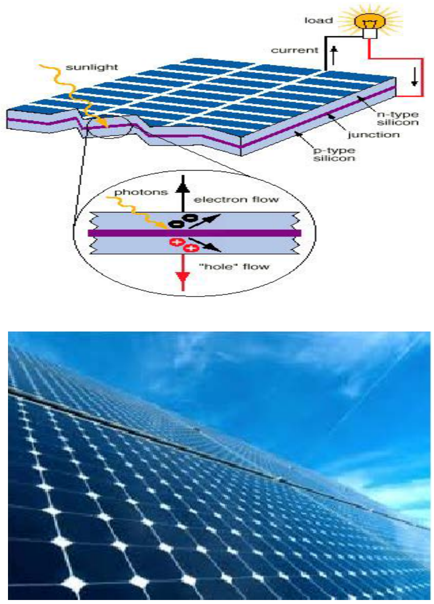

Fig.1 Solar Module

2.2 System Module

The PV hybrid system comprises of the following module :

- PV module
- Battery 150 Ah
- Inverter 1kW
- Load matrix (Max 1kW)

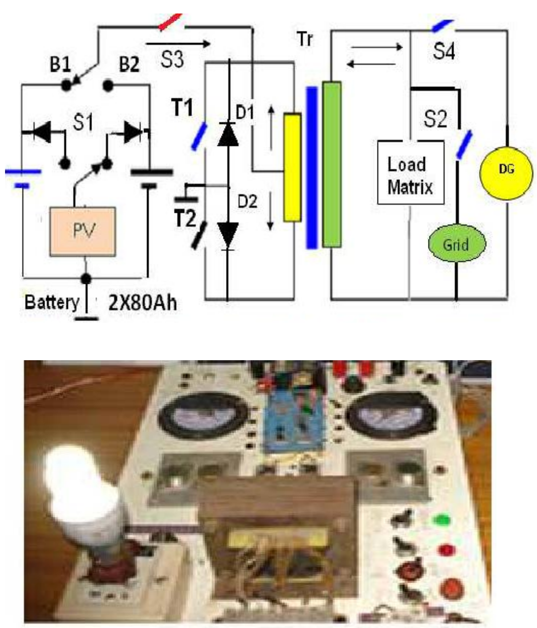

Fig.2: Power Circuit and Prototype Laboratory Module

A prototype PV system module, as proposed, has been developed and installed in laboratory as per computed load energy requirement of rural house over a period of 24 hours of the tribal village in the outskirt remote area of Jamshedpur city (India). The primary source of power supply to house is the PV power stored in the battery. Load power is managed either by battery back up PV system or supplementary integrated grid/DG source. The power converter unit of the PV system takes the low 12V DC voltage input from PV backed up energy source, stored in battery bank, as shown in Fig.2 and convert it into usable 220VAC, 50 Hz 300W/750VA output with the help of a transistorized centre tapped transformer (Tr) based push-pull configured BJT/MOSFET bi-directional converter (inverter) circuit. The controller circuit generates PWM square wave control pulses of 50Hz using IC CD 4047, to activate and switch on IRF 540 MOSFET/2N3055 transistors T1 and T2 alternatively producing AC PWM voltage with low THD at the output of secondary of transformer across the load. DG set is connected to load when the stored PV energy falls below load energy in absence of grid or when the battery reaches a discharge cut off level of 10.4V. It remain on till battery attain a charge level to match with load energy requirement in the range of 12.8V to 13.4V. The intelligent, adaptive control action of the controller performs load power/energy management and thus monitor and manage to deliver continuous power to load. The charging operation is performed either by PV source or grid/DG source through bidirectional converter (inverter) circuit in its rectifying mode (comprising of diodes D1 and D2 while transistor T1 and T2 remain off). The intelligent controller prevents the battery to go into deep discharge/or overcharge as the case may be and thus battery never allows attaining a cut-off low voltage of 10.4V for deep discharge condition or 13.4V in case of overcharging.

In case of load which exceed critical load of 300W the Intelligent controller share the power with grid limiting the withdrawal of energy upto 300W-hr only from the PV source .the rest of energy is withdrawn from the grid sources/DG. This has been reflected in Fig.3.

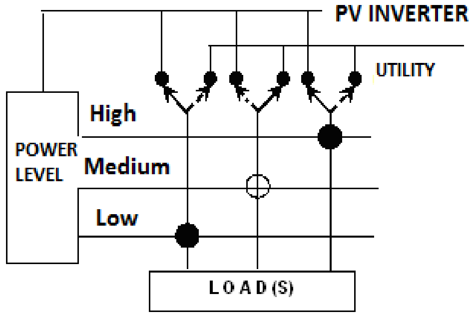

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Fig 3: Load matrix

2.3 Specification : The system is designed for a rural home as per load energy requirement with the specifications as given below:

- Load Energy = 1800 – 2000 Watt-hours over a period of 24 hour, with a demand factor of 0.9 and 50% sharing with grid power.
- PV size = 4 x 75 W_p, 12 V
- Battery Size = 2 x Dual 150 Ah, 12V low self discharge inverter grade tubular lead acid battery.
- Load(s) = CFL lamps, Fans, TV and pump etc.
- Converter = 300 W/750 VA, 12 DC ~ 220 V SPWM AC , 50 Hz (Distortion 5- 15%)
- Grid/DG set = Grid distributed network/Portable LPG 2x550VA/Diesel based 1.5 KVA

3. Design of PV-Grid Power System

Power consumption of a typical rural home is computed considering its requirement on per day basis, taking Load as TV, light /Fan and pump etc and is reflected in Table -1.

Table 1: Power Consumption

Electrical appliance	*Power (Watt)*	*Time (hr)*	*Energy (watt-hr)*
Light/Fan	100W	8	800W-h
TV	100W	4	400W-h
Pump	750 W	1	750 W-h
		Total	2000W-h

3.1 PV Sizing : The PV size is computed considering the sun hour falling on surface of PV module as 6 hours (9AM -3PM) and its efficiency of conversion as 0.9

i.e No. of PV Module (75W_p) = (Energy consumption (W- h)/ (75Wp*6 hr * η = 0.9) ………………………..(1)

3.2 Battery Sizing : The battery store the electrical energy converted by PV module during the sun hour

Battery sizing : Energy consumption / Battery voltage (12V)

i.e., = 2000 W-h/12V= 150 Ah ………………………(2)

3.3 Inverter : The unit convert DC voltage into usable AC. Voltage 220V,50V 50Hz. To deliver a peak load of 1kW, the Inverter is selected to sustain this load. The Inverter has been designed as a bi directional converter which charges the battery bank of 2*150 Ah also.

3.4 DG Set : In case of grid failure, the power is drawn from DG set. It must sustain the peak load of 1.5 kVA.

4. Results and Discussion

4.1 Load Power Management

The power delivery to load(s) is governed by the adaptive energy balance equation

$$\text{i.e. } P_L = P_{GRID} + (P_{PV} + / - P_{BATTERY})$$

The consistency in load power (P_L) delivery is obtained due to integration of input sources i.e. PV (P_{PV}), grid (P_{GRID}) and battery source ($P_{BATTERY}$).

4.2 Load Sensitivity Analysis

It has been conducted with varying load as well as insolation and the results were found consistent.The bar diagram for the results found is shown in the Fig. 4

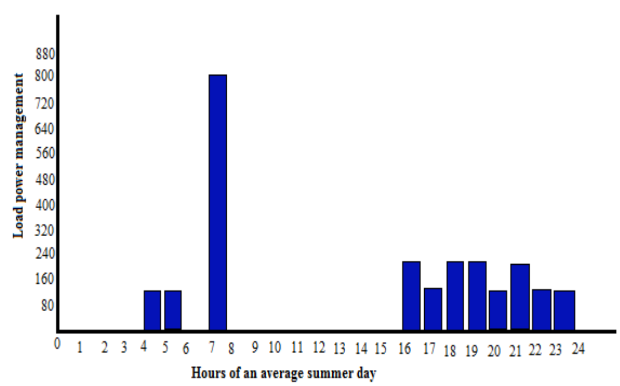

Fig.4: Load Power consumption

4.3 Power Saving:

The average approximated power drawn by the PV system and shared with Grid during each month of year 2014 is reflected in Table-2.

Table-2: Power sharing between PV and Grid

Month	*PV*	*Grid*	*Month*	*PV*	*Grid*
Jan’14	60	40	July’14	40	60
Feb’14	45	55	Aug’14	35	65
Mar’14	40	60	Sep’14	40	60
Apr’14	50	50	Oct’14	45	55
May’14	50	50	Nov’14	50	50
June’14	40	60	Dec’14	40	60

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4.4 Payback Period:

It has been observed that The cost of Electricity, initially at high value , reduces with time Thus prices reduces with a payback period of 5-6 years while compared with cost of grid sources. This has been reflected in Fig5.

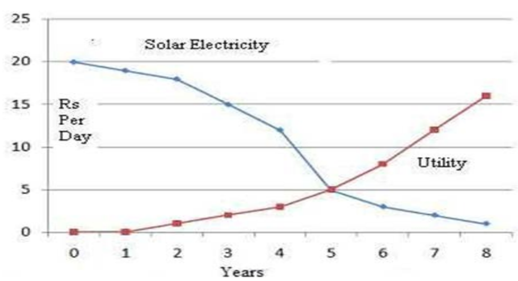

Fig.5 Payback period of PV power supply

5. Socio Economic Impact in Spreading Vocational Literacy in Rural Society : A Case Study

The study revealed that availability of power from the grid in rural houses 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 proposed solar integrated grid power source provided to these rural houses.An example of spreading Vocational Literacy in rural society is reflected in Fig.6.

The impact of sustainable power from the integrated sources could be able to bring many benefits and upliftment in rural society in the field of literacy such as **:**

- Approximately 30 - 40% potential youth were trained in income generating vocational skill formation courses in solar powered lighting schools.
- 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).
- They could start the production of 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.
- School dropout children, along with their mother started going to literacy schools and thus literacy rate could be increased from 30% to 60.
- Villagers could be able to engage themselves in production of cottage industry products during evening hours. Thus economic status increased by 30%

Fig.6: Vocational literacy classes run by rural houses

6. Conclusions

The utility interfaced Power System has been designed for rural masses. The system can work as a standalone unit also at places where Grid connectivity is still to be done. Minimizing the withdrawal of Grid power with the use of PV source, the sustainability of electricity through rural Grid can be increased at low cost of electricity. The system

offers various other features like : high efficiency, simple solar conversion technology, generation of pollution free green electricity etc. The system can find its applications in many areas of rural sectors of Indian villages for supplying power for lighting, pumps used for irrigation or drinking water supply, running schools for children as well as for adults, community centres, shops, clinics, cottage industry equipment etc .The proposed system is very promising for residential solar energy in rural areas in India.
The experimental results prove that the proposed system can reduce the Energy Consumption drastically to an extend of 50% or more and give a reliable support to the Grid. But the technology still has shortcomings such as high initial installation cost and low energy-conversion efficiency thus requiring continuous improvements of both PV cell and power inverter technologies. The impact on rural society in spreading literacy was found with excellent result.

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Biographies

Ms VS Prathiba is pursuing her B.Tech degree in Electronics and Communication Engineering from National Institute of Technology, Jamshedpur(India). She has keen interest in doing innovative research project on solar power conversion technology. She had presented and published one paper in year 2015. She is also investigating the impact of solar electricity on socio- economic development of Indian rural tribal sectors in the Jharkhand state.

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Dr S.N. Singh had completed doctoral PhD degree at the Department of Electrical Engineering, National Institute of Technology Jamshedpur (India). He obtained his B.Tech degree in Electronics and communication engineering from BIT Mesra (A Deemed university), Ranchi - Jharkhand (India) in 1979/80. Presently his area of interest is solar energy conversion technology. He had published more than 50 papers in National and International journals based on his research work. He is Head of Department of Electronics and Communication Engineering and remained in this position earlier also for two terms . He is also heading Govt. of India sponsored VLSI SMDP- C2SD Project.