SOLAR (PV) - GRID/DG GREEN POWER SUPPLY FOR RURAL INDIA

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Abstract: *In the present study Intelligent, adaptive solar photovoltaic (PV) power supply system integrated with grid supply has been proposed to minimize the use of DG source being used as an alternative source during grid off period by a rural house. The design aspect of components of PV system such as PV sizing, Battery and Converter (Inverter) etc has been described for varying load energy requirement. The prototype unit has been developed for a rural house. Performance of system was carried out to verify design objective and operational feature of the system.*
Key words: *Off-grid power supply, Solar Hybrid System, Single Pulse Width Modulation (SPWM), State of Charge (SOC), Diesel Generator (DG)*

1. Introduction

With the rapid growth of population, the energy demand is increasing day by day where as resources of grid supply are diminishing, as a result further expansion specially in remote rural sectors of the country have become almost standstill. Load shading has become a common feature of grid supply system. DG sets are being used as a complementary source of the grid power supply but due to heavy expenditure on the fuel consumption , maintenance and pollution of environment, need has been felt to use non conventional energy sources like solar etc to supplement the grid power. Many standalone PV devices have been developed to produce electricity in the past as reported by many authors [1, 2, 3, 5] but integration of PV source with grid incorporating in built feature of intelligent, adaptive power control action has not been thought much.

In the present study, a modular grid assisted solar power system with intelligent, adaptive power control feature has been proposed to minimize the operational time of DG set.

2. System Configuration and operation

The PV system (Fig.1) consists of the following:

- PV module
- Battery
- Bidirectional Converter
- Controller unit
- Grid as a primary and DG as a standby source

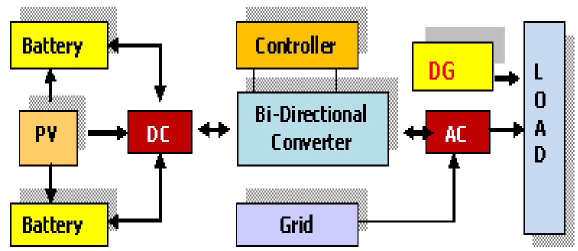

Fig. 1. Block schematic of a Grid assisted solar power converter with a standby DG Set

The primary source of supply to rural houses is the grid power. Load power is managed either by grid power supplemented by PV system or alternatively by a DG source through switches S2, S1 and S3 respectively. The power converter unit of the PV system takes the low 12V DC voltage input from PV source, stored in battery, as shown in Fig.2 and convert it into usable 220VAC output with the help of a centre tapped transformer (Tr) based push-pull configured BJT/MOSFET Bi directional Converter(inverter/Rectifier) circuit. The controller circuit generates PWM pulses to activate transistors T1 and T2 alternatively producing AC voltage across the load. The intelligent, adaptive control action of the controller perform load power management and thus monitor and manage to deliver continues power to load. DG set is connected to load only when the battery reaches at a discharge level of 10.8V observed during prolonged grid off period and remain on till the grid supply is restored or battery become fully /sufficiently recharged at a level of 12.8V-13.8V. The charging operation is performed by PV system and /or converter (rectifier) circuit comprising of diodes D1 and D2 while transistors T1 and T2 remain off.

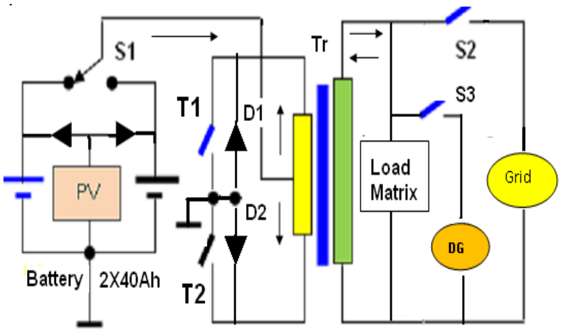

Fig. 2. Circuit diagram of PV system integrated with Grid supply and DG as a standby source

3. Optimal Design of PV System Components [4]

3.1 PV Sizing

The empirical formula based on energy balance equation has been used to compute the optimal size of PV module for critical load as stated below:

PV Cell Rating (P_{PV}) = ($P_{TL} * S.F$) / sun hour (1)

Where,

Sun hour [watt] = 6.2 for adopted area

Safety Factor (S.F) = 1.5 for cloudy weather

P_{TL} is total load energy in watt- hours (i.e. total load power over a period of 24 hours assuming hourly load power (P_L) as constant.)

$$P_{TL}\ (Wh) = \sum_{0}^{24} P_L\ Watt - Hours \quad (2)$$

The optimal number of PV module = P_{PV} / Standard PV module rating (3)

The design of components of solar (PV) hybrid system for PV is computed using Eq.1 – Eq.3 for different varying daily load power i.e. energy requirement of rural houses as depicted in Table 1.

Table 1
Number of standard PV module

Load Energy (Watt-Hours)	No. of 75 Wp PV module
300	1
500	2
1000	3
2000	6

3.2 Battery Sizing

The battery stores the energy to a maximum value as per average load power requirement.

Battery capacity (Ah) = P_{TL} / (12V * SOC) (4)

Where,

SOC (State of Charge) of Battery = 50%

The design of Battery sizing is computed using Eq.4 for different varying daily load power i.e. energy requirement of rural houses as depicted in Table 2 respectively.

Table 2
Battery capacity

Load Energy (Watt-hour)	Battery Capacity (Ah)
300 - 500	80 Ah
1200	150 Ah
2000	300 Ah

4. Prototype System Module

Load energy sharing profile of DG and Grid of a rural house has been acquired (Table 3) to select the PV module sizing, battery capacity and other components of the system.

Table 3
Average Load energy shared by DG during Grid off period computed on daily basis over the period of one year (2008 – 2009)

Month	Daily Average Energy shared by DG Wh)	Grid Power supply (Wh)
Jan	630	1770
Feb	800	1600
Mar	750	1650
Apr	900	1500
May	900	1500
Jun	700	1700
July	800	1600
Aug	710	1690
Sept	740	1660
Oct	800	1600
Nov	700	1700
Dec	800	1600

From the table 3, it is apparent that an average load energy varying from 630Wh - 900Wh is the supplementary energy requirement of a day of house during the grid off period. Accordingly the PV system module has been developed to meet this energy requirement with the following specification:

Load Energy	=	2400 watt-hours over 24 hours
Power shared	=	Grid (710 -1770 Wh) supplemented by PV system Module (900Wh), DG Standby power source
PV size	=	2*75 Wp,12 V
Load	=	CFL lamps , Fans, Pump and Electrical equipment
Converter	=	300 VA, 12VDC ~ 220 V SPWM AC , 50Hz
Mobility	=	Portable

The system module was installed at site in a rural tailoring house at Ghatsila, Jamshedpur (India)

Fig. 3. Solar panel installation at tailoring house at Ghatsila, Jamshedpur (India)

5. Performance of the System

Performance of the system is considered in terms of the following:

5.1 Quality of Power

5.1.1 Load wave form

The output waveform of the inverter as observed in the oscilloscope Fig. 4.

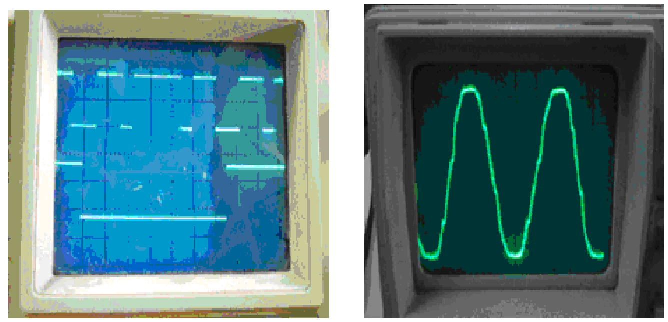

Fig. 4. Control PWM pulses (Left) and Output waveform of converter (Right)

5.1.2 Computational Analysis

The simulated PWM pulses are generated by the following mathematical expression (Fig.5)

$$P_i = K \frac{180}{2N} \times \left[2 \sin(2i-1) \frac{\pi}{2N} \right] \qquad (5)$$

Where,

i = 1 …N (number of PWM pulses)

P_i = Pulse width of PWM pulses

K= (Voltage Regulating Factor (0-1)

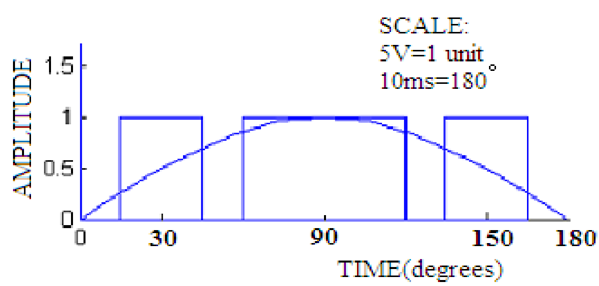

Fig. 5. PWM Wave form Generation

The Pulse width of PWM pulses can be computed using Direct Modulation strategy (equation 6)

P_i = (180/2N)* 2 sin (2*i-1) * (π /2N) (6)

Where,

i = 1........N (Number of PWM pulses per half cycle of approximated sine wave)

The values of switching angles corresponding to different values of N were calculated from the formula (equation 7 and 8) given below:

For rising edge of PWM pulses

Theta Θ = 180 / 2N – 180 * sin (2*i-1) * π /4N (7)

For falling edge of PWM pulse

Theta Ө = 180 / 2N + 180 * sin (2*i-1) * π /4N (8)

The simulated result by the MATLAB program using the above algorithm show low THD (<5%).

5.2 Cost saving in the use of DG

The use of DG was monitored over a period of one month during which a maximum reduction of 90% in its operational time was observed resulting in large saving in the cost of Diesel fuel. More number of PV modules with higher capacity of Battery, if cascaded in parallel, may make the system independent of use of DG standby source.

5.3 Efficiency of system:

The efficiency of the system was found to be almost constant value in the range of 96% or more under varying load conditions as shown in Fig 6 leading to an indication of low loss and maximum utilization of energy resources.

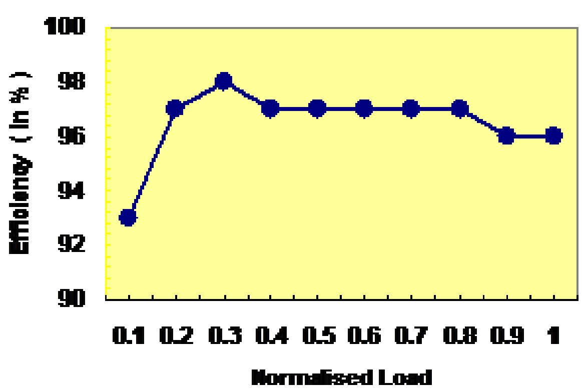

Fig. 6. Normalized load Vs Efficiency

6. Conclusion

Solar (PV) - grid hybrid system has a great potential in future as one of renewable energy technologies. The hybrid technology, integrating PV with grid, offers solution to local power generation in terms of providing uninterrupted reliable qualitative and high efficient supply without /with minimum use of standby DG at an effective cost. The easy installation and maintenance free operational feature of the system has gained more popularity among the rural masses. The successful implementation of system has following outcomes:

- Generating green electricity and meeting increasing load(s) demand of a rural house with minimum use of DG sets as well as preserving the nature.
- Minimum use of DG set reducing the maintenance and operation cost of the system Cost Effective i.e. the minimum running hours also reduces the maintenance cost of a diesel generator.

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Biographies

Dr S.N.Singh had completed doctoral Ph.D degree at the Department of Electrical Engineering, National Institute of Technology Jamshedpur (India) in 2009. He completed his Master's degree in Electrical Engineering from Ranchi University (India) with specialization in Power Electronics in1991. He obtained B.Tech degree in Electronics and communication engineering from BIT Mesra, Ranchi - Jharkhand (India) (A Deemed University) in 1979. Presently his area of interest is in *solar energy conversion technology*. He had published more than 10 papers in National and International journals based on his research work and contributed a lot particularly in spreading vocational literacy among potential youth of weaker section of rural society He had carried out consultancy and R&D work in industry and developed software and carried out innovative project work there. He had remained *Head of Department of Electronics and Communication Engineering for* two terms and presently heading VLSI Project as a *Co-coordinator* of VLSI Project (SMDP-II) sponsored by Ministry of Information Technology, Government of India and also Prof-in charge of several administrative and academic committees of the Institute. He had total *30 years of experience* including administrative, research and industrial experience at executive level in different industries and CSIR (Govt. of India) lab and presently *a senior faculty* in the Department of Electronics &Communication Engineering in National Institute of Technology (An Autonomous Institution under MHRD, Govt. of India) Jamshedpur (India).

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