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Research Article

Simulation of grid-assisted solar power converter: an effective solution for power crisis in rural India

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Abstract

This paper presents integration of the grid distribution network in Indian scenario with solar power converter to meet the additional electrical energy demand of households in urban as well as rural sectors which are both rapidly expanding. A simulation approach using PSIM software has been adopted to explore the feasibility of developing such system to work as a supplementary source. The SPWM conversion technique used in the development of the proposed solar power converter produces a grid quality usable AC power supply from PV and/or battery source. The optimal design of system components such as PV, battery and inverter etc. has resulted in a cost effective system and offers a stabilized consistent power supply for household loads. The PV converter system can also work as a standalone system in remote areas of Indian villages where the grid is either not existing or its availability is very poor and grid extension or expansion is not possible due to various technical and economic reasons.

Keywords: Pulse Width Modulation PWM, Photovoltaic (PV), Solar Charge Controller (SCC), Watt(W), Watt-hour (Wh) , Ampere hour (Ah), PSIM, SPWM.

Introduction

Electrical energy is the basic need of human beings. The demand for electrical energy is increasing day by day with rapid growth of population. On the other hand, power generation through conventional sources of energy is being limited due to diminishing trend of its raw material such as coal etc. and is expected to be exhausted in near future. This has forced engineers and scientists to look for alternative non-conventional energy sources like solar, wind, biomass, etc. which can supplement the existing grid power source and thus reduce over burdening of the grid supply [1, 2].

An investigation has been carried out to search for an effective solution towards the present power crises which has arisen especially in rural sector of India and solar energy was found to be the most appropriate solution for the same. Simulation approach [3] has been adopted to develop a cost effective solar power converter which can produce pollution free green electricity and can have a better socio- economic impact on the society [4].

The system comprises the following components**:**

- PV array
- Battery bank
- Bi-directional inverter
- Intelligent solar charger

The block schematic diagram (Figure 1) reflects the model of the proposed scheme:

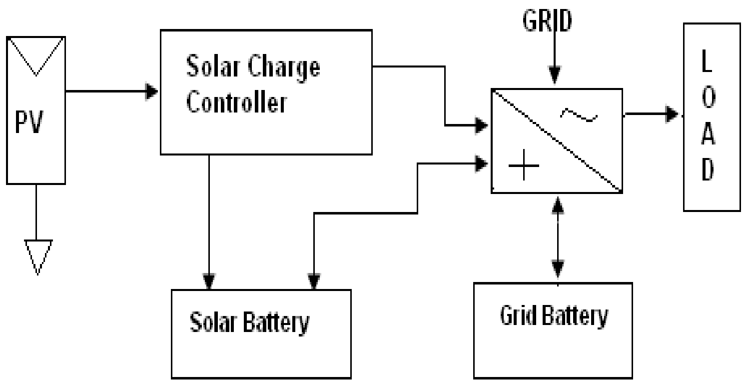

Figure 1. Block schematic diagram of the proposed scheme.

The PV cell converts solar energy into DC electrical power which is conditioned through an inverter to produce usable 220V, 50Hz approximated sine wave AC supply. The excess solar energy is stored in a battery bank which is used to supply power during intermittent/cloudy weather condition or beyond sun hour period. The intelligent solar charge control unit takes care to prevent battery from overcharge as well as deep discharge condition of the battery and charges the battery at normal c-10 rate during sun hour period. The grid battery gets its charge either from grid supply or PV panel. The novel scheme of dual battery system (i.e solar as well as grid battery) the consistency in power delivery during 24 hours a day across load(s). The load is powered normally by grid and is supplemented by PV system under weak grid or complemented during grid failure condition.

The control unit generates PWM control pulses for the inverter module. The power circuit module of converter system has been simulated using PSIM software as shown in Figure 2.

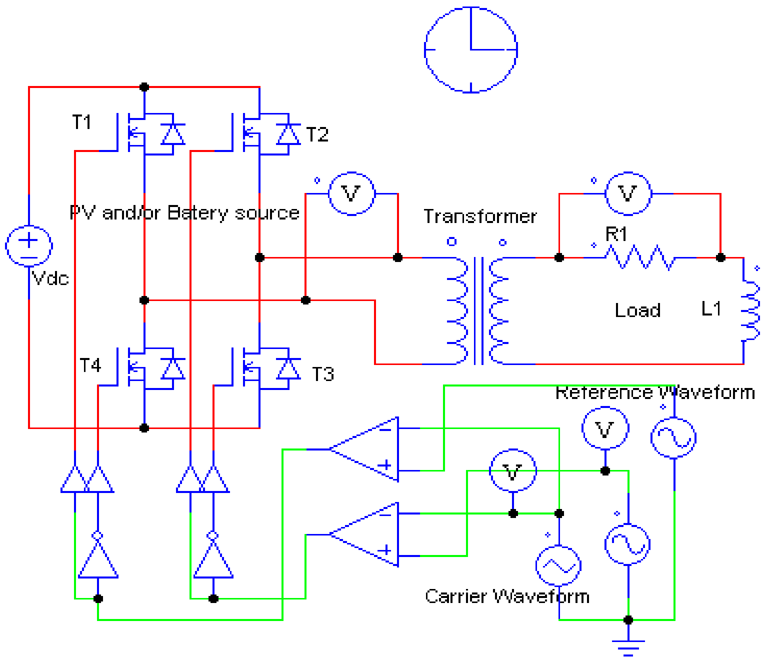

Figure 2. Simulation model of solar (PV) converter.

The PWM control pulses switches on H bridge configured MOSFET power devices [5,6] i.e. T1 - T3 and T2 -T4 alternatively for generating positive and negative half cycle of PWM AC at the output and thus covert DC supply , obtained from integrated input sources i.e PV and/or Battery, into sinusoidal PWM AC supply. Multiple odd number of PWM pulses i.e. N (1 3 5 7…11) per half cycle of a sine wave are generated on comparing a reference sine-wave of 50Hz with a synchronized carrier sine wave having multiple frequency of fundamental frequency (i.e 50Hz) at a modulation index of 0.8 and are optimized for minimum distortion level while tested at different value of N.

The simulated result of relevant wave forms at various test points of the power module circuit and load wave form for typical load is shown in Figure 3.

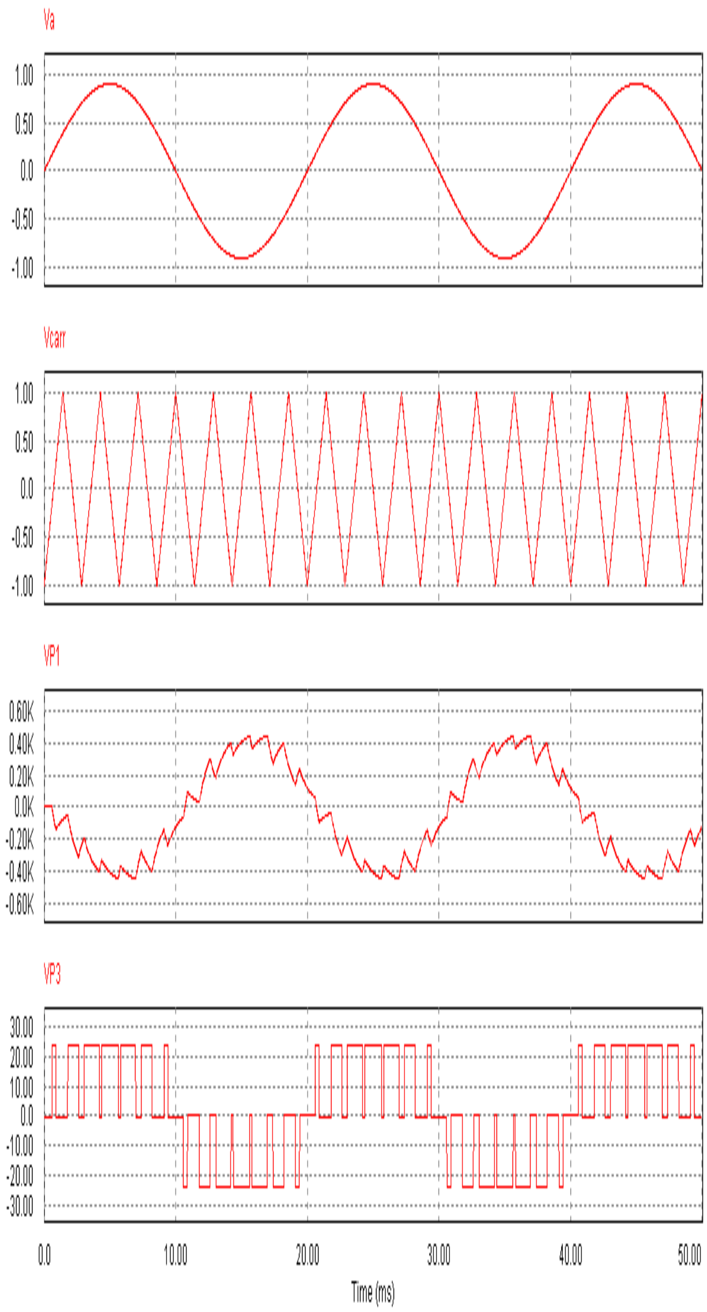

Figure 3. Reference wave 50Hz (First from Top), Carrier wave 550 Hz for N = 7 (Second from Top), Load wave form (Third from Top , Control PWM Pulses (Bottom) X axis = Time (ms) ,Y axis = Amplitude (V).

The FFT waveform at optimized number of PWM pulses, as found for N = 7, is shown in Figure 4. The THD value on computation comes out to be 1.8% at the optimum value of N.

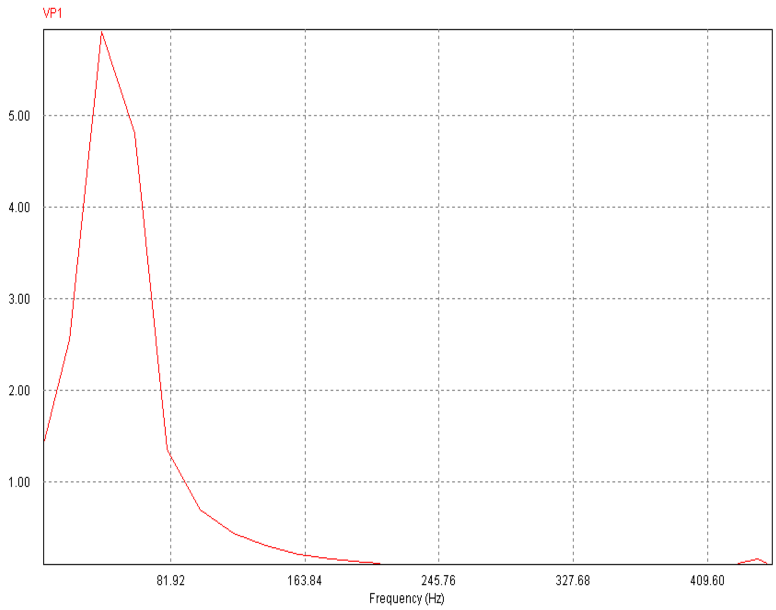

Figure 4. FFT of PWM signal for N = 7 (Number of PWM pulses in one half cycle) X axis = frequency in Hz, Y axis Amplitude in %.

System Components Design

The PV, battery and inverter size is evaluated on the basis of average per day load power requirement by a house [5].

PV Size (W) =
Total load power requirement (W-hr) / (sun hour x $\eta_{pv\ cell}$).

The battery size (Ah) =
Total load power requirement (Wh) / (battery voltage x SOC).

The inverter rating (W) =
Total load power (considering all the loads to be switched on at a time).

The design parameters of system are computed as follows:

PV Size =75 W
Battery size = 150Ah (2 x 80Ah)
Inverter =750 W

Total load watt hour per day = 1800Wh, Load (R = 50 ohm L = 0.8H).

(Assumption: Sun-hour= 6.2h, Efficiency of PV cell ($\eta_{pv\ cell}$) = 0.8, and State of charge of battery (SOC) = 0.8).

Load Power Management

The power delivery to load(s) is governed by the adaptive energy balance equation [5] i.e.

$$P_L = P_{GRID} + (P_{PV} +/- P_{BATTERY})$$

The consistency in load power (P_L) is obtained due to integration of input sources i.e. PV(P_{PV}), grid (P_{GRID}) and battery source ($P_{BATTERY}$). The simulated result of response time on integration of input power sources at step changing of load(s) for getting stabilized output power is shown in Table 1.

Table 1. Load change and response time.

S No.	% Load change	Response Time (ms)
1	0% to 50 %	10 ms
2	50% to 100%	12 ms
3	0% to 100%	12 ms

Conclusion

An attempt has been made to develop a grid assisted solar power converter as a supplementary source of supply. Its physical realization through hardware circuit may bring green electrical revolution especially in rural sector of Indian villages where grid supply is inadequate or almost negligible. This will also have a good socio-economic impact on society. The PWM technique used to convert DC power into grid quality AC power results in minimum loss due to less harmonic component. The optimal number of PWM pulses in positive and negative half cycle in output wave can be approximated to sine-wave. 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.

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