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# A Photovoltaic Uninterruptible Power Supply System Synchronised to the Grid

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**Abstract:** This study presents a pragmatic implementation of photovoltaic Uninterruptible Power Supply (UPS) using battery storage. The system incorporates a 100 W photovoltaic array, a 100 VA power conditioning unit which can operate both in charging and inverting modes and a 25-Ah battery bank. The system can provide uninterruptible power, load voltage stabilization in conditions of voltage or frequency fluctuations beyond tolerable level. The conditioner is desired to give maximum power tracking and power factor correction. A pwm-gate control utilizes multilevel form of output voltage and effectively increases the switching frequency of inverter without increasing the switching frequency of the power semiconductor switches. Simulation studies over inverter output voltage and the output on grid side have been done on MATLAB. The simulation results show that the proposed design can significantly improve power quality of photovoltaic generators.

**Key words:** PV module, irradiation, pulse width modulation, power conditioner

## INTRODUCTION

In India and other developing countries, all the appliances experience severe power shortage and its associated power quality problems. Also the quality of power supply is characterized by large voltage and frequency fluctuations, power cuts (both scheduled and unscheduled) and load peak restrictions. It is extremely perceptible and obvious fact that the gap between power demand and power supply is gradually increasing every year.

This is mainly because of the problem of load shedding in the major cities and also due to power shortage and faults. This has led to the rapid proliferation of battery-inverter sets in rural as well as urban areas. It is known that fuel powered generators lead to severe environmental pollution. They are used in houses, shops and offices when load shedding occurs. A mixture of kerosene and petrol is also used which also results in pollution and gross misuse of the subsidized fuel.

The idea of development and usage of photovoltaic (PV) integrated with conventional power sources has been increased in India and other countries in tropical areas where the heat of the sun can be effectively utilized is the solar power generation sector Nayar (1997). It is also a welcome signal that governments are taking necessary steps to fuel the spread of solar power generation considering the myriad number of advantages and effectiveness of campaigns from environmentalists against use of fossil fuels.

A system to provide uninterruptible power which integrates a PV, battery and inverter has been proposed. This new system includes power conditioning circuit and a charge controller which gives a constant voltage at the battery side irrespective of time.

This study presents a practical implementation of a photovoltaic system incorporates a 100 W photovoltaic array, a 100 VA power conditioning unit which can operate both in charging and inverting modes and a 25-Ah battery bank

## SYSTEM DESCRIPTION

The overall block diagram of the proposed system is visualized as in Fig. 1.

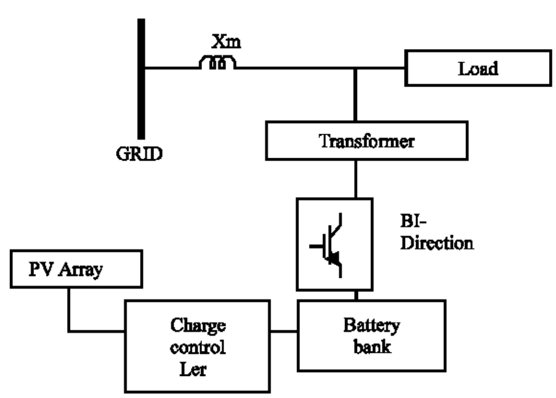


Fig. 1: Block diagram of proposed system

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The grid and converter are separated by a link inductor $X_m$. A charge controller is used to interface the PV array and the battery. It maintains the charging power to the battery and maximizes the power drawn from the PV. The charge controller is a step-up chopper that maintains a constant voltage at the battery side irrespective of the voltage from panel. Changes in voltage across the panel can occur as a result of varying angle at which the sun's ray's fall on the panel Ramkumar and Abouzhar (1993). Sun's intensity varies with passage of time. The load is connected through a transformer across the output terminal of the bi-directional inverter (converter).

When the default supply is available it will supply the necessary active power to the load and the converter will supply the reactive power with minimum power flow cycling through the battery. The load voltage is maintained constant by the converter. The converter has a full bridge configuration using Insulated Gate Bipolar Transistor (IGBT) Mohan *et al.* (1995). Whenever the default supply fails or exhibits intolerable irregularities like frequency surges or voltage black outs it is possible to detect such a situation by means of a potential transformer which acts like sensor and in turn activates the converter circuit to provide the necessary supply to the load.

A dc capacitor C1 is connected to the battery bank. This will regulate the battery voltage when the load requires sudden change of power. The switches Q1 and Q4 are turned ON and OFF simultaneously using sinusoidal Pulse Width Modulation (PWM) technique to generate first half cycle of AC output voltage. The length of the conduction is controlled proportionally to the sine wave magnitude. For the next half cycle, Q2 and Q3 are modulated with the same pattern.

Under normal conditions the battery does not supply any active power but only the reactive power demanded. When the PV array generates electrical power, the converter will automatically deliver the maximum amount of power from the PV to the load. This provides greater economic value when the peak load demand coincides with the availability of maximum sunshine. It also reduces the battery size regardless of PV array size.

## SIMULATION RESULTS

The design is carried out assuming the grid voltage to be $V_m \angle \delta$ and the converter voltage to be $V_c \angle 0^\circ$. The grid current and converter current are respectively, $I_m$ and $I_c$. The link inductor $X_m$ is designed to ensure that the system provides a stabilized converter voltage, $V_c$, of 230 volts when the grid voltage is below or above nominal voltage by 15-25%. The power flow is controlled by varying phase difference (δ) between converter and grid voltage Rahman *et al.* (1993).

Fig. 2: PWM output pulses

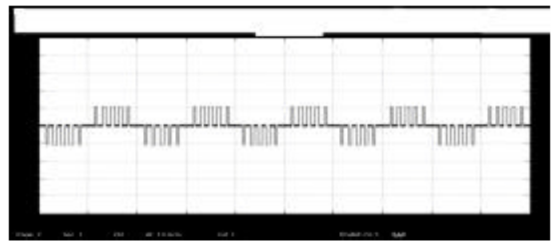

Fig. 3: Inverter output voltage

The simulation consists of applying a 24 V dc at the inputs of a bridge converter that uses an Insulated Gate Bipolar Transistor (IGBT). The pulses that turn the IGBT ON and OFF alternatively are given from a PWM generator where the modulation index is specified.

$$\text{Modulation Index} = A_r/A_c$$

$A_c$- Amplitude of carrier wave

$A_r$- Amplitude of carrier wave

A modulation index of 0.5 is found to be optimal. Again, for an optimal design the frequency of carrier signal is kept higher that five times the supply frequency and so 300 Hz is taken as carrier frequency since the input frequency is 50 Hz Nayar and Ashavo (1998). The modulating signal is generated internally and no separate source is required. Figure 2 shows the PWM pulses generated. Since a 2 arm bridge is used there are 4 pulses as can be seen from the Fig. 2.

The output of the bridge converter is connected to a 24/230V step up transformer. This is then connected to the grid. The inverter output voltage is shown in Fig. 3.

Figure 4 shows the output voltage across the load when the system is not driving power from the grid. The output seen here in Fig. 4 and 5. include the fundamental as well as harmonic components and hence the pulses. The voltage across the inverter is stepped up by 9.58 times at the output and is available across the load.

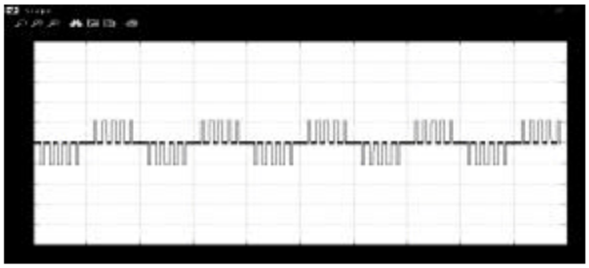

Fig. 4: Voltage across the load after being stepped up

Fig. 5: The fundamental component of output voltage

The currents are also transferred to the load side by the transformer and a current of 0.5A is obtained on the load side. The inverter along with a charge controller and a few other elements perform the function of power conditioning.

A power conditioner is designed to perform the following tasks,

- It should meet the reactive power during normal conditions and this improves the power factor of the grid system Boegli and Wmi (1986).
- Under fluctuating voltages during early evening and over voltage conditions of grid (especially during midnight) the power conditioning maintains constant voltage of 230 V at the load.
- Whenever the voltage output from the solar panel varies the charge controller maintains a constant voltage output of 24 V at the battery bank.

The Fig. 5. shows the fundamental frequency component of the voltage output across the load when the higher frequency components have been eliminated using filter circuits designed with filters of appropriate values. Also the number of turns in the transformer and the reactance and resistance of the transformer have been designed based on the requirement of voltage transfer.

The outputs indicate an improved power factor. They also hint a considerable reduction in Total Harmonic Distortion (THD). These calculation can be found using the grid current which is given by

$$I_m = V_m \angle \delta - V_c \angle 0^{o)} / X$$

## CONCLUSIONS

A photovoltaic uninterruptible power supply synchronized to the grid is presented in this paper. It can be seen from the simulation results that the system is able to effectively stabilize the load voltage against fluctuations in voltage from the grid. The improvement in power factor and the reduction in Total Harmonic Distortion are also significant.

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