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Simulation and Analysis of Solar PV System with Boost Converter for Load management

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Abstract
Photo energy conversion is a direct conversion that allows the generation of electricity by photovoltaic cells. Now-a-days studies on photovoltaic system are extensively increasing due to energy crisis and increasing pollution. Solar power causes no greenhouse gas emission and is pollution free. It also reduces dependence on foreign oil and fossil fuels. This paper aims at the priority based power supply to the load and simulation of a DC-DC boost converter. The high step-up DC-DC converter converts low voltage to high voltage. The energy obtained from the dc-dc converter is stored in the battery, then, power distribution is done based on load priority. The demand for the electricity on power grid can be monitored and controlled by applying a priority based load supply. The simulation results based on MATLAB simulation are presented.

Keywords: *Solar PV, DC_DC Converter, load management.*

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I. INTRODUCTION

The environmental problems on the global warming and because of the fast exhaustion of the fossil fuel renewable energy sources are used. These sources are wind energy, geo-thermal, photovoltaic, hydro and fuel cells. In this direction, the use of solar energy is gaining importance among researchers. Solar PV has specific advantages as an energy source: once installed, its operation generates no pollution and no greenhouse gas emissions. A single phase high step up converter to boost the relatively low photovoltaic voltage to a high voltage with improved efficiency is presented in this paper. In this direction, MPPT technique is useful to develop load management strategy according to their priority. Use of intelligent control techniques/algorithms for solar PV - Load is expected to play a vital role in the implementation of Smart Grid. Proper grid support functions can be suggested based on the prototype model.

The problem of global warming and exhaustion of fossil fuel will tend to increase in the usage of renewable energy sources[1].The utilization of renewable energy sources as gained more interest due to the advancement in technologies. The distributed PV generation systems have received increasing popularity in the residential areas .Solar energy is considered as one of the most reliable, daily available, and environment friendly renewable energy source [2].

Solar energy is considered as one of the most reliable, daily available, and environment friendly renewable energy source. All PV modules provided in markets gives 12 or 24V (2 to 5 A) but load requirements need higher voltages so boost converter is needed. Therefore many researches concentrate on small size PV system, which is desired for the low power and high efficiency applications. In the low power PV system the transformer less configuration has become a widespread tendency due to its higher efficiency, smaller size, lighter weight and lower cost compare with the isolated counterparts [3]. These converters are the simplest and widely used in computers, DC motor drives, office and home equipments etc but mostly for power factor correction. The conversion of voltage in boost converters is done by changing the duty cycle of the switches in the circuit[4].The concept of increasing the voltage by using DC-DC converter solves this issue. They reduce losses, improve efficiency and provide power supply based on their priority of load. This conversion system provides regulated power supply [5].

However, their potentially high cycle life, calendar life, power capability and safe operation can be reached only if they are managed correctly. Besides the exact monitoring of each individual cell's voltage, current, and multiple temperature measurement points, active charge balancing is fundamental [6].Machine learning algorithm will be used for load management by automation of switchover based on priority. Load management plays an important role in planning and operation of power system. As these algorithms are for, suggesting optimized human like decisions [7-8].The Forecasting load demand at the substation level is generally more difficult and less accurate compared to forecasting total system load demand. As the proposed agency can be the consumer's key to take advantage of a DSM program automatically. To effectively deal with these changes, energy providers and consumers alike require new levels of capability for management and control of their energy systems[9].A new control strategy involves the decisions for the dynamic charge-discharge transactions in the energy storage systems like battery and pumped hydro (PH) units connected to the smart micro grid in order to maintain a real time balance of generation and load[10].The PWM inverters have been usually used for interfacing the renewable energy source to the utility grid. It should operate in grid-connected operation mode and islanding operation mode [11]. This paper aims at; to maximize the use of solar energy for priority load change based on the stored energy in the battery.

1.1 METHODOLOGY

The solar energy is efficiently converted into electrical energy. For that PV panels are used, which when exposed to light are capable of producing electricity without any harm to the environment or device. MPPT is a method of tracking the point in which maximum power is produced from PV panels. MPPT controller is used to extract maximum power from the PV panels. Then the generated power is provided as input to the DC boost converter. The boosted voltage is supplied to loads through batteries. The block diagram of the proposed work is shown in Fig. 1. Maximum Power Point Tracking(MPPT) and Perturb and Observe method implemented in [2,4-5] are used for further implementation of the proposed load management strategy.

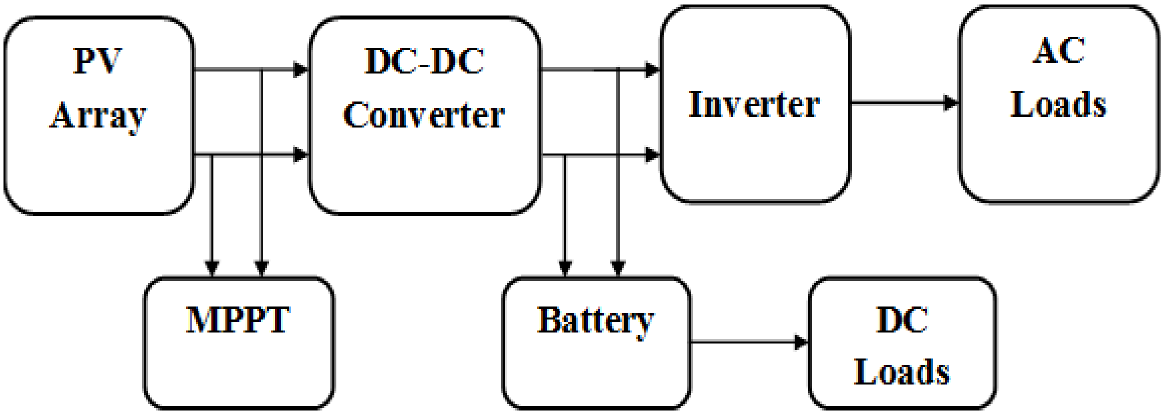

Figure 1: Block Diagram of solar PV system for load management.

1.1.1 Dc Boost Converter

Boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage while stepping down current from its input to its output load. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

1.2 DESIGN EQUATION OF BOOST CONVERTER

The parameters considered for Boost Converter are, Vin= 218.8 volts, R = 50Ω, f = 5 kHz and Duty cycle = 0.5.

$$Vout = \frac{V_{in}}{(1-D)} \quad (1)$$

$$L = \frac{(1-D)^2 * R}{2f} \quad (2)$$

$$C = \frac{D * V_O}{V_{ref} * r * f} \quad (3)$$

1.3 LOAD MANAGEMENT

The load connected to supply are divided into three sections, i.e. high priority (H.P), Medium load (M.P) and low priority (L.P) and is controlled through switch. To reduce the load demand on power grid, one can use solar panels to produce electricity. Priority based method can be applied to all of the energy source power generation. It is a useful power supply method and can be implemented by many other methods. This is shown in Fig. 2.

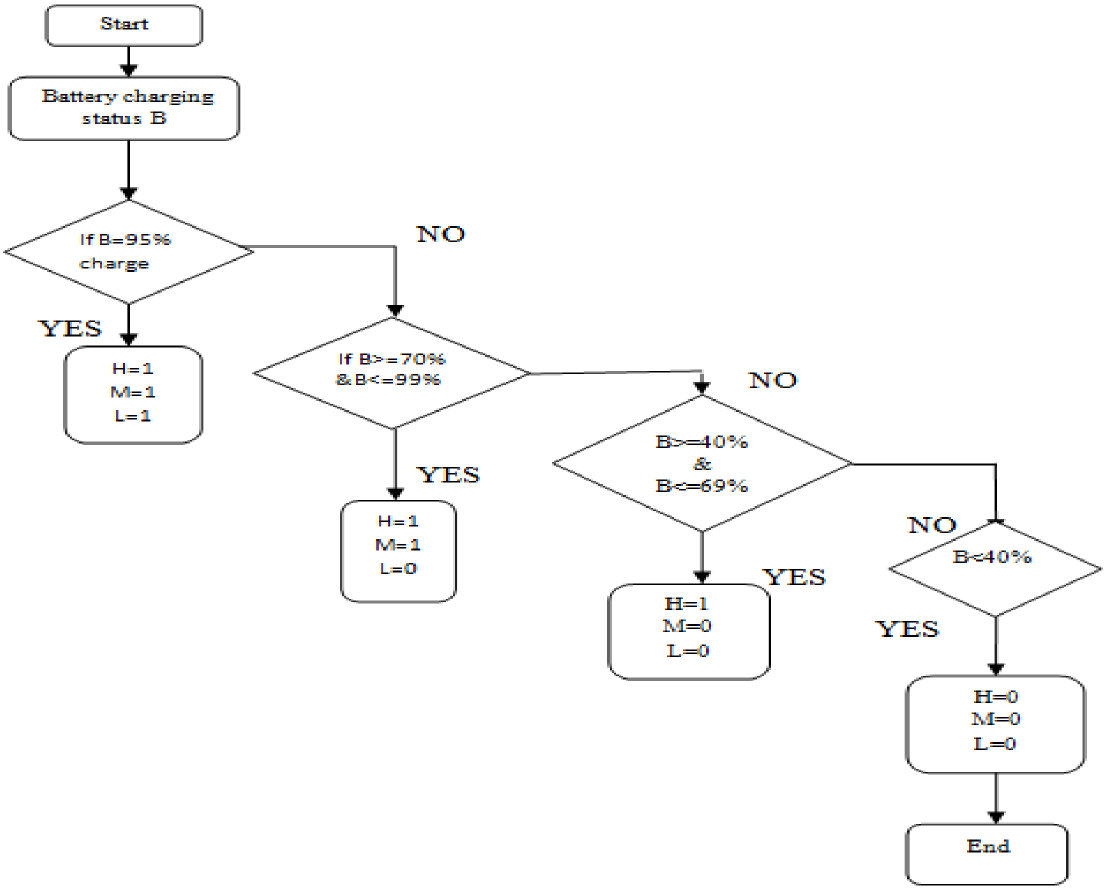

Figure 2: Flow chart for Priority based load management.

II. RESULTS AND DISCUSSIONS

In this section, the results obtained by applying priority based load management for given loads are discussed. Various results obtained are discussed in the following sections.

2.1 SIMULATION RESULTS OBTAINED FROM PV ARRAY

The reported work is carried out for the standard test conditions of 1000W/m^2 and 25 degree Celsius. For the different irradiations with temperature constant, the readings are tabulated. By increasing irradiations, the solar panel output voltage is increased as shown in Table 1. By increasing the temperature the solar panel output voltage is getting reduced as depicted in Table 2.

Table 1: Varying irradiations and keeping temperature constant.

Irradiation in w/m^2	Solar Panel Output (Volts)	Boost Converter output (Volts)
700	215.6	427.3
800	216.8	429.8
900	217.8	431.9
1000	218.8	433.9
1100	219.6	435.6
1200	220.2	437.2
1300	221	438.6

Table 2: Varying temperature and keeping irradiance constant.

Temperature	Solar Panel Output (Volts)	Boost Converter output (Volts)
21	221.5	439.3
22	220.5	438
23	220.1	436.6
24	219.4	435.2
25	218.8	433.9
26	218.1	432.5
27	217.4	431.2
28	216.7	429.8

29	216	428.4
30	215.3	427.1
31	214.6	425.7
32	214	424.3

The simulation model is obtained for 100W solar panel. For 100W solar panel, the open circuit voltage is 22V, short circuit current is 6.06A, number of cells connected per module is 72.Since the output voltage for each PV module is expected to be 22V, 10 PV modules are connected in one string. From the simulated results, the output voltage obtained from the PV array is 218.8V. The output voltage from the PV array is fed as input to the boost converter to obtain a boosted voltage with a magnitude higher than that of the initial fed voltage.

2.2 MAXIMUM POWER POINT TRACKING (MPPT):

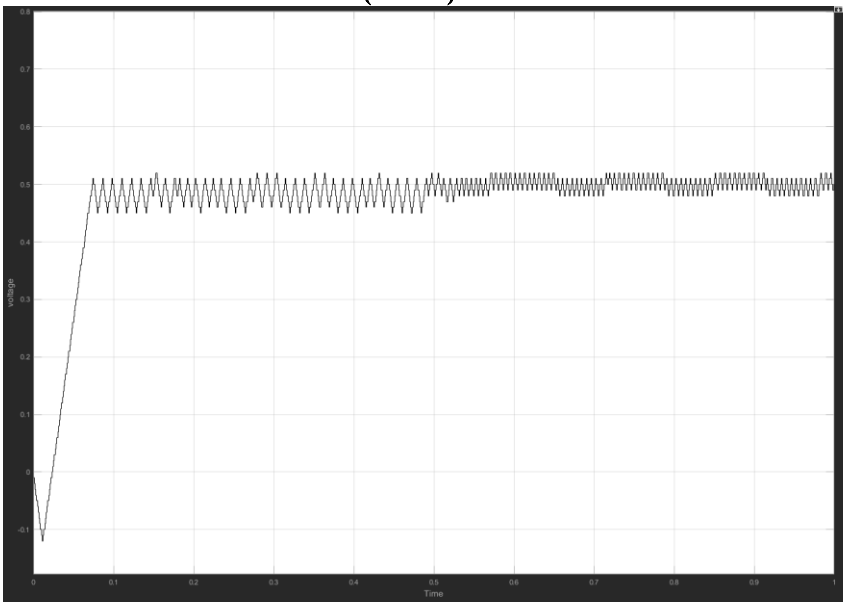

Figure 3: simulation result of MPPT.

2.3 DC-DC BOOST CONVERTER:

In a boost converter, the output voltage is always higher than the input voltage. When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive. When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (meaning the left side of the inductor will become negative). As a result, there will be higher voltage to charge the capacitor through the diode D.

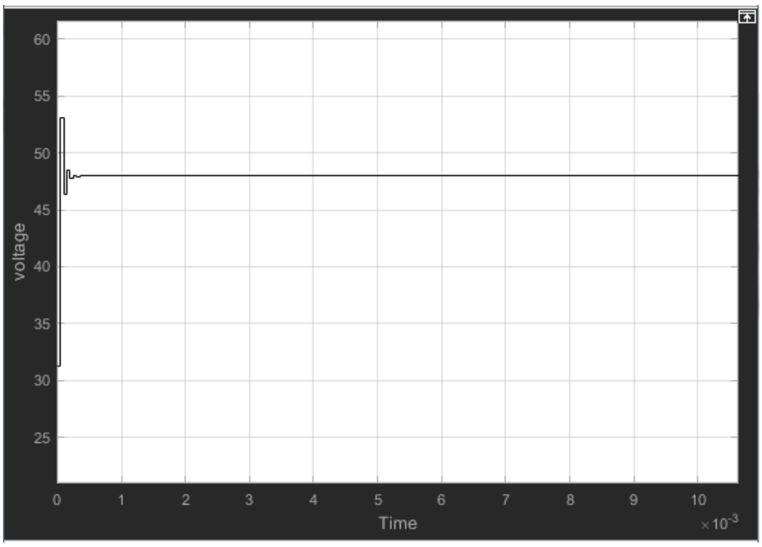

Figure 4: simulation result of DC-DC boost converter.

The output voltage of solar panel is given as input to the boost converter, here the voltage is boosted to 433.9V. The output voltage verses time waveform is shown in figure 3 and 4.

2.4 SIMULATION RESULTS OBTAINED FOR BATTERY CHARGING

Lithium ion (Li-ion) battery packs are the preferred power source for handheld devices due to their small size and light weight. Li-ion battery packs have no "memory effect" (also known as voltage depression) , common in older cell chemistries. With a higher energy density than Nickel-based battery packs and a low self discharge rate, Li-ion battery packs have revolutionized the design of portable devices that were previously restricted by power source size, weight, and run-time limitations. It provides theHigh energy density - potential for yet higher capacities. Relatively low self-discharge - self-discharge is less than half that of nickel-based batteries. The output voltage of boost converter is given to the battery. The battery is used to store the energy. The voltage we are getting is 692.9V. The figure 5 & 6 shows the voltage, current, state of charge (SOC) waveforms of the battery.

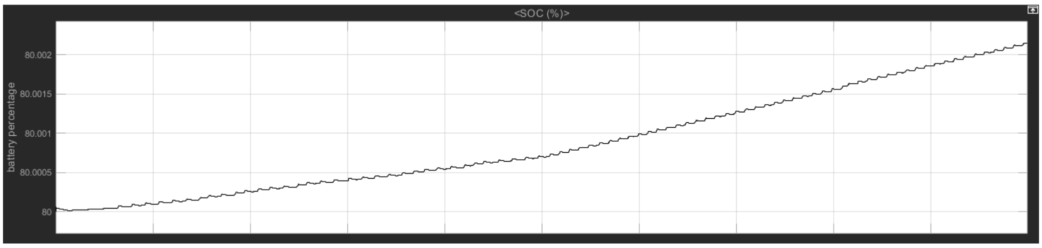

Figure 5: simulation result of battery Charging.

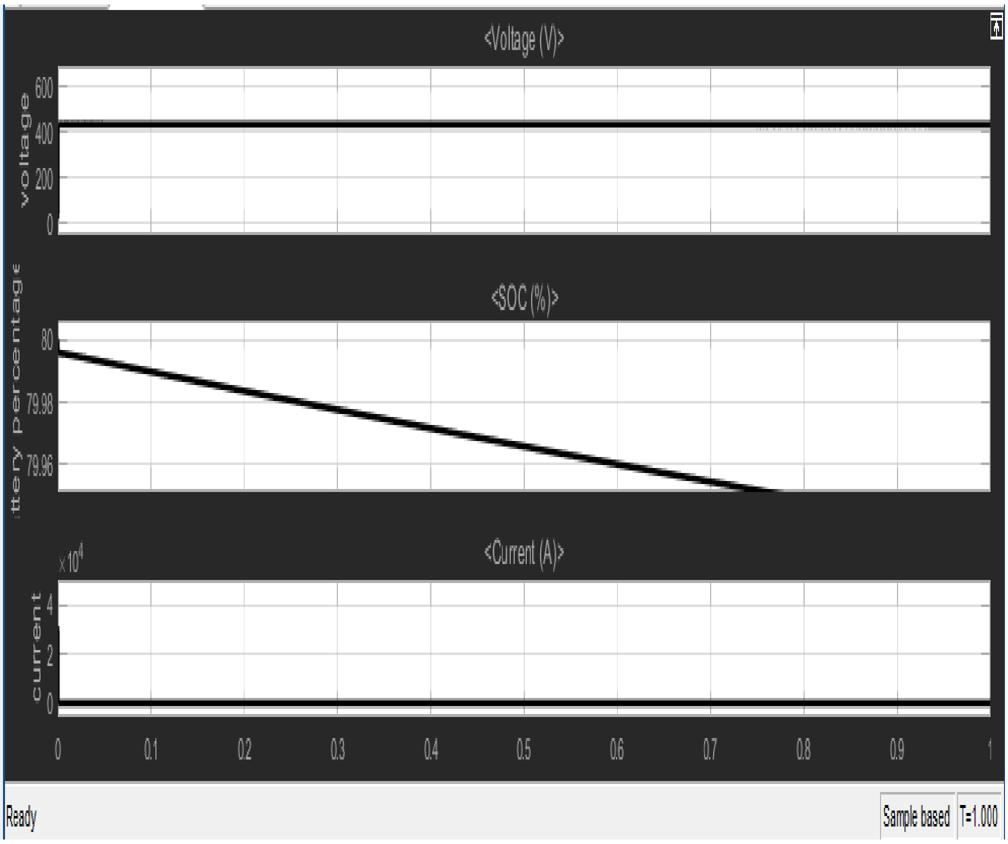

Figure 6: simulation result of battery Discharging.

2.5 SIMULATION RESULTS OBTAINED FROM INVERTER

The output from the DC-DC boost converter is fed to the three-phase inverter. The output from this inverter is fed to be a three phase balanced load. Its three arms normally delayed by an angle of 120 0 so as to generate a three-phase AC supply. It is most suitable for a delta connection in a load because it results in a six step type of waveform across any of its phases.

2.6 SIMULATION RESULTS OBTAINED FROM PRIORITY BASED LOAD MANAGEMENT

The stored energy in the battery is given to the loads based on their priority. Here we are diving loads into three types such as High load, Medium load and Low load. The simulated model of solar PV system with DC-DC boost converter for priority based load management is obtained in figure 7. Here we are showing the output waveform of load current for all the loads in figure 8. Based on the condition the current will be flowing to the particular loads

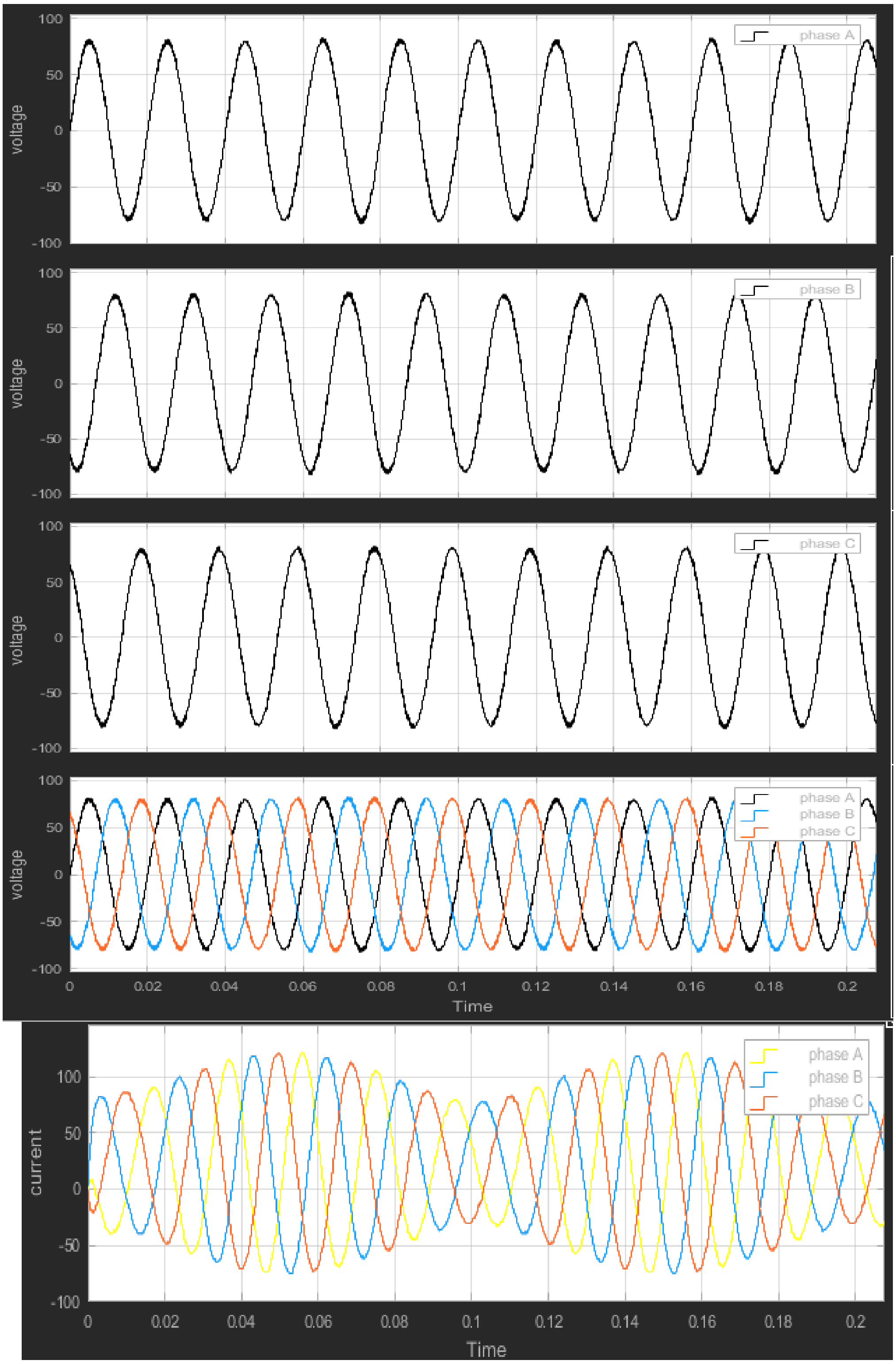

Figure 7: simulation result of Inverter.

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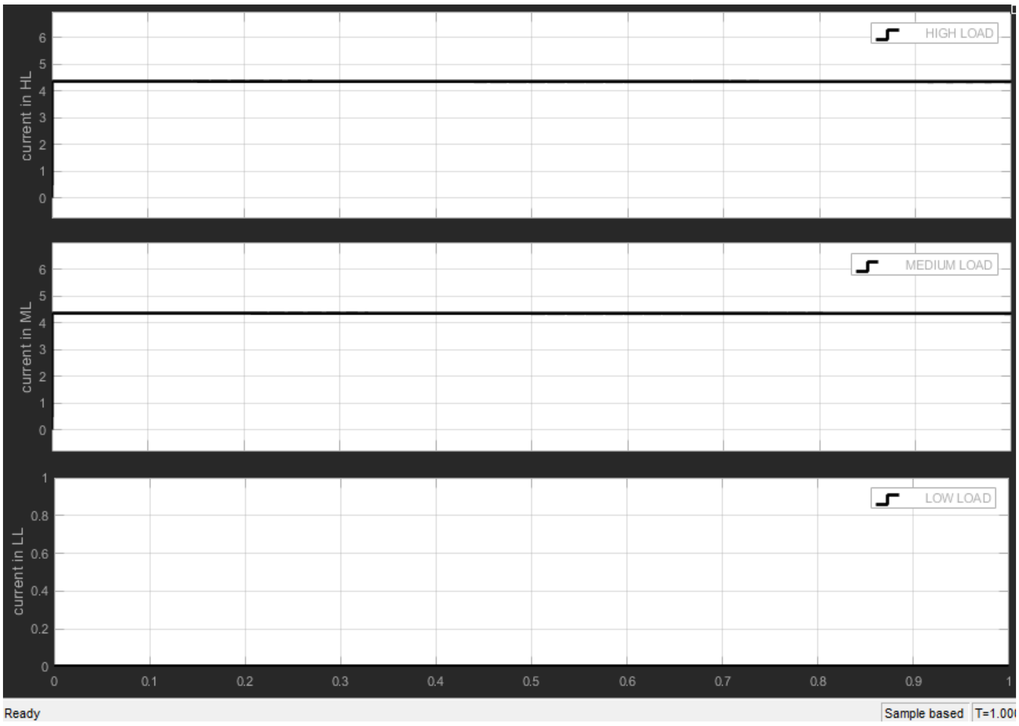

Figure 8: simulation result of priority based load management.

III. CONCLUSIONS

The simulation model of the dc-dc Boost converter connected to load through battery is presented. The application of load management based on priority load control techniques play an important role in the present electrical energy scenario in India. Injecting the PV power to the DC-DC boost converter to boost the voltage to the load management system with the available battery charging capacity of switching operation based on MATLAB/ Simulink program. The technique carried out in this work is effective in identifying maximum power point.

The project implements the design of a system by which we can control the load through voltage charging status of battery through switchover operation in MATLAB simulink program. Using MATLAB simulation tool, we can establish the link between load and battery. Load management according to convenience is possible. This efficient high step-up DC-DC converter is used to get the high voltage gain.

The residential, Commercial, Industrial, Municipal are different sectors which consumes power.. Therefore reducing their consumed power during all time for all load with the efficient use of battery power. The next step of this work is to adopt the simulation based program in realistic conditions. It can be a very efficient technique for energy conservation. An attempt is made in this paper to develop load management control, that reduces the power consumption from grid by effectively switching the loads between grid and renewably energized local storage.

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