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Power Management Strategy in parallel connected PV arrays by Integrating Buck boost converter with Single phase Bidirectional Inverter

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Abstract—In this project is to develop a MPPT based power management system for parallel connected PV arrays by integrating buck-boost dc-dc converter with single phase inverter. The V-I characteristic of PV array is nonlinear in which the voltage decreases with increase in current. The decrease in voltage is less until a peak point and after the peak point voltage decreases drastically. Since power is product of voltage and current, considerable output power is possible until the peak point and after the peak point the power output will be very low. In order to draw maximum power from PV panels a number of MPPT (Maximum Power Point Tracking) algorithms are developed, in which the power is drawn as long as the voltage is above peak value. When the voltage goes below peak value the PV array is disconnected for a small duration and the voltage is allowed to rise and then reconnected when the voltage attains a specified value which is above the peak value. In the proposed system the output voltage of two PV arrays are individually boosted/bucked to a high dc voltage and interfaced to a dc bus. When the PV array voltage is lesser than bus voltage boost operation is performed and when it is greater buck operation is performed. A bidirectional inverter is also interfaced to dc bus which is used for energy transfer from dc bus to ac grid and vice versa. When the dc power is excess, the inverter is used to convert excess dc power to ac power and inject to grid, and when there is deficiency in dc power the inverter is used to convert ac power to dc power and supply to dc bus. Simulation results are verified using MATLAB/SIMULINK Software.

Keywords- Boost converter, solar panel, dc link voltage control, voltage source inverter

I. INTRODUCTION

One of the major concerns in the power sector is the day-to-day increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard. The continuous use of fossil fuels has caused the fossil fuel deposit to be reduced and has drastically affected the environment depleting the biosphere and cumulatively adding to global warming. Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to power rural areas where the availability of grids is very low. Another advantage of using solar energy is the portable operation whenever wherever necessary. In order to tackle the present energy crisis one has to develop an efficient manner in which power has to be extracted from the incoming solar radiation. The power conversion mechanisms have been greatly reduced in size in the past few years. The development in power electronics and material science has helped engineers to come up very small but powerful systems to withstand the high power demand. Among the various power electronics converter, boost converter

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has an important role to extract he power from renewable energy sources. Photovoltaic (PV) offers an environmentally friendly source of electricity, of which the fuel is sunshine, a renewable energy. To date, this way of electricity generation, however, has been relatively costly. Very often, the success of a PV application depends on whether the power electronics device can extract sufficiently high power from the PV arrays to keep overall output power per unit cost low. The maximum power point tracking (MPPT) of the PV output for all sunshine conditions, therefore, becomes a key control in the device operation for successful PV applications. The MPPT control is, in general, challenging, because the sunshine condition that determines the amount of sun energy into the PV array may change all the time, and the current voltage characteristic of PV arrays is highly nonlinear.

A PV system for the grid-connected applications is typically composed of five main components: 1) a PV array that converts solar energy to electric energy, 2) a dc-dc converter that converts low dc voltages produced by the PV arrays to a high dc voltage, 3) an inverter that converts the high dc voltage to a single- or three-phase ac voltage, 4) a digital controller that controls the converter operation with MPPT capability, and 5) a ac filter that absorbs voltage/current harmonics generated by the inverter. The main technical requirements in developing a practical PV system include a) an optimal control that can extract the maximum output power from the PV arrays under all operating and weather conditions, and b) a high performance-to-cost ratio to facilitate commercialization of developed PV technologies. Since the PV array has a highly nonlinear characteristic, and its performance changes with operating conditions such as isolation or ambient temperature, it is technically challenging to develop a PV system that can meet these technical requirements.

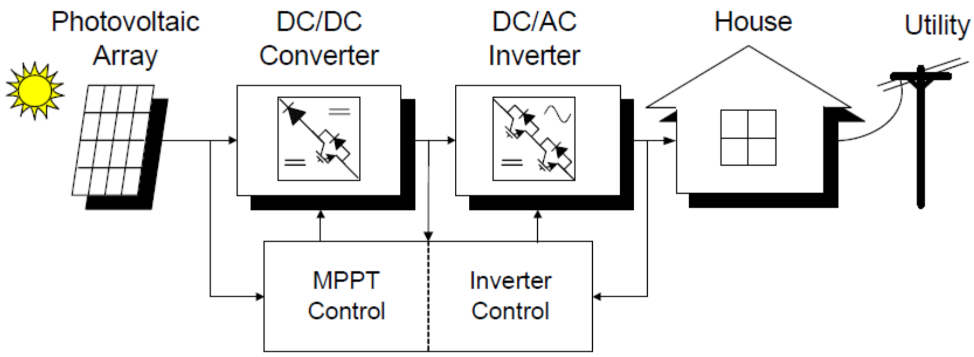

Fig.1. Photovoltaic power system

This project proposes a new method for the MPPT control of PV systems. This method uses one estimate process for perturb processes in search of the maximum PV output.

II. OPERATION AND ANALYSIS OF THE PROPOSED BUCK/BOOST MPPTS

Many types of renewable energy, such as photovoltaic (PV), wind, tidal, and geothermal energy, have attracted a lot of attention over the past decade. Among these natural resources, the PV energy is a main and appropriate renewable energy for low-voltage dc-distribution systems, owing to the merits of clean, quiet, pollution free, and abundant. In the dc-distribution applications, a power system, including renewable distributed generators (DGs), dc loads (lighting, air conditioner, and electric vehicle), and a bidirectional inverter, is shown in Fig. 1, in which two PV arrays with two maximum power point trackers (MPPTs) are implemented. However, the i–v characteristics of the PV arrays are nonlinear, and they require MPPTs to draw the maximum power from each PV array. Moreover, the bidirectional inverter has to fulfill grid connection (sell power) and rectification (buy power)with power-factor correction (PFC) to control the power flow between dc bus and ac grid, and to regulate the dc bus to a certain range of voltages, such as 380 ± 10 V. Nowadays, a conventional two-stage configuration is usually adopted in the PV inverter systems. Each MPPT is realized with a

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boost converter to step up the PV-array voltage close to the specified dc-link voltage, as shown in Fig. 2.

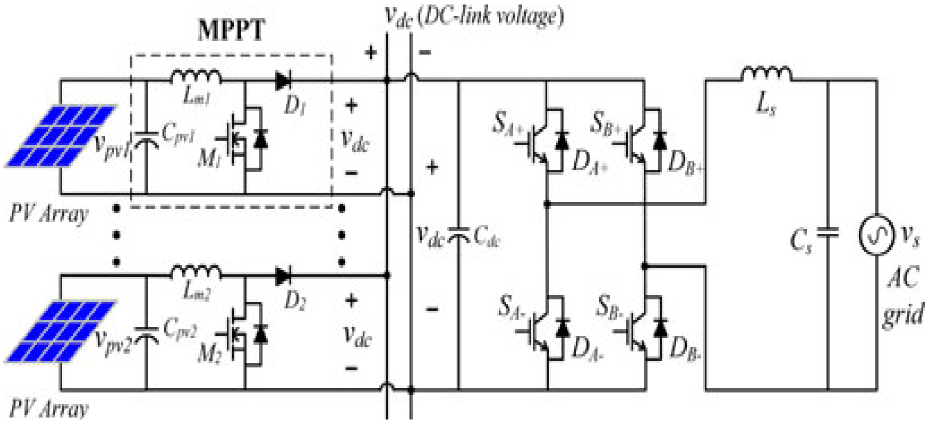

Fig. 2. Conventional two-stage PV inverter system with boost-type MPPTs.

The boost converter is operated in by-pass mode when the PV-array voltage is higher than the dc-link voltage, and the inverter will function as an MPPT. However, since the characteristics of PV arrays are different from each other, the inverter operated in by-pass mode cannot track each individual maximum power point accurately, and the inverter suffers from as high-voltage stress as the open voltage of the arrays. array is essential in a PV system. An MPPT based power management system for parallel connected PV arrays by integrating buck-boost dc-dc converter with single phase inverter is shown in Fig.2. In the proposed system the output voltage of two PV arrays are individually boosted/bucked to a high dc voltage and interfaced to a dc bus. When the PV array voltage is lesser than bus voltage boost operation is performed and when it is greater buck operation is performed.

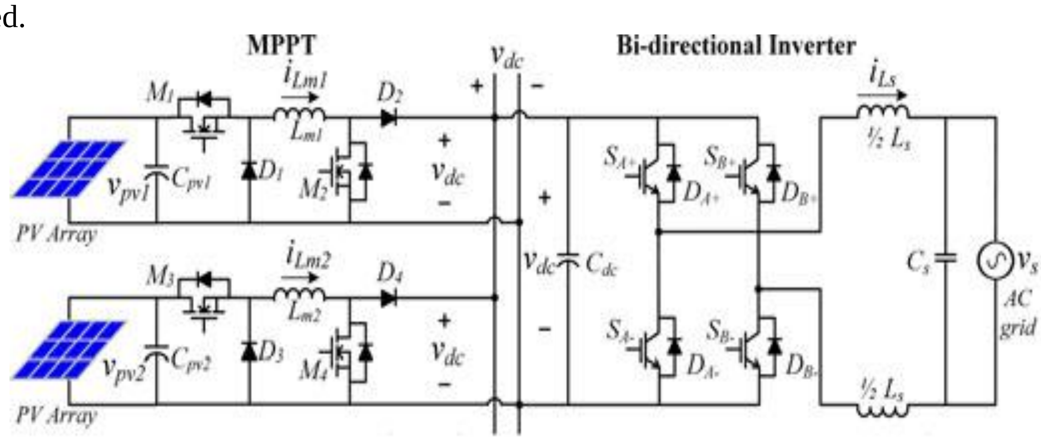

Fig.3. Configuration of the studied PV inverter system with the buck/boost MPPTs.

During boost operation, a LC-circuit with high quality factor (Q-factor) is employed to amplify the dc input voltage to required high voltage level. Here, a MOSFET power switch is employed to make and break a high current pulse through the inductance. When current is made to flow through inductance, energy is stored in inductance and when this current is cut the stored energy in inductance is transferred to capacitance, which results in a high voltage across capacitor and this high voltage is filtered and fed to dc-bus. During buck operation, the high dc voltage is chopped by using a MOSFET power switch in series with a source and then the resultant pulsating dc is filtered and fed to dc-bus.

A bidirectional inverter is also interfaced to dc bus which is used for energy transfer from dc bus to ac grid and vice versa. When the dc power is excess, the inverter is used to convert excess dc

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power to ac power and inject to grid, and when there is deficiency in dc power the inverter is used to convert ac power to dc power and supply to dc bus.

By the MPPT topology is formed from a buck converter and a boost converter but with a shared inductor to accommodate wide PV-array voltages from 0 to 600 V. For various PV-array applications, the two MPPTs will be connected separately or in parallel. The MPPT senses PV voltage v_{PV}, dc-bus voltage vdc, and inductor current i_{Lm} to determine operational mode and duty ratio for tracking the maximum power point accurately.

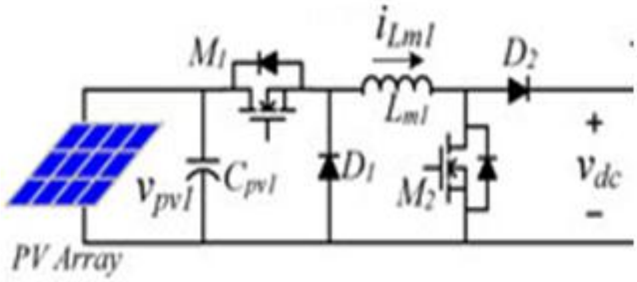

Fig.4 MPPT Buck Boost Converter

When voltage V_{PV} is higher than vdc, the MPPT is operated in buck mode, and switch M1 is turned ON to magnetize inductor Lm and thus increase inductor current i_{Lm}. While switch M1 is turned OFF, inductor Lm releases its stored energy through diodes D1 and D2 . On the other hand, the MPPT is operated in boost mode when voltage vPV is lower than vdc, and switches M1 and M2 are turned ON to magnetize inductor Lm. While switchM2 is turned OFF, inductor Lm releases its stored energy through diode D2 . Thus, the control laws can be expressed as follows:

$$d_{\text{buck}} = \frac{v_{\text{dc}}}{v_{\text{PV}}} \text{ (for buck mode)}$$

$$d_{\text{boost}} = \frac{v_{\text{dc}} - v_{\text{PV}}}{v_{\text{dc}}} \quad \text{(for boost mode)}.$$

To draw maximum power from PV arrays, a perturbation and observation control algorithm for tracking maximum power points is adopted. The perturb-and-observe method, also known as perturbation method, is the most commonly used MPPT algorithm in commercial PV product. This is essentially a "trial and error" method. The PV controller increases the reference for the inverter output power by a small amount, and then detects the actual output power. If the output power is indeed increased, it will increase again until the output power starts to decrease, at which the controller decreases the reference to avoid collapse of the PV output due to the highly non-linear PV characteristic. Perturb-and-observe (P&O) method is dominantly used in practical PV systems for the MPPT control due to its simple implementation, high reliability, and tracking efficiency. It shows the flow chart of the P&O method. The present power *P(k)* is calculated with the present values of PV voltage *V(k)* and current *I(k),* and is compared with the previous power P(k-1). If the power increases, keep the next voltage change in the same direction as the previous change. Otherwise, change the voltage in the opposite direction as the previous one.

` The proposed regulation mechanism is similar to the concept of the adaptive voltage position (AVP) method, but it is more like a droop one. In the discussed dc-distribution system, for reducing dc-bus capacitance and mode-change frequency, a droop dc-bus-voltage regulation mechanism is proposed, in which the dc-bus voltage is regulated according to the inductor current linearly. When the bidirectional inverter sells higher power, which means less load-power requirement, the dc-bus voltage will be regulated to a higher level. If there is a heavy step-load change suddenly, this mechanism can avoid a voltage drop below 380 V abruptly and it will not change the operation mode from grid connection to rectification, or can avoid under voltage protection. On the other hand, when the bidirectional inverter buys higher power, the dc-bus voltage is regulated to a lower level,

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reducing the frequency of mode change, and thus, reducing the dc-bus capacitance around 15%. proposed single-phase bidirectional inverter, which can fulfill either grid-connection mode or rectification mode with PFC. The proposed bidirectional inverter, is a full-bridge configuration, which can fulfill grid connection and rectification with PFC.

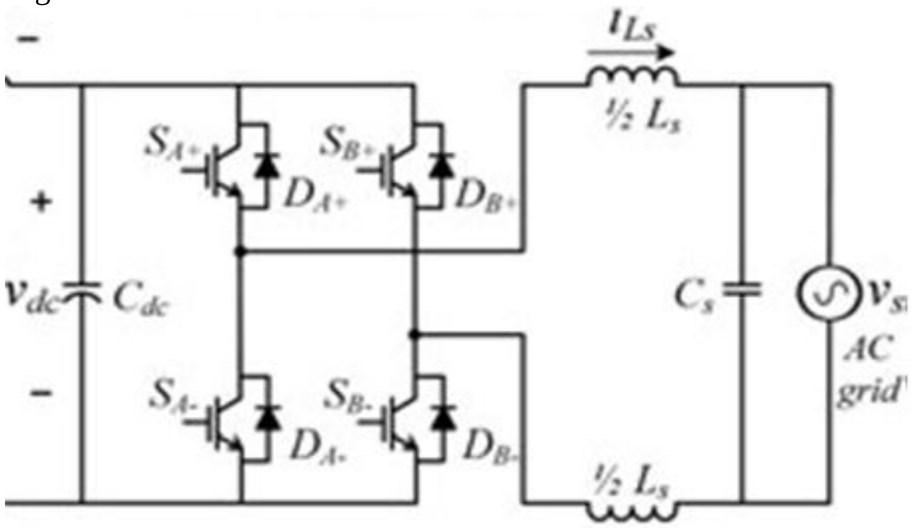
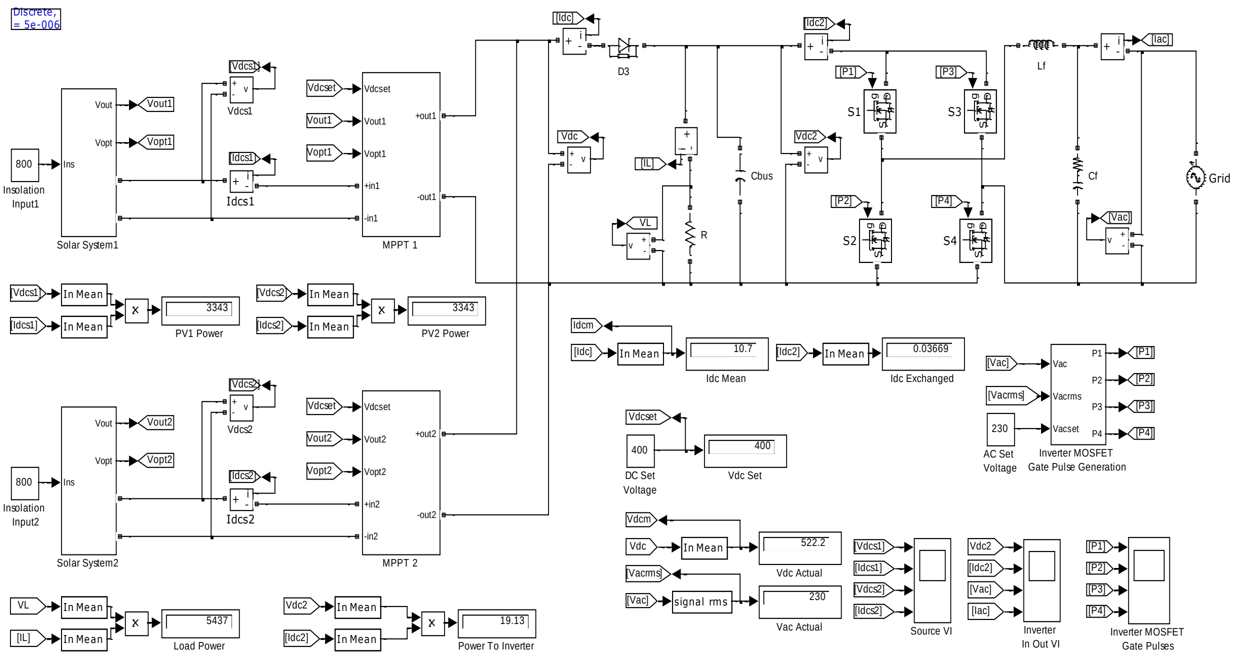


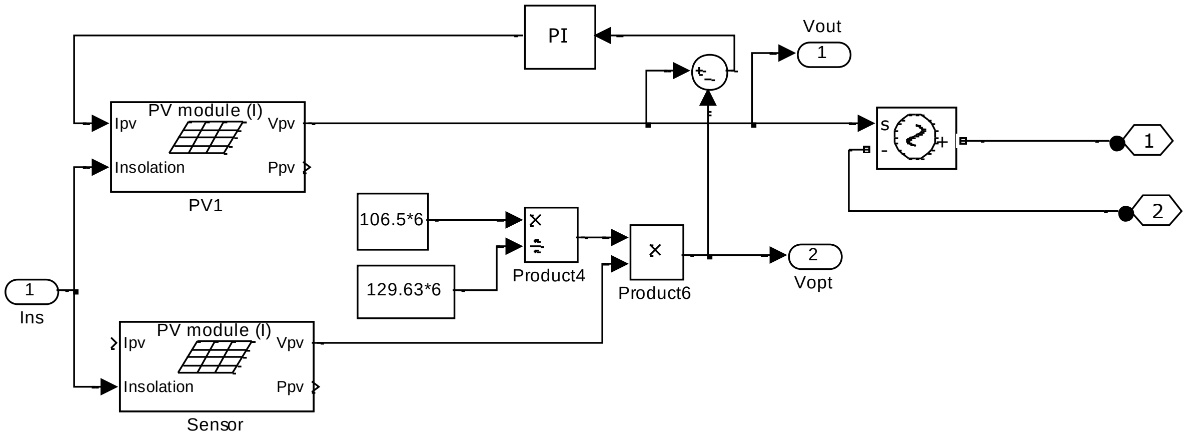
Fig. 5 Bidirectional Inverter

The inverter senses dc-bus voltage *v*dc, line voltage *vs* , and inductor current *iLs*, and uses the variable inductance, which is a function of inductor current, obtained with self-learning algorithm to determine the control for operating the inverter stably. When the output power from PV arrays is higher than load requirement, the dc-bus voltage increases; thus, the inverter is operated in grid-connection mode to inject the surplus power into ac grid. On the other hand, the inverter is operated in rectification mode with PFC to convert ac source to replenish the dc bus.

III. SIMULATION AND EXPERIMENTAL RESULTS

To verify the feasibility of the proposed strategy, simulations is carried out.

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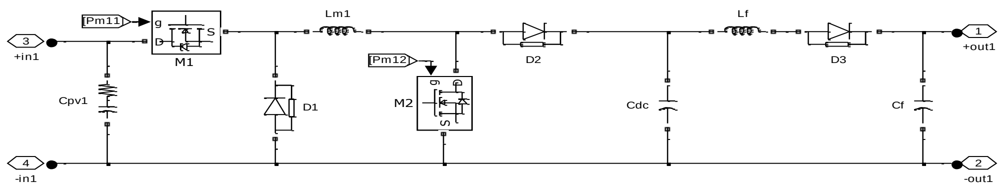
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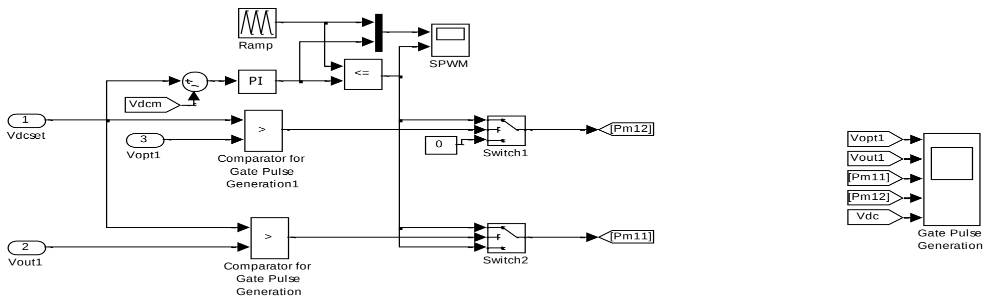
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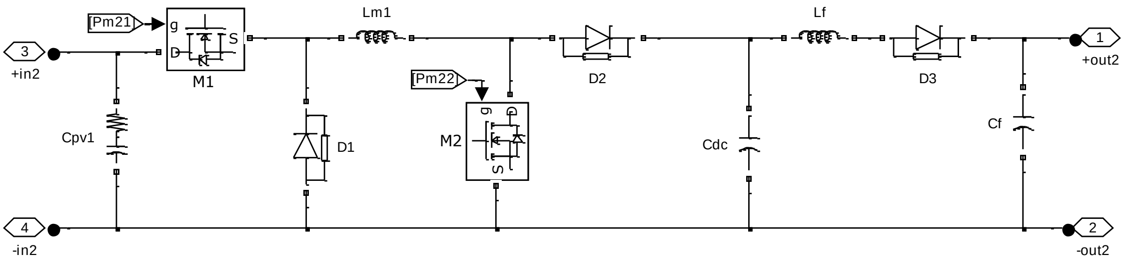
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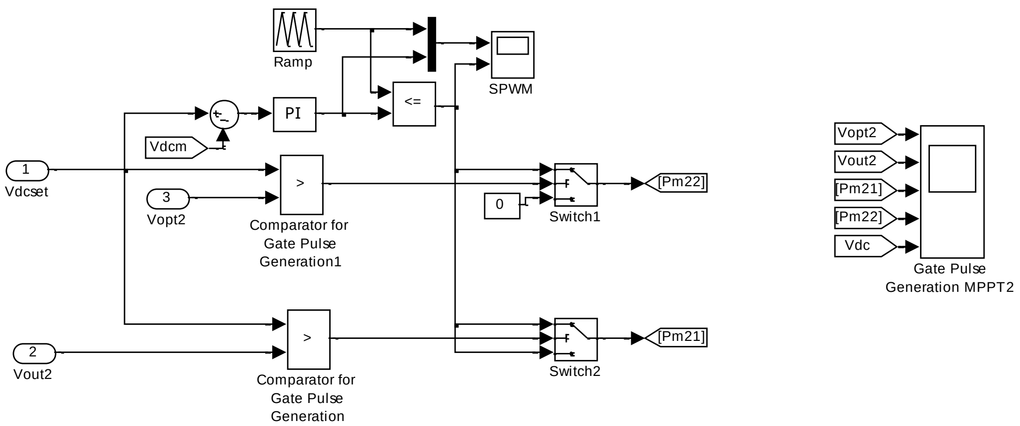
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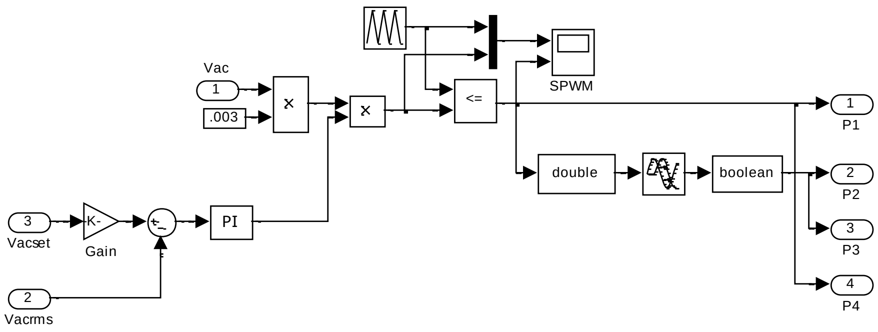

Fig.6. Proposed system Simulink diagram

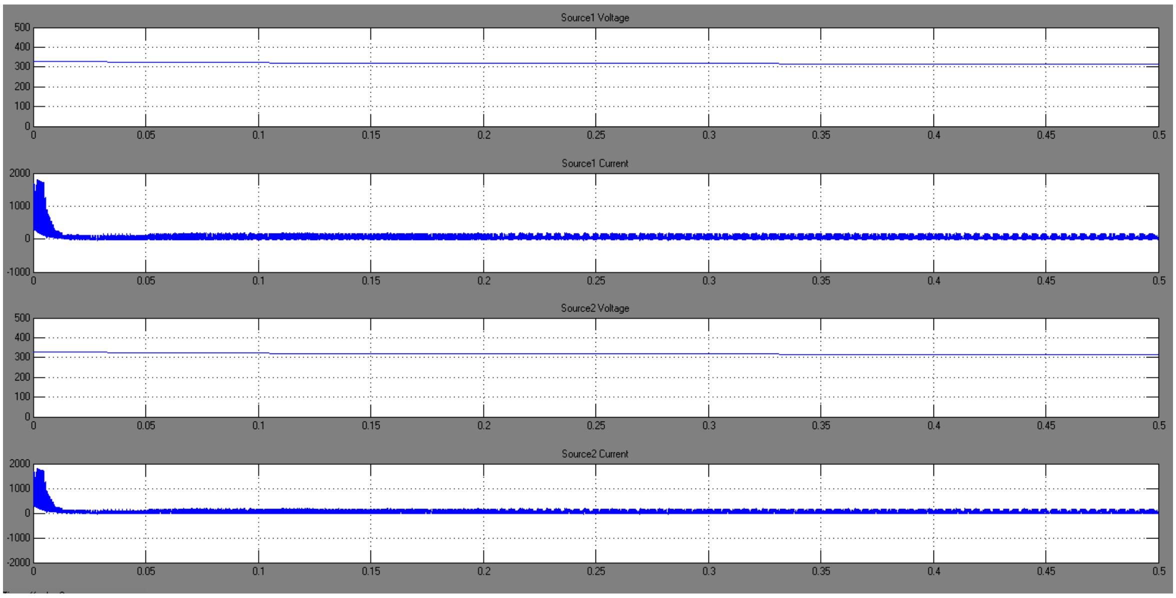

Fig.7. Input DC voltage from PV panel

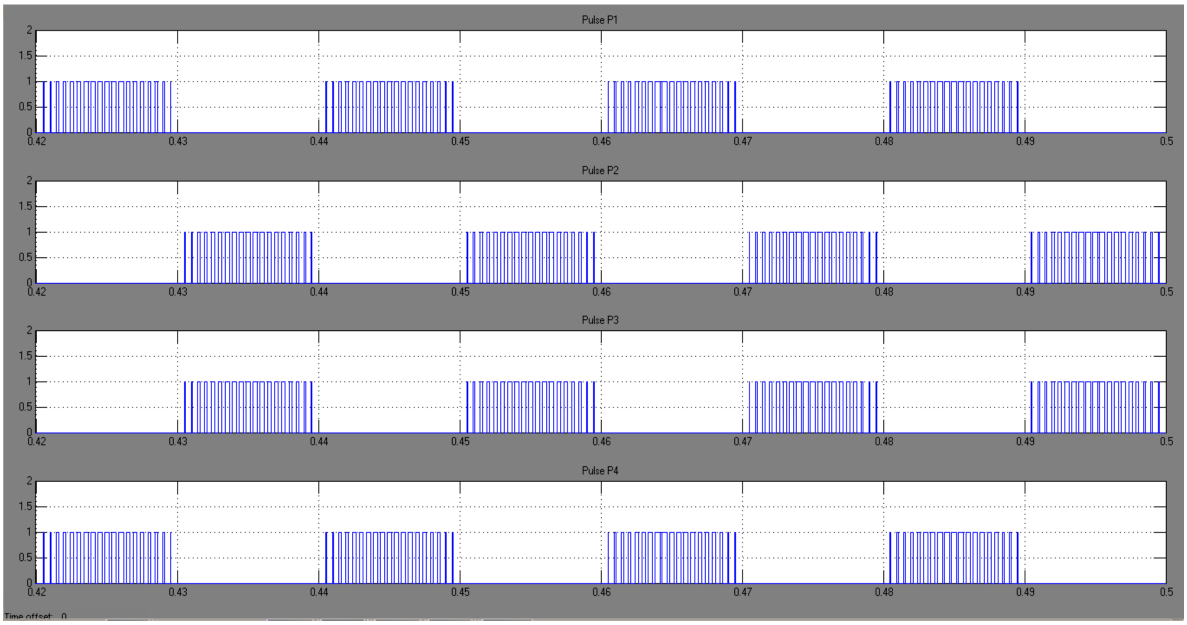

Fig.8. Pwm pulses to the voltage source inverter

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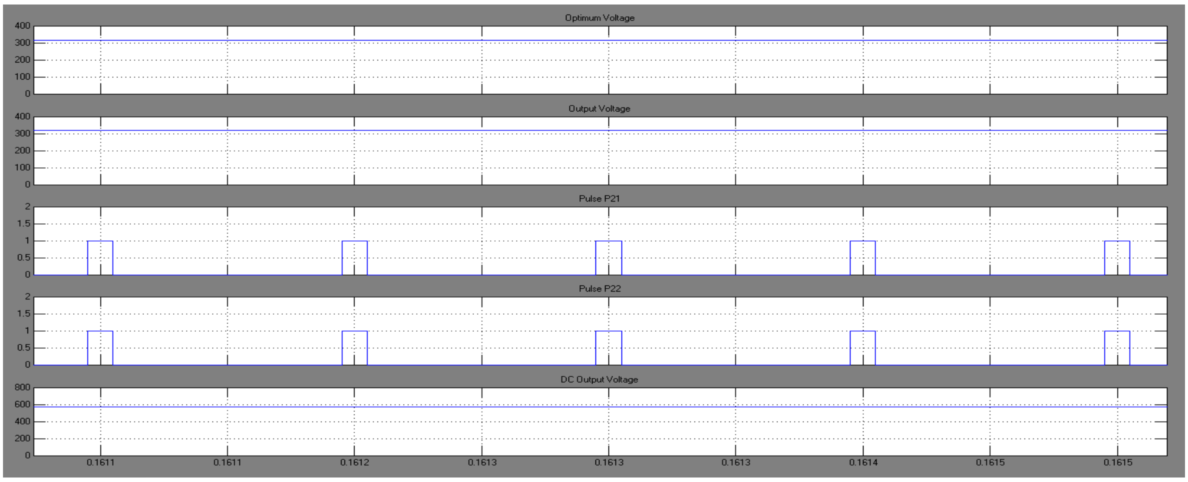

Fig.9. Pwm pulses to the buck boost converter 1.

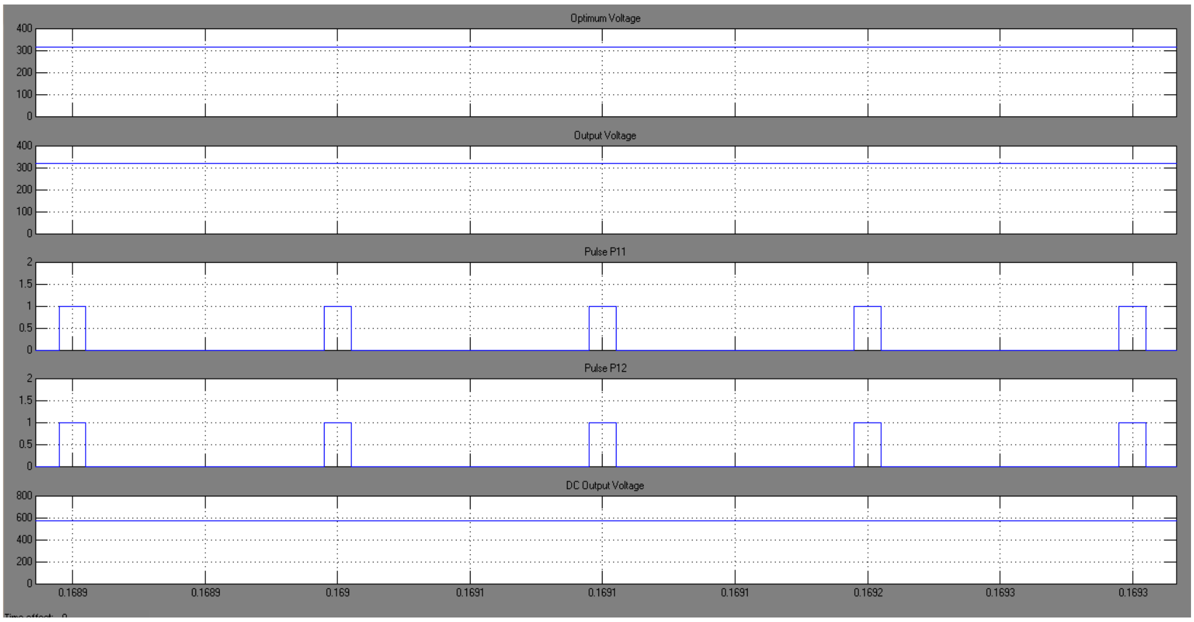

Fig.10. Pwm pulses to the buck boost converter 2.

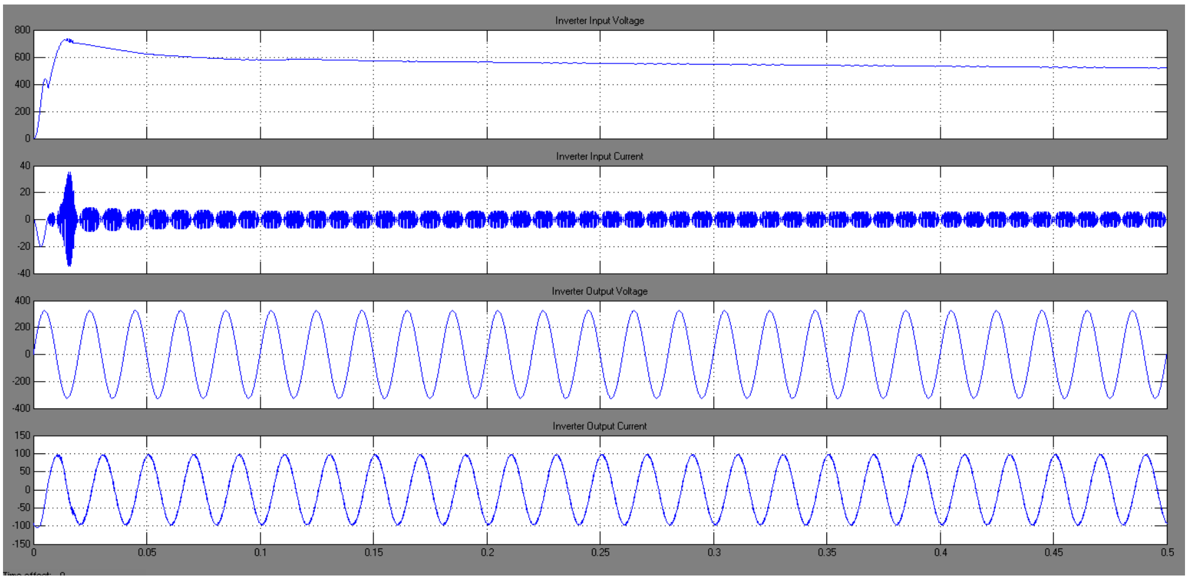

Fig.11. Output voltage from the inverter.

IV. CONCLUSIONS

In the proposed work, a single-phase bidirectional inverter with two buck/boost MPPTs has been designed and implemented. The inverter controls the power flow between dc bus and ac grid, and regulates the dc bus to a certain range of voltages. A droop regulation mechanism according to the inductor current levels has been proposed to balance the power flow and accommodate load variation. Since the PV-array voltage can vary from 0 to 600 V, the MPPT topology is formed with buck and boost converters to operate at the dc-bus voltage around 400 V, reducing the voltage stress of its followed inverter. Integration and operation of the overall inverter system have been discussed in detail, which contributes to dc-distribution applications significantly. Simulation results obtained from a single-phase bidirectional inverter with the two MPPTs have verified the analysis and discussion.

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