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Hysteresis Current Control Based Grid Connected Pv System

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Abstract: *This paper present a control strategy for the operation of solar energy generation integrated with grid. Boost converter is used to achieve maximum power extraction from the available solar power. The buck converter and bi-directional converter connected with common dc bus, that dc bus connected different loads with constant dc voltage. The hysteresis current controller has implemented in inverter to control the real power with bidirectional power flow capability, which is integrated to grid. The proposed control strategy improves the performance of the photovoltaic system for a wide range of variation in solar irradiance condition with reduces the complexity of a controller. Thus the system achieves higher reliability and better regulation, especially in poor environmental condition. Performance of the complete proposed system under different environmental condition with different load availability is verified through the MATLAB/SIMULINK simulation studies.*

Keywords: *PV ARRAY, Bidirectional converter, MPPT (Maximum Power Point Tracking), IM, SEDC, MPP (Maximum Peak Power), SPWM.*

1. INTRODUCTION

The solar photovoltaic power will play an important role in alleviating the energy crisis and reducing the environment pollution. An inherent feature of all renewable energy sources is the available energy varies randomly, resulting in a wide variation in the available output voltage and power that makes power converter, a necessary part of all such generation systems.

The input of the converter in renewable generation can be either varied low dc voltage (like fuel cell or photovoltaic array) or ac voltage with wide variation of both amplitude and frequency (wind generator).The output of the solar PV system is dc, which can be fed to the dc load or connected to the utility through an inverter. The fluctuation nature of most renewable energy resources, like wind and solar, makes them unsuitable for standalone operation as the sole source of power.

It has many advantages such has abundance, pollution free and renewability. The voltage and current relationship is observed by maximum power point algorithm. In MPPT large number of techniques such as constant voltage tracking (CVT), the incremental conductance (INC) method, the perturb and observe method (P&O or hill climbing) method.

To charge and discharge the storage element, the bidirectional dc to dc converter is used .The dc to dc converter often ensures an electrical isolation between low voltage and high voltage parts of the system and then transformer is used. Bidirectional dc to dc converter is operated in three modes of operation namely, Buck, Boost and Bidirectional.

The sinusoidal PWM method also known has triangulation; sub harmonic method is very popular in industrial application. In this modulation techniques are multiple numbers of output pulse per half cycle and pulses are of different width. The width of the each pulse is varying in proportion to amplitude of the sine wave evaluated at the center of the same pulse. The gating signals are generated by comparing the sinusoidal reference with a high frequency triangular signal. This technique is called sinusoidal pulse width modulation (SPWM) mainly used because of its simplicity and ease of implementation. The output voltage magnitude is controlled by closed loop control system using PI controller.

The algorithm was verified with MATLAB-SIMULINK that it can track the real MPP very fast when the temperature changes. The closed loop operation of proposed system is verified with MATLAB simulations including load and source disturbances.

2. Proposed System Configuration

2.1. Block Diagram

This block diagram consists of solar panel, boost converter, buck converter, bidirectional DC to DC converter and different loads.

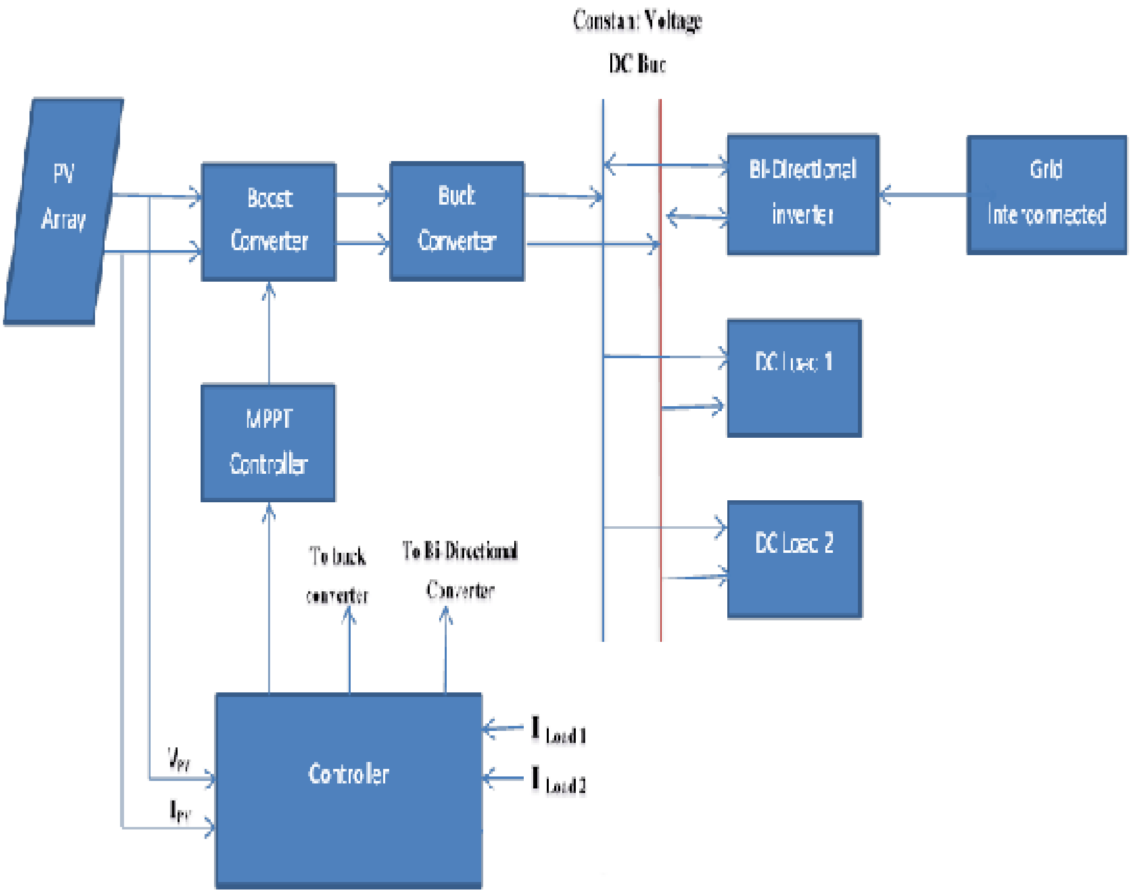

Fig1. *Block diagram of proposed system*

The buck converter and bi-directional converter connected with common dc bus, that dc bus connected different loads with constant dc voltage. The system has several advantages, 1) Improve efficiency, Reliability, Fast dynamic response. 2) The overload power is supplied to the grid. 3) To introduce bidirectional converter for power flow capability for energy management.

2.2. Maximum Power Point Tracking

The maximum power point tracking is achieved with the help of DC-DC converter interfaced between the solar PV module and the load. The automatic tracking of the MPP can be achieved by utilizing various MPPT algorithms. These algorithms can be implemented in digital controller to track the maximum power from the solar PV module. The algorithm adjusts the duty cycle of the DC-DC converter and makes it to operate at the peak power point of the solar PV module under different environmental conditions. The Hill climbing or perturb and observe (P&O) method and incremental conductance (Inc Cond) method are the most popular and recommended MPPT algorithms.

2.3. Modified Perturb and Observe

The MPPT algorithms based on hill top or P&O algorithm is more popular because of its simplicity and ease in implementation. However oscillation problem is unavoidable in these algorithms. The INC algorithm is able to track the MPP under rapidly changing environmental changes, but the major disadvantage of this algorithm is the increased complexity as compared to conventional P&O algorithm. Therefore the hill-top algorithm is modified such that it gives better response during the transients and rapidly varying atmospheric conditions.

As shown in Figure, if change in power ΔP is positive, the operating point is expected to move closer to the MPP. Thus a further voltage perturbation is added in the operating voltage that leads to the movement of operating point in the same direction towards the MPP. If ΔP is negative, the operating point has moved away from the MPP, and the direction of perturbation is reversed to move it back toward the MPP.

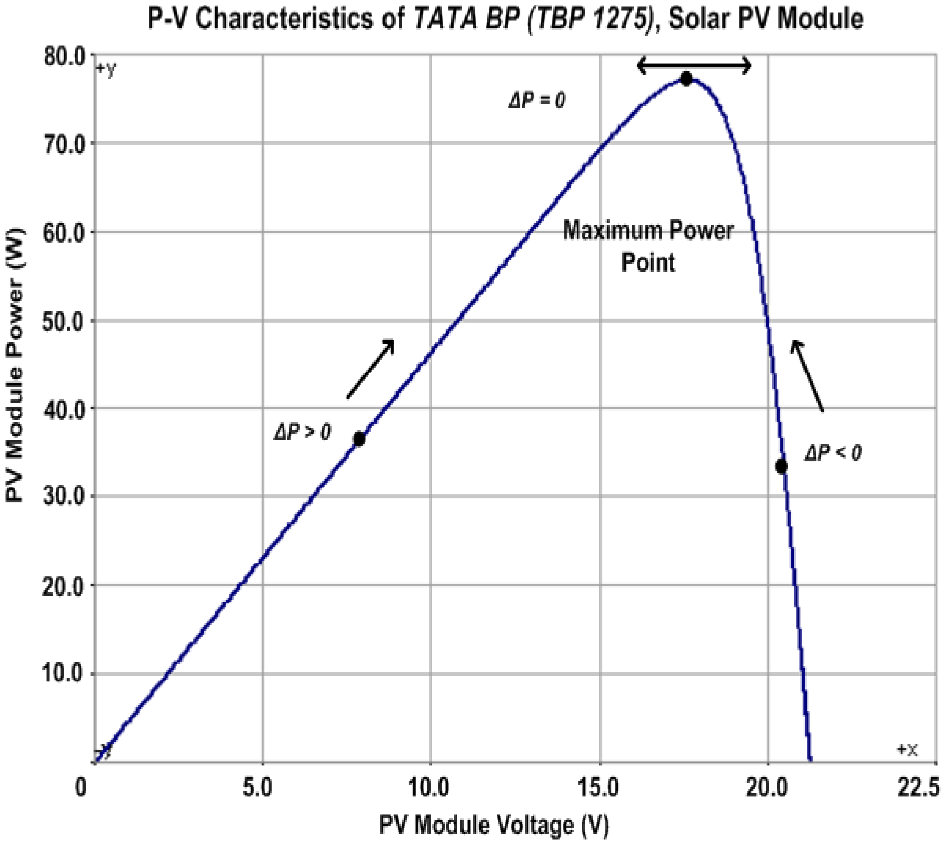

Fig2. *P-V characteristics of solar PV module with hill climbing operation*

The conventional P & O algorithm a small perturbation in the voltage is introduced to change the power of the solar PV module. But this algorithm fails to act under fast varying atmospheric conditions. The modified hill top algorithm gives better performance during rapid changes in the atmospheric and sudden changes in the load.

In the modified hill top algorithm proposed in this section two tolerance limits are chosen, one is larger and other is smaller. For a large change in conditions, a large change in duty cycle is used while for smaller change a small change in duty cycle is used. This modification in the hill top algorithm makes the maximum power point tracking technique to give better response during sudden change in load conditions and rapid changes in the atmospheric conditions. The flow chart of the modified hill climbing algorithm is shown in Figure.

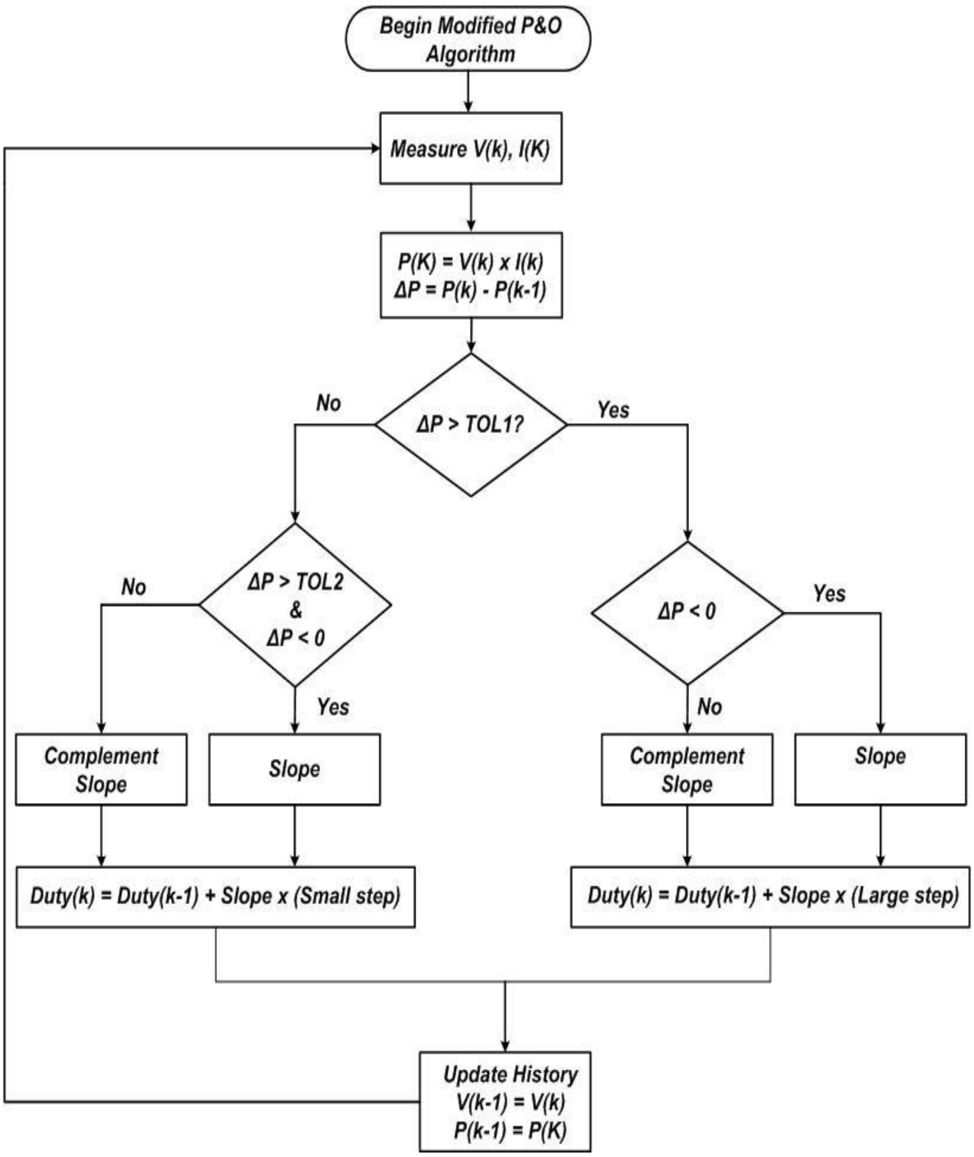

Fig3. *Flowchart of modified hill climbing algorithm*

3. Bidirectional Dc to Dc Converter

The essential part of the renewable energy system is a storage element. The storage element gathers the energy fluctuations and enables to improve the system dynamic properties. A chemical battery or super capacitors, used as a typical energy storage element, are characterized by the low nominal DC voltage value. To charge and discharge the storage element, the bidirectional DC-DC converter is used. The DC-DC converter often ensures an electrical isolation between low voltage and high voltage parts of the system, and then the transformer is used. In order to feet the transformer a Dc power must be converted into AC power and next rectified to DC power. To minimize the transformer size, weight and cost. the frequency of the Ac power should be as high as possible. The frequency increase is limited by the transistor conduction and switching losses. It should be noticed that the main source of the power dissipation is the low voltage side converter because it conducts a high current. So, the main effort of the research is directed to the low voltage converter eiffiency.

The first proposal of the bidirectional DC-DC converter system was a DAB (Dual active bridge) converter. The DAB converter consists of the two voltages –fed inverters at each side of the transformer. The energy flow value and the direction were controlled by the phase shifting angle of the both inverters. The main drawback of the DAB converter is that it does not accept a high difference between voltages of low and high sides of transformer, because then the current stress and losses caused by the circulating current become to high. Additionally this system does not ensure ZVS conditions of the transistor switching process in a wide range of the voltage variations.

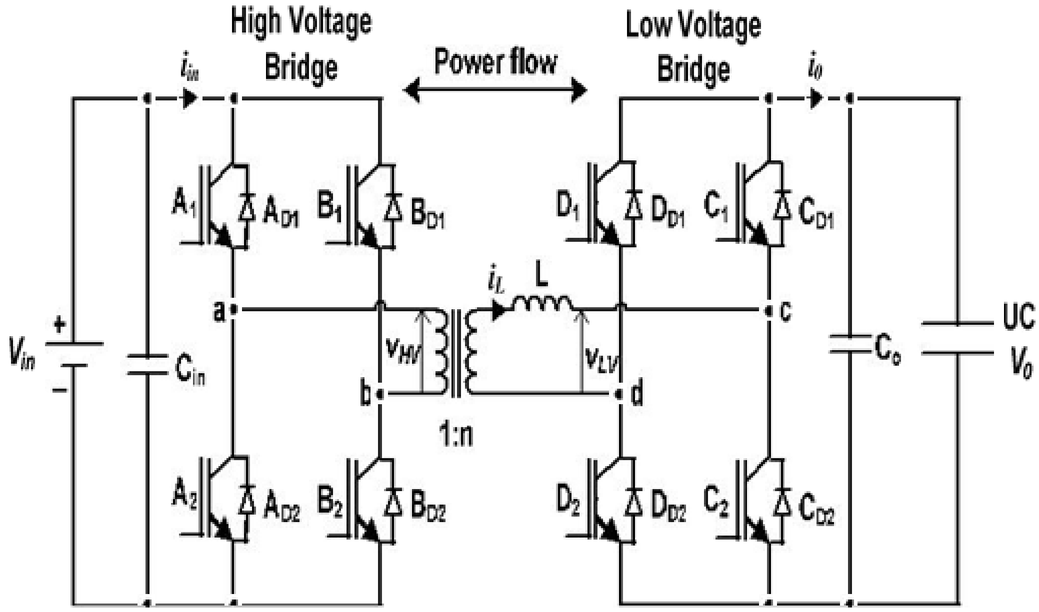

Fig4. *Bidirectional DC to DC converter*

Other solution of the bidirectional DC to DC converter system consists of a current-fed(boost) inverter at a low voltage-fed (buck) inverter at a high voltage side. The drawback of this system is the high voltage spikes provoked by the transformer leakage inductance when the boost converter is switched. The transformer leakage inductance can be used as a useful element in the resonant. A bridge configuration class-E boost resonant converter is proposed. The bridge configuration class-E boost resonant converter was proposed. The class-E converter guarantee ZVS switching condition for converter transistors in the whole operating range and apart from that do not generate the parasitic oscillation which invoke the voltage spikes.

3.1. Principle of Operation – Charging Mode

During this mode, the HV bridge leads the LV bridge by $dT_s/2$, where '*d*' is the duty ratio and 'T_s' is the time period for one cycle. Thereby power flows from the HV side to the LV ultra-capacitor side to charge it. The primary, HV bridge performs inverter operation and the secondary, LV bridge performs rectification function. During description of the states, it is assumed that the energy stored in the coupling inductance is sufficient to realize zero-voltage switching (ZVS) of all transistors. The key operating waveforms of the converter during the charging mode, when power flows from the HV side to the LV ultra-capacitor side.

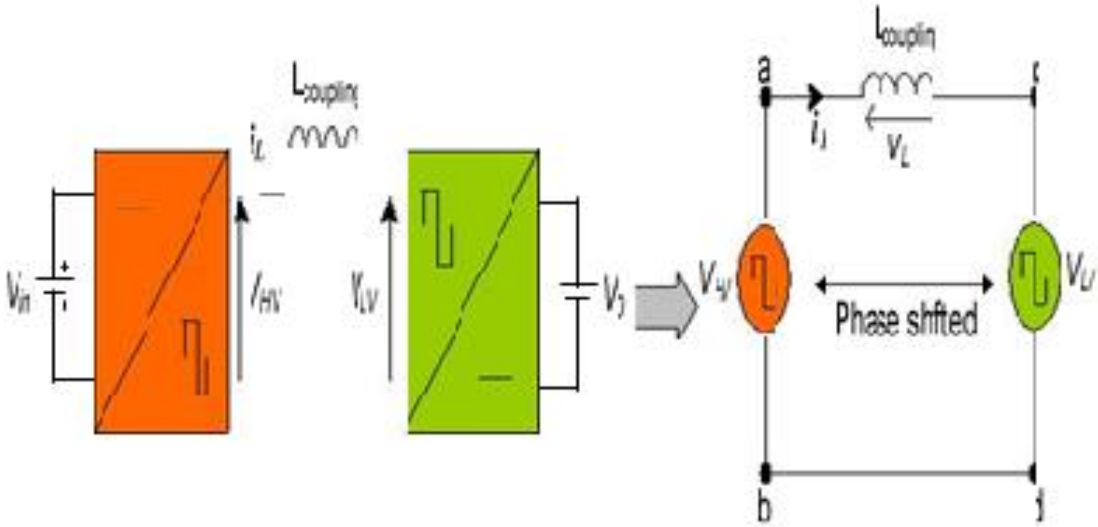

Fig5. *Simplified equivalent circuit*

3.2. Principle of Operation – Discharging Mode

In this mode, the LV Bridge leads the HV bridge by $dT_s/2$, thereby power flows from the LV side to the HV side, assuming the source is capable of accepting the stored energy. Such a situation arises in an aircraft when peak power demand occurs in electric loads. Compared to the previous mode, the circuit operation is reversed. As a result, the secondary LV bridge performs an inverter operation and the primary HV bridge performs rectification to discharge the ultracapacitor.

4. Modes of Operation

The operation of the charging station can be categorized into four modes: Mode-1 (grid-connected rectification),Mode-2 (PV charging & grid-connected rectification),Mode-3 (PV charging) and Mode-4(grid-connected inversion).

The four modes of operation are described as follows:

4.1. Mode-1: Grid Connected Rectification

In this mode the PV system does not generate any power due to bad weather conditions or low radiation condition.

The power is required to operate the induction motor and SEDC motor .so the grid supplies the power to the load by using bidirectional converter.

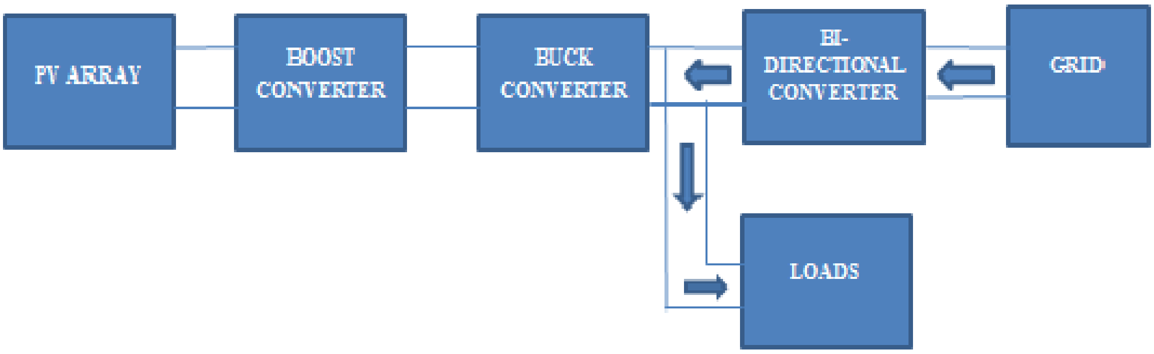

Fig6. *Grid connected rectification*

4.2. Mode 2: PV Charging & Grid Connected Rectification

In this mode the power generated by the PV system is less than the power required to the loads. Therefore all the power generated by the PV is transferred to the load and the deficit is supplied by the grid. The dc link voltage varies with the change in irradiation condition

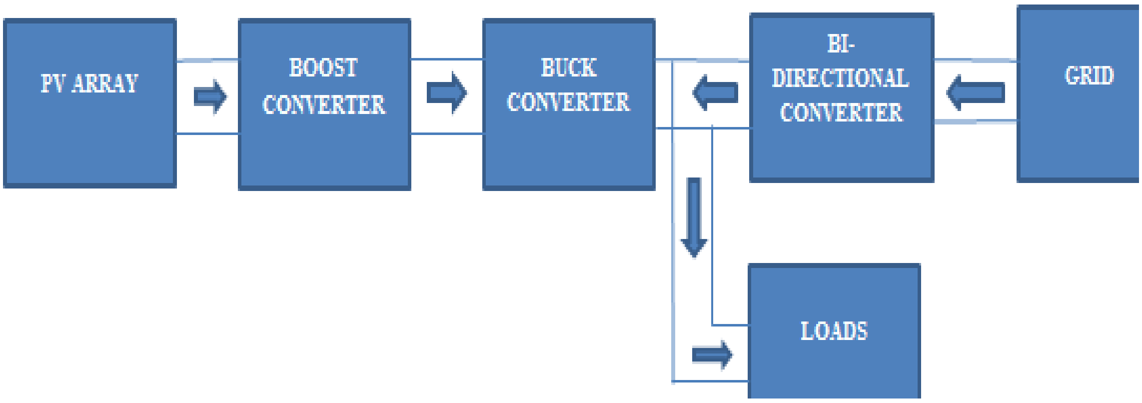

Fig7. *PV charging and grid connected rectification*

4.3. Mode 3: PV Charging

In this mode the PV array generate all the power required to operate the loads. As the distribution transformer is not over load the PV systems need not deliver any power to the grid.

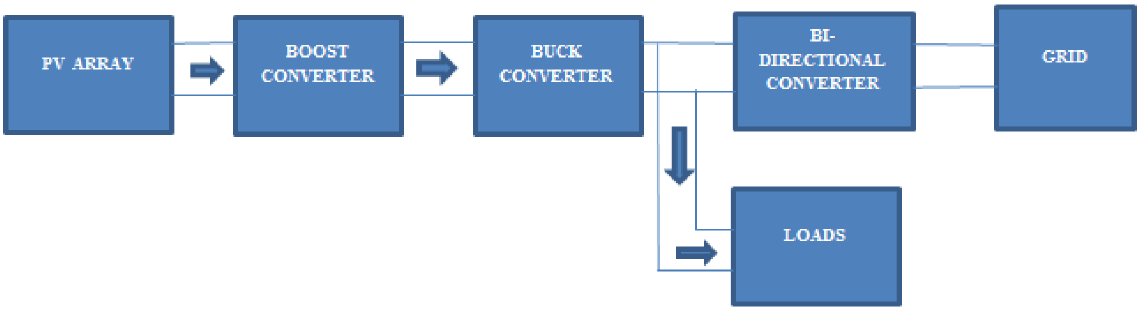

Fig8. *PV charging*

4.4. Mode 4: Grid Inversion Mode

This mode operate the PV array generate excess power once the dc link voltage exceeds the required voltage shown in figure 8. This additional power generated by the PV array is sent to the grid by using bidirectional converter.

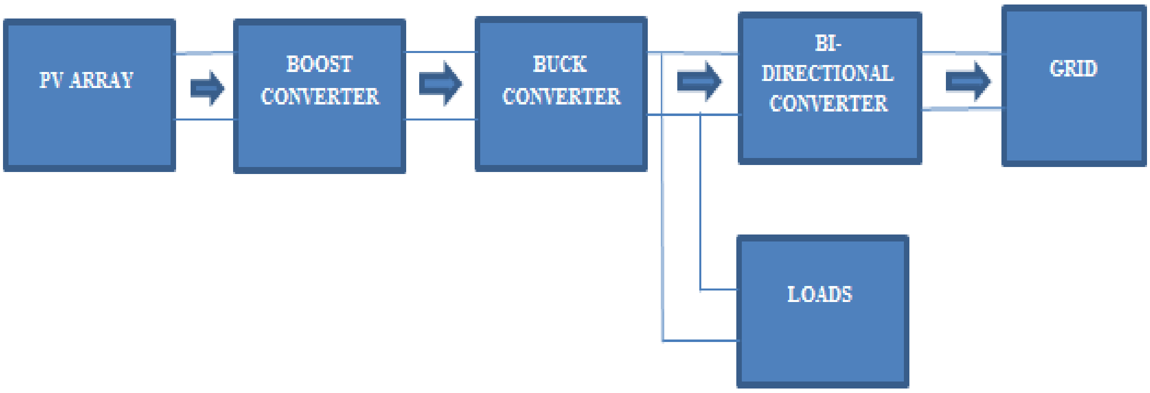

Fig9. *Grid inversion mode*

5. Simulation Diagram

5.1. Bidirectional Dc -Dc Converter

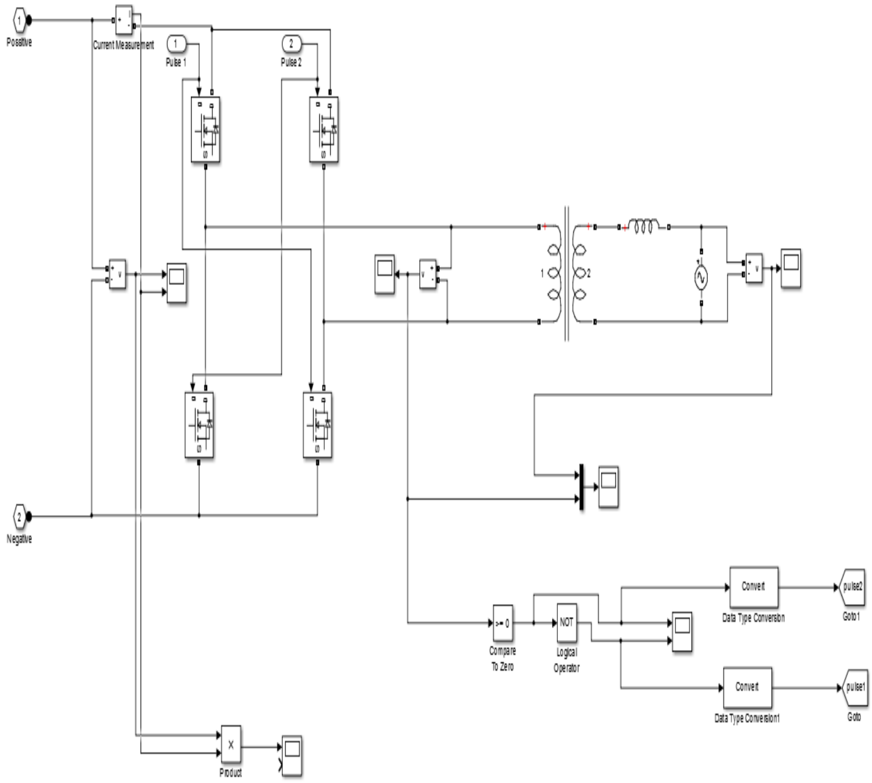

Fig10. *Simulation diagram of bidirectional dc -dc converter*

5.2. Hysteresis Current Control

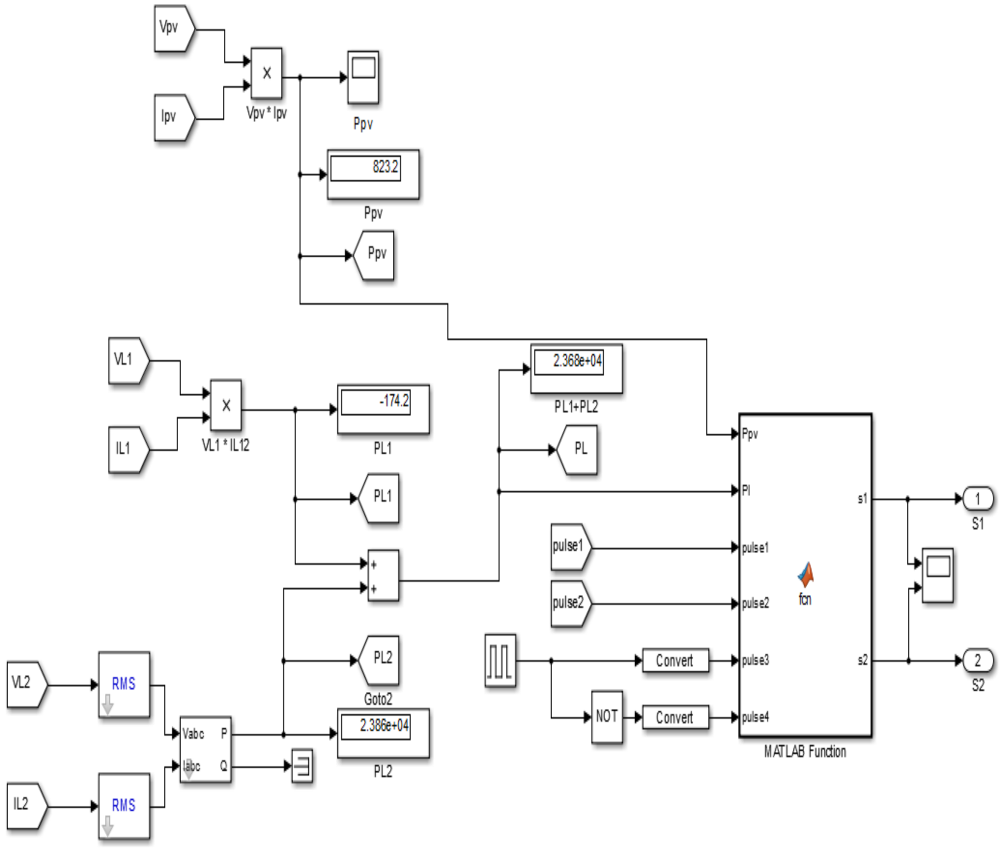

Fig11. *Simulation diagram of Hysteresis current control*

5.3. Full Circuit

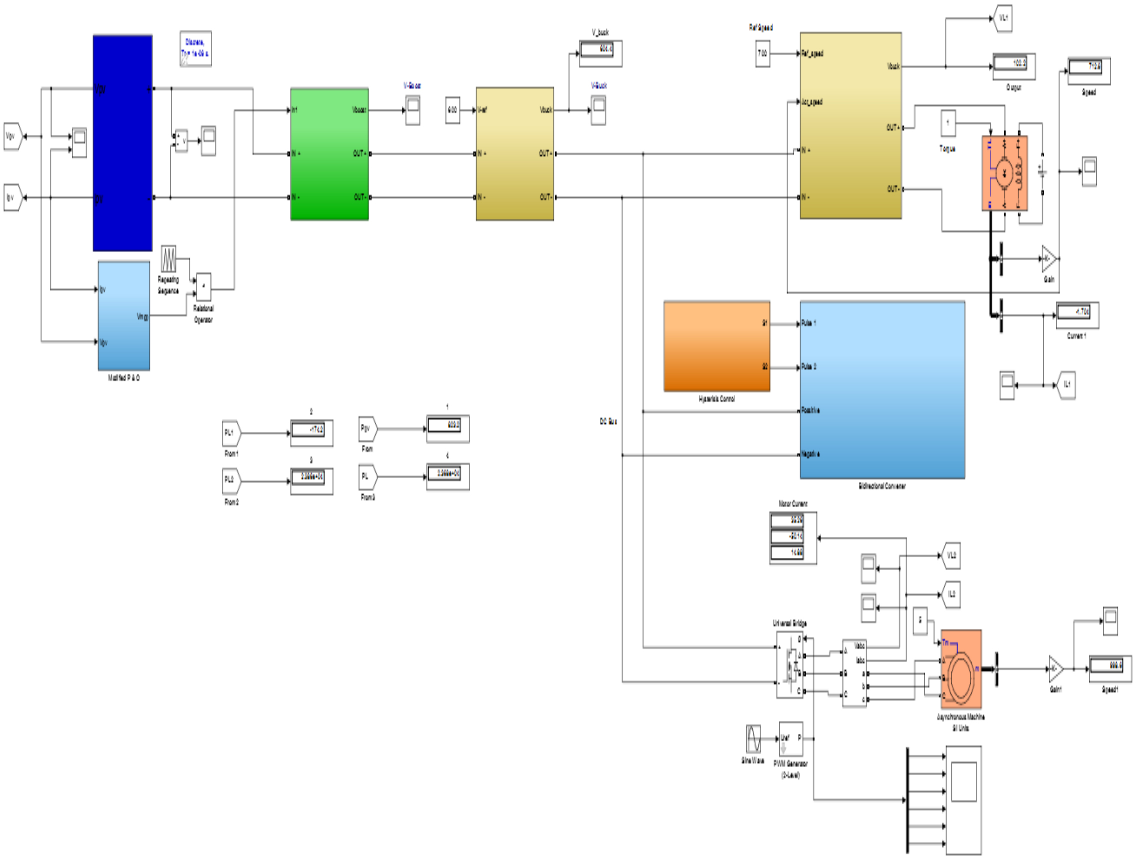

Fig12. *Simulation diagram of proposed system*

6. Simulation Results

6.1. Solar PV Output

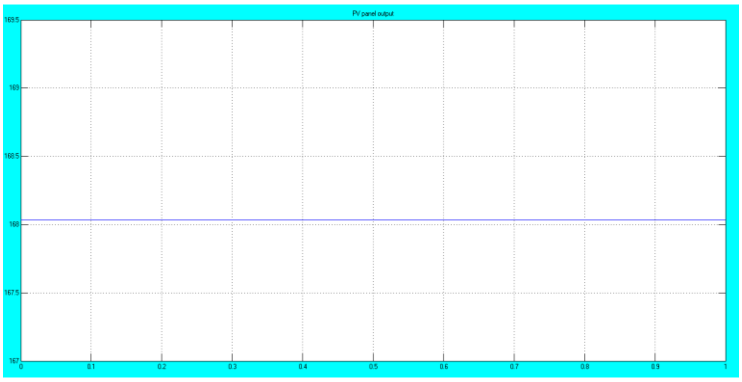

Fig13. *Simulation result for solar PV output*

6.2. Boost Converter

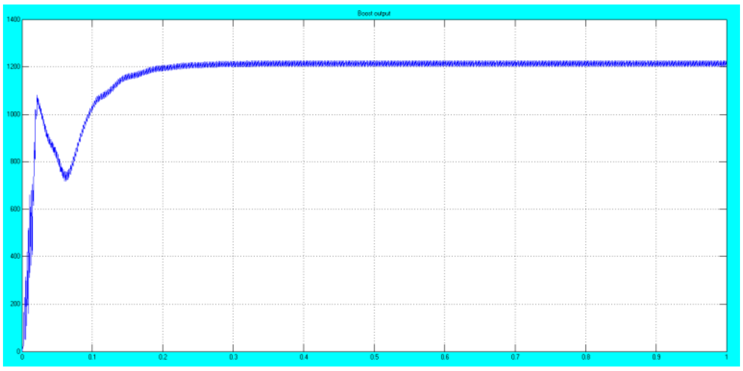

Fig14. *Simulation result for boost converter*

6.3. Buck Converter

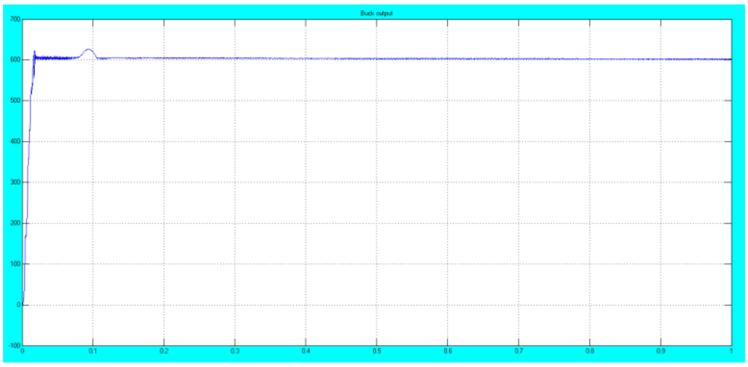

Fig15. *Simulation result for buck converter*

6.4. Dc Motor Speed

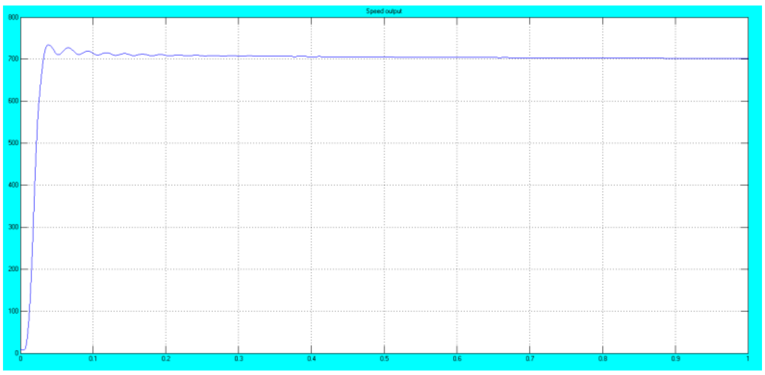

Fig16. Simulation result for DC motor speed

6.5. Dc Motor Current

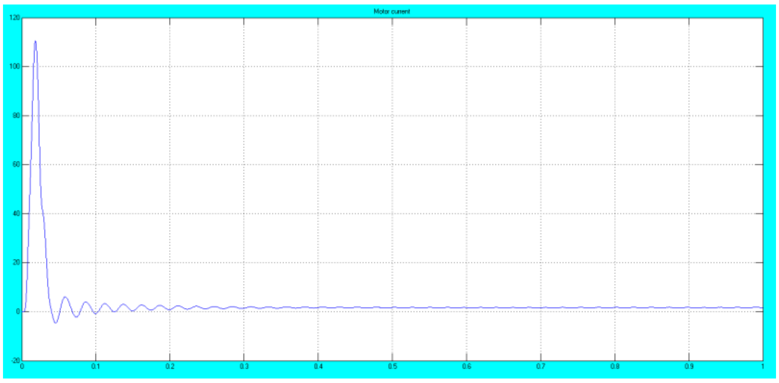

Fig17. *Simulation result for DC motor current*

6.6. Bidirectional DC voltage & DC current

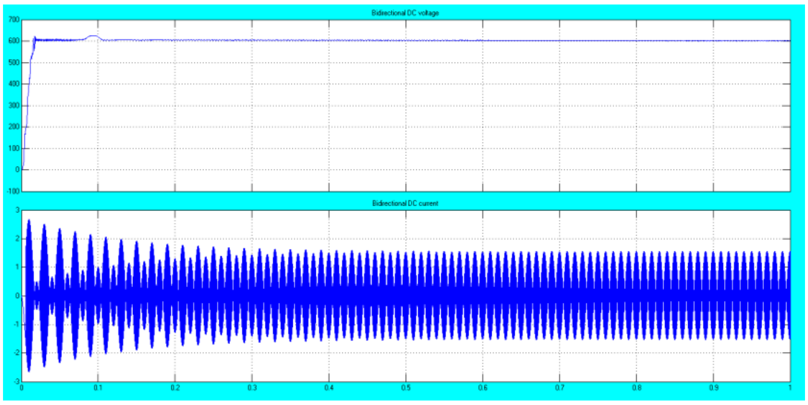

Fig18. *Simulation result for DC voltage & DC current*

6.7. Grid Voltage

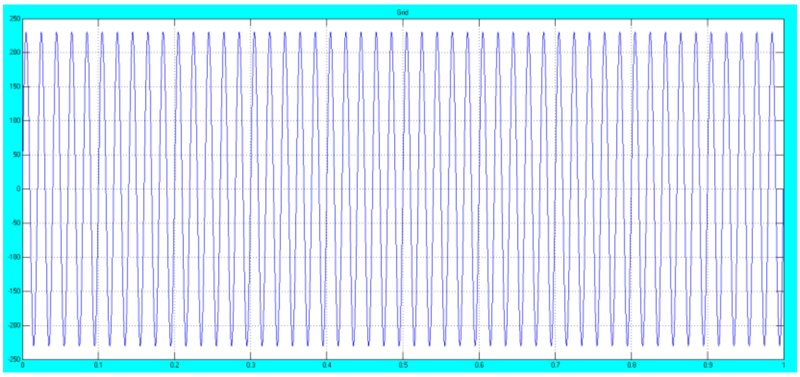

Fig19. *Simulation result for grid voltage*

6.8. Asynchronous Motor Speed

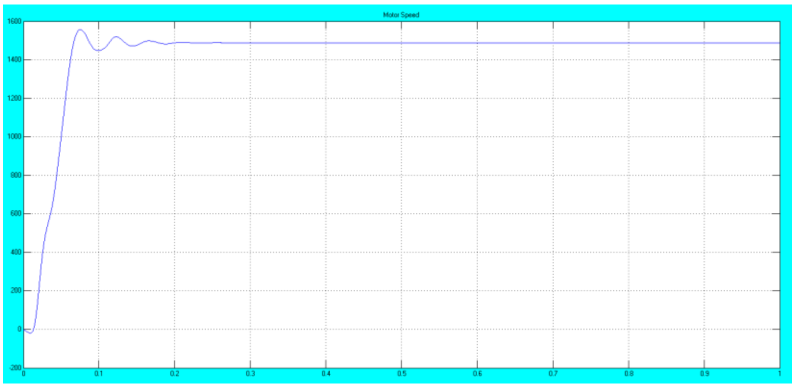

Fig20. *Simulation result for asynchronous motor speed*

6.9. Asynchronous Motor Voltage

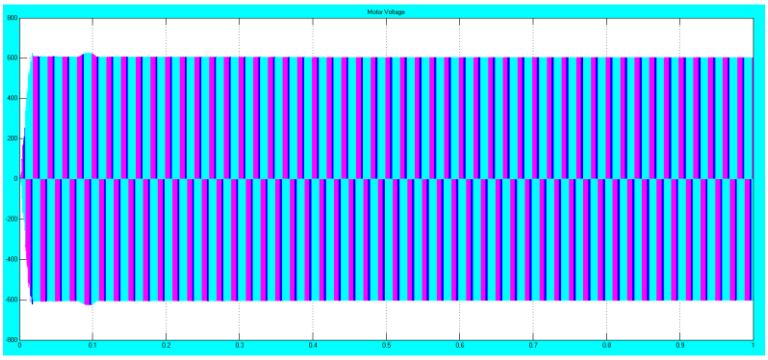

Fig21. *Simulation result for asynchronous motor voltage*

6.10. Asynchronous Motor Current

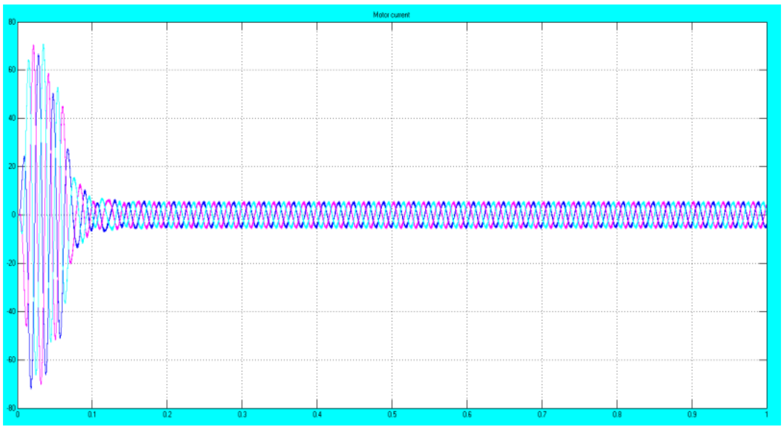

Fig22. *Simulation result for asynchronous motor current*

7. CONCLUSION

In this work, the importance of hysteresis current control based grid connected PV system has been highlighted. A bidirectional topology with improved features has been proposed. Relevant analysis, including derivations of the expressions for peak voltage and current stresses across the switching devices, has been performed and a design procedure has been presented. The topology is simple, symmetrical and easy to control. The other desirable features include good efficiency due to optimal number of device switching and reduced switching losses. The diodes which are inherent to the inverter operation, also serve to prevent any reverse power flow from the power grid to the PV array. HCC operation ensures better control apart from facilitating the generation and feeding of high quality current into the grid. The grid current THD is less than 5% with a good grid voltage waveform (closer to a pure sine wave), the THD can be limited as per IEEE-519 (current THD 5%) and the topology will be able to feed high quality current into the grid.

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