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Power Flow Control Using Bidirectional Dc/Dc Converter for Grid Connected Photovoltaic Power System

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Abstract: *This project presents 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. DC-DC bidirectional converter, which is connected between batteries bank and DC-link voltage is used to control the power through DC-link voltage. It is also used to make the batteries bank stores the surplus of solar energy and supplies this energy to the load during solar power shortage. The load side voltage source inverter uses a relatively complex vector control scheme to control the output load voltage in terms of amplitude and frequency. Also the power generation is feeding to the grid when excess power generation. The control strategy works under different solar radiation as well as with variable load. Extensive simulation results have been performed using MATLAB/SIMULINK simulation studies.*

Keywords: *PV ARRAY,Bidirectional converter, MPPT(Modified P&O),IM*

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, bidirectional DC to DC converter and different loads.

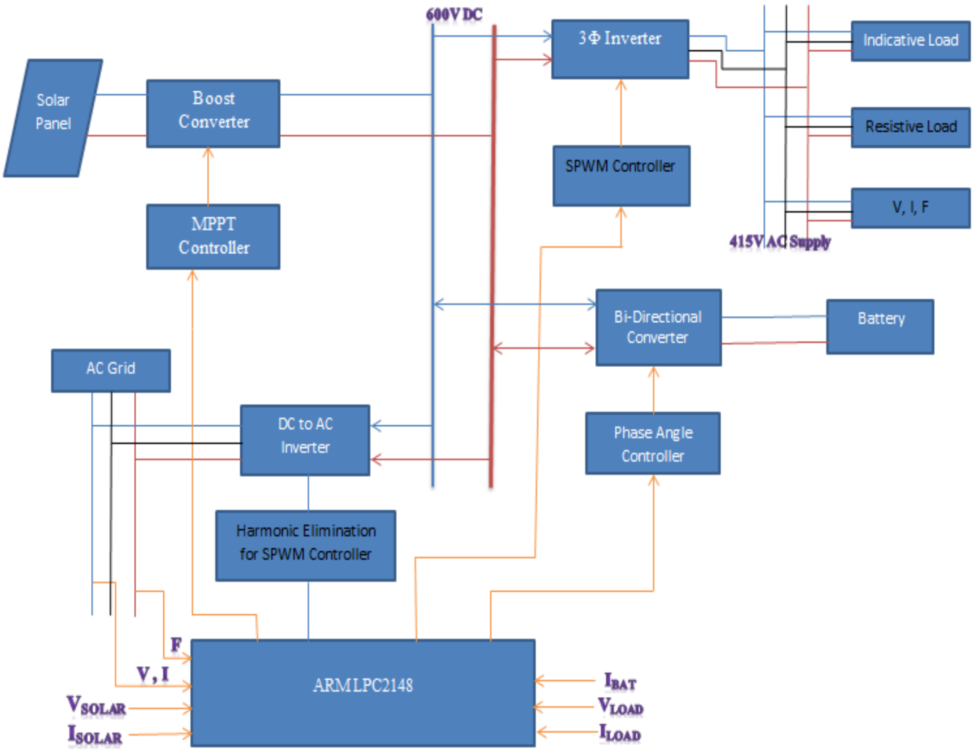


Fig. *Proposed System Block Diagram*

DC-DC bidirectional converter, which is connected between batteries bank and DC-link voltage, is used to control the power through DC-link voltage. 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 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.

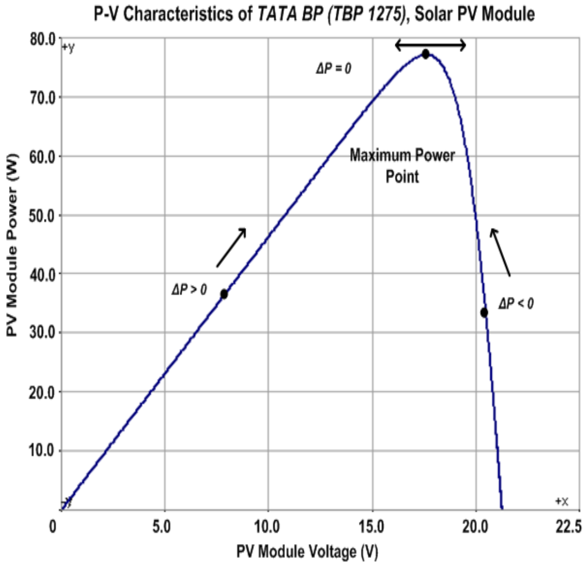


Fig. *P-V characteristics of solar PV module with hill climbing operation*

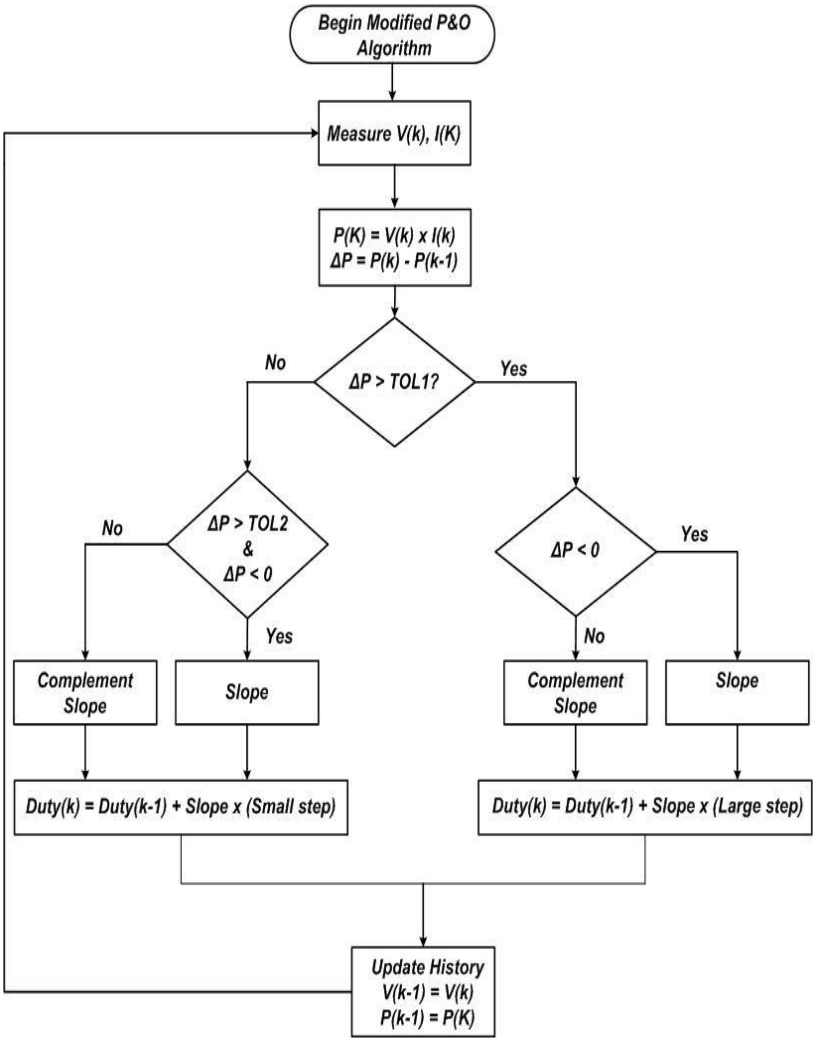


Fig. *Flowchart of modified hill climbing algorithm*

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.

3. Bidirectional Dc/ 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.

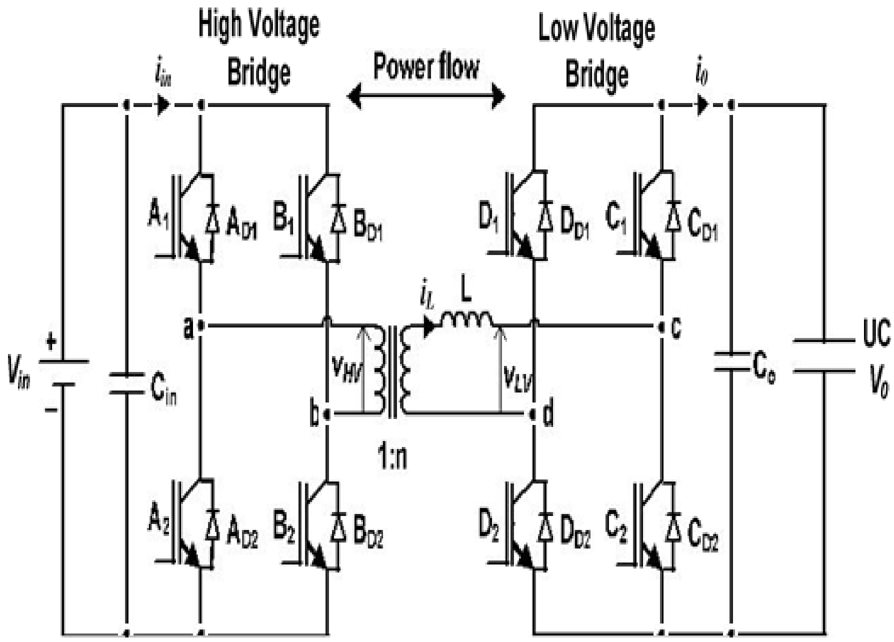


Fig. *Bidirectional DC to DC converter*

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.

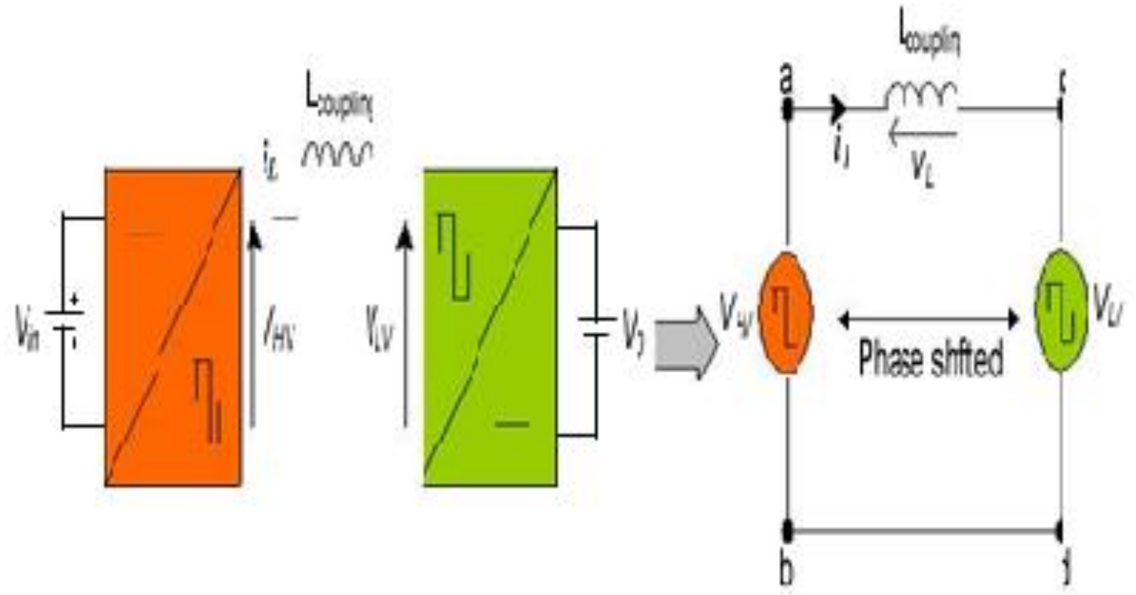


Fig. *Simplified equivalent circuit*

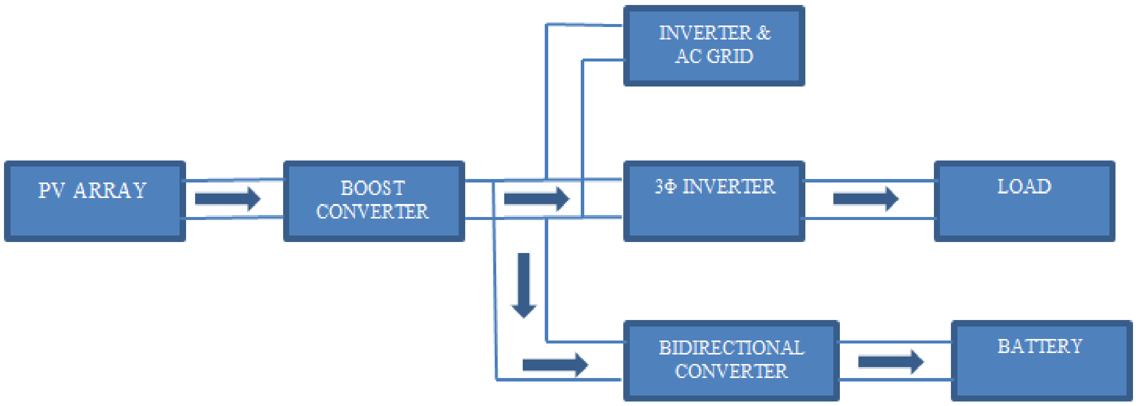
3.2. Principle of Operation – Discharging Mode

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

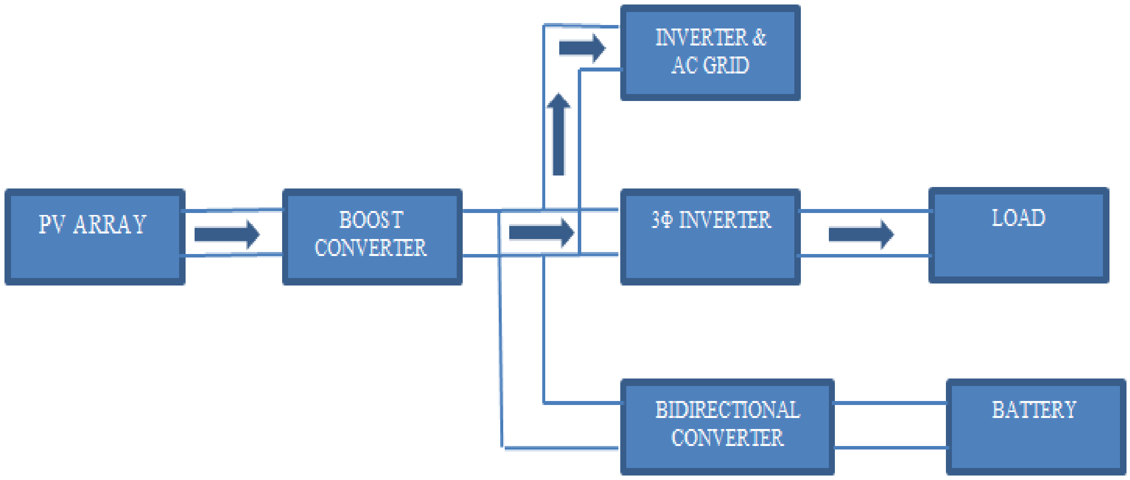
4.1. Mode I (Solar power > Load power)

In this mode the power generated by the photovoltaic system is greater the load power. The PV array generates excess power. Once the DC link voltage exceeds the load power. This additional power generates by the PV array is sent to the battery via the bidirectional DC/DC converter and also connected to the load. As the distribution is not over loaded the pv system need not delivery any power to the grid.



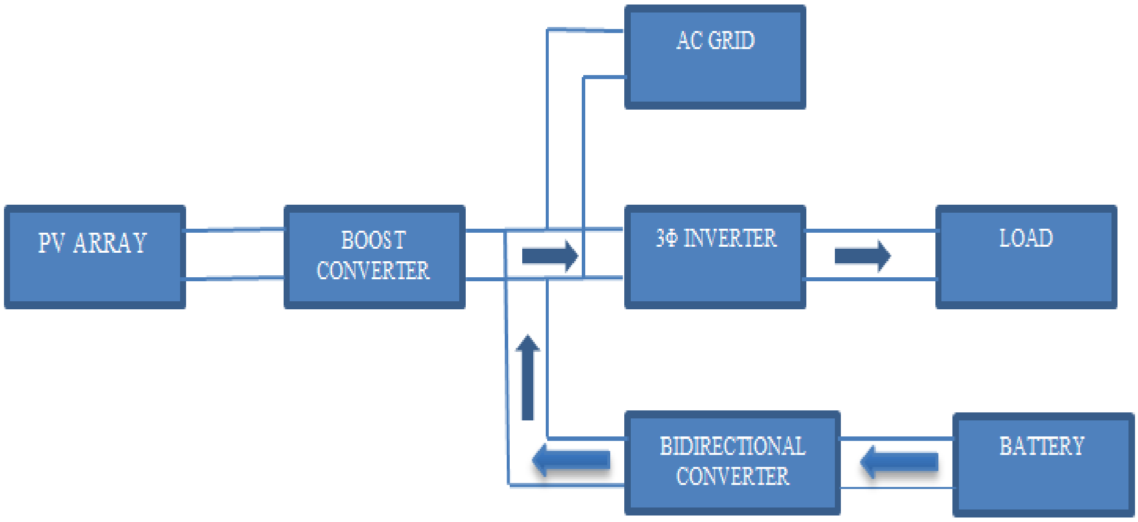
Case1.

This mode with an overload on the distribution or load and also the battery are charged, that the exceeds power from the PV array sent to the grid.



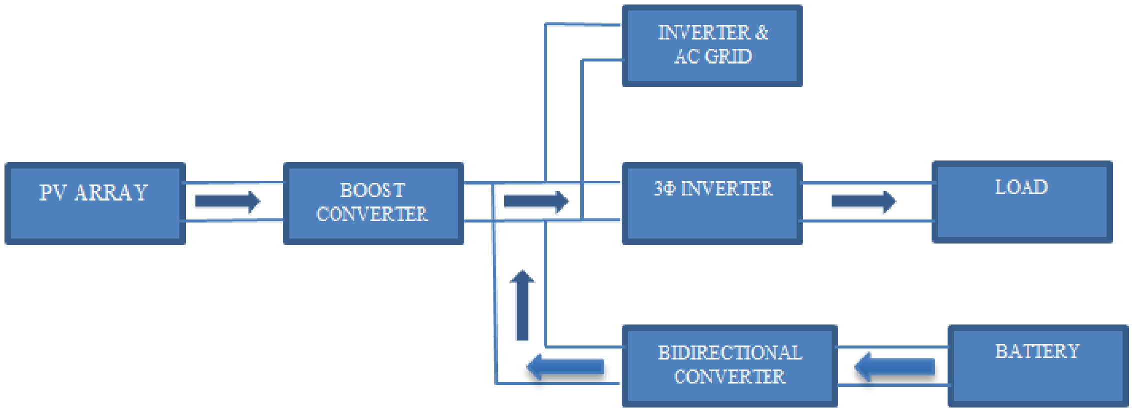
Case2.

In this mode the photovoltaic system does not generate any power either due to low radiation or bad weather conditions. The power required to load the battery is provided through the bidirectional DC/DC converter.



4.2. Mode II (Solar power < Load power)

In this mode the power generated by the photovoltaic system less than the load power. Once the DC link voltage demand the solar power. The additional power sent from the battery via bidirectional DC/DC converter.



5. SIMULATION DIAGRAM

5.1. Bidirectional Converter (With Battery Storage)

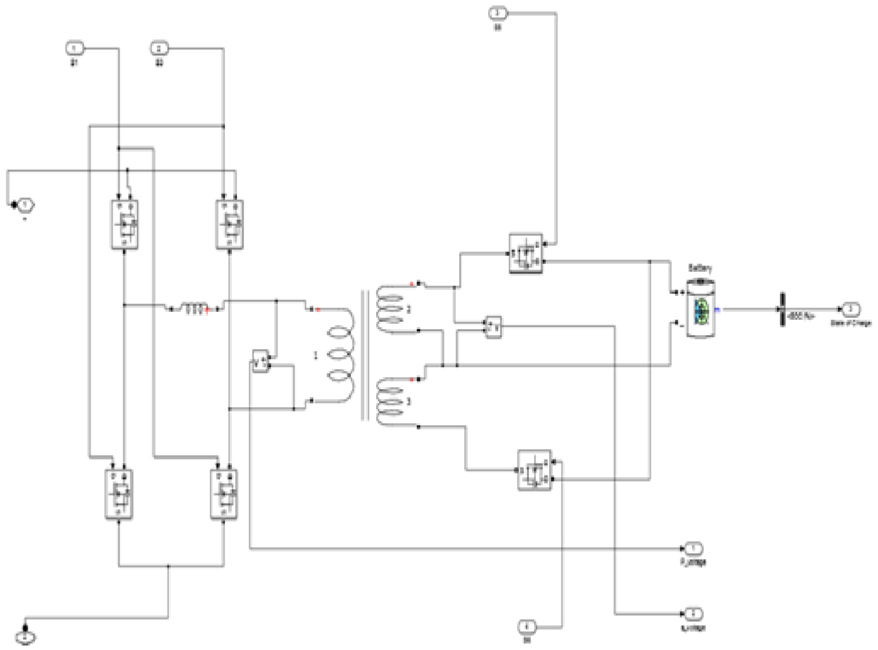


Fig. *Simulation diagram for Bidirectional converter with battery storage*

5.2. AC Grid

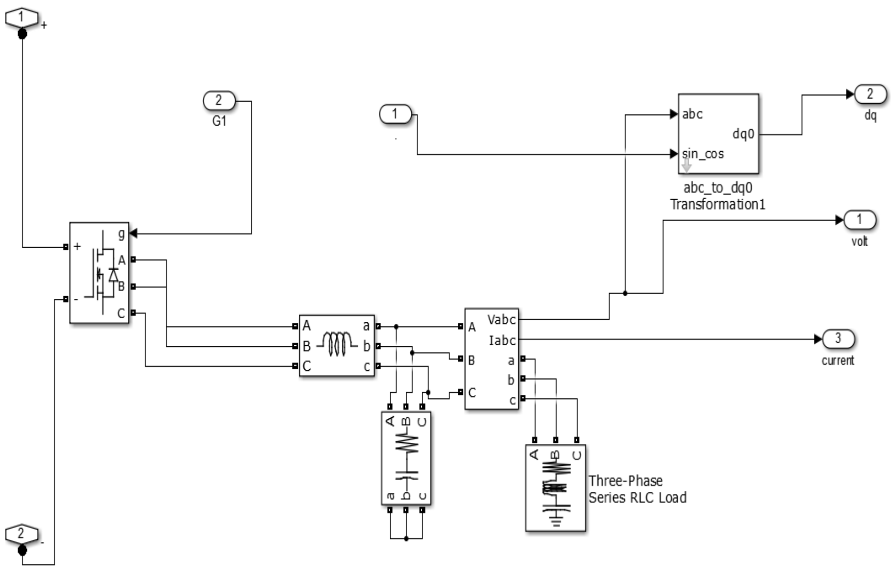


Fig. *Simulation diagram for AC grid*

5.3. SPWM Controller

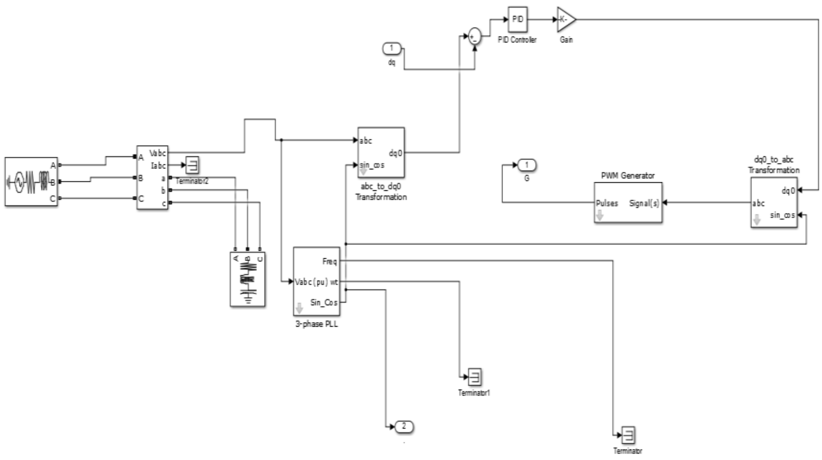


Fig. *Simulation diagram for Sinusoidal Pulse Width Modulation*

5.4. Full Circuit

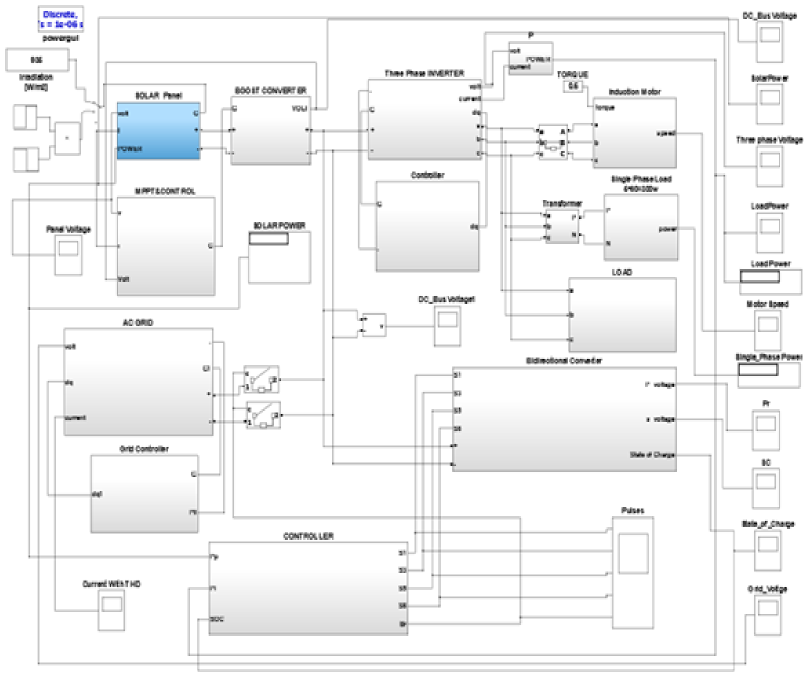


Fig. *Simulation diagram for proposed system*

6. Simulation Results

6.1. Solar Power

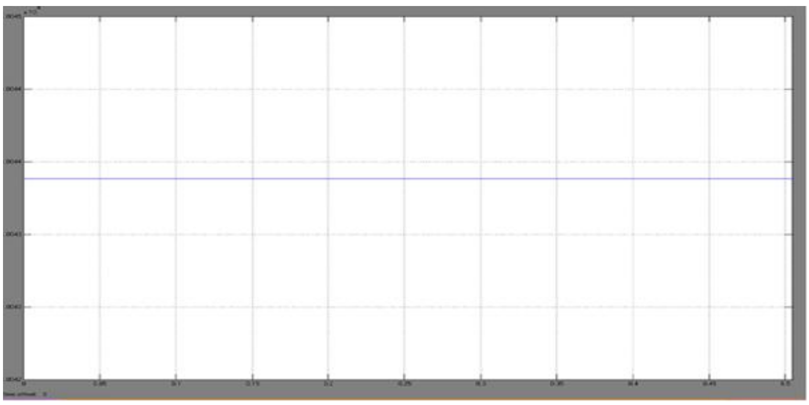


Fig. *Simulation result for solar power*

6.2. Boost Converter (or) Dc Bus Voltage

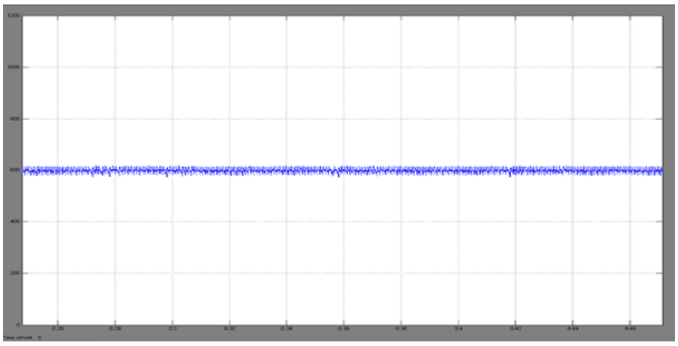


Fig. *Simulation result for DC bus voltage*

6.3. Load Power

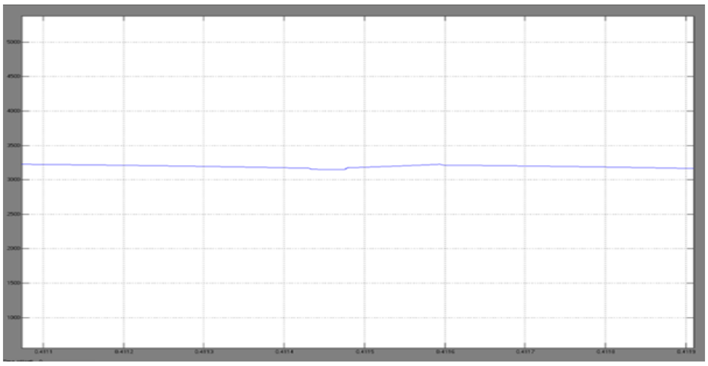


Fig. *Simulation result for load power*

6.4. Three Phase Voltage

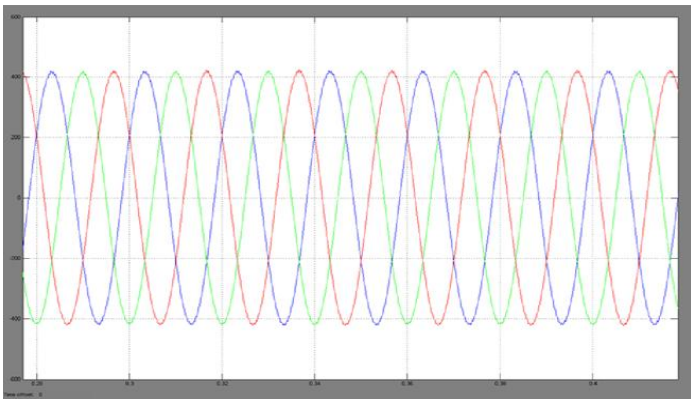


Fig. *Simulation result for three phase voltage*

6.5. Indication Motor Speed

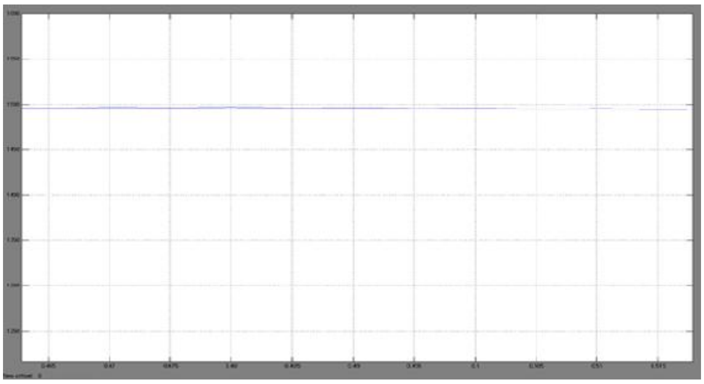


Fig. *Simulation result for indication motor speed*

6.6. Primary Voltage

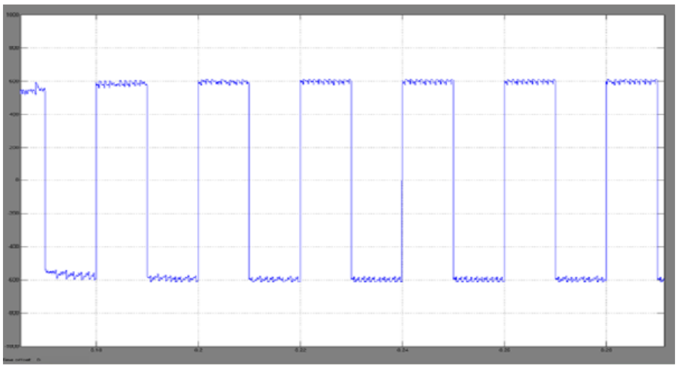


Fig. *Simulation result for primary voltage*

6.7. Secondary Voltage

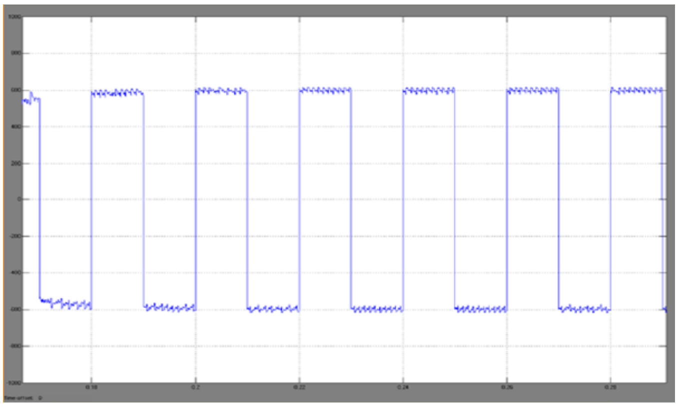


Fig. *Simulation result for secondary voltage*

6.8. State of Charge

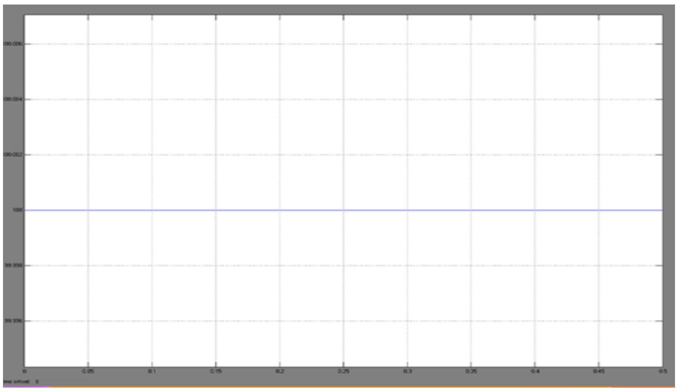


Fig. Simulation result for state of charge

6.9. Grid Voltage

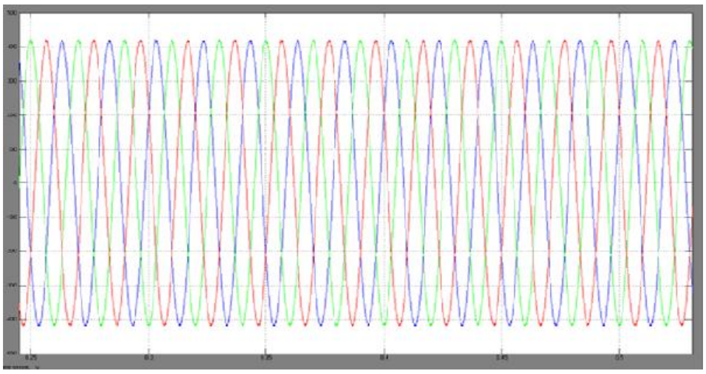


Fig. *Simulation result for grid voltage*

6.10. Grid Current

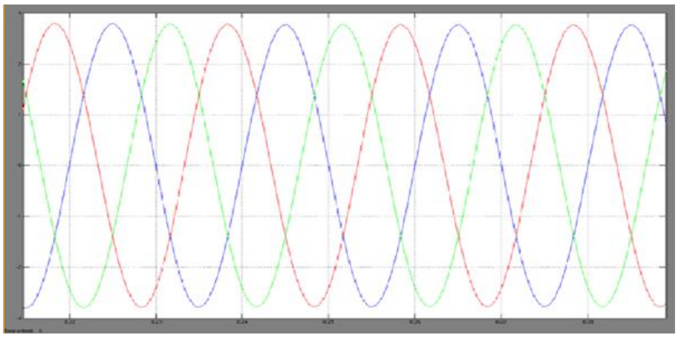


Fig. *Simulation result for grid current*

6.11. Current with THD

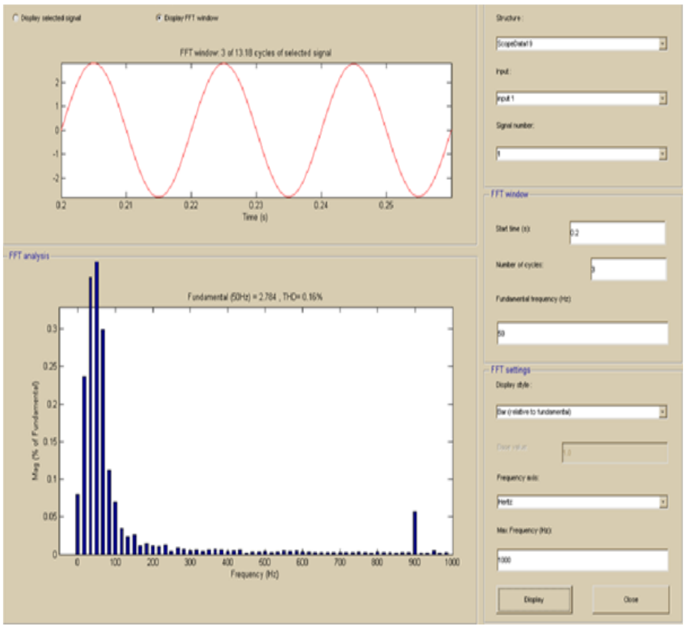


Fig. *Simulation result for total harmonics distortion*

7. Conclusion

The guideline to control the power flow and the properly selected control parameter to achieve MPP operation for grid-connected PV system with battery storage are presented. This will lead initiated idea for the future research concerned with such PV system. The three control strategies are examined via the small PV system which can also extend to other strategies. These approaches are inspired by the fact that transferred active and reactive power across an inductance is highly associated with terminals voltage phase angles and amplitudes, respectively. Although the experimental results show the success of the power flow control, however, in the view of economic, energy storage is an additional cost. For this reason, in the future work the techno-economical optimization should be applied in order to achieve the optimum system configuration and a suitable control strategy in the future work.

References

[1] S. Jalbrzykowski, A. Bogdan, and T. Citko, "A dual full-bridge resonant class-E bidirectional dc–dc converter," IEEE Trans. Ind. Electron., vol. 58, no. 9, pp. 3879–3883, Sep. 2011.

[2] A.Virtuani and H.M.ullejans, E. Dunlop, "Comparison of indoor and outdoor performance measurements of recent commercially available solar modules," Prog. Photovoltaic: Res. Appl., vol. 19, pp. 11–20, 2011.

[3] F.Krismer and J.W.Kolar, "Closed form solution for minimum conduction loss modulation of DAB converters," IEEE Trans. Power Electron., vol. 27, no. 1, pp. 174–188, Jan. 2012.

[4] J. Everts, J. Van den Keybus, F. Krismer, J. Driesen and J. W.Kolar, “Switching control strategy for full ZVS soft-switching operation of a dual active bridge AC/DC converter,” in Proc. IEEE 27th Ann. Appl.Power Electron. Conf. Expo., pp. 1048–1055, Feb. 2012.

[5] F.Jauch and J.Biela, “Single-phase single-stage bidirectional isolated ZVS AC–DC converter with PFC,” in Proc. 15th Int. Power Electron. Motion Control Conf., pp. 1–8, Paper LS5d.1, Sep. 2012.

[6] Moacyr Aureliano Gomes de Brito, Luigi Galotto, Jr., Leonardo Poltronieri Sampaio,Guilherme de Azevedoe Melo, and Carlos Alberto Canesin, Senior Member, IEEE “Evaluation of the main mppt techniques for photovoltaic applications” IEEE Transactions on Industrial Electronics, vol. 60, no. 3, March 2013.

[7] B. Zhao, Q. Song, and W. Liu, “Efficiency characterization and optimization of isolated bidirectional dc–dc converter based on dual-phase-shift control for dc distribution application,” IEEE Trans. Power Electron., vol. 28, no. 4, pp. 1711–1727, Apr. 2013.

[8] Dharuman, Mahalakshmi, Sankaridevi “Photo-voltaic system with battery storage by mppt algorithm using voltage controller” Nehru International Journal of Engineering & Technology-March 2014 Volume 1 No.2 ISSN: 2348-60.

[9] Jordi Everts, Member, IEEE, Florian Krismer, Member, IEEE, Jeroen Van den Keybus, Johan Driesen, Senior Member, IEEE, and Johann W. Kolar, Fellow, IEEE “Optimal zvs modulation of single-phase single-stage bidirectional DAB AC–DC converters” IEEE Transactions on Power Electronics, vol. 29, no. 8, August 2014.

[10] Biao Zhao, Student Member, IEEE, Qiang Song, Wenhua Liu, and Yandong Sun “A synthetic discrete design methodology of high-frequency isolated bidirectional dc/dc converter for grid-connected battery energy storage system using advanced components” IEEE Transactions on Industrial Electronics, vol. 61, no. 10. October 2014.

[11] R. T. Naayagj, N. E. Mastorakis “Performance verification of dual active bridge dc-dc converter” Recent Researches in Applications of Electrical and Computer Engineering ISBN: 978-1-61804-074-9.

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