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Fuzzy Based Multiport Resonant Converter for Photovoltaic system

S.B. Yasaswini* and G.C. Prabhakar**

Abstract : In this paper a four port resonant bidirectional DC-DC converter is designed for two PV based sources from which maximum output is obtained using the MPPT technique. The DC converter employed here is of full bridge type. The switching legs are shared common by both the bidirectional dc-dc converters and the full bridge converter. The model is an advanced one for renewable energy regulation systems including the merits of simple understanding of the converter design, less number of devices considered, and the power conversion obtained in a single stage. PI controller is used for charging near the battery, discharging control purpose at the load side and the output voltage current waveforms are obtained. The PI controller used for the two PV sources is replaced by the fuzzy controller, earlier stability state of dc voltage regulation is observed. The regulation and control of voltage is modulated using the PWM (Pulse Width Modulation) technique or the phase-angle shift control scheme. The concept of zero voltage switching is used in this paper to minimize the switching losses. The simulation results are presented using MATLAB software.

Keywords : Bidirectional dc–dc converter (BDC); Full-bridge converter (FBC); multiport converter (MPC); renewable power system.

1. INTRODUCTION

In this paper the concept of resonant converter has been adopted for the converter design. Reducing the switch losses tends to increase in efficiency which can be easily achieved using the soft switch technique. Zero voltage switching is inhibited in this paper. These topologies have their primary interest in cases where less EMI is to be achieved or in cases where switching losses to be reduced in order to allow higher frequencies for miniaturization. Resonance is allowed to occur simply before and through the simulation and turn-off processes therefore produce ZCS and ZVS conditions, aside from that behave like a standard PWM converters.

Based on the simple and easy controlling techniques adopted and the inborn non-linearity DC-DC converters are adopted majorly now a days. The DC-DC control strategies which include voltage control mode current control mode and hysteresis control [1], are inhibited with certain disadvantages such as slow response of the system, poor reliability. The design of converters adopting these control strategies is easy to design and simple to execute but the problem relies with the selection of parameters because of extant of parasitic elements, loads varying according to time and the changeable supply voltages but they guarantee an appropriate conduct in any working conditions.

The selection of parameters and the stability obtaining condition is simple and convenient in the case of lower order dc-dc converters but as the order of the converter increases, the stabilization and design of control parameters becomes difficult. This is because the number of switching devices, diodes and additional storage elements increases in number. Its major merit is no difficult calculations are involved in

* VNR VJIET College, Bachupally, Hyderabad, India, 500085 Email: yesh.ammu@gmail.com.
** VNR VJIET College, Bachupally, Hyderabad, India, 500085 Email: gcprabhakar@gmail.com.

this methodology [2-4]. The design of the controller is effortless as it depends upon only semantic rules, example: "if output error is negative and its rate of change is positive then reduce the power factor" etc. The proposed topology can be easily adopted for higher order systems which include large parameter changes and higher signal dynamics. But the problem is that FLC cannot be efficiently used for obtaining small-signal response. The FLC implements simple non-linear control laws to face the non-linear nature of dc-dc converters.

2. SYSTEM DESCRIPTION

The Buck Boost-Four Port Converter (BB-FPC) shown in Fig 1 is taken for instance to substantiate the effectiveness of the proposed topologies. This converter is applied to a dual-channel PV-sourced system with a battery backup for example consider satellite application.

Switching State

The key waveforms of the proposed BB-FPC have been shown in Fig 2, where the two switches of each leg are operated in complementary to generate a rectangular voltage from the midpoint of the leg. Duty cycles of any of the two switches, either S2 and S4 or S1 and S3 are utilised as two control parameters to control the power exchange between the ports PV1 and the battery or PV2 and the battery.

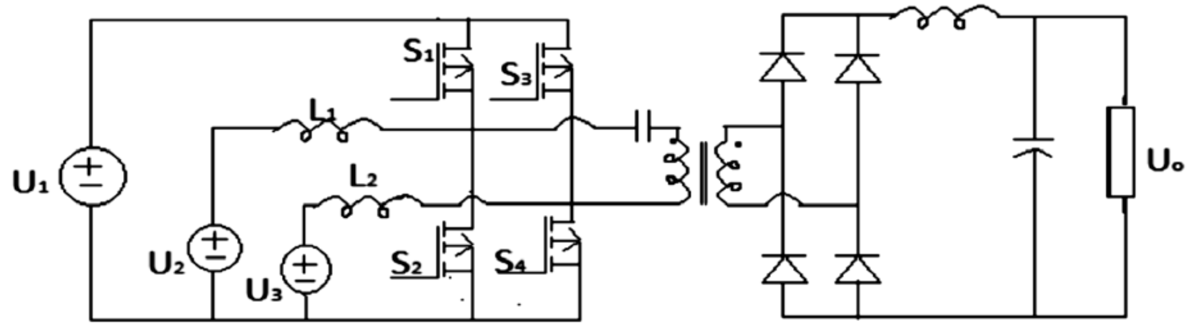

Fig. 1. Block Diagram of Proposed BB-FPC.

The output voltage Uo is obtained and controlled by an angle ϕ. The voltage on the block capacitor Cb is termed as UCb. There are six switching states in one switching cycle, three states for positive cycle and three states for negative cycle.

State I [$t0 - t1$] : At $t0$, S1 is turned off, S2 is turned on, and S3 remains on. L1 begins to be charged, and L2 is still discharged linearly. The filter inductor current, iLo, freewheels through the rectifier diodes, Do1 − Do4.

State II [$t1 - t2$] : At $t2$, ip = − niLo, and Do1 and Do4 bear reverse bias. The transformer is used for supplying the power from the primary sources to the load.

State III [$t2 - t3$] : In this state the switch S2 continues to be in ON state while the switch S3 is turned off and S4 is turned on. An increase in the inductor current iL2 is observed. The voltage of the block capacitor, UCb, the voltage from capacitor Cb is applied on the transformer primary winding.

State IV [$t3 - t4$] : At $t3$, S2 is turned off, S1 is turned on, and S4 remains on. L1 begins to be discharged, and L2 is still charged linearly. iLo begins to freewheel through the rectifier diodes, Do1 − Do4, and the voltage applied on the leakage inductance Lk is (Ub − UCb). $\frac{di\mathrm{L1}}{dt}$

State V [$t4 - t5$] : In this state, Do2 and Do3 bear reverse bias. The filter inductor current iLo fully flows through Do1 and Do4.

State VI [$t5 - t6$]: At $t5$, S4 is turned off, S3 is turned on, and S1 remains on. UCb applies on the transformer primary windings, iL2 begins to decrease, and iLo flows through Do1 and Do4 .

3. OPERATION MODES AND ANALYSIS

The operation of the PV–battery power system is categorized into five modes.

Mode I : Zero power is obtained from PV in this mode, and power to the load is supplied by the battery alone. Battery discharges in this mode to supply the required power. This mode can be called as one-input one-output mode.

Mode II : The generated PV power is not capable meeting the load demands in this mode. The power to the load is supplied by both PV and battery supply. The two PVs in this mode operate in MPPT state. This mode is termed as named dual-input mode.

Mode III : In this mode, the load demands are lesser than the power generated from PV modules. The PVs work in MPPT state, and the battery ingests all the excess PV power.

Mode IV : In this mode, the maximum power that can be generated from PV exceeds the sum of the load and battery charging demands. The battery operates in CC or CV charging state. Only one of the PV module operates in MPPT state and the other does not.

Mode V : In this mode, the maximum power that can be generated from PV exceeds the sum of the load and battery charging demands. The battery operates in CC or CV charging state. None of the two PV modules operates in MPPT state. The name dual-output mode is given to the modes III, IV, V.

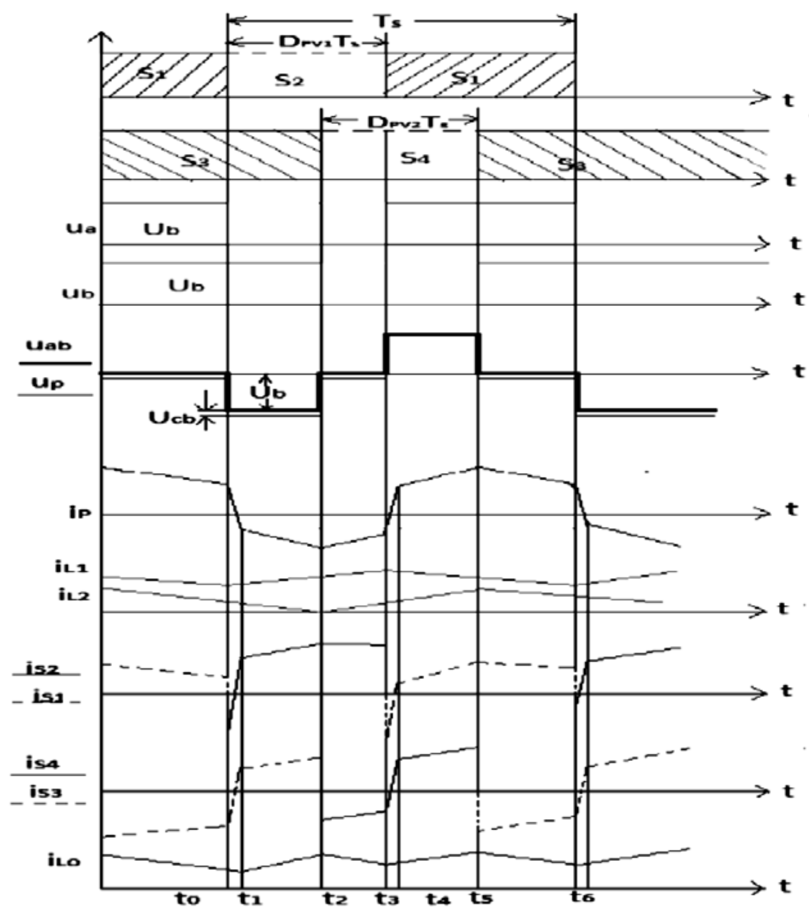

Fig. 2. Waveforms of BB-FPC.

4. CONTROL THROUGH FEEDBACK

The key strategy adopted here is to control the power between the battery and PV sources[8-9]. The output voltage is controlled using the phase shift angle as the voltage obtained from the battery is almost constant.. The control block diagram of the Full Bridge-Bidirectional DC-DC converter is shown in figure 3 below.

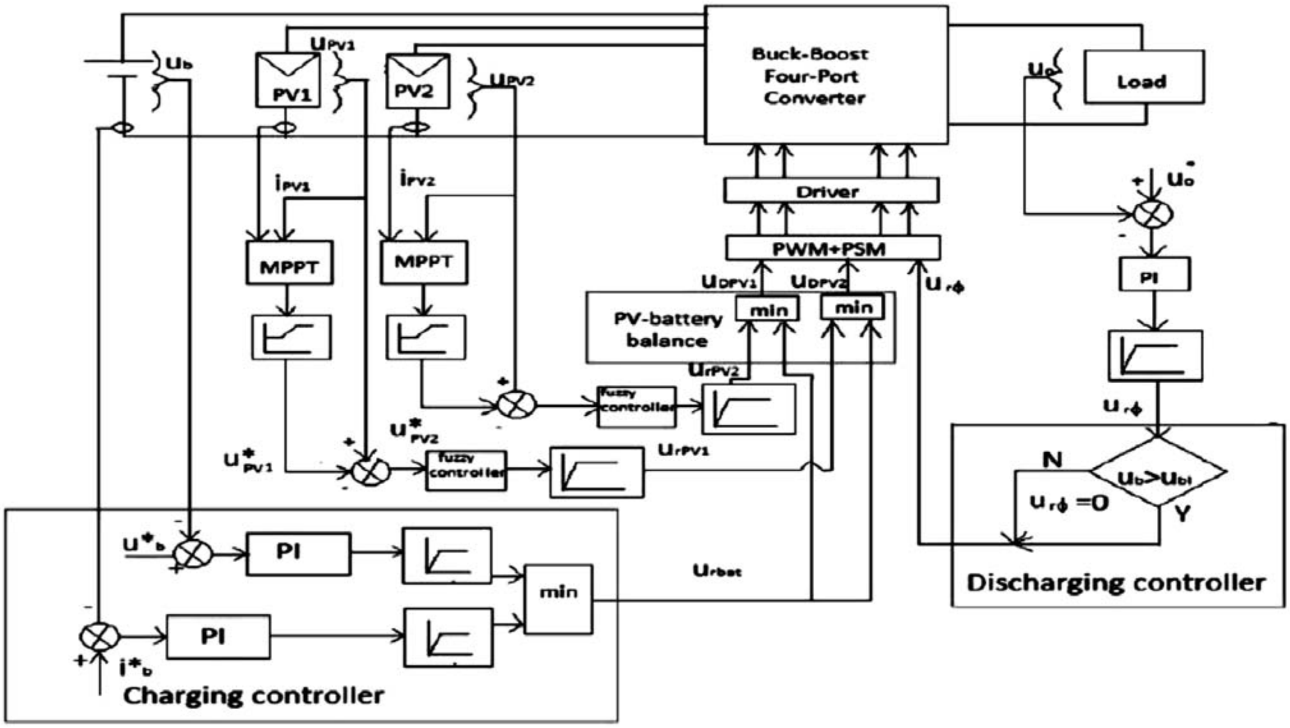

Fig. 3. Control block diagram of the BB-FPC.

5. SIMULATION BLOCK DIAGRAM AND SIMULATION RESULTS

PI controller based full bridge-bidirectional dc-dc converter:

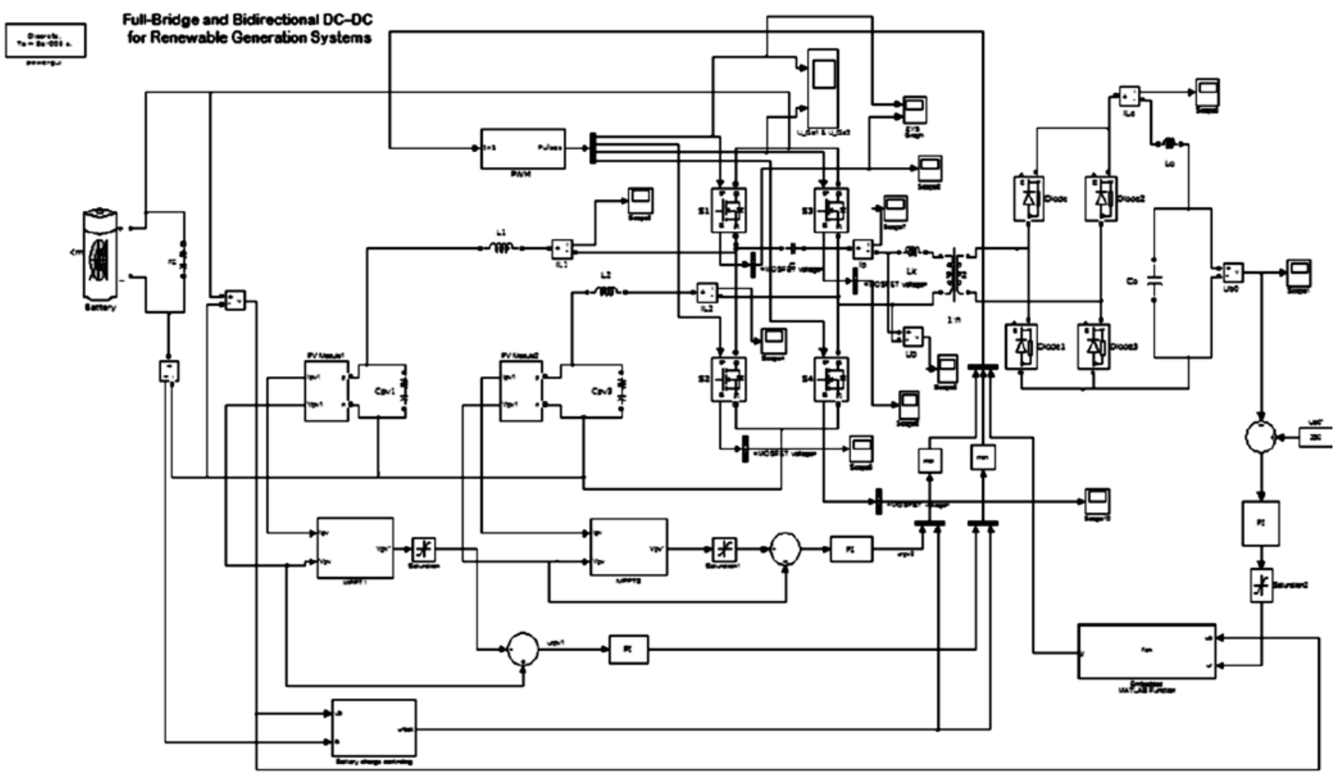

Fig. 4.

Block diagram of PV module :

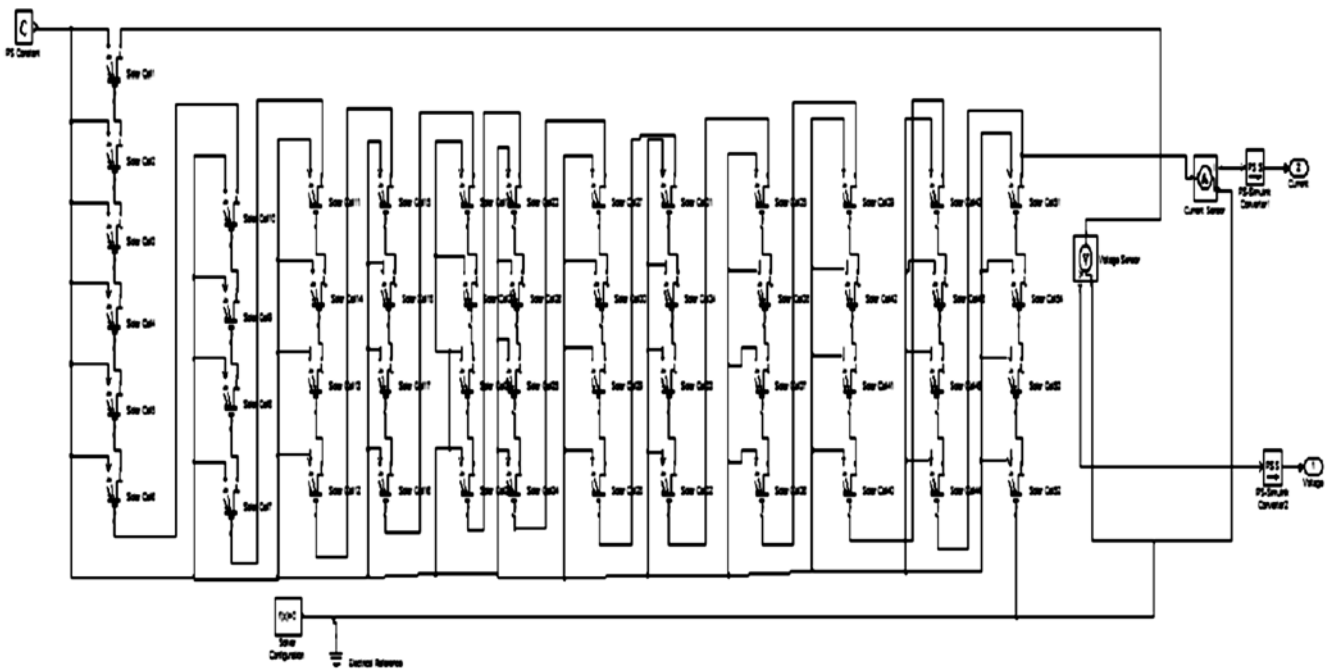

Fig. 5.

Fuzzy controller based full bridge-bidirectional dc-dc converter:

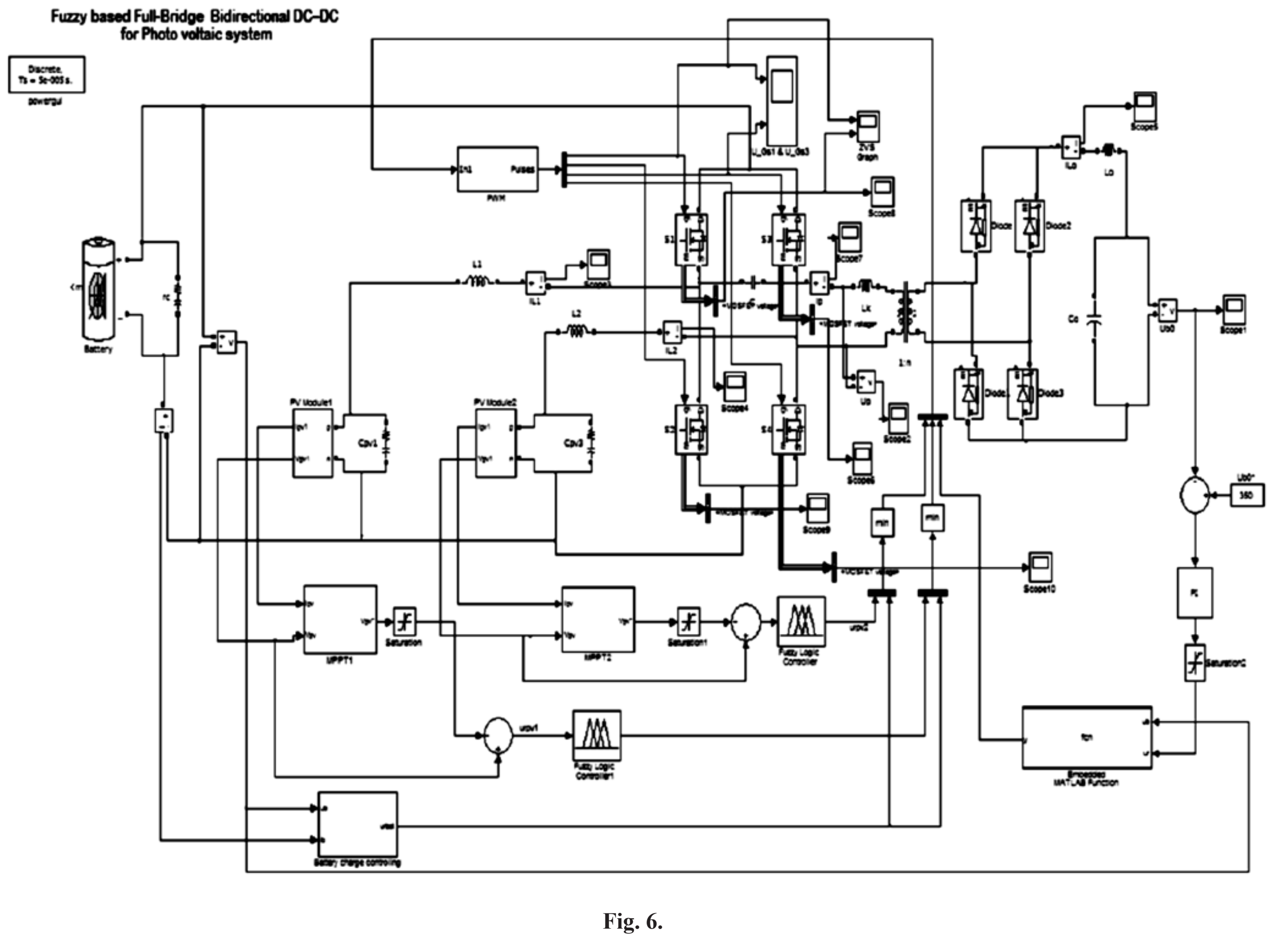

Fig. 6.

Simulated block of MPPT technique :

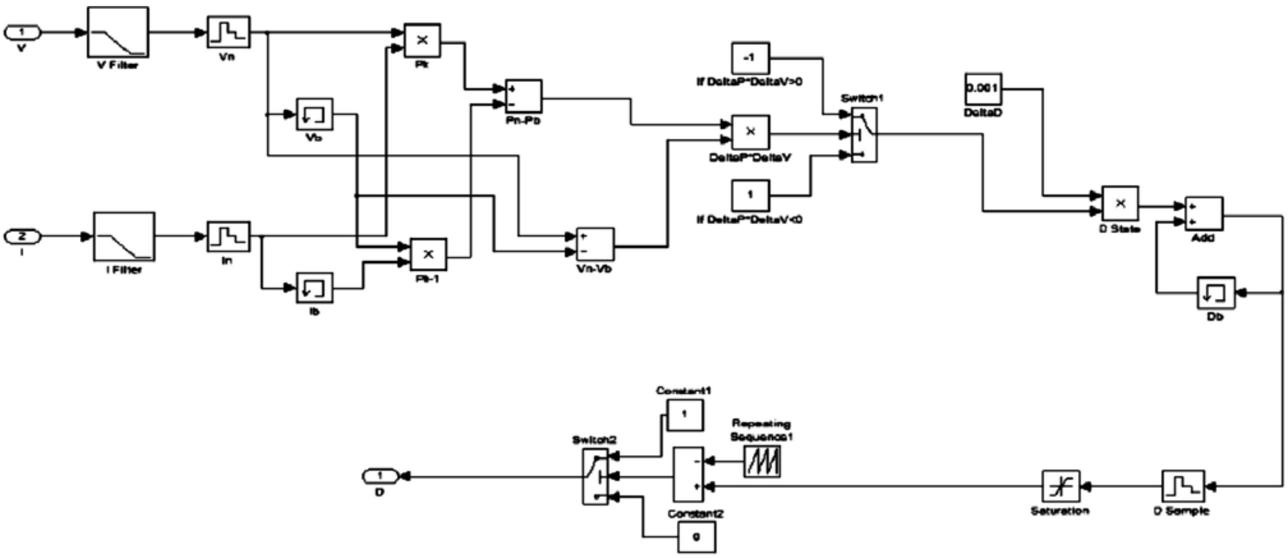

Fig. 7.

PV source outputs :

Voltage :

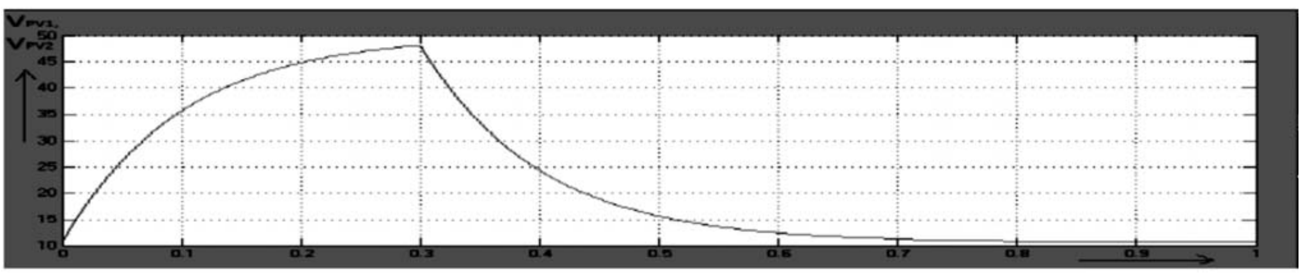

Fig. 8.

Current :

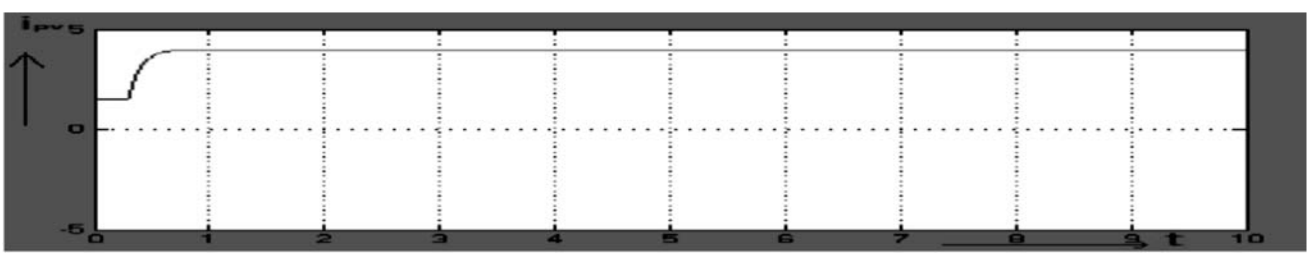

Fig. 9.

Power :

Fig. 10.

Il1:

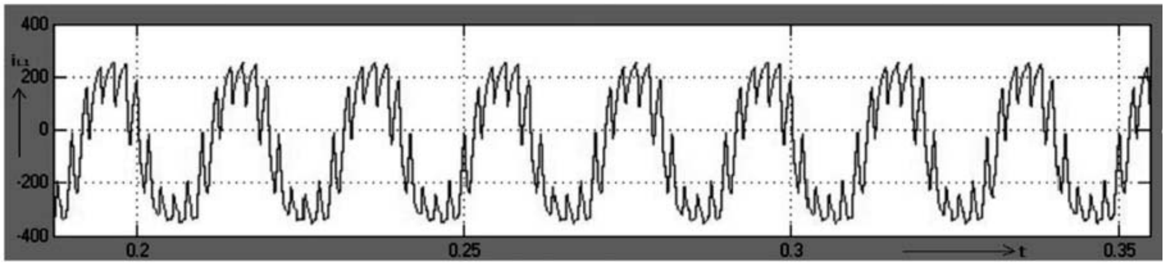

Fig. 11.

iL2 :

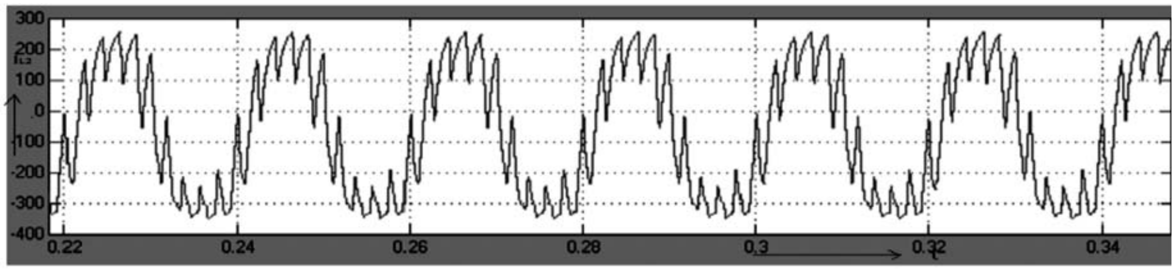

Fig. 12.

UP:

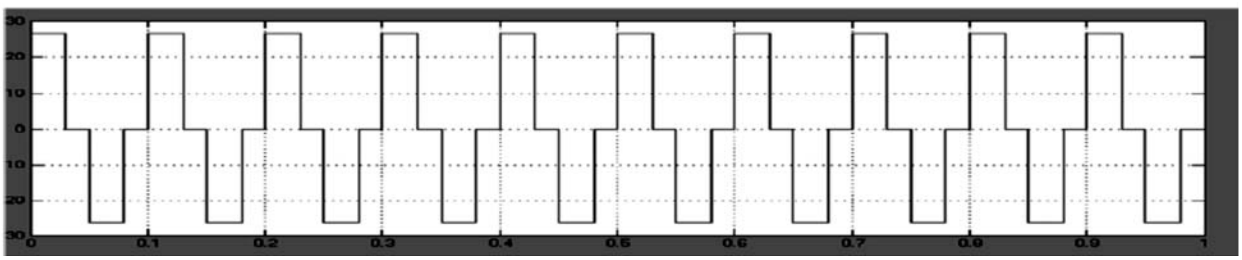

Fig. 13.

iP:

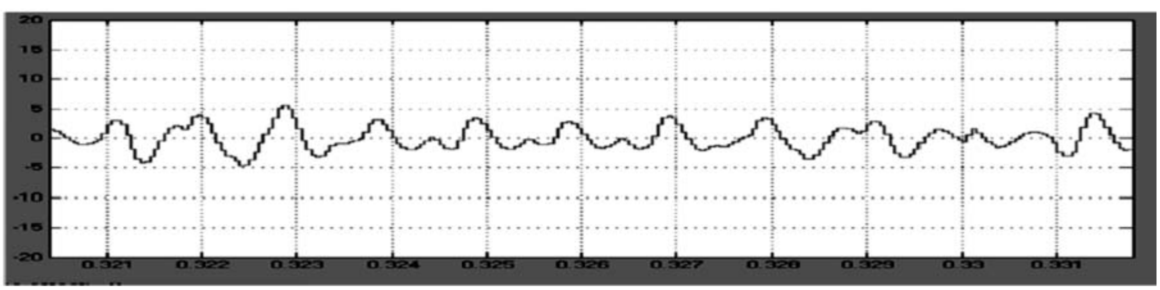

Fig. 14.

Ugs1 and Ugs 3:

Fig. 15.

ILo:

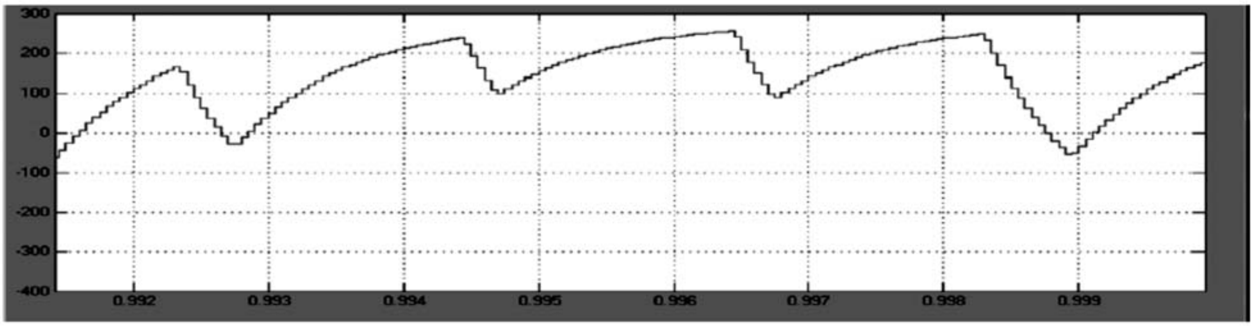

Fig. 16.

Output voltage when PI controller employed :

Uo :

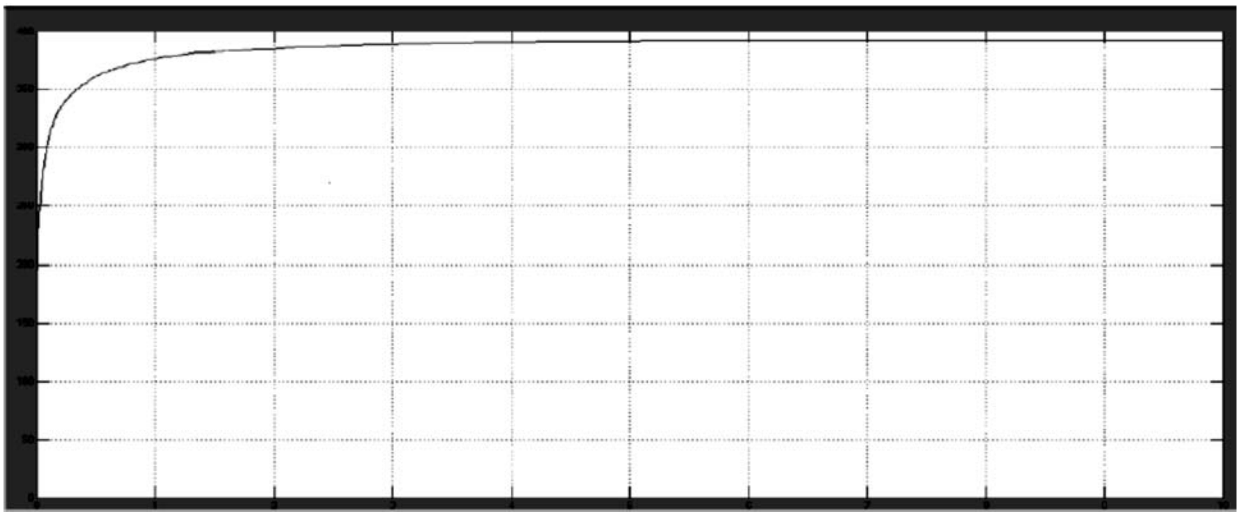

Fig. 17.

In case of fuzzy controller :

Uo:

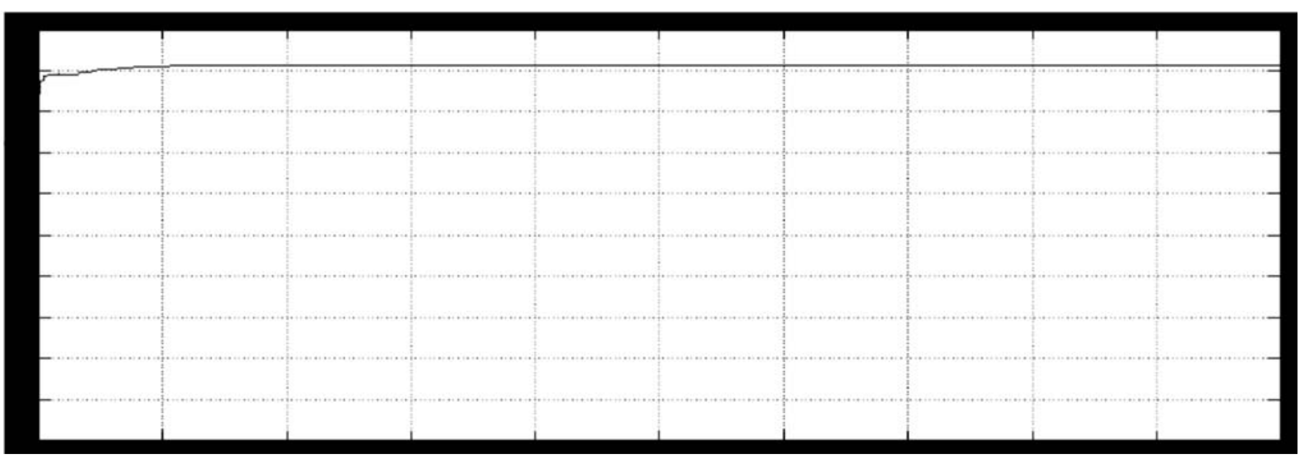

Fig. 18.

6. CONCLUSION

PV based four port resonant converter which constitutes of the full bridge (FB) converter (FBC) and bidirectional dc–dc converters (BDCs) with minimum switching losses is shown in this paper. The MPPT technique used in this project is the perturb and observe method which is applied to the PV sources for the purpose of obtaining the maximum output from them. The voltage at the output side and its stability condition can be obtained faster using the fuzzy logic controller. Charging state and discharging state controllers are properly designed for obtaining the output voltage with the ripple content minimized. The merits using this topology constitute of less number of devices, power converted in a one go, simple design and operation comprehension. Modulation strategies pulse width modulation and phase-angle shift control scheme are adopted for voltage purpose. Zero-voltage switching whose major advantage is lower switching losses for higher frequencies is adopted in the proposed FB-BDC-MPCs.

7. REFERENCES

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