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Harnessing Renewable Power Using A High Step-Up Three-Port DC-DC Converter

Sk. Bilal, M. Manogna* A.R.Vijay Babu* and G.Srinivasa Rao*

Abstract : The concept of multiport converters for hybrid power generation is increasing rapidly. In this paper, the hybrid PV/battery system is proposed using a high step-up three-port dc-dc converter. A mode selection controller is proposed to choose the operating mode of a converter depending on the voltage levels of the different sources and storage limits. The proposed converter can handle multiple inputs as demonstrated in the simulation results.

Keywords : *dc–dc* converter; three port converter; hybrid system.

1. INTRODUCTION

Owing to the intermittent nature of the renewable power generating sources, storage elements are essential along with separate dc–dc converters in stand-alone units [1-2].Multi port converters are used to complement the drawbacks of conventional method of multiple stage conversion to achieve high power density and efficiency [3-21]. The Solar photovoltaic and battery energy storage systems can be interfaced simultaneously using a multi port converter along with maximum power point trackers for each source to overcome the impacts of power mismatches and to optimize the output power of the system. Whenever the utility grid is not available, a bidirectional interfacing is essential for the MPC to improve the stability and steady-state performances.

Depending on the applications, various topologies of MPCs are proposed which includes capacitors, magnetic cores and sharing switches [17]. A simple converter topology for the hybrid PV/battery system is proposed in the paper which uses coupled inductors to attain high voltage conversion ratio with minimum number of switches. The advantage of the proposed converter is that, the output voltage is always maintained at 380V and there is no need to change the mode of operation after every charging/discharging transition.

2. TOPOLOGY OF THE PROPOSED CONVERTER

The proposed three-port dc-dc converter is shown in Fig. 1. The converter has two switches S1 for battery and S2 for the PV. Bidirectional power flow for the battery is consummated by driving switches S3 and S1 reciprocally. Two coupled inductors are used as voltage gain extension cells with winding ratios n1 and n2. Two sets (S4, Lk1, Cc1 and S5, Lk2, Cc2) are used as active-clamp circuits.

The two controllable switches S1 and S2 are operated with duty cycles d1 and d2, which allows the control over the two ports whereas the power balance is at the load port. The auxiliary switches S3 and S4 are driven with fixed frequency in complementary to primary switch S1 And also S5 with S2 by maintaining phase shift of 180-degrees in between S1 and S2.

* VFSTR University, Vadlamudi 522213, India

Initially the sun shines on the solar panel that irradiation is used for supplying the load demand along with the battery. As the increase in solarisation is larger than the load demand, then the battery will preserve extra solar power for backup. To prevent overcharging, a preset level of voltage is set for the battery.

Depending upon load demand and the solar irradiation the converter can be operated in two modes. In the first mode (mode-1), the dc-dc converter is always operated for the PV to extract the maximum power from the solar panels while the battery stores the unconsumed solar power under light load condition and delivers the power during heavy load condition.

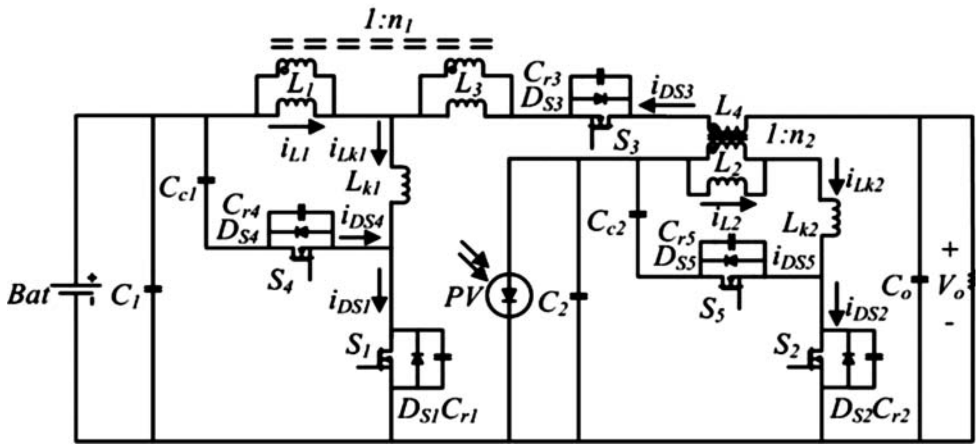

Fig. 1. The proposed converter.

The power sharing can be represented as:

$$P_{load} = Ppv1 + Pbat1. \tag{1}$$

Where P_{load} is the load power, Ppv1 is the PV power and Pbat1 is the battery power.

The power is drawn from PV to battery depending on the load demand in mode-1.so that Pbat1 may be positive or negative. When the battery charging voltage is more than the preset voltage value then the converter will be switched into second mode

In the second mode (mode-2) dc-dc converter is disconnected so that only part of the solar power is drawn even though battery voltage control can be achieved for the protection of overcharging

The power sharing can be represented as :

$$P_{load} = Ppv2 + P\,bat2 \tag{2}$$

Where Pbat2 is the PV power, Pbat2 is the battery charging power under mode-1.

Whenever load demand is increased or battery voltage is decreased the converter switches to mode1. in both mode of operations output voltage is kept at 380V.

3. RESULTS AND DISCUSSIONS

The operation region for the converter is verified as follows :

- Supply the load from each input source independently;
- Share the load between the input sources;
- The main source (PV) supplies the load and charges the battery.

In the simulation results, the maximum power rating is set as 300 W (1 p.u.). The Pbat, p.u is 0.3 p.u. because the maximum charging current is limited. In all the figures showing simulation results, the unit of *x*-axis is sec and *y*-axis is volt for voltage waveforms and ampere for current waveforms. It is noted that the direction of battery current measurement in operating points A and B is opposite to operating points C and D.

3.1. Operating point A (PPV, p.u, Pbat, p.u) = (0,1), load demand = 300 W

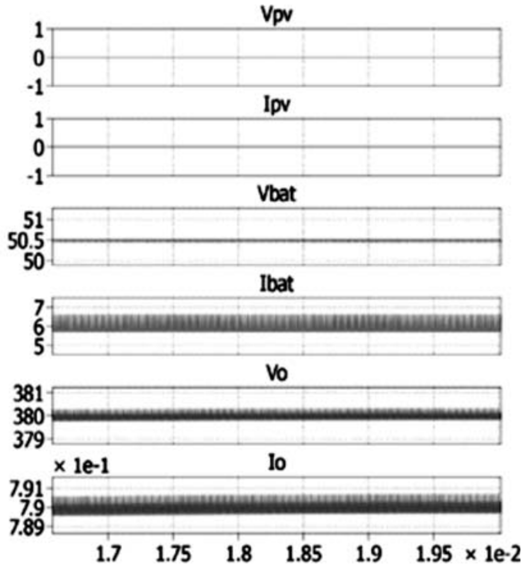

Fig. 2. Operating point A: voltage and current waveforms of three ports.

It is observed from Fig. 2 that the load demand is 300 W and is supplied by the battery port at operating point A. The solar irradiation level at this operating point is 0 W/m2.

3.2. Operating point B (PPV, p.u, Pbat, p.u) = (0.5,0.5), load demand = 300 W

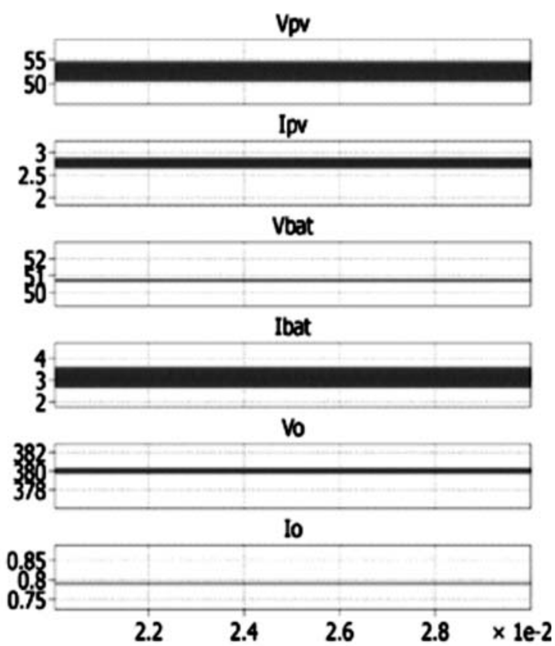

Fig. 3. Operating point B: voltage and current waveforms of three ports.

It is observed from Fig. 3.23 that the load demand is still 300 W but the solar irradiation level is increased to 500 W/m2. Therefore, the load is equally shared by the battery port and the PV port at operating point B.

3.3. Operating point C (PPV, p.u, Pbat, p.u) = (1,0), load demand = 300 W

It is observed from Fig. 4 that the 300W load is supplied by the PV port at operating point C since the solar irradiation level is increased to 1000 W/m2.

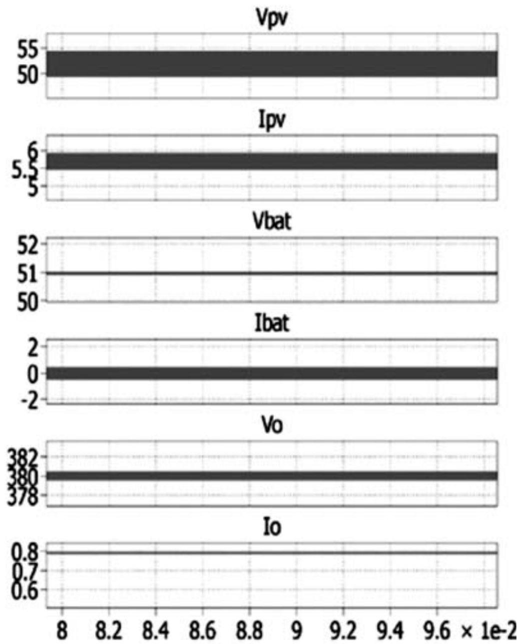

Fig. 4. Operating point C: voltage and current waveforms of three ports.

3.4. Operating point D(PPV, p.u, Pbat, p.u) = (1, -0.3), load demand = 210 W

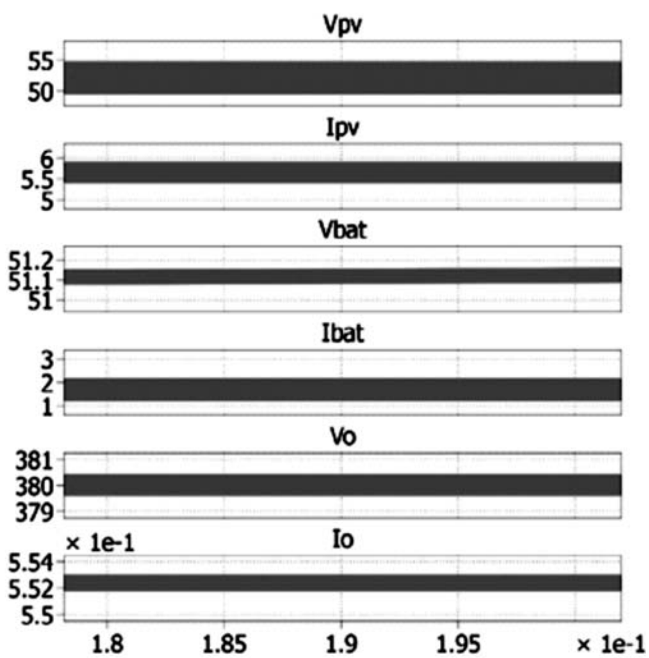

Fig. 5. Operating point D: voltage and current waveforms of three ports.

It is observed from Fig. 5 that the load is reduced to 210 W at operating point D and the solar irradiation level remains 1000 W/m2.

3.5. Operating point C to D, load demand = 300 W to 210 W

It is observed from Fig. 3.31 that the load is change from 300 W to 210 W at $t = 0.1s$ while the solar irradiation level is still 1000 W/m2. After the load transition, The PV power starts to charge the battery but MPPT is still operated and output voltage is regulated as well. An overshoot < 5% is observed. At $t = 0.225s$ the operation mode changes from battery balance mode to battery manage mode to prevent overcharging. The MPPT operation is therefore disabled

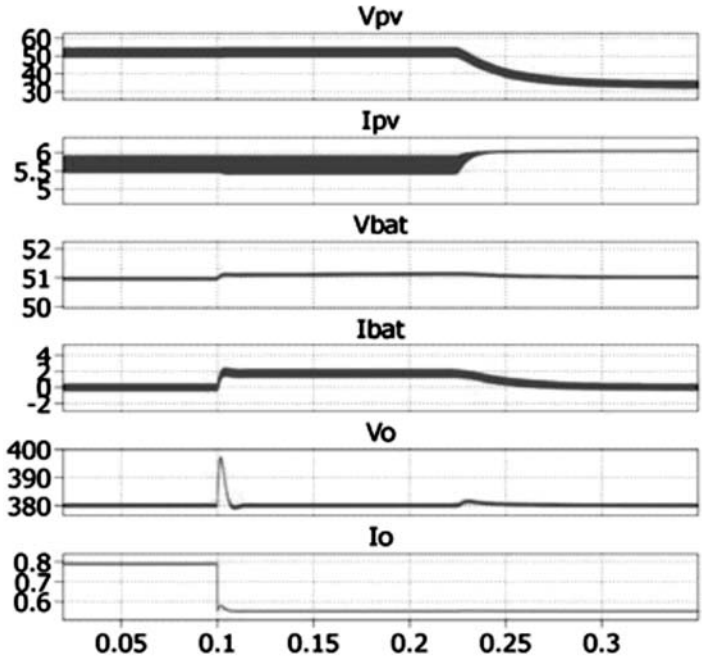

Fig. 6. Operating point C to D: voltage and current waveforms of three ports.

4. CONCLUSION

In this paper the hybrid PV/battery system is proposed using a high step-up three-port dc-dc converter a simple converter topology for the hybrid PV/battery system is proposed which uses coupled inductors to attain high voltage conversion ratio with minimum number of switches. The advantage of the proposed converter is that, the output voltage is always maintained at 380V and there is no need to change the mode of operation after every charging/discharging transition with two modes of operation. For different applications the control method can be modified this renewable power generations used in many applications like satellites, electrical vehicles.

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