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An Isolated Multiport DC-DC Converter for Different Renewable Energy Sources

K.Pradeepkumar[1], J.Sudesh Johny[2]

PG Student [Power Electronics & Drives], Dept. of EEE, Sri Ramakrishna Engineering College, Coimbatore, Tamil Nadu, India[1]

Assistant Professor, Dept. of EEE, Sri Ramakrishna Engineering College, Coimbatore, Tamil Nadu, India[2]

ABSTRACT: This paper presents a new isolated multiport dc–dc converter for concurrent power management of several renewable energy sources which can be of similar types. The proposed dc–dc converter uses only one controllable switch in each port to which a source is connected. It has simple configuration and minimum number of power switches. The proposed converter is applied for simultaneous maximum power point tracking (MPPT) control of a wind/solar hybrid generation system consisting of one Wind Turbine Generator (WTG) and two different Photovoltaic (PV) panels. The experimental results are provided to validate the incisiveness of using the proposed converter to achieve MPPT simultaneously for the WTG and both PV panels.

KEYWORDS: Multiport converter, maximum power point tracking (MPPT), photovoltaic (PV), wind turbine generator (WTG) solar energy, wind energy.

I.INTRODUCTION

Nowadays, there is a growing interest in generating electricity from distributed renewable energy sources. In numerous applications, it is required to connect multiple renewable energy sources of different types to a power grid or load. The multiport DC-DC converter has been proposed to efficient power management and grid integration for the multiple origins and development in a new era in a demand quality power in remote communities[8][9]. The isolated dc–dc converter has multiple input ports for connecting different sources, such as photovoltaic (PV) panels, wind turbine generators (WTGs), fuel cells, etc., The multiport dc–dc converter not only regulates the low-level dc voltages of the sources to a constant high level required by the inverter but also provides other important control functions, such as maximum power point tracking (MPPT).

The proposed isolated multiport dc–dc converter for simultaneous power management of multiple renewable energy sources uses only one power electronic switch in each input port connected to a source. The proposed converter does not use any controllable switch on the secondary side of the transformer [2]-[4]. The proposed converter has the least number of switches and thereby a lower cost. The newly introduced converter is applied for power management of a wind/solar hybrid generation systems, which consists of a WTG and two varied PV panels. The power generation from solar and wind energy are designed using perturbation and observation (P&O) MPPT algorithm, in which the WTG and PV panels can be controlled at the same time and extract the maximum power.

II.PROPOSED ISOLATED MULTIPORT DC-DC CONVERTER

The Fig 1 shows the block diagram of the proposed isolated multiport DC-DC converter. Itconsists of PV Panels, Wind turbine generator, Boost converter, MPPT controller, High frequency transformer and an inverter.

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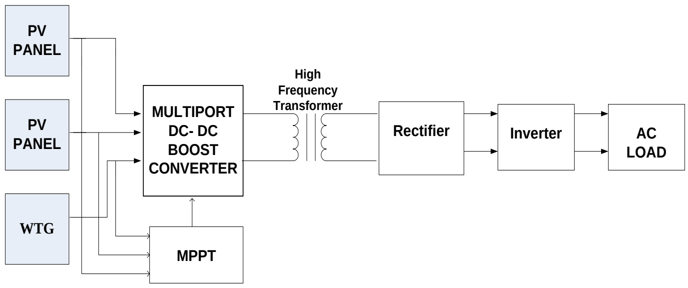

Fig 1 Block Diagram of the proposed system

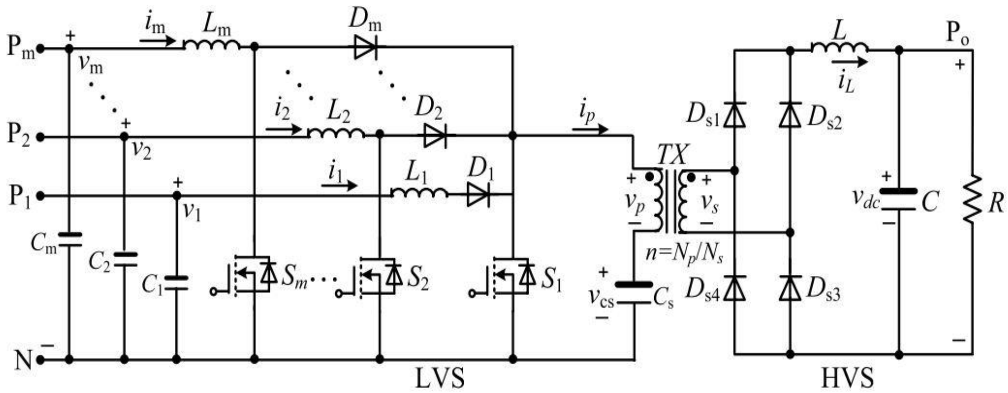

Fig 2 Circuit Diagram of the isolated multiport dc–dc converter

The fig 2 shows the circuit diagram of the isolated multiport dc-dc converter. It consists of a low-voltage side (LVS) circuit and a high-voltage-side (HVS) circuit connected by a high-frequency transformer TX. The LVS circuit consists of m ports in parallel, one energy storage capacitorC_s, and the primary winding of the transformer. Each port contains a controllable power switch, a power diode, and an inductor. The HVS circuit consists of the secondary winding of the transformer connected to a full bridge diode rectifier, and a low frequency LC filter.The transformer's turn ratio is defined as n= N_p/N_s .

This converter has three operating modes: 1) All switches are on; 2) Switch S_1 is off while at least one of the other switches is on; and 3) All switches are off. The equivalent circuits of the converter in the three operating modes are shown in Figure3.

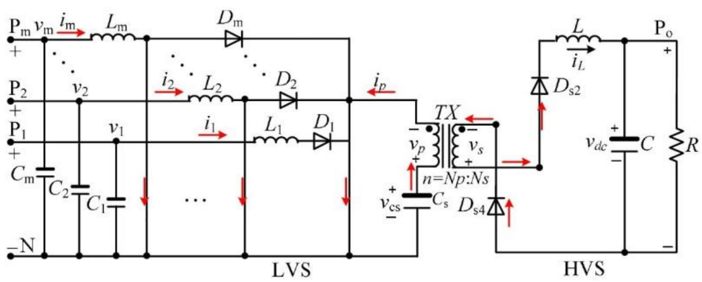

Fig 3(a). Equivalent circuits of the operating Mode 1

The fig 3(a) which shows the equivalent circuit diagrams of mode 1 for all switches are on and also signal flows in the generation system managed by the proposed dc-dc converter.

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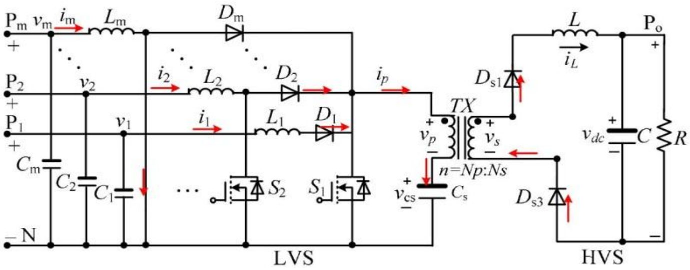

Fig 3(b). Equivalent circuits of the Mode 2:S_1 is off and at least one of the other switches is on.

The fig 3(b) which shows the equivalent circuit diagram of mode 2 i.e., switch S_1 is off and at least one of the other switches is on and also signal flows in the generation system managed by the proposed dc-dc converter.

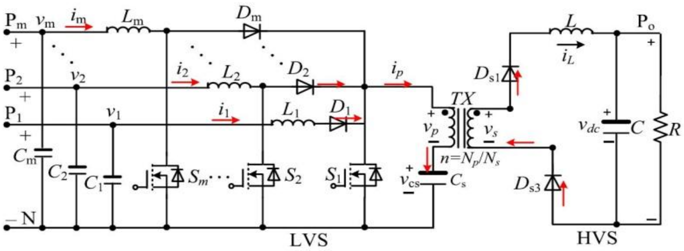

Fig 3(c). Equivalent circuits of the Mode 3 all switches are off.

The fig 3(c) which shows the equivalent circuit diagram of mode 3 i.e., all switches are off and also signal flows in the generation system managed by the proposed dc-dc converter.

To facilitate the explanation of the converter operation, the state-space equations for different modes are written in the following form:

$$M * \dot{X} = A * X + B \qquad \text{---------- (1)}$$

where M = diag($L_1, L_2, . . . , L_m, C_s$, L,C) is a (m + 3) × (m + 3) diagonal matrix, X = $[i_1, i_2, . . . , i_m, v_{cs}, i_L , v_{dc}]^T$ is a (m + 3) × 1 state vector, A is the (m + 3) × (m + 3). Coefficient matrix, and B is a (m + 3) × 1 vector containing input signals and some state variables.

The proposed converter is applied for MPPT control of a wind/solar hybrid generation system consisting of a WTG and two PV panels, as shown in Fig 3.

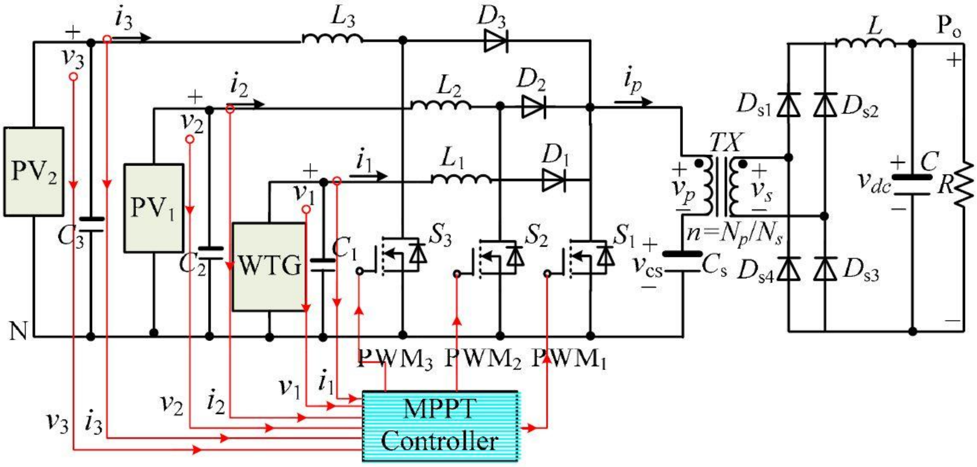

Fig 4 Signal flows in the wind/solar hybrid generation system managed by the proposed dc-dc converter.

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The MPPT controller uses a P&O MPPT algorithm to maximize the output power of the WTG and two PV panels simultaneously under various weather conditions. Since the wind flow changes more drastically than the solar radiation and the temperature, the updating frequency of d1 is set to be the highest. The MPPT controller uses the output voltage and current of each source as the input to generate an appropriate pulse width modulated signal for the corresponding switch.

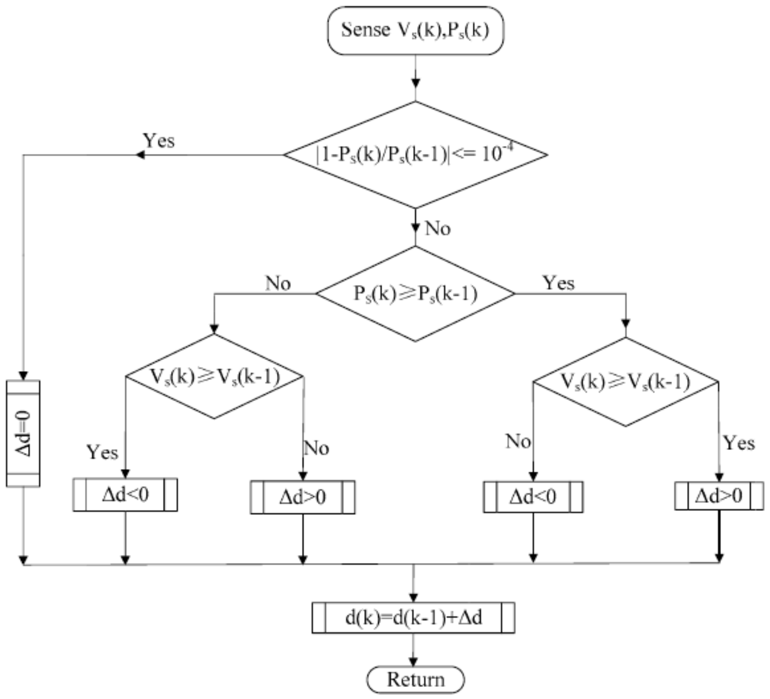

Figure 5 flowchart of the P&O MPPT algorithm

The flowchart of the P&O MPPT algorithm is shown in Fig. 5, where $V_s(k)$ and $P_s(k)$ are the sampled voltage and power of each source at the kth step, respectively, and Δd is a predefined perturbation value of the switch duty cycle in two consecutive switching periods. The updated duty cycle causes a change in the source current, which leads to the variation of the output power of the source. The power variation and duty cycle perturbation in the previous step are used to determine the direction (i.e., positive or negative) of the duty cycle perturbation in the next step.

To test the MPPT results for the two PV panels and the WTG, it is necessary to obtain the ideal maximum power points (MPPs) of the three sources under various conditions. For a PV panel, the power–voltage (P–V) characteristic curve can be assumed unchanged within every 3-min interval in a clear day. Then, the MPPs can be derived by gradually increasing the duty ratio from a low to a high value.

III.SIMULATION OF THE PROPOSED SYSTEM

The proposed converter is applied for MPPT control of a wind/solar hybrid generation system consisting of a WTG and two PV panels, as shown in the Simulink model. The MPPT controller uses a P&O MPPT algorithm to maximize the output power of the WTG and two PV panels. Since the wind flow changes the updating frequency of d_1 is set to be the highest.

For a PV panel, the power voltage (P–V) characteristic curve can be assumed unchanged within every 3-min interval in a clear day. Then, the MPP can be derived by gradually increasing the duty ratio from a low to a high value. The MPP of the WTG are calculated using the measured wind speed and other parameters provided by the manufacture as follows. The Simulink model of the proposed isolated dc-dc converter is shown in fig 4.

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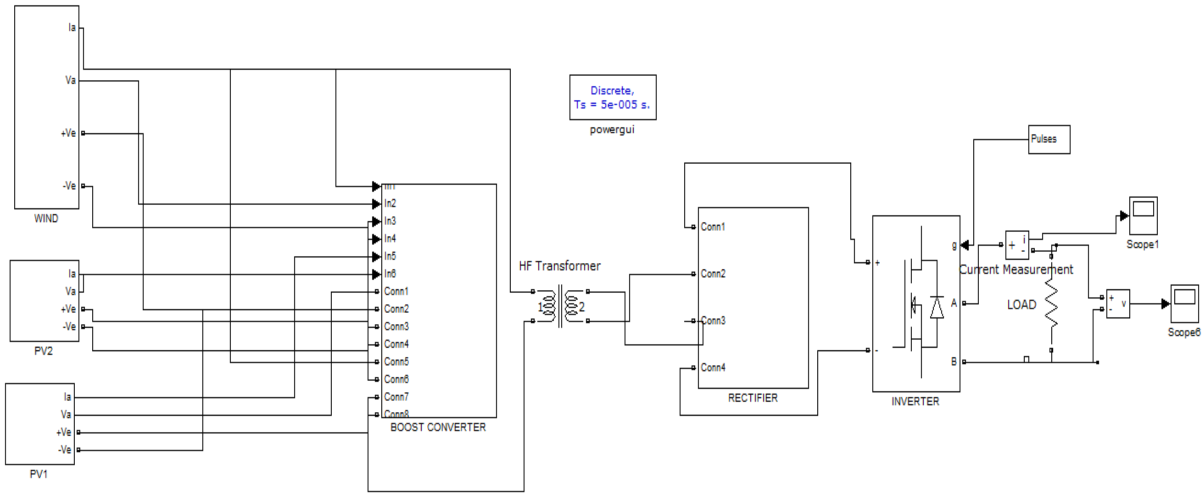

Fig 6 Simulation circuit for the proposed system

The Fig 6 shows the simulation circuit of proposed multiport DC-DC converter which is connecter through the two PV panel and Wind Turbine Generator and it is connected to the load through the inverter.

IV. SIMULATION RESULTS

The following results shows the output voltage and current waveforms of PV panel and wind turbine generator

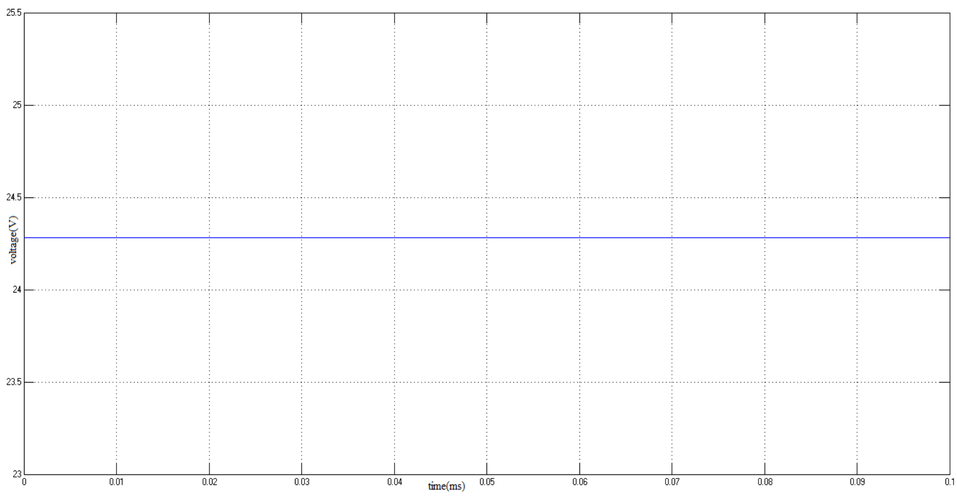

Fig 7(a) PV panel 1 output Voltage waveform

The fig 7(a) shows the result of PV panel 1 has the output voltage of approximately 24 V.

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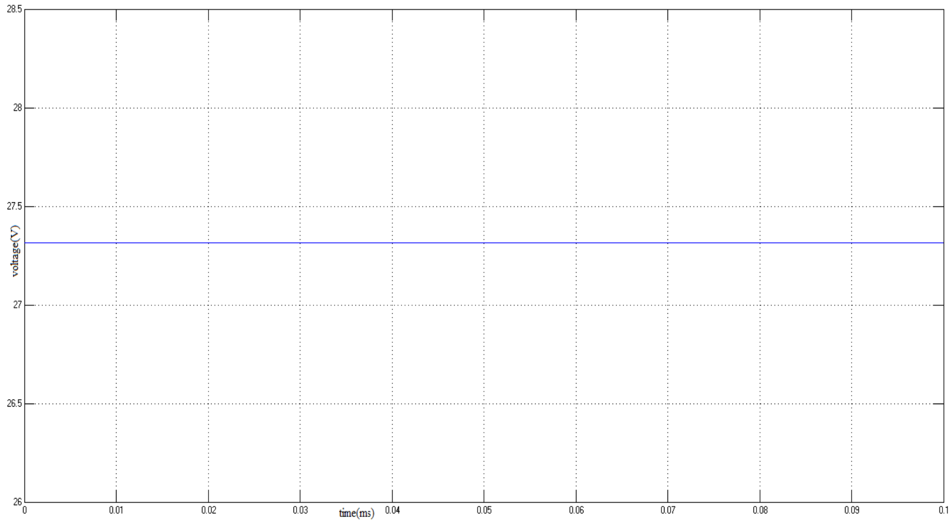

Fig 7(b) PV panel 2 output voltage waveform

The fig 7(b) shows the result of PV panel 2 has the output voltage of approximately 27 V.

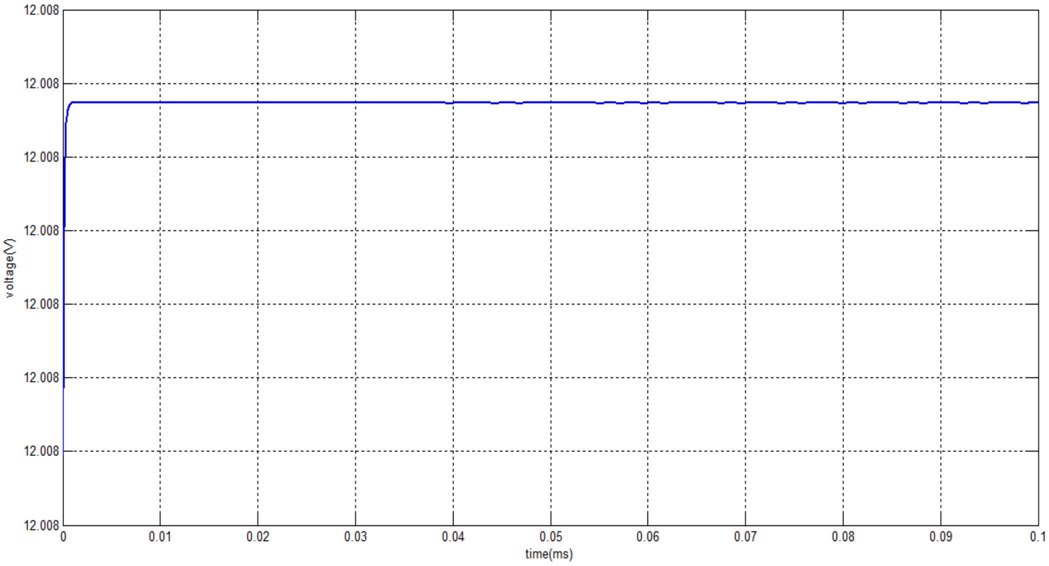

Fig 7(c) Wind turbine generator output voltage waveform

The fig 7(c) shows the result of Wind Turbine Generator has the output voltage of approximately 12 V

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V. SIMULATION OUTPUT RESULTFROM INVERTER

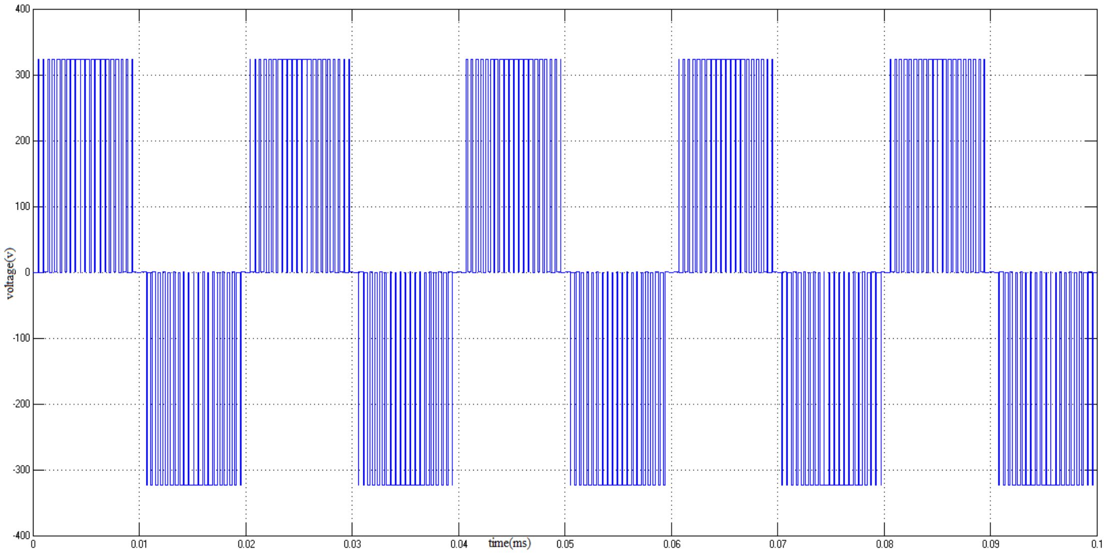

Fig 8 Inverter output voltage waveform

The fig 8 shows the inverter output result for the proposed system. The results are obtained using light load connected to the inverter terminal.

VI.CONCLUSION

An isolated multiport dc–dc converter that uses the minimum number of switches has been proposed for simultaneous power management of multiple renewable energy sources. The proposed converter has been applied for simultaneous power management of a three-source wind/solar hybrid generation system. The experimental results have been provided to show the effectiveness of the proposed converter. The advantage of the proposed multiport dc–dc converter is its simple topology while having the capability of MPPT control for different renewable energy sources simultaneously. Moreover, the proposed converter can be easily applied for power management of other types of renewable energy sources.In future the hybrid energy system can be further altered to some other renewable sources like PV-Fuel cell Hybrid Energy System to meet large load depending on various applications.

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