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DC–DC CONVERTER FOR SIMULTANEOUS POWER MANAGEMENT OF HYBRID RENEWABLE ENERGY SOURCES

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ABSTRACT: In present days, there has been a growing interest in generating electricity from distributed renewable energy sources. In many applications it is required to connect multiple renewable energy sources of different types and capacities to a power grid or load. This paper proposed an isolated multiport DC-DC converter used for interconnection of different types of renewable energy sources to a power grid. To perform efficient power management and grid integration for the multiple sources, multiport dc–dc converters have been proposed model. A two-stage, grid-connected multisource renewable energy system, which consists of an isolated multiport dc–dc converter and an inverterIn this converter a high frequency transformer gives isolation for circuit. It has an advantage of simple topology and minimum number of switches. For an area near power grid, usually a grid connected renewable energy system is more appropriate option because energy storage technologies are not very efficient and satisfactory at present. By interconnection of both PV energy and WIND energy the continuity and reliability of power supply is increases more. All simulation results and analysis of concept are presented using MATLAB/SIMULINK.The simulation results which shows the performance of the system

I. INTRODUCTION

In recent days, the number of applications which require more than one power source is increasing. Distributed generating systems or micro-grid systems normally use more than one power source or more than one kind of energy source. Also, to increase the utilization of renewable energy sources, diversified energy source combination is recommended. The combination of more power sources and diversified power sources make it possible to obtain higher availability in a power system. India has tremendous energy needs and increasing difficulty in meeting those needs through traditional means of power generation. Electricity consumption has been increasing at one of the fastest rates in the world due to population growth and economic development. Our economy faces increasing challenges because energy supply is struggling to keep pace with demand and there are energy shortages almost everywhere in the country. Such chronic lack of energy and unreliable supplies threaten our economic growth.Renewable Energy Sources (RES)[4] such as wind and solar, produce power intermittently according to the weather

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conditions rather than to the power demanded. Energy Storage Systems may be used to mitigate the intermittent generation from RES and to increase the quality of power supply. This makes it difficult to integrate the power generated from these RES into the electric network. One major advantage with the use of renewable energy is that as it is renewable and so will never run out. Their fuel being derived from natural and available resources reduces the costs of operation. It facilities generally require less maintenance.Wind energy is the kinetic energy of air in motion, also called wind. Wind is the movement of air across the surface of the Earth, affected by areas of high pressure and of low pressure. The surface of the Earth is heated unevenly by the Sun, depending on factors such as the angle of incidence of the sun's rays at the surface which differs with latitude and time of day and whether the land is open or covered with vegetation. Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to make electrical power, windmills for mechanical power, wind pumps for water pumping or drainage, or sails to propel ships. Wind power consumes no fuel, and emits no air pollution, unlike fossil fuel power sources.

II. PROPOSED ISOLATED MULTIPORT DC–DC CONVERTER

Fig. 1 shows the circuit diagram of the proposed 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 capacitor Cs, 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 = Np/Ns, where Np and Ns are the numbers of turns of the primary and secondary windings, respectively.

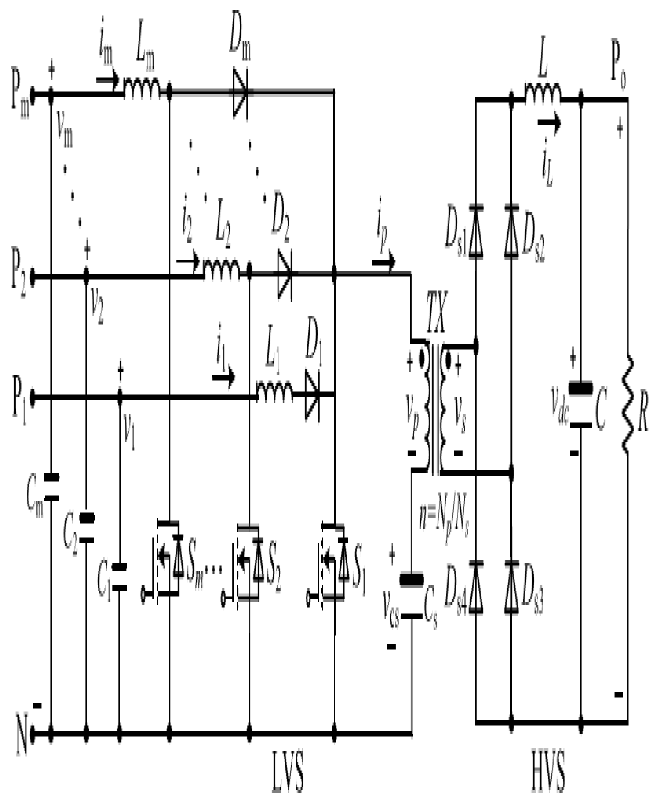

Fig. 1. Topology of the proposed isolated multiport dc–dc converter.

This converter has three operating modes: 1) all switches are on; 2) switch S1 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 Fig. 2. Fig. 3 shows the steady-state waveforms of the converter in

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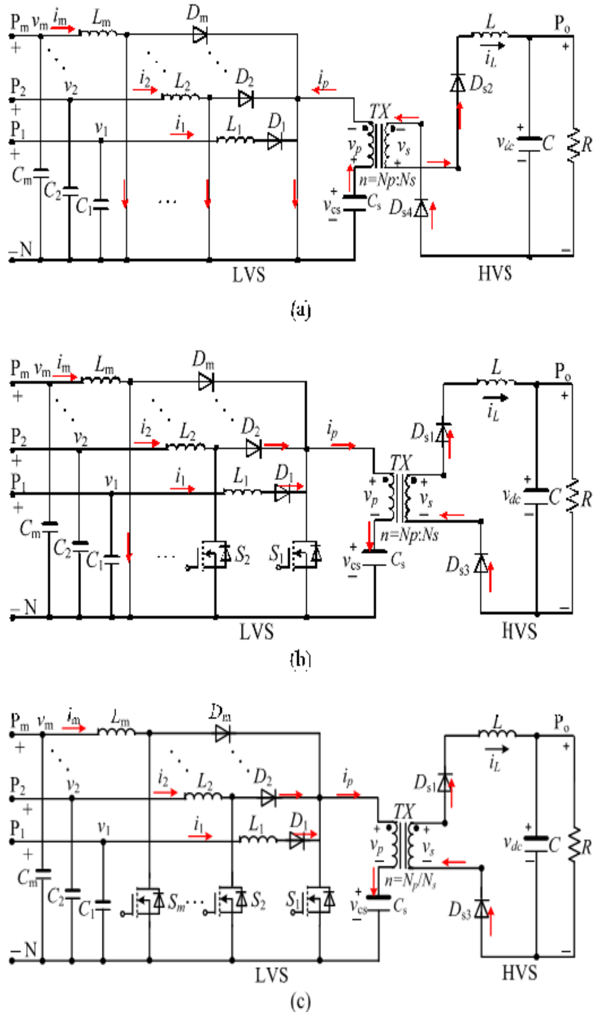

Fig. 2. Equivalent circuits of the three operating modes of the proposed converter. (a) Mode 1: all switches are on. (b) Mode 2: S1 is off and at least one of the other switches is on. (c) Mode 3: all switches are off.

one switching period covering the three operating modes when m = 3. To facilitate the explanation of the converter operation, the state-space equations for different modes are written in the following form:

$$M \cdot \dot{X} = A \cdot X + B \quad (1)$$

where M = diag(L1, L2,..., Lm, Cs, L, C) is a (m + 3) × (m + 3) diagonal matrix, X = [i1, i2,..., im, vcs, i L, vdc]T is

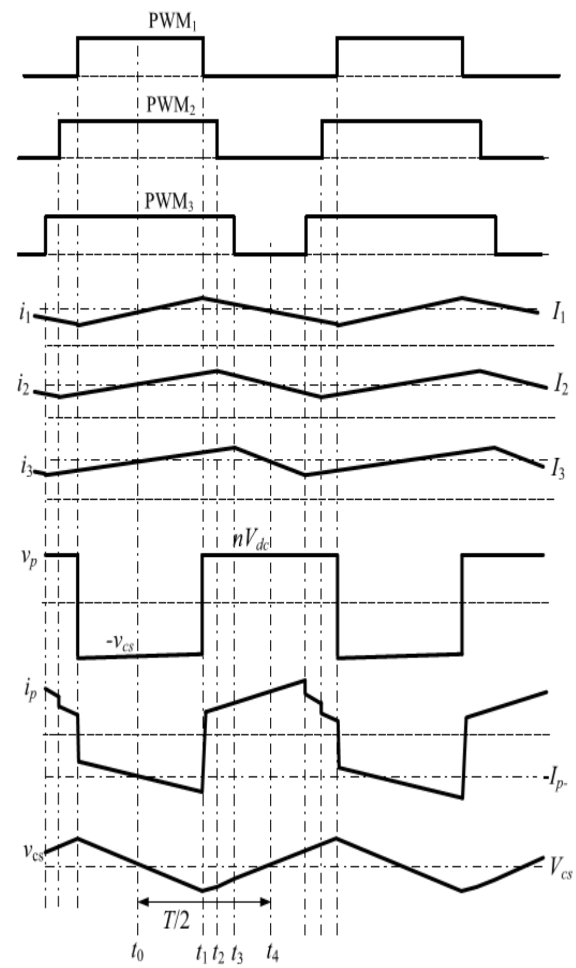

Fig. 3. Waveforms of the proposed converter when m = 3.

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.

Mode 1: t ∈ [t0, t1] (see Fig. 3), during which all of the switches are on and the inductors L1,..., Lm store the energy extracted from the sources; while the energy stored in the capacitor Cs in the previous switching cycle is delivered to the HVS through the diodes Ds2 and Ds4. The state-space equations can be described as follows:

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$$M \cdot \dot{X} = \begin{bmatrix} 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 1/n & 0 & -1 \\ 0 & 0 & \cdots & 0 & 0 & 1 & -1/R \end{bmatrix} \cdot X + \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_m \\ -i_p \\ 0 \\ 0 \end{bmatrix} \quad (2)$$

Mode 2: t ∈ [t1, t3], during which S1 is off and at least one switch Sk (k = 2,..., or m) is on. Actually, there are 2m−1−1 different scenarios in this mode depending on the states of the other (m − 2) switches S2,..., Sk−1, Sk+1,..., Sm. One scenario is illustrated as an example, in which only one switch Sk is on and all other switches are off. The state-space equations are

$$M \cdot \dot{X} = \begin{bmatrix} 0 \cdots 0\,0\,0 \cdots 0 & -1 & 0 & 0 \\ \vdots \ddots \vdots\,\vdots\,\vdots \ddots \vdots & \vdots & \vdots & \vdots \\ 0 \cdots 0\,0\,0 \cdots 0 & -1 & 0 & 0 \\ 0 \cdots 0\,0\,0 \cdots 0 & 0 & 0 & 0 \\ 0 \cdots 0\,0\,0 \cdots 0 & -1 & 0 & 0 \\ \vdots \ddots \vdots\,\vdots\,\vdots \ddots \vdots & \vdots & \vdots & \vdots \\ 0 \cdots 0\,0\,0 \cdots 0 & -1 & 0 & 0 \\ 1 \cdots 1\,0\,1 \cdots 1 & 0 & 0 & 0 \\ 0 \cdots 0\,0\,0 \cdots 0 & 0 & 0 & -1 \\ 0 \cdots 0\,0\,0 \cdots 0 & 0 & 1 & -1/R \end{bmatrix} \cdot X + \begin{bmatrix} v_1 - v_p \\ \vdots \\ v_{k-1} - v_p \\ v_k \\ v_{k+1} - v_p \\ \vdots \\ v_m \\ 0 \\ v_p/n \\ 0 \end{bmatrix} \quad (3)$$

Mode 3: t ∈ [t3, t4], during which all switches are off. The state-space equations are

$$M \cdot \dot{X} = \begin{bmatrix} 0\,0 \cdots 0 & -1 & 0 & 0 \\ 0\,0 \cdots 0 & -1 & 0 & 0 \\ \vdots\,\vdots \ddots \vdots & \vdots & \vdots & \vdots \\ 0\,0 \cdots 0 & -1 & 0 & 0 \\ 1\,1 \cdots 1 & 0 & 0 & 0 \\ 0\,0 \cdots 0 & 0 & 0 & -1 \\ 0\,0 \cdots 0 & 0 & 1 & -1/R \end{bmatrix} \cdot X + \begin{bmatrix} v_1 - v_p \\ v_2 - v_p \\ \vdots \\ v_m - v_p \\ 0 \\ v_p/n \\ 0 \end{bmatrix} \quad (4)$$

With (2)–(4), the average state-space model can be derived as follows:

$$M \cdot \dot{X} = \begin{bmatrix} 0 & 0 & \cdots & 0 & -(1-d_1) & 0 & 0 \\ 0 & 0 & \cdots & 0 & -(1-d_2) & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & -(1-d_m) & 0 & 0 \\ (1-d_1) & (1-d_2) & \cdots & (1-d_m) & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & d_1/n & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 1 & -1/R \end{bmatrix} \cdot X + \begin{bmatrix} v_1 - (1-d_1)v_p \\ v_2 - (1-d_2)v_p \\ \vdots \\ v_m - (1-d_m)v_p \\ -d_1 \cdot i_p \\ (1-d_1) \cdot v_p/n \\ 0 \end{bmatrix} \quad (5)$$

Where dk (k = 1,..., m) is the duty cycle of the switch Sk. The equilibrium points can be calculated by setting all time-derivative terms in (5) to be zero, then

$$D_k = 1 - (1 - D_1) \cdot V_k / V_1 \quad k = 2, \ldots, m \quad (6)$$

$$I_{p-} \cdot D_1 = \sum_{k=1}^{m} I_k (1 - D_k) \quad (7)$$

Where Dk represents the steady-state value of dk and Vk is the steady-state voltage of the kth input port of the converter. Equation (7) shows the power conservation law in the capacitor Cs, where Ip−, as shown in Fig. 3, is the mean absolute value of ip when S1 is on, and Ik is the steady-state values of ik.

III. DESIGN CONSIDERATIONS

To make multiple sources work effectively, the following requirement should be satisfied: the switch Sk (k = 2,. . ., m) should not be turned off before S1 is switched off; otherwise, Lk will continuously store energy through S1 even Sk is off, which is not desired. To meet this requirement, the following inequality should be satisfied for the converter

$$\min\{d_2,\ d_3, \ldots,\ d_m\} \geq d_1 \quad (8)$$

Inequality (8) is met if the input voltage of Port 1 (P1) is the largest, namely the following inequality is satisfied:

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$$V_1 \geq \max\{V_2, V_3, \ldots, V_m\} \tag{9}$$

Where Vk is the output voltage of the kth source (k = 1,. . ., m). In practice, the renewable energy source with the largest nominal output voltage will be connected to Port 1. A violation of (9) may lead to one of the following two scenarios. Scenario 1 (V1 = 0): If no power is available from Port 1, (9) is no longer valid but (8) should still be satisfied. In this scenario, the duty cycle of the switch S1 is set to be a constant value such that (8) is satisfied, e.g., d1 = 0.4, and the function of the switch S1 is to change the direction of the current ip flowing through the transformer. Specifically, when S1 is off, the current i p flows from the other sources to the transformer to charge the capacitor Cs. When S1 is on, the capacitor Cs discharges so that the direction of the current ip reverses. Scenario 2 (0 < V1 < max{V2, V3,. . . , Vm}): If the maximum power that can be generated by the renewable energy source at Port 1 is low such that (9) cannot be satisfied, (8) should still be satisfied. In this scenario, the duty cycle of the switch S1 will be increased to a predefined maximum value (e.g., 0.4) by the MPPT controller such that (8) is satisfied, and the function of the switch S1 is the same as that in Scenario 1. In this scenario, the power generated by the renewable energy source connected to Port 1 might be less than the maximum power that can be generated by the source. However, the difference between the generated and the maximum power at Port 1 is small because the maximum available power at Port 1 is usually very low in this scenario. It should be noted that in the aforementioned two scenarios, the sources connected to other ports (i.e., Ports 2–m) can still be controlled simultaneously and independently in the MPPT mode by appropriately controlling the duty cycles of the corresponding switches. Therefore, in Scenario 1, the power management of all the ports is still independent. In Scenario 2, the power management of Port 1 is not independent, which slightly affects the power generated from Port 1. However, Scenario 2 can be avoided by connecting a boost type voltage regulator between the source and Port 1 [27] so that (9) is always satisfied.The parameters of the components of the converter need to be properly designed. These include the transformer turn ratio n, inductances Lk (k = 1,. . ., m) and L, capacitances Ck (k = 1,. . ., m) and CS, and the switches Sk (k = 1,. . ., m). The turn ratio of the transformer is designed based on the output voltage Vdc and the source voltage V1 of Port 1 [27]

$$n = 2 \cdot V_1 \cdot D_1 / V_{\mathrm{dc}} \tag{10}$$

The design of the inductance Lk (k = 1,. . ., m) is the same as that in the dc–dc boost converter. When Sk is on, the voltage across the inductor Lk is Vk, then

$$V_k = L_k \frac{\Delta I_k}{D_k \cdot T_s} \qquad k = 1, 2, \ldots, m \tag{11}$$

Where Ik is the desired current ripple of the inductor Lk and Ts is the switching period. Therefore, the inductance can be calculated by the following formula:

$$L_k = \frac{V_k \cdot D_k}{f_s \cdot \Delta I_k} \qquad k = 1, 2, \ldots, m \tag{12}$$

Where fs is the switching frequency of the converter. When S1 is on, the voltage across the secondary inductor L is V1/n−Vdc, and therefore

$$L = \frac{(V_1/n - V_{\mathrm{dc}}) \cdot D_1 \cdot T_s}{\Delta I_L} = \frac{V_1 \cdot (1 - 2D_1) \cdot D_1}{f_s \cdot n \cdot \Delta I_L} \tag{13}$$

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Where ΔIL is the desired current ripple of the inductor L. particularly, when D1 = 0.25, L achieves its peak value

$$L_{\max} = \frac{V_1}{8 f_s \cdot n \cdot \Delta I_L} \tag{14}$$

Then, ΔIL can be controlled within a certain value if selecting L > Lmax. In the steady state, the inductor current equals to the source current in each input port, and the capacitor Ck (k = 1. . . m) provides the ripple current ΔIk of the inductor

$$\Delta I_k = C_k \frac{\Delta v_k}{D_k \cdot T_s} \qquad k = 1, 2, \ldots, m \tag{15}$$

Where Δvk is the voltage ripple of Ck. Then

$$C_k = \frac{\Delta I_k \cdot D_k}{f_s \cdot \Delta v_k} \qquad k = 1, 2, \ldots, m \tag{16}$$

Similarly, the capacitor C provides the extra current to balance the ripple current ΔIL caused by the inductor L. Then, the capacitance C can be calculated from (16) with the use of ΔIk = ΔIL, Dk = D1, and Δvk = vdc. When Sk is off, the current flowing through Cs is increased by Ik, then the capacitance Cs is determined as follows:

$$C_s = \frac{\sum_{k=1}^{m} I_k (1 - D_k) \cdot T_s}{\Delta v_{cs}} = \frac{\sum_{k=1}^{m} I_k (1 - D_k)}{f_s \cdot \Delta v_{cs}} \tag{17}$$

Where Δvcs is the voltage ripple of Cs.

The peak voltage of the switch Sk (k = 2,. . ., m) is Vk/(1 − Dk), which equals to V1/(1 – D1) according to (6). The peak current flowing through the switch Sk (k = 2,. . ., m) is Ik, which is less than that flowing through S1. When S1 is on, as shown in Fig. 2(a), the inductor L1 stores energy and the capacitor Cs discharges, then the current flowing through S1 becomes

$$I_{S_1} = I_1 + I_{p-} = \frac{I_1 + \sum_{k=2}^{m} I_k (1 - D_k)}{D_1} \tag{18}$$

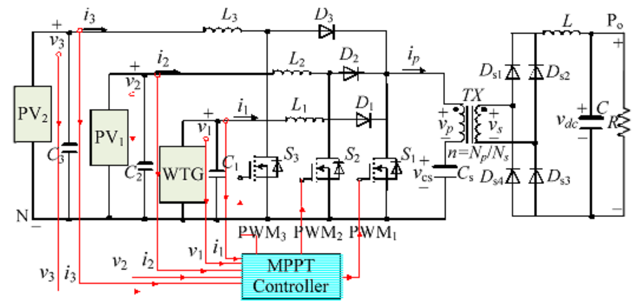

Fig. 4. Signal flows in the wind/solar hybrid generation system managed by the proposed converter.

Where IS1 is the maximum drain-to-source current of the switch S1. Then, the switches are selected based on their peak voltages and maximum currents. In this paper, the allowed maximum voltages and currents of the selected switches are twice their calculated peak values.

V.EXTENSION TO PROPOSED CONCEPT

This paper presents An Isolated DC-DC converter for simultaneous power management of hybrid renewable energy sources to feed power grid. Two reference signals identical to each other with an offset equivalent to the amplitude of the triangular carrier signal were used to generate PWM signals for the switches. The inverter offers much less total harmonic distortion and can operate at near-unity power factor. The proposed system is verified through simulation and is implemented in a prototype, and the experimental results are compared with that with the conventional single-phase three-level grid-connected PWM inverter.A grid-connected photovoltaic power system, orgrid-connected PV system is an electricity generating system that is connected to the utility grid. A grid-connected PV system consists of solar panels, one or several inverters, a power conditioning unit and grid connection equipment. They range from small residential and commercial rooftop systems to large utility-scale solar power stations. Unlike stand-alone power systems, a grid-connected system rarely includes an integrated battery solution, as they are still very expensive. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load, Residential, grid-connected rooftop systems which have a capacity more than 10 kilowatts can meet the load of most consumers. They can feed excess power to the grid where it is consumed by other users. The feedback is done through a meter to monitor power transferred. Photovoltaic wattage may be less than average consumption, in which case the consumer will continue to purchase grid energy, but a lesser amount than previously. If photovoltaic wattage substantially exceeds average consumption, the energy produced by the panels will be much in excess of the demand. In this case, the excess power can yield revenue by selling it to the grid. Depending on their agreement with their local grid energy company, the consumer only needs to pay the cost of electricity consumed less the value of electricity generated.

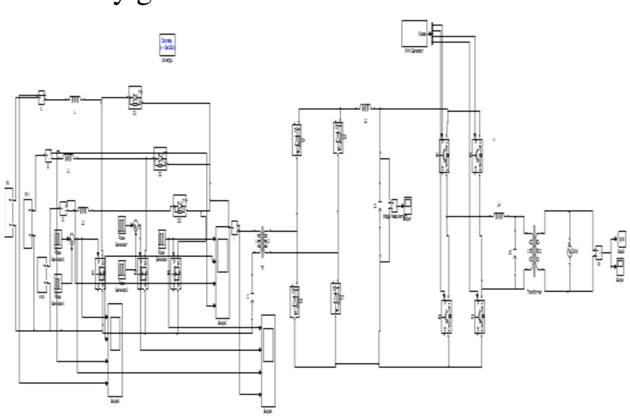

Fig.5: Simulation circuit diagram

In base paper the DC DC converter circuit is analyses only with dc load that is R load. The performance of multi port DC DC converter for simultaneous power management of renewable energy sources is analyzed by observing input current of transformer and currents of solar and wind plants with R-load connected at the secondary of theDC DC converter through diode bridge rectifier.The block diagram in Fig.1, presents the control strategy and power management for an integrated multi-port DC-DC converter, which interfaces one wind energy port, two solar input port and an isolated output is connected to power grid. Converters has one bi-directional input, two solar input and one wind energy based source so it is called multi port circuit. Input side has three inputs and output side has one output. The input is from different sources such as solar and wind. It is converted into high frequency AC with help of inverter. High Frequency Transformer is used for step down purpose. It is also used for isolation purpose. The transformer size should be small due to high frequency. Converter-2 is used to convert DC to AC voltage in reverse mode. In forward mode converter act as a rectifier .so the power flow in both direction. Filter Rectifier converts AC to DC. This output has ripples. It is filtered with a help of Capacitor filters. The output is DC voltage which can be used to to feed power grid. Micro controller is used to generate triggering pulse for IGBT's. It is used to control the outputs. There has been a growing interest in generating electricity from distributed renewable energy sources. In many applications, it is required to connect multiple renewable energy sources of different types (e.g., wind and solar) and capacities to a power grid. To perform efficient

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power management and grid integration for the multiple sources, multiport dc–dc converters have been proposed.A two-stage, grid-connected multisource renewable energy system, which consists of an isolated multiport dc–dc converter and an inverter. The isolated dc–dc converter has multiple input ports for connect ing different sources, such as photovoltaic (PV) panels, wind turbine generators (WTGs), fuel cells, and so on. The multiport–dc converter not only regulates the low-level dc voltages of the sources to a constant high level required by the inverter, but also can provide other important control functions, such as maximum power point tracking (MPPT), for the renewable energy sources. There are two categories of integrated isolated multiport converters. One category of converters uses a transformer with a separate winding for each port. Therefore, all ports are electrically isolated. The other category of converters has multiple ports connected to a single winding on the primary side of a transformer. It requires a common ground point for all the input sources. The second topology is preferable due to the advantage of using less number of windings in the transformer. A number of isolated multiport converters belonging to the second category have been proposed. A widely used topology is the isolated half-bridge converter, which used 2m+2 controllable switches, wherem (m≥2) is the number of input ports. Thereafter, in this paper, controllable switches are also called switches. The number of switches was reduced to 2m by either using one source as the dc link or reducing switches on the secondary side of the transforme. Recently, a multiport converter topology withm+3power switches has been proposed. When>3, this multiport converter has the least number of switches among the existing topologies. This paper proposes a new isolated multiport dc–dc converter for simultaneous power management of multiple renewable energy sources, where only one switch is used in each input port connected to a source. Similar to the converter , the proposed converter does not use any controllable switch on the secondary side of the transformer.

IV.MATLAB/SIMULINK MODEL

(i). Simulation model for Extension

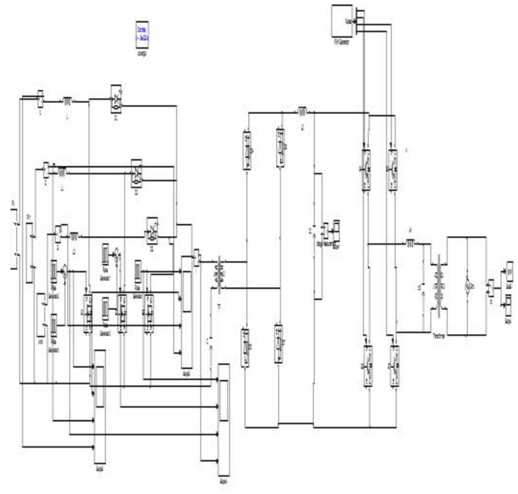

Fig.6: Simulation circuit diagram

(ii). Simulation results

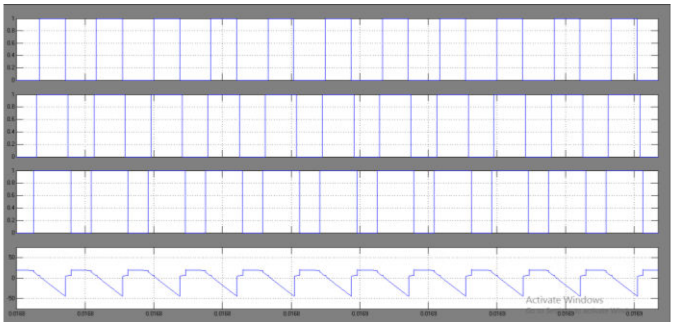

Fig.7: switching pulses and transformer primary current waveform

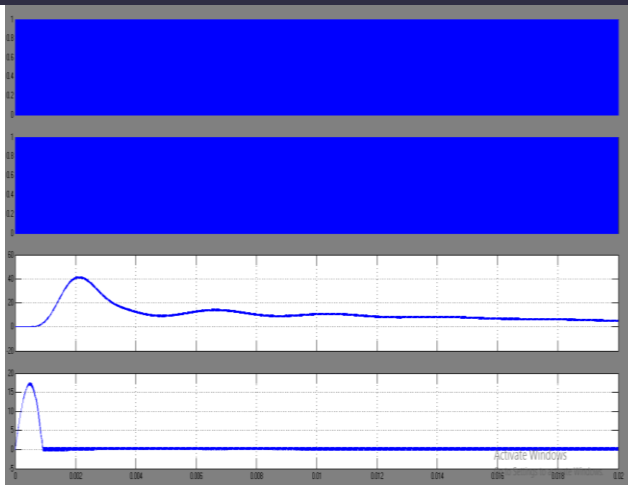

Fig.8:Wind and Solar plant current waveform

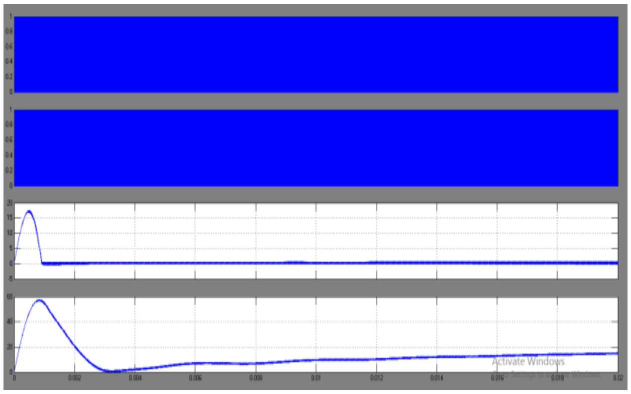

Fig.9: Solar(Pv1 and solar(pv) current waveforms

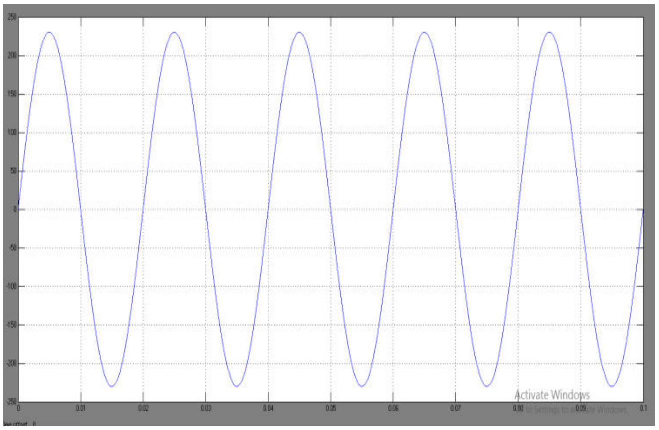

Fig.10 Voltage waveform across grid

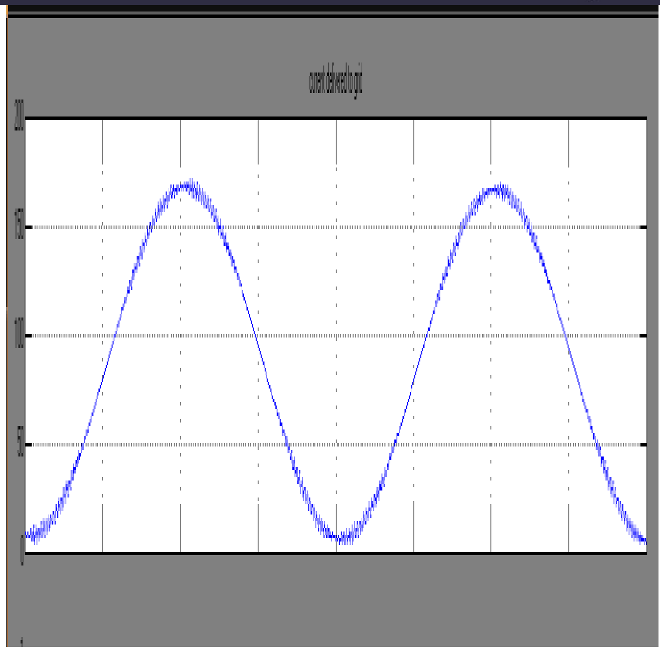

Fig11 : current delivered to grid

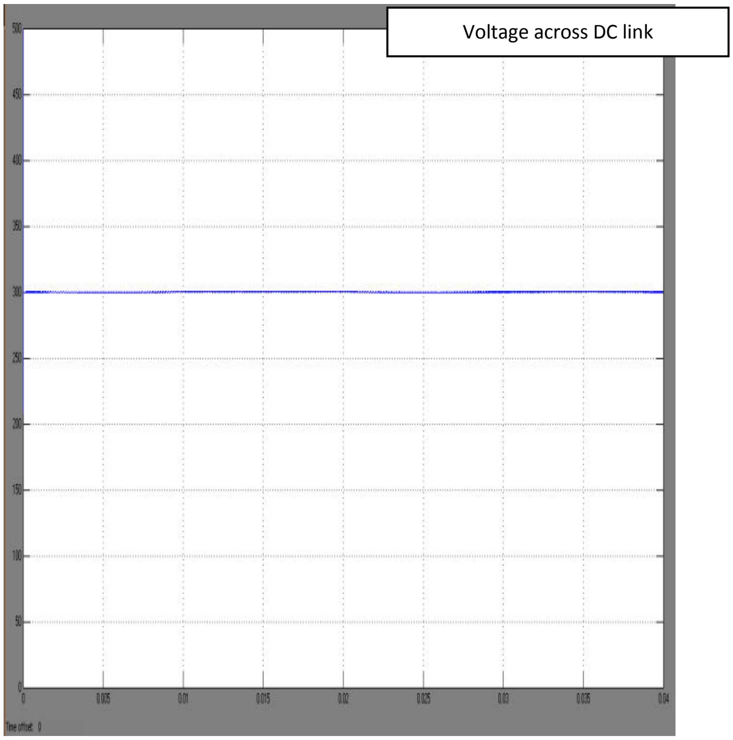

Fig12: voltage waveform appears across DC link

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V. CONCLUSION

An isolated multiport dc–dc converter that uses the minimum number of switches has been proposed for simultaneous power management of hybrid renewable energy sources. The proposed converter has been applied for simultaneous power management of a three-source wind/solar hybrid generation system to feed power grid. The simulation 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 hybrid renewable energy sources simultaneously. Moreover, the proposed converter can be easily applied for power management of other types of renewable energy sources to feed power grid or any other load. Because of power grid is having so many advantages, the renewable energy sources are connected to it for better utilization of power.

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