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An Isolated High Step-Up DC–DC Converter for PV Applications

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Abstract: For the requirement of clean energy there is an increased dependency on the renewable energy resources like Photovoltaics cells. A PV panel normally generates low dc voltage that need to be boosted before converting it to ac voltage. Therefor an isolated high gain dc-dc converter is proposed to obtain a high voltage gain. The converter is a cascade combination of the boost and buck boost converter. The Incremental Conductance (INC) method is employed to track the maximum power from the panel and it will offer a smooth transition to the maximum power point. To improve the dynamic performance of the high gain dc-dc converter a double closed loop control strategy has been used. A simulation of the proposed system is modelled and evaluated with desirable results in MATLAB/Simulink.

Keywords: DG – Distributed Generation, PV – Photovoltaics Panel, MPPT – Maximum Power Point Tracking, PWM – Pulse width modulation

I.INTRODUCTION

The Distributed Generation system (DG) [1-2] which are composed of micro sources like fuel cells, Photovoltaics (PV) cells, wind etc. are rapidly gaining importance. In recent years, Photovoltaics (PV) systems are being actively researched as a sustainable power solution. As a result, the world global market installation reached a record high of 228 GW in 2015. This is because of the clean energy available from these panels, also it is cost effective. However, the typical PV cells and fuel cells are low voltage sources. That is, the output voltage level obtained from the PV panels are normally in the range of 40V-60V [3]. While in application point of view, the inverter in the next stage requires an input voltage that is sufficiently high (400–600 V) to obtain the desired AC output voltage. In order to obtain such a high voltage level a DC–DC converter with a high voltage gain is needed in the intermediate stage to complete the conversion. Hence the high step-up DC–DC converter becomes the key component that connects the PV panel or fuel cell to the high voltage DC bus.

Conventional boost converters are not able to attain such a high voltage without an extremely higher duty ratio [4]. If so, there will be serious reverse recovery problems along with conduction losses. Both isolated and non-isolated converters can be used. The non-isolated converters have simple controls and are not bulky systems. So, with a cascade structure or a coupled inductor structure high voltage gain is possible. But the LC network in this type of circuit will lead to oscillations. Using of coupled inductor [5] technologies are also limited due to the complexity of the magnetic devices.

Isolated high step-up DC–DC converters have been extensively studied and widely used. These are due to high voltage gains and galvanic isolation. A flyback converter [6] can achieve high step up voltage gain by simply adjusting the turns ratio of the transformer winding. However, large leakage energy of the converter causes large voltage spikes which may destroy the main switch. With a snubber circuit the above issue can be eliminated, but the leakage energy gets consumed. This method will affect the conversion efficiency. Switched capacitor and voltage lifting techniques are also used. But the switches will suffer from high current and conduction losses. A reliable energy source is supposed to dispatch at required power level without compromising stability.

In this paper a novel isolated high gain dc-dc converter is proposed for a PV panel application. The converter is nothing but a cascade combination of a boost and buck boost converter. Comparing with the existing converters, the proposed converter achieves higher voltage gain with a lower transformer turn ratio and higher efficiency. In addition to this the integrating structure makes the system more reliable and compact. With the converter the input current is continuous, which is suitable for fuel or PV cell applications. The double closed loop control scheme is used which can improve dynamic performance and stabilizes the capacitor voltage.

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II. PROPOSED SYSTEM

The block diagram of proposed system is shown in Fig. 1. Solar cell is a varying dc source. The output from these panels will be very low and varying. In order to

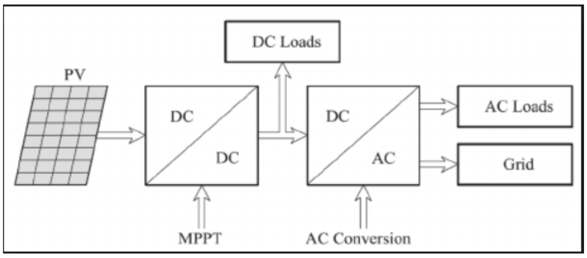

Fig. 1 Block diagram description

make it a constant dc output voltage an isolated high gain dc-dc converter is integrated in the intermediate stage, that is in between the PV panel and load. The same can be used in the induction motor applications. MPPT techniques are required to obtain maximum power from these panels. The output voltage from the dc converter can supply the power directly to the dc microgrids. The same can be applied as an input to the inverter. Applications include single phase Induction motors in traction, capacitor start- capacitor run motors in domestic field etc. It is also possible to connect directly with the AC microgrids.

III. OPERATING PRINCIPLE

The circuit of the proposed converter is shown in fig.2. Here the DC output voltage from the PV panel is given as the input to the converter. Two inductors are present. Inductor L1 should operates only in continuous conduction mode, otherwise it will damage the source due to high peak current during the operation in discontinuous conduction mode. But L2 can operate in both modes. That is in continuous conduction mode (CCM) and discontinuous conduction mode (DCM). The inductance of the inductor L2 is the sum of the leakage inductance of transformer and that of the external inductor connected to the primary winding in series in the actual system. A H bridge is present in the primary side of the transformer. Six modes of operations are possible during both modes. The voltage spikes caused by the leakage inductance of the transformer is reduced by the capacitor C_1.

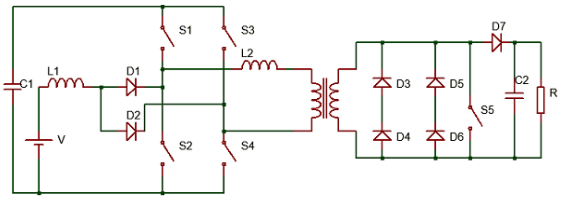

Fig.2 proposed converter

The double closed loop control scheme [8] is used. Here the capacitor voltage is also fed back along with the output voltage and the inductor current. This is to ensure the dynamic stability of the system. The reference voltage V_{ref}, which is the reference value of output voltage, is compared with the instantaneous value of output voltage. This error is compensated by voltage loop proportional –integral controller. The resultant is again compared with the error value obtained from the V_{c1} and i_{L1}. Then by using a current compensator PWM signals are generated.
The switching scheme is shown in the Table1.

S_1	S_2	S_3	S_4	S_5
1	0	0	1	1
1	0	0	0	0
1	0	1	0	0
0	0	1	0	0
0	1	1	0	1
0	0	1	0	0
1	0	1	0	0
1	0	0	0	0

Table. 1 Switching Scheme

IV. MPPT ALGORITHM

The output of the PV panel always depends upon both irradiance and environmental factors and this shows the non-linear characteristic of the voltage and current. Due to this it is necessary to use any of the MPPT techniques for maximum power delivering to the load [9]. Among these techniques we are using incremental conductance method. Incremental conductance method is used due to its high tracking accuracy and good adaptability towards the rapidly changing atmospheric conditions. Here the MPP is calculated by the comparison of the incremental conductance ($\Delta I_{PV}/\Delta V_{PV}$) to the array conductance (I_{PV}/V_{PV}). That is here slop of the V-I curve is considered. When $I_{PV}/V_{PV} = \Delta I_{PV}/\Delta V_{PV}$, the output voltage will be the maximum power point voltage. Fig. 3 shows the algorithm of incremental conductance.

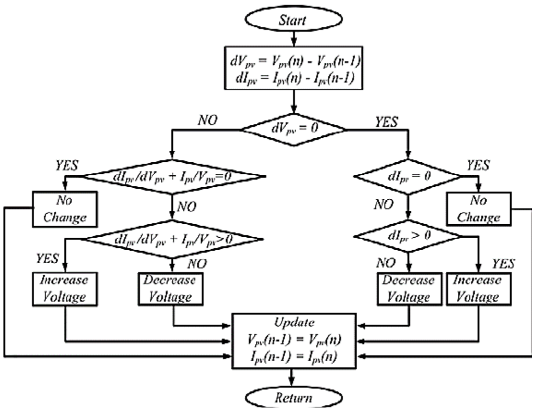

Fig. 3 Algorithm of incremental conductance.

V. SIMULATION RESULTS

The proposed isolated DC-DC converter along with the PV panel is simulated and analyzed using the MATLAB software. The fig.4 represents the simulated circuit of the proposed converter along with an input from PV panel. The DC source which is the Photovoltaics panel gives an output of 20V. The output voltage obtained from the isolated high gain converter will be 230V. Because of the presence of both isolated and non-isolated converter, the entire converter structure is equivalent to that of a two-stage circuit. The same can then be supplied to an inverter to drive an induction motor.

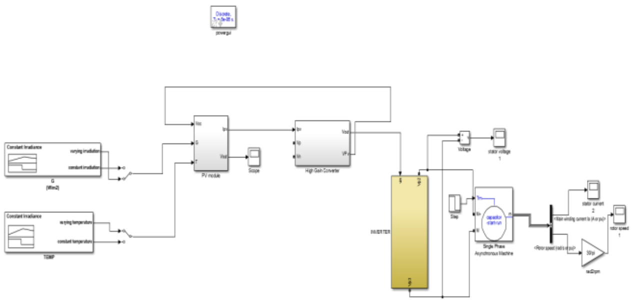

Fig. 4 Simulation diagram.

The output voltage and current waveform of the converter feeding IM drive are shown in fig.5 and 6 respectively. The output voltage of the DC-DC converter is obtained as 230V. That is for an input of 20V dc voltage.

Fig. 6 shows the output current waveform of the dc-dc converter and the steady state value is obtained as 0.5A. The converter is designed for an output power of 200W. Fig. 7 and Fig.8 depicts the waveform of stator voltage and stator current of the capacitor start-run induction motor.

However, solar Photovoltaics (PV) electricity is not available during night and are less available depending on the time of the day and the weather conditions. So, the proposed converter is not reliable. The continuity of the supply from the dc converter can be maintained by a bidirectional converter.

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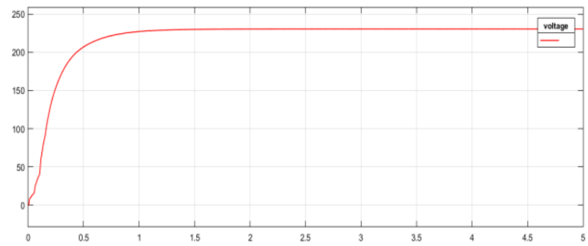

Fig. 5 Output voltage of DC-DC converter.

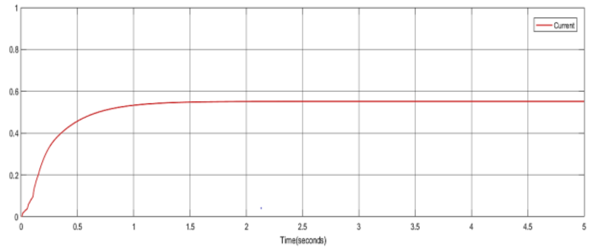

Fig .6 Output current of DC-DC converter

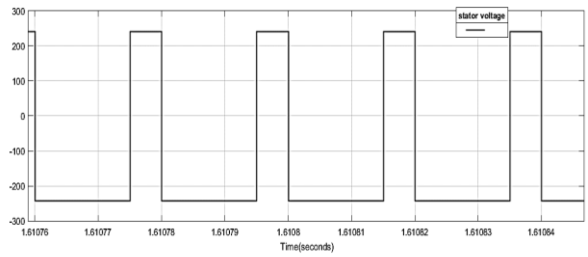

Fig. 7 Stator voltage waveform.

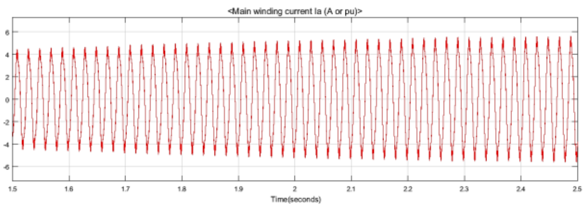

Fig. 8 Stator current waveform.

6. CONCLUSION

A novel high gain DC-DC converter for PV panel application is proposed. The converter structure is equivalent to that of a cascade structure consisting of a boost and an isolated buck–boost converter. The proposed system provides isolation between the high voltage and low voltage side with bridge rectifier which will decrease the cost and complexity of the system and also losses can be reduced. The incremental conductance method is used that will offer smooth transition to the MPP. Double closed loop control strategy is employed for the control of switches hence dynamic stability is obtained. For load variation the output voltage is maintained at constant value. The efficiency of the converter is also improved.

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