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Multi-Input DC-DC Converter Fed Hysteresis Controlled Grid Connected Inverter

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***Abstract**: The objective of the paper is to propose grid connected multi-input converter and its control scheme for simultaneous as well as individual power flow in order to support power system. The proposed converter has been derived by connecting source of buck converter in series with buck-boost converter. The operation and control scheme for DC-DC converter has been explained. DC-AC inverter and its operation under grid integration has been controlled using hysteresis control scheme. Simulation has been done using MATLAB/simulink and results are shown.*

1. Introduction

Recently renewable power generation has been focused as most significant energy sources due to the rising concern about global warming, and the increase of electrical power consumption.To feed power from these sources different DC-DC converters are used with isolated and non-isolated topologies. Isolated topology come with advantage of isolation but provide poor efficiency and bulky in size. Recently non-isolated converters are getting more attentions for its efficiency and compactness. When two intermittent sources are available conventionally, two separately DC-DC converters were used for each sources. An alternative way is to use a multiple input DC-DC converter (MIC) instead of two separate converters. The advantage of MIC is its compactness and reduced cost.[1]

The objective of the work is to propose the system two dc sources connected MIC with grid connected hysteresis current controlled inverter. Power from both the sources should be transferred to grid in all environmental conditions.

2. System background

The schematic of converter is shown in figure1.it is derived from buck-boost and buck converter [1] by inserting pulsating voltage source of buck converter in series with buck-boost converter. Two DC sources are connected to DC-DC converter (MIC). Control for MIC is based on conduction of switches S1 and S2 according to reference current and control scheme shown in fig. x. The inverter is controlled by hysteresis current control scheme to feed power and take care of grid synchronization as shown in fig 1.

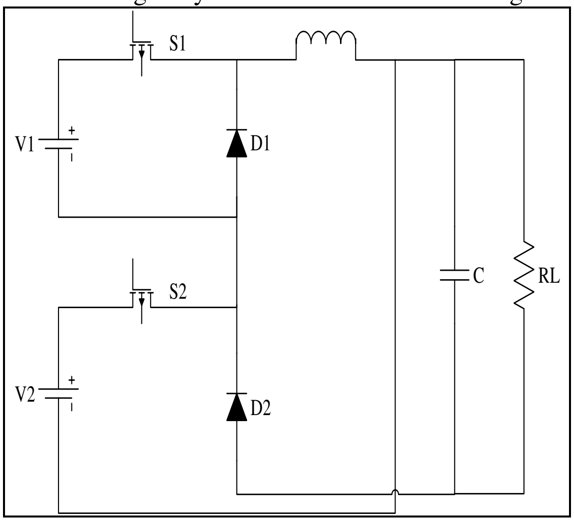

Figure 1 (DC-DC converter topology)

Two DC sources are connected with DC-DC converter. Based on current from the source switches S1 and S2 will conduct. According to status of the switches there are four operating modes of DC-DC converter.fig.1. Shows equivalent circuit in all four modes of operation respectively. When switches S1 and S2 turned off D1 and D2 will provide path to inductor current respectively. In case of failure of any source other source will provide electrical energy normally. Detailed operation of DC-DC converter can be found in [1].

Control scheme of DC-DC converter is shown in fig. 2, 4.

3. Multi-input DC-DC converter operation and control

According to status of the switches there are four operating modes of DC-DC converter. Fig. 3 shows equivalent circuit for all four modes of Operation respectively. When switches S1 and S2 turned off D1 and D2 will provide path to inductor current respectively. In case of failure of any source other source will provide electrical energy normally.

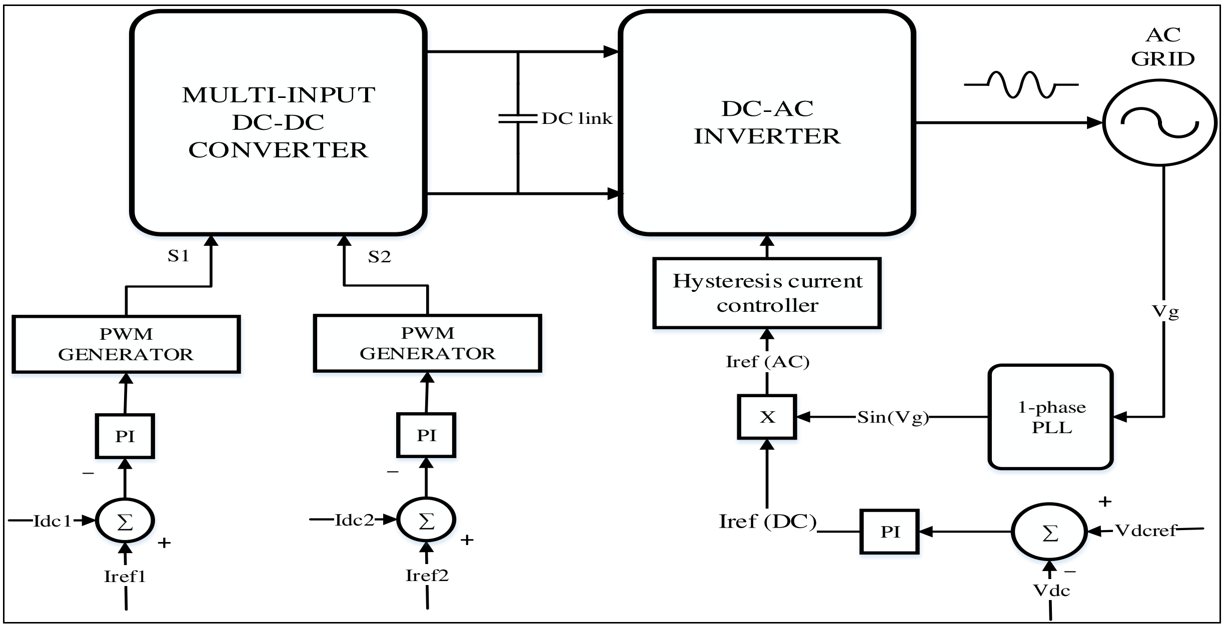

Figure 2 (schematic diagram of MIC based system)

Output voltage relationship can be derived using volt-ampere balance analysis of an inductor. If more current is generated by PV source (in day time) then S1 will get turn ON for longer period. In night time wind will be there so S2 will get longer conduction time than S1.in both the cases output voltage is given by,

$$(d - d_2) \times T_s \times V_{pv} - V_{wind} + d_2 \times T_s \times (V_{pv} + V_{wind}) +$$
$$(1 - d_1) \times T_s \times (-Vdc) = 0..........(1)$$

$$Vdc = \frac{d_1}{1 - d_2} V_{pv} + \frac{d_2}{1 - d_2} V_{wind} ....(2)$$

Similarly input and output current relationship can be derived,

$$I_{pv} = \frac{d_1}{1 - d_2} I_o..........(3)$$

$$I_{wind} = \frac{d_2}{1 - d_2} I_o..........(4)$$

Where d_1 and d_2 are the duty ratio for switches S_1 and S_2 respectively, from the above derived steady-state voltage and current equations different power distribution demands of the multi-input dc–dc converter can be achieved.

As increase in reference current from any source will increase duty ratio of that source. So, control of each source is independent and can deliver power by their capabilities individually or simultaneously.

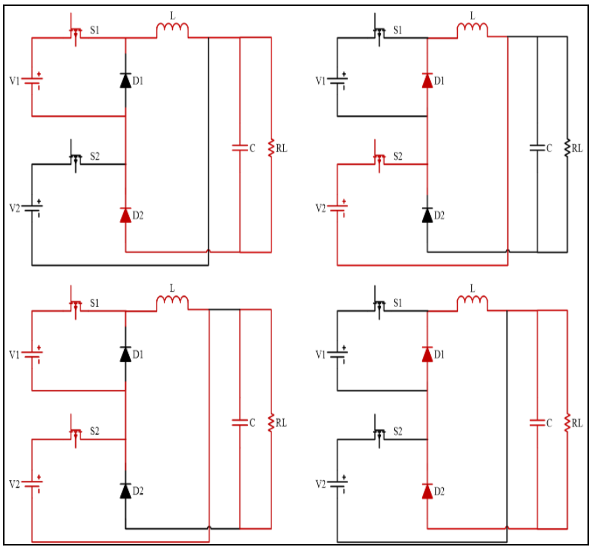

Figure 3 (operating modes of DC-DC converter)

4. Control scheme

In absent of any one source its reference current will become zero and other source will continue to deliver power as per operating principle as discussed earlier. Detailed operation of the DC-DC converter can be found in [12].

Similar control scheme can also be implemented for reference voltage also for either or for both the sources this scheme can be used to track maximum power by current reference in renewable sources like photovoltaic and wind energy. Detailed operation with voltage reference and grin connected system can be found in [1, 12]

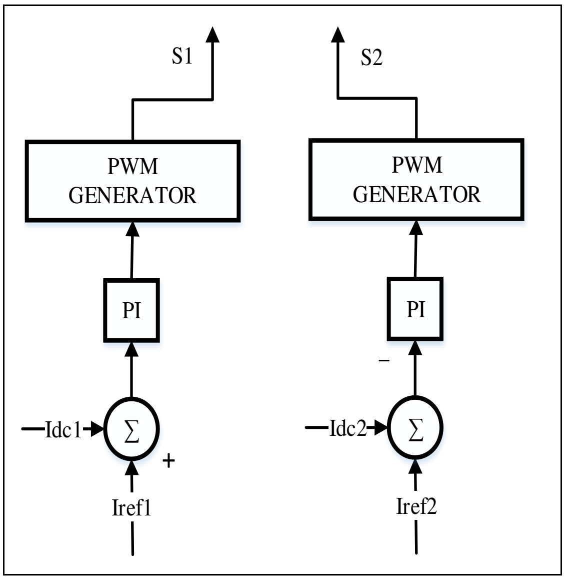

Figure 4 (control scheme of DC-DC converter)

Control scheme for DC-AC inverter is based on hysteresis current control scheme as shown in fig 5. Grid voltage is sensed and given to PLL to determine grid sine to synchronize grid frequency with inverter output frequency. DC link voltage error is multiply with sine of PLL (grid) to generate reference current for inverter and to make DC link voltage constant. As DC link voltage increases will increase in error which increases reference current more to pass through inverter to reduce DC link voltage and vice versa. Generated reference current is given to hysteresis band which is having certain value of upper and lower limit by which it sets 1 or 0 for turn the switch on or off.

Detailed concept of hysteresis is shown in fig. This generates a band to follow the current within its limit. Rise in current above limit will turn appropriate switch off and fall below band will turn appropriate switch on to follow reference current accurately.

For operation of DC-DC converter generated reference current are given for each sources according to applied control scheme. For DC-AC inverter hysteresis current loop controller is used which stables DC link voltage by taking voltage error of DC link and reference voltage. As DC link voltage increases current reference will increase to transfer more power to grid as a result DC link capacitor will discharges and DC link voltage will decreases and vice versa. Inverter control scheme also synchronizes inverter with grid using 1-phase PLL to ensure active power flow and injects sinusoidal current to grid.

Discussed control scheme and hybrid system has been simulated in MATLAB/simulink environment. Results are shown with different environmental conditions.

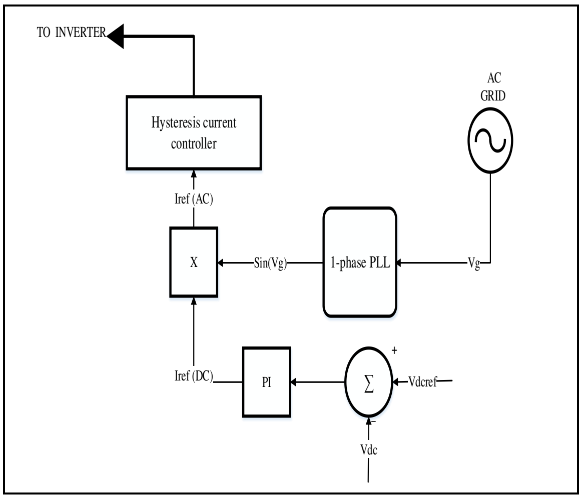

Figure 5 (control scheme of inverter)

5. Simulation & results

To validate operation and control scheme of proposed multi-input converter simulation has been done with following specifications and parameters.

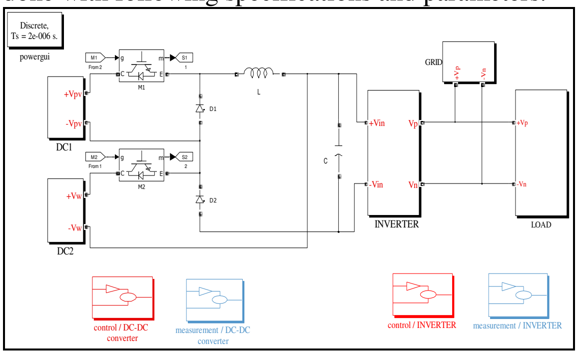

Figure 6 (MATLAB/simulink model of MIC system)

Simulation results are shown step by step from DC-DC converter to grid. Fig 7 shows generated pulses for switches S1 and S2 and inductor current rise and fall slops.

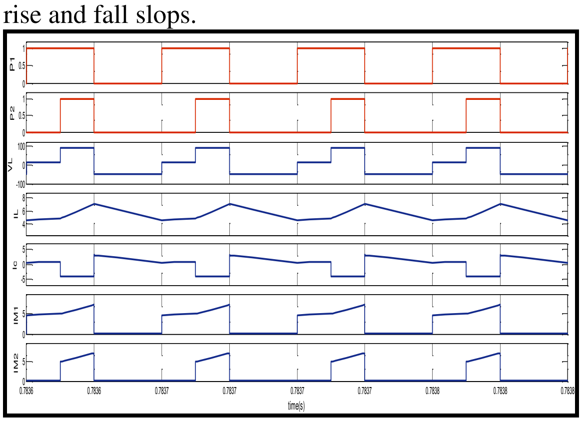

Figure 7 (waveform of key-components for DC-DC converter)

Generated pulses for switches S1 and S2 with turn off transition are shown where DC1 is generating more power than DC2. Inductor current slop when both switches S1 and S2 are on is different from when only S1 is on. Which realizes that power from both source are transfers simultaneously to the load.

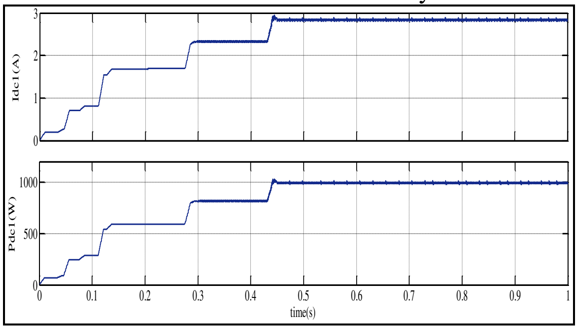

Figure 8 (current (Idc1) and power (Pdc1) from source V1)

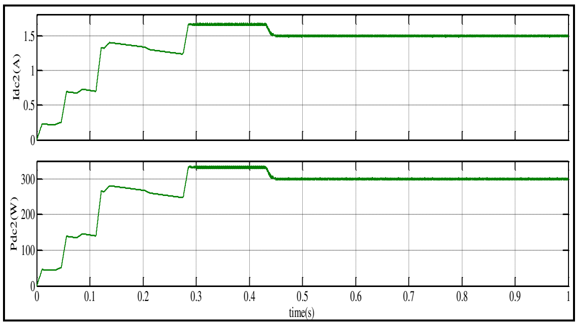

Figure 9 (current (Idc2) and power (Pdc2) from source V2)

Fig 8 shows current and power through DC source V1 where reference current is set to the value 2.9 which is achieved by the controller in steady state. Similarly fig. 9 shows for V2 where reference current is set to value 1.5 which is as shown in the results.

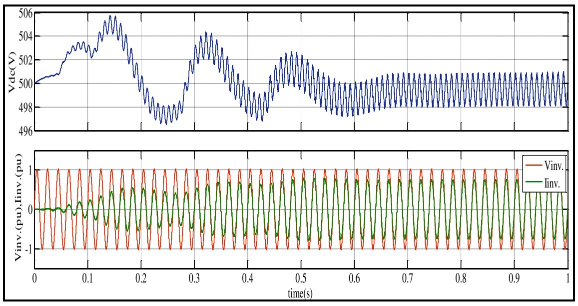

Figure 10 (DC link voltage (Vdc) and inverter output voltage, current in (pu))

Fig 10 shows DC link voltage which set to 500V which is controlled by inverter control scheme. Inverter output current and voltage are also shown here where,

Voltage 1pu=325V

Current 1pu=10A

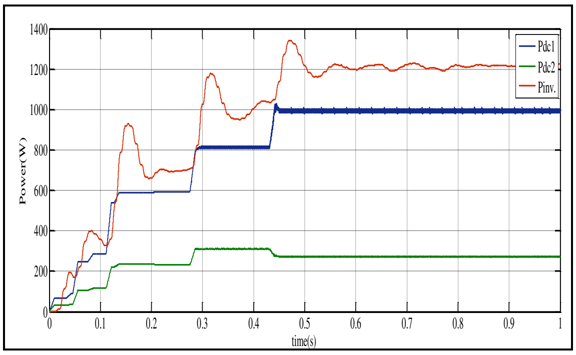

Figure 11 (power from the sources V1 and V2 and total inverter output power (Pinv.))

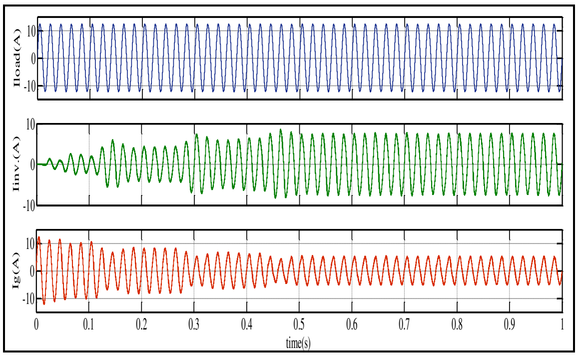

Figure 12 (load current (Iload), inverter output current (Iinv.), Grid current (Ig))

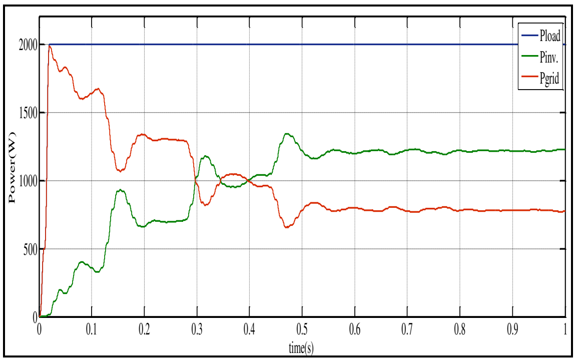

Figure 13 (load power (Pload), Inverter Power (Pinv.), Grid power (Pg))

Fig 11 shows power from sources and total output power by which we can calculate efficiency of the converter and also prove that power from both sources are transfer simultaneously to grid. Fig 12 shows current from grid as well as current from inverter and all the time total current to load is equal to sum of grid current and inverter current so we can say that system is supporting to grid and realizes grid synchronization which is shown in Fig 13 in terms of power balance.

In fig 10 DC link voltage is set to 500 V as a reference voltage 325 V (peak) to ensure power transfer from inverter to grid. Power balance for each sources and between grid and inverter are shown here which ensures the support of inverter to grid.

6. Abbreviation

V1&V2=DC sources
S1 & S2=respective switches for V1 & V2
Vdc= DC link voltage set to 500 V
Iref (dc) =DC reference current for inverter.
Iref (ac) =AC reference current which determines hysteresis band.

7. Conclusion

A multi-input DC-DC converter based system has been simulated in MATLAB/simulink with hysteresis controlled and grid integrated inverter. Operation of DC-DC converter and hysteresis band inverter is explained and results are shown to verify the operation with grid integrated system along with R load connected to it. Load is supplied by grid as well as inverter to support the grid.

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