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PSIM Model and Power Loss Calculation of Full Bridge DC- DC Converter used for Renewable Energy Applications

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***Abstract*:- This paper introduces a redundant , independent and modular type full bridge DC-DC converter to interconnect the output of renewable energy sources like solar, wind, fuel cells etc effectively to the dc grid The dc to dc converter uses high frequency transformer and MOSFET switches .The converter is intended to work in boost mode providing a 400V DC output to serve as the input of inverter which provides a 230V AC supply to the single phase line .The PSIM model is used here to validate the operation of the converter. Further the paper calculates the MOSFET power loss and efficiency of the converter using analytical equations and verified the results using simulation model.**

Keywords:- Intelligent green energy management system, DC-DC boost converter, switching loss, Conduction loss

I. INTRODUCTION

In recent years, a variety of collaborated developments on renewable, sustainable energy conversion devices technologies and advanced power electronics have been strongly required toward concrete realization of non-carbon society from a global point of view [1]-[3]. The energy production from renewable energy sources, such as wind, solar and tidal energy, is strongly fluctuating daily and seasonally, this is due to the nature of these energy sources. During high energy demand peaks or during low energy production from renewable energy sources, it is necessary to relay on other more predictable energy sources. Vice versa, when the energy demand is low or there is an energy surplus from renewable sources it is desirable to store this energy. For this reason, smart grids and energy storage started to play an important role in today's energy market and energy policies. The power capacity of renewable energy sources are in the range of 100W-300W and voltage range varies from 15V-40V.so we need an intelligent green energy management system to effectively incorporate various renewable sources to the power grid.[2]-[4]. The main basic blocks of intelligent green energy management system are DC-DC boost converter ,DC micro grid, inverter and single phase AC grid.

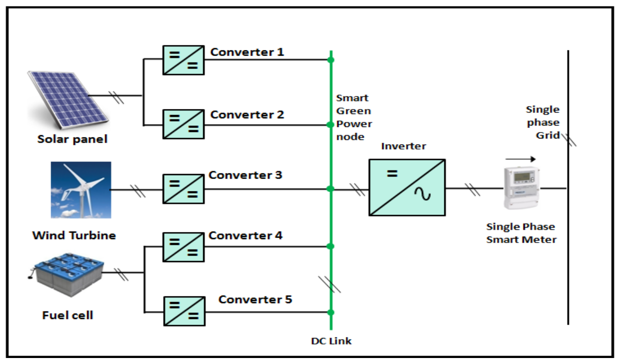

Fig. 1. Intelligent green energy management system

The power rating of DC grid applications is normally greater than 1000W, so full bridge converter configuration is only applicable in these conditions. Here we use a full bridge converter to boost the output of renewable energy sources to a high voltage about 350-400V and supply it to DC grid through smart green power nodes ,after then high voltage dc is converted to single phase AC using sine modulated inverters and is supplied to AC grid after metering. The basic block diagram of intelligent green energy management is shown in the figure 1. The paper mainly focus on design and development of a full bridge DC-DC converter (3kW) required for intelligent green energy management system.

II. PWM FULL BRIDGE DC - DC CONVERTER

The schematic of pulse width modulated (PWM) full bridge DC - DC Converter is shown in the figure 2. Here Q_1 to Q_4 are MOSFET switches used in the primary side of converter and Q_5 to Q_8 are MOSFET switches used in the secondary side of the converter. L_f and C_f are output filter inductor and output filter capacitor. Here C_{in} is the input capacitor and T_s is the switching period. In this configuration, full bridge voltage fed converters are used at both sides of the isolation transformer [2]-[4] . All the switches in the secondary side of converter is turned OFF to achieve unidirectional power transfer such that converter work in boost mode. The switching topology used for the full bridge converter is the bipolar voltage switching, where the MOSFETs are switched in pairs. The MOSFET switches (Q_1 and Q_4) are considered as one switch pair and MOSFET switches (Q_2 and Q_3) are considered as the other switch pair. The output voltage (V_o) is controlled and regulated by the PWM scheme as shown in figure 3, where a saw tooth signal is compared with a voltage control signal from the control circuit to generate switching pulses . Switch pair (Q_1 and Q_4) are conducting as long as the saw tooth signal is lower than the control signal. When it exceeds the control signal the transistors stops to conduct until the second half period takes place when the switch-pair (Q_2 and Q_3) starts to conduct until the saw tooth signal yet again exceeds the control signal. This procedure repeats itself from period to period, which results in the voltage levels of V, 0 &-V applied to the transformer primary winding. The voltage conversion ratio M(D) of the PWM full bridge DC-DC converter can be obtained as:

$$\text{Voltage conversion ratio, } M(D) = V_0/V_g = 2.(N_2/N_1).D$$

Where V_0 and V_g are output voltage and input voltage respectively, D is the duty cycle of MOSFET switches and N_2/N_1 is transformer turns ratio. According to the turns ratio boost and buck operation can be achieved in full bridge DC - DC converter.

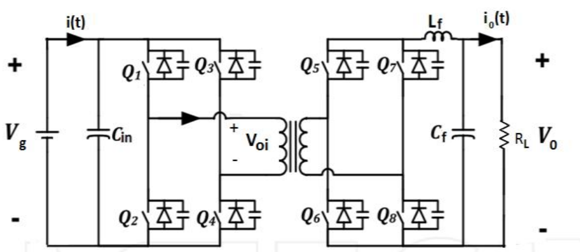

Fig. 2. Topology of conventional PWM full bridge DC - DC converter.

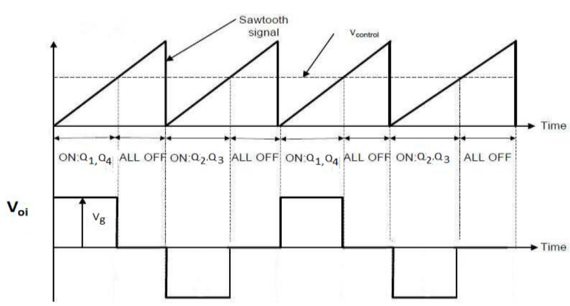

Fig. 3. Switching topology and Transformer primary voltage waveform

III. PSIM MODEL AND SIMULATION RESULTS

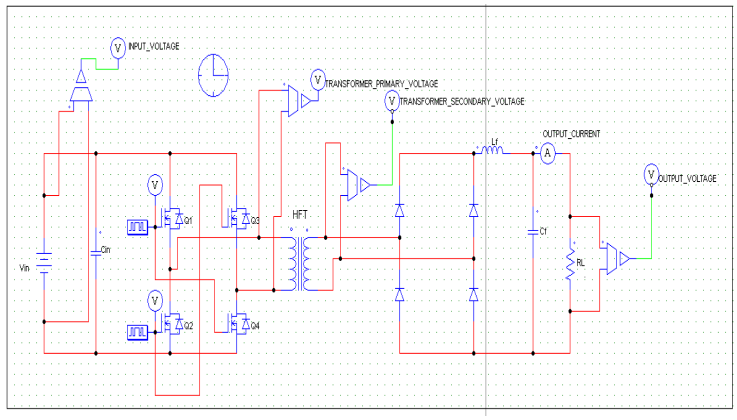

Fig. 4. PSIM model of PWM full bridge DC - DC converter.

The simulation circuit of conventional PWM full bridge DC - DC converter in PSIM is shown in figure 4. The input voltage given to the converter is 48V and the boosted output voltage obtained is 400V .The theoretically designed parameter values such as input capacitor (C_{in}) = 8800μF, filter inductor (L_f) = 1.3mH and filter capacitor (C_f) = 1120μF are used in the PSIM model. The transformer's turns ratio (N_2/N_1) is given by 8.34 and switching frequency of MOSFET switches are fixed at 100 kHz. The voltage conversion ratio M(D) is also obtained as 8.34 with duty cycle(D) as 0.5 .The figure 5 shows switching pulses of MOSFET switching pairs (Q_1, Q_4) and (Q_2, Q_3), transformer primary voltage and transformer secondary voltage waveforms. The input voltage, output voltage and output current waveforms are shown in figure 6. The simulated waveforms are identical to theoretical waveforms which proved the fact that the design and operation of PWM full bridge DC - DC converter is satisfactory producing sufficiently boosted DC output required for the inverter stage.

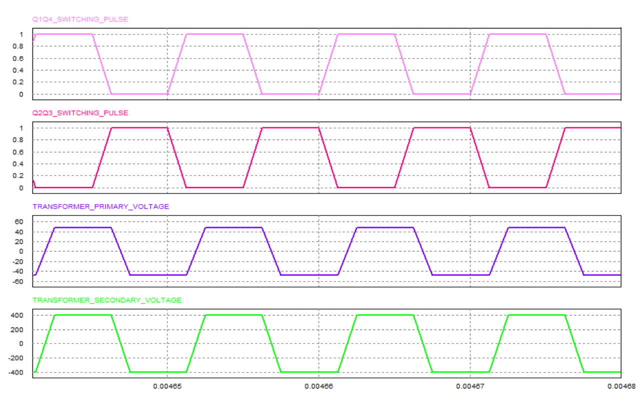

Fig. 5. Switching pulses & transformer voltage waveforms.

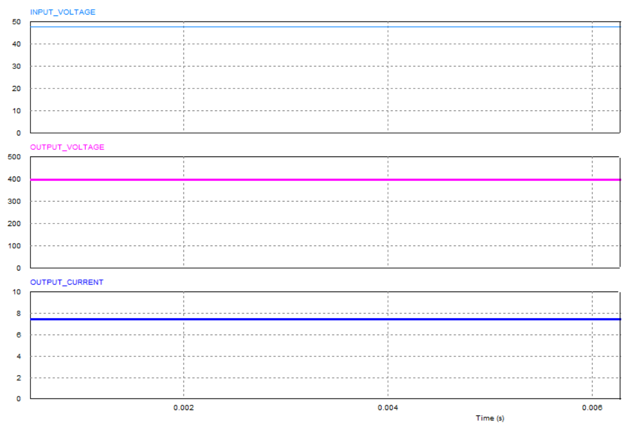

Fig. 6. Voltage & current waveforms

IV) CALCULATION OF MOSFET POWER LOSS AND EFFICIENCY OF CONVERTER

The total power loss in MOSFET is equal to the sum of conduction loss (P_c) and switching loss (P_{sw}) occurring in the MOSFET. Here practical MOSFET (IXYSFK230N20T) is used in the full bridge DC-DC converter. The data sheet values of the MOSFET IXYSFK230N20T are shown in the table below.

Sl.No	Data Sheet Parameters	Values
1	Maximum Drain to source saturation voltage, (V_{DSM})	200V
2	Maximum drain current (I_{DM})	230A
3	Drain source resistance (R_{ds})	7.5mΩ
4	Rise time (t_r)	38 ns
5	Fall time (t_f)	17 ns
6	Switching Frequency (f_{sw})	100kHz

Using the data sheet parameters we can calculate the power loss of the MOSFET using the analytical equations as given below. The efficiency is obtained as 94.5% and total MOSFET power loss is obtained as 164 W. Here drain to source saturation voltage (V_{DS}) is taken as 48 V and drain current (I_D) as 62.5 A .

Total power loss (P_{tot}) = switching Power loss (P_{sw}) + conduction loss (P_{cond})

Switching power loss of each MOSFET, P_{sw}

$$= \frac{1}{2} V_{DS}.I_D.(t_r+t_f) . f_{sw} = 12W$$

Conducting power loss of each MOSFET, P_{cond}

$$= (I_D)^2 .R_{ds(on)} = 29W$$

Total power loss of four MOSFETs

$$= 4 (12+29) = 164W$$

Efficiency , η = [(input power – total power loss)/ input power] *100

$$= [2836/3000] *100 = 94.5 \%$$

The power loss in the boost mode operation of the converter is also calculated using PSIM model as shown in figure .7 by replacing the ideal MOSFETs by practical MOSFET. The data sheet parameters and characteristics of practical MOSFET is loaded into the ideal MOSFET and convert it into practical device. Then the Converter is simulated and the output voltage and current is calculated as 392V and 7.3A as shown in the figure 8. Here the efficiency of the system is obtained as 95.3% from simulated model which proved the fact that the power loss and efficiency of simulated model is comparable with that of analytical equations.

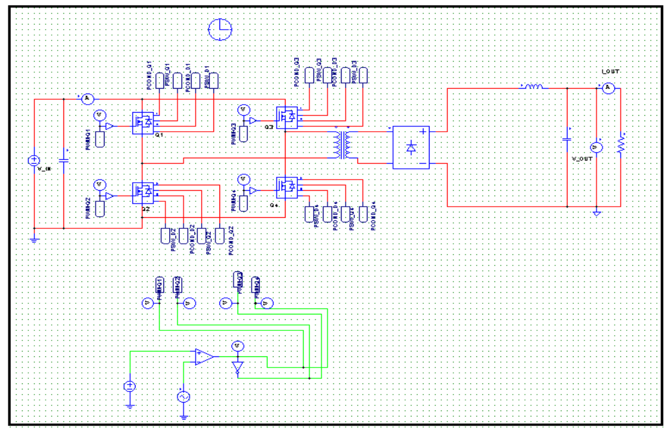

Fig.. 7 PSIM model of converter with practical MOSFET

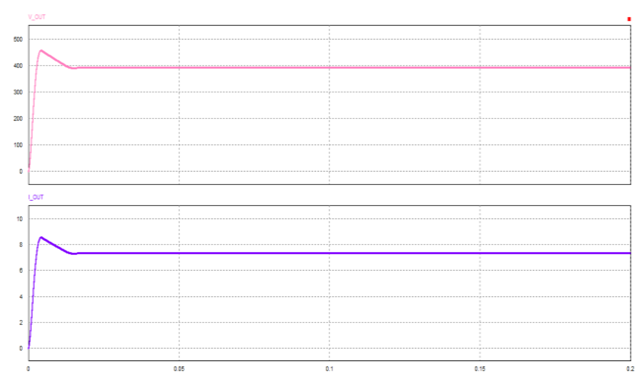

Fig. 8 Output voltage and current waveform of practical circuit

VIII. CONCLUSION

This paper proposed a Modular, redundant & independent PWM full bridge DC –DC converter which is compatible with wide renewable energy sources. The parameters and elements of a 3kW converter is designed and the simulation are done in PSIM software .The converter produced a voltage of 400V with a given input of 48V when operated in the boost mode

The proposed DC- DC converter has the following advantages, operates at 100kHz switching frequency which reduced the size of filters and make the size of the converter more compatible, provide a stable dc link to inverter and provides bidirectional operation mode to charge the batteries from dc grid incase of overvoltage conditions. The power loss of all the four MOSFETs in the primary side of converter during boost mode is calculated analytically as 164W and the efficiency of the converter is obtained as 94.5% which proved the fact that the power loss and efficiency of simulated model is comparable with that of analytical equations

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