Simulation of 5kw/20khz Soft Switched DC-DC Converter

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Abstract
This paper presents the design and simulation of a Full Bridge Soft Switched DC-DC Converter, working with an internal frequency of 20khz with an output power of 5kw. Since the ZVS range is independent of the switch capacitance, IGBT'S are used by adding the external capacitors to the switches without increasing the switching losses. However, it is not easy to design a hard-switched converter structure using these devices to operate at such high switching frequencies and voltages. Soft-switching strategies offer an attractive alternative, but converter design using these strategies is still quite challenging.   Design details, theoretical predictions, and experimental results are presented in this paper for the conversion system that was developed.

I. INTRODUCTION

In most of the high power applications, a FB ZVS PWM DC-DC converter has been using in recent years. FB ZVS pwm converter consists of Full Bridge with phase shift control & uses the Resonance between the switch capacitance and transformer leakage inductance to achieve ZVS for primary switches. All these features have made it a very popular Soft Switching converter topology.

This paper also presents the structure of a full-bridge converter with the phase shift pwm which is used to obtain the zero-voltage switching in the transformer primary side.

The zero voltage switching DC/DC converter is achieved by using the resonant behaviour between the transformer leakage inductance and the output capacitance of active switch.

The design consideration of the resonant the zero voltage switching are describe in detail. In order to increase the power level of the topology there should be a need of reducing the turn-off switching loss. To reduce the turn-of switching loss additional capacitors are needed in parallel with the IGBT's.

This paper proposes the a FB ZVS PWM Converter (5kw/20khz) for high power applications .the circuit topology of the proposed converter is shown in fig. 1.The IGBT's ca n be used to increase the power density by increasing switch capacitance with an external capacitance.

Semiconductor devices are switched on or off other than at the zero crossing of their voltage or current waveforms. Hard switching results in

Reduction of the reliability of a converter, Increases switching losses,   reduce efficiency.

So, the attractive solution is the soft switching techniques like Zero voltage switching, Zero current switching. Semiconductor devices are switched on or off at the zero crossing of their voltage or current waveforms. Soft switching can mitigate some of the mechanisms of switching loss and possibly reduce the generation of EMI compared to hard switching technique. Soft switching, especially zero voltage switching (ZVS) have become more and more popular in the power supply industries

II. BLOCK DIAGRAM AND DESCRIPTION

DC-DC converters are converters which can convert the one level of direct current voltage to another level of direct current voltage .They are primarily of use in battery powered appliances and machines which possess numerous sub circuits, each requiring different levels of voltage. A DC-DC converter enables such equipment to be powered by batteries of a single level of voltage , preventing the need to use numerous batteries with varying voltage to power each individual component.
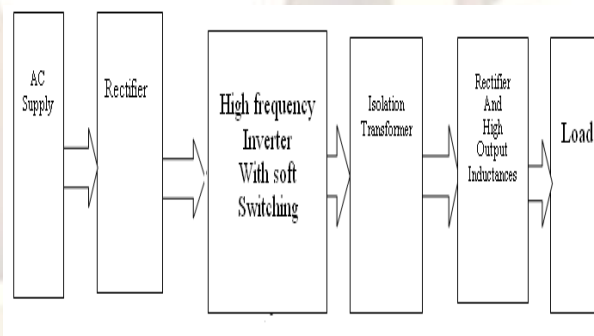

Figure 1 proposed converter circuit

Three-phase supply taken by the line which is feed to the 3-phase rectifier, there from DC voltage is generated .This voltage is given to the converter circuit that is inverter, which converts DC into AC. It uses pulse generator for the main switches so as to control the output voltage and has to eliminate the effect of harmonics present at the output side. It consists of four IGBT switches S1,S2, S3 and S4.The purpose of this inverter is to convert dc signal to ac signal.This AC is supplied to Isolation Transformer . The main purpose of isolation transformer is to isolate load from the source and also it is used to

transform electrical power from a source of alternating power to some device while isolating the power device from the power source .Again , the secondary of the transformer is given to the rectifier circuit, which is directly connected to battery or load.

III.   ZERO VOLTAGE SWITCHING

A typical zero voltage switch consists of a switch in series with a diode. The resonant capacitor is connected in parallel, and the resonant inductor is connected in series with this configuration. A voltage source connected in parallel injects the energy into this system. The circuit and waveforms are shown in figure 4.2. Then the switch is turned on, a linear current flow through the inductor. When the switch turns off, the energy that is stored in the inductor flows into the resonant capacitor. The resulting voltage across the capacitor and the switch is sinusoidal. The negative half-wave of the voltage is blocked by the diode. During this negative half wave, the current and voltage in the switch are zero, and so it can be turned on without losses.

Resonance is allowed to occur just before and during the turn-on and turn-off processes so as to create ZVS and ZCS conditions. Other than that ,they behave just like conventional PWM converters. So that the switching losses and stress have been reduced .Soft switched converters provide an effective solution to suppress EMI problems, reduce the dv/dt effect and have been applied to DC-DC ,
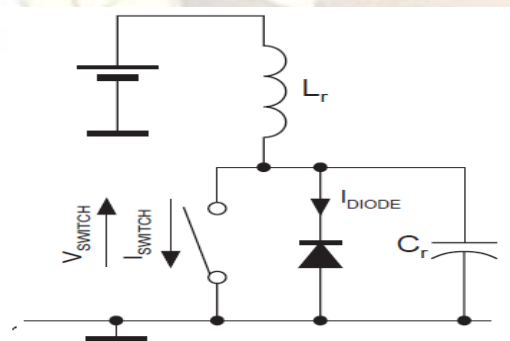AC-DC and DC-AC converters.

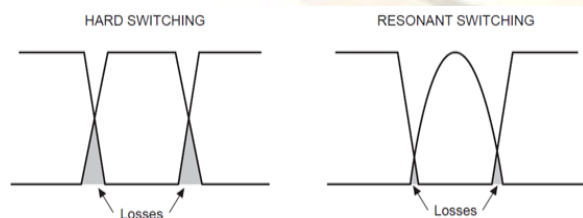Fig 2.zero voltage switch topology

Fig 3. hard switched wave form and soft switched waveform .

By comparing these two switching losses the soft switching technique is having low losses.

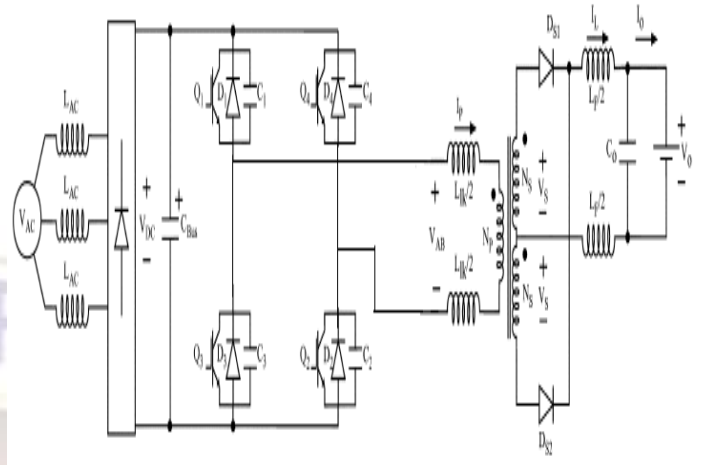### IV.   ZVS OF A FULL BRIDGE CONVERTER

Fig 4. Topology of ZVS FB converter

Fig shows the topology of the transformer coupled FB DC-DC Converter . In this application, the converter is fed from a three phase AC supply , and the complete system includes a diode rectifier, a high – voltage IGBT based H-bridge , a high-frequency   center-tapped-output   transformer, associated full wave rectifier and an LC output filter. The H-bridge control principle is simple—each phase leg is switched with a 48% duty cycle, and the active power flow through the converter is controlled by varying the phase shift between the two phase leg square waves [1]–[7]. This approach, known as phase-shifted square-wave modulation , is illustrated in Fig. 5, and can be applied to both hard and soft-switched converters.

The most common soft-switching technique used for a FB converter is ZVS, where capacitors (i.e.,C_1 toC_4) are placed in parallel with the bridge IGBTs, and a series inductance is added to the high-frequency transformer. At each phase leg transition, the primary side inductance and device capacitors cause a resonant transition of the phase leg voltage to the opposite DC rail [3], [4]. Typically, if the dead time is set to be a quarter of the resonant period , the phase legs will complete their resonant transition before the complimentary IGBT turns on, with essentially no loss. Analysis shows that the phase leg transition that terminates the active pulse (i.e., Q_2 and Q_4 in Fig. 4) will soft switch throughout almost all of the load range, since the primary side current remains at the referred output filter current. Hence, the soft-switching range is primarily determined by the resonant transition that starts the active pulse (i.e., Q_1 and Q_3 in Fig. 4) [1]–[3].
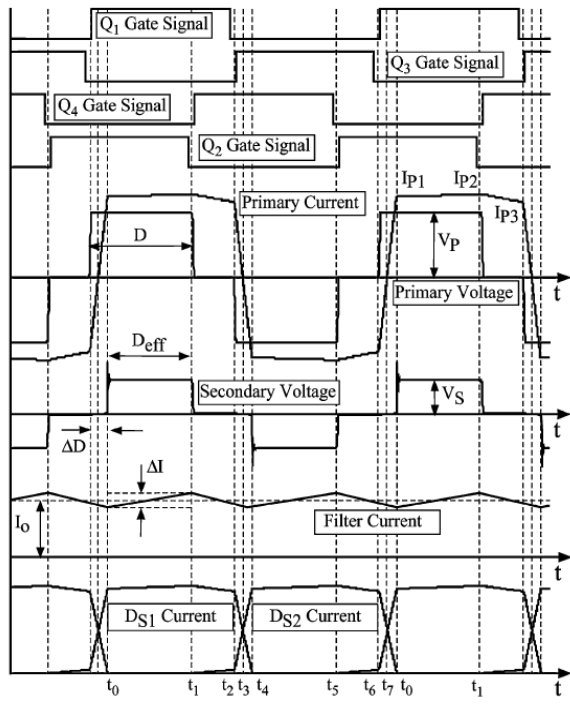
.fig 5. ZVS FB converter output wave forms

Hence, a conventional ZVS FB converter is more attractive for the application described here.

V. THEORETICAL ANALYSIS OF ZVS OPERATION

I. PRINCIPLE OF OPERATION

The full-bridge PWM converter is operated in a mode that provides zero-voltage tum-on for the active switches. The current and voltage in the transformer primary are shown in Fig. 5. The gating signals are such that, instead of turning on the diagonally opposite switches in the bridge simultaneously, a phase shift is introduced between the switches in the left leg and those in the right leg.

The zero-voltage turn-on is achieved by using the energy stored in the leakage inductance of the transformer to discharge the output capacitance of the switches before turning them on.

The switches of each leg ($Q_{1 \& } Q_3$ or $Q_{2 \& } Q_4$) turn-ON and OFF alternatively with 48% duty ratio and the phase shift between the two legs determines the operating duty cycle of converter.

Mode1(from t_0 to t_1) : In the power circuit the switches Q_1 & Q_2 will conduct and in the output rectifier D_{s1} will conduct. So the active power will pass through the circuit, So that the filter inductor current is increased linearly.And during this period the capacitance of switch Q_3 will charge .

Mode2(from t_1 to t_2): In this period, the switch Q_2 will turn off ,then the current flowing through primary charges of the switch capacitance of Q_2 and discharges the capacitance of $Q_{4.,}$ subsequently   the

body diode D_4 is turned on. During this period only one active power switch will switch on , so that the primary voltage will be zero and the primary current will decrease linearly. In the output rectifier D_{S1} will conduct.

Mode3(from t_2 to t_4): This period is called duty cycle loss period . This period of operation occurs when the primary current changes polarity. During this time, output diodes DS1 and DS2 must simultaneously conduct to maintain both transformer mmf balance and output current continuity.and Q_2 can be turned off.

Mode4(from t_4 to t_5): After the diode D_4 starts conducting the switch Q_4 can be turned-on with zero voltage. In this period the two active switches Q_3 & Q_4 and DS2 will conduct. So that the active power will pass through the circuit.

Mode5(from t_5 to t_6): In this period, the switch Q_4 will turn off ,then the current flowing through primary charges the switch capacitance of Q $_4$ and discharges the capacitance of $Q_{2.,}$ subsequently   the body diode D_2 is turned on. After conduction of body diode   of the switch Q_2 can be turned on with zero voltage.
so that switching losses and stress on the devices can be reduced by this soft switching approach. Here the energy of the large filter inductor in the secondary is used to achieve ZVS.

VI.   ANALYSIS

The expressions for these three duty cycle elements can be derived as follows. Assuming continuous conduction in the output filter, the filter current increases linearly during the active power transfer period according to

$$\Delta I_r = \frac{[(N_S/N_P)V_{DC} - V_o]D_{eff}}{2f_s L_F} \qquad (1)$$

Where f $_s$ is the converter switching frequency.
During the null and duty cycle loss periods, the output current will decrease linearly according to

$$\Delta I_f = -\frac{V_o(1 - D_{eff})}{2f_s L_F}. \qquad (2)$$

Since $\Delta I_r = -\Delta I_f = \Delta I$, the effective duty cycle can be defined by combining (1) and (2) to give

$$D_{eff} = \frac{N_P}{N_S} \frac{V_o}{V_{DC}}. \qquad (3)$$

Using this result, expressions for the three primary side current

peaks, I_{p1} I_{p2} and I_{p3} and , can be derived as

$$I_{P1} = (N_S/N_P)[I_o - \Delta I/2] \tag{4}$$

$$I_{P2} = (N_S/N_P)[I_o + \Delta I/2] \tag{5}$$

$$I_{P3} = (N_S/N_P)[I_o + \Delta I/2 - V_o(1-D)/(2f_sL_F)]. \tag{6}$$

Now, the duty cycle loss is directly related to the primary inductor, the required change in primary current (i.e., from $\pm I_{P3}$ to $\pm I_{P1}$), and the applied DC link voltage V_{DC}, as

$$\Delta D = \frac{2f_sL_{lk}(I_{P1}+I_{P3})}{V_{DC}}. \tag{7}$$

Equations (1)–(7) can now be combined to derive an expression for the actual duty cycle that the H-Bridge must apply, which after some algebra can be shown to be

$$D = D_{eff} + \Delta D = D_{eff}\left[1 + 4f_sL_{lk}\left(\frac{N_S}{N_P}\right)^2\left(\frac{I_o}{V_o}\right)\right]. \tag{8}$$

This well-known expression [1]–[3] identifies the increase in duty cycle required for a given output as a function of the resonant inductor, and transformer turns ratio. Equations (1)–(8) form the key design expressions that relate the primary and secondary side inductors, the required duty cycle, and the transformer turns ratio.

VII.   SIMULATION AND RESULTS
The   simulation of proposed   converter is developed and it is simulated for an input 415V. The simulink diagram of DC-DC converter is shown in fig.6.
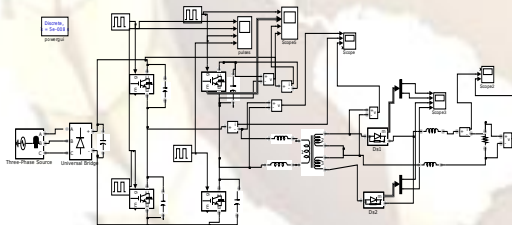

Fig.6.simulink diagram for proposed converter.

- Simulation specifications

Table.1

Input voltage	: 415v
Filter capacitance	:5400μF
Switching Frequency	20khz
Expected output voltage	:28v
Output current	:215A
Transformer turns ratio	: 1:1
Inductance	: 68mh

The input voltage is 415V peak amplitude, is given to the rectifier .The output of the rectifier is about 700V. fig.8.shows the input DC voltage.

- Switching pulses
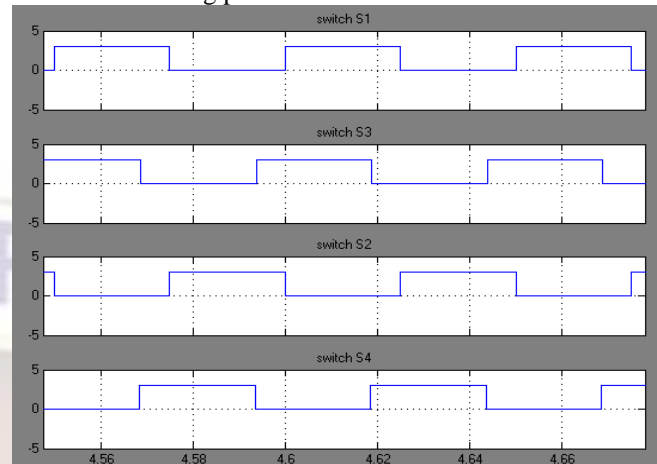

Fig.7. converter Switching pulses

Fig.7. shows the converter switching pulses which are having 48% duty cycle and phase shifted.

- Rectifier output

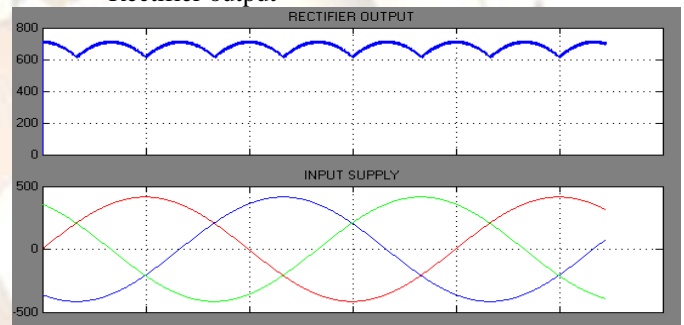
Fig.8. Input supply voltage and dc output
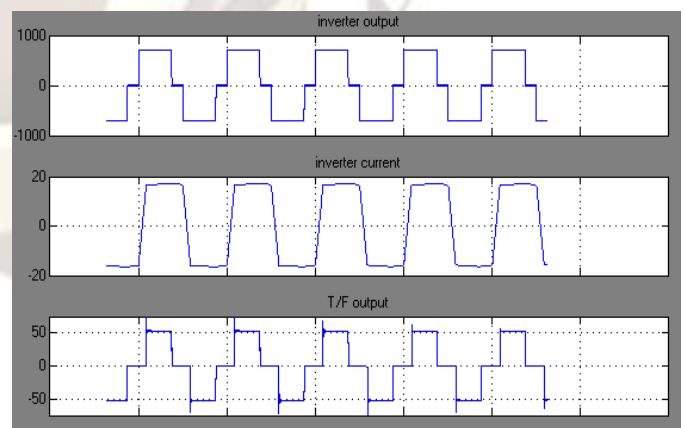
- Inverter output voltage and current

Fig9. Transformer primary and secondary voltage

- Zero voltage switching

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During the zvs turn-on, the voltage across the switch will increase slowly so that the switch will be having less stress .
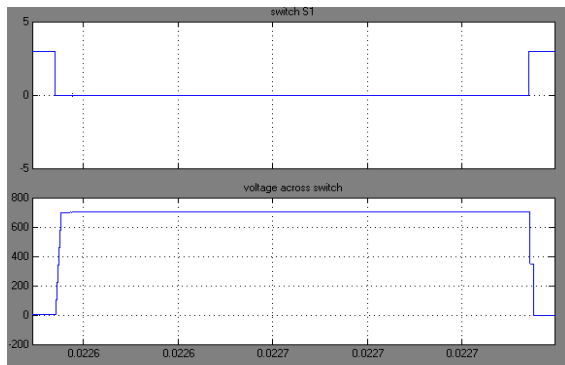

Fig.9. zero voltage turn-on of the switch

• Converter outputs

Fig 10. Shows the converter output voltage and current .the magnitude of output voltage is   : 28V .
And the current value is   :215A.
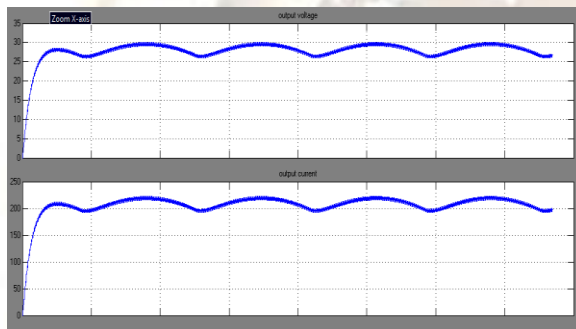Total power is   : 6KW.

Fig.10. converter output voltage and output current

VIII.   CONCLUSION

The ZVS-PWM converter provides ZVS for the switches by using the leakage inductance of the transformer and the output capacitance of the switches. The advantages of the soft switched method ,includes:

(a) Low duty cycle loss
(e) No severe parasitic ringing in the secondary
(c) Lower cost, higher power density (IGBTs can be used).
(d)High efficiency,
 (e) Reduced EMI problems

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