HYBRID CONTROL STRATEGY TO ENHANCE THE PERFORMANCE OF PHOTO VOLTAIC SYSTEM

G. Rohini1, V. Jamuna2
Electrical and electronics engineering, Jerusalem college of engineering, Chennai-100.
1rohinimukunthan@gmail.com; 2jamuna_22@yahoo.com
J. Cynthia nancy
M.E., Power Electronics and drives, Jerusalem college of engineering, Chennai-100.
cindulit05@gmail.com
A.Jenifer
Electrical and electronics engineering, RMK engineering college, Chennai-601206.
jeniinbox@gmail.com

ABSTRACT
This paper presents a isolated high boost ratio DC-DC converter for aerospace application. The proposed converter utilizes a hybrid transformer to incorporate the resonant operation mode into a traditional high boost ratio active-clamp coupled-inductor (ACCI) pulse-width-modulation (PWM) DC-DC converter, achieving zero-voltage-switching (ZVS) turn-on of active switches and zero-current-switching (ZCS) turn-off of diodes. As a result of the inductive and capacitive energy being transferred simultaneously within the whole switching period, a high boost ratio is achieved. Moreover, since both main and auxiliary switches can be turned on with zero-voltage-switching, switching loss can be reduced, and conversion efficiency can be improved significantly. The voltage stresses on the active switches and diodes are also maintained at a low level. Various control strategies have been developed and applied on the converter circuit. As the line and load fluctuates in nature, efforts are taken to regulate the output voltage at the required design value. Simulation of the converter is carried out in MATLAB/Simulink software.

Keywords- ZCS/ZVS DC-DC Converter, VMC, CMC, HMC.

INTRODUCTION
The demand for soft switched converter has been gradually increasing in accordance with the growth in DC back up energy system for Uninterruptible Power System (UPS), Photo Voltaic (PV) systems, fuel cell systems and hybrid electric vehicles. Generally conventional boost converters operate at high duty cycle in order to achieve high output voltage resulting in high switching losses and electromagnetic interference problems. In hard switched converter, when switch is turned-on, a large quantum of current spikes through the diode and main switch and there will be the shoot-through at the output capacitor. Therefore it is not capable of achieving high efficiency.

To overcome these entire problems soft switched converter is used. In this circuit, a high boost ratio ZVS/ZCS DC-DC converter with hybrid transformer is presented. The hybrid transformer incorporates both PWM and resonant mode of operation to achieve high voltage gain. This converter provides zero-voltage-switching (ZVS) turn-on of switches and zero-current-switching (ZCS) turn-off of diodes. Thus the switching losses are reduced.

A coupled inductor with a lower-voltage-rated switch is used for raising the voltage gain (whether the switch is turned on or turned off). Moreover, a passive regenerative snubber is utilized for absorbing the energy of stray inductance so that the switch duty cycle can be operated under a wide range, and the related voltage gain is higher than other coupled-inductor-based converters [1]. Single-Switch PWM Converters with High Step-Up Conversion Ratio posses higher voltage gain with small output voltage ripples [2]. Boost Converter with Coupled Inductors and Buck-Boost Type of Active Clamp the active-clamp circuit is used to eliminate the voltage spike that is induced by the trapped energy in the leakage inductor of the coupled inductors. More over since both main and auxiliary switches can be turned on with zero-voltage switching, switching loss can be reduced, and conversion efficiency therefore can be improved significantly [3].

In [4] the current-fed full-bridge boost converter can achieve ZCS by utilizing the leakage inductance and parasitic capacitance as the resonant tank. The steady-state analysis and the ZCS operation conditions under various load and input voltage conditions are discussed. In [5] energy regenerative snubber can recover leakage energy from snubber capacitor compared to other snubbers. A multi-power-port topology which is capable of handling multiple power sources are discussed in [6]. In [7] a highly efficient battery charger with an improved series-loaded resonant converter for renewable energy applications to improve the performance of traditional switching-mode charger circuits.

A Cuk-type converter is integrated to the first phase to achieve a much higher voltage conversion ratio and avoid operating at extreme duty ratio. In addition, additional capacitors are added as voltage dividers for the two phases for reducing the voltage stress of active switches and diodes, which enables one to adopt lower voltage rating devices to further reduce both switching and conduction losses in [8]. In [9-10] a half-bridge LLC resonant circuit shares the lagging leg with a phase-shift full-bridge (PSFB) DC–DC circuit to guarantee ZVS of the lagging-leg switches from zero to full load. The primary-side circulating current of the PSFB DC–DC circuit is instantly reset to zero, achieving minimized circulating losses.

A ZVS high boost ratio active-clamp coupled inductor (ACCI) converter could be derived from traditional active-clamp flyback converter by splitting secondary side and series connecting the output winding with the clamping capacitor Cc. Besides of
II CIRCUIT DESCRIPTION

The circuit configuration of converter with hybrid control strategy is shown in figure 1. The ripple content with the ZCS/ZVS DC-DC converter is reduced to a greater extent with respect to other converter. DC input is given to the ZCS/ZVS DC-DC converter to drive the load. Voltage and current signals are sensed and given as feedback to the controller. Firing pulses generated by the controller are given to the switches of ZCS/ZVS DC-DC converter to regulate the output voltage and current at the prescribed level.

III PHOTO VOLTAIC MODULES

A photovoltaic system broadly normally consists of photovoltaic array comprise a few numbers to a few hundreds of modules. The sun pointed to PV array and the charge controller will regulate the power. Then the power will stored at the battery bank that consisting of deep cycle batteries. Lastly, the inverter will convert the dc power from array into ac power. The daily energy output from PV array will vary depending on its size, orientation and location, season of the year and the daily weather conditions. Energy storage is required for the power when sun is not shining. Battery sizing depends on the application, the daily solar radiation, the total load, peak load and the number of days which storage required. The charge controller is placed between the PV array and the storage battery to prevent the battery from being damaged either due to overcharging or over-discharging to enhance its life. The power from the PV system is dc.

The connection of photovoltaic modules with different operating currents and/or voltages characteristic may result in the performance of the array being less than the sum of the potential performances of individual modules. When connected in series, the current flowing through the lowest productive cell limits the entire array output. The problem arises when modules have different sizes, which may be a result of individual modules not exposed to the same lighting conditions, such as is the case with differently oriented modules or irregular shading of the array. Mismatch is more likely in large systems than in independent arrays, because individual modules may be oriented differently or they may be subject to varying degrees of shading and heating.

Taking into account that real operating conditions of a solar array are difficult to reproduce during tests, simulations to determine electrical characteristics will
allow the researcher to gain more insight for better understanding and design. As the fine modeling of a cell’s behavior is the basis for any solar generator, the solar cell model needs to be properly determined. Consider a fixed environmental condition, a typical I-V characteristic of a solar cell is shown in Figure 2.2.

![Figure 2.2 Typical I-V characteristics of a solar cell](image1)

The operating point on power vs. voltage curve (P-V curve) will depend on the solar array characteristic and the load is shown in Figure 2.3. Assuming that initially there is no load, the operating point will be at the far right at the open-circuit voltage, Voc, of the solar array with zero current (V = Voc, I = 0). As the load increase, the operating point will move up and to the left, i.e. voltage at the solar array terminal decreased, while the power increases. As the load increases further, it will reach the maximum power point (MPP), where the power drawn from the solar cell is maximized. The voltage at this point is denoted by the maximum-power voltage (Vmp), and the current by maximum-power current (Imp). If the load increases beyond this point, the voltage decreases and power drew from the solar array decreases. Eventually, the operating point will reach the far left at the short-circuit current, Isc, with zero voltage output (V = 0, I = Isc).

![Figure 2.3 Typical P-V characteristics of a solar cell](image2)

III ZCS/ZVS DC-DC CONVERTER

The circuit diagram of the ZCS/ZVS DC-DC converter is shown in the figure 4. HT is a hybrid transformer with primary to secondary turns ratio n; Llk, Cr, Cs, Dr, and Cj represents the equivalent parasitic junction capacitors of MOSFETs, Cs is the equivalent capacitor of the diodes Do and Dr, Co is the output capacitor; Ro is the equivalent resistive load, and Vin represents the input side equivalent voltage.

![Figure 4. Circuit diagram of ZVS/ZCS DC-DC converter](image3)

The working of the ZCS/ZVS DC-DC converter can be analyzed with the eight modes according to the operating conditions as:

During the mode 1, S2 is turned off. The negative magnetizing current iLm starts to charge Cj. Due to the voltage potential change of the drain node of S1, a parasitic minor resonant loop composed of secondary side of HT, Llk, Cr, Cs, and Cj starts to resonate until Dr is forward-biased. Vin is applied on Lm and iLm is linearly increased.

![Mode 1](image4)

During the mode 2, vds1 is reduced to zero. iS1, which is equal to the sum of iPand n·iCr, flows through the body diode of S1. This provides a ZVS condition for S1.
Mode 2
Meanwhile, the secondary-reflected input voltage $n \cdot V_{in}$ along with VCC charge Cr in a resonant manner through the resonant loop including secondary side of $H_t$, $L_{ik}$, $C_r$, $D_r$, $C_c$ and body diode of S1. S1 is turned on with ZVS in mode 3.

Mode 3
During mode 4 $i_{Dr}$ resonates back to zero so $D_r$ turns off with ZCS. $V_{in}$ continues to linearly charge $L_m$.

Mode 4
During mode 5, S1 is turned off. $i_{Lm}$ starts to discharge $C_j$. Due to the voltage potential change of the drain node of S1, a parasitic minor resonant loop composed of secondary side of $H_t$, $L_{ik}$, $C_r$, $C_s$, and $C_j$ starts to resonate.

Mode 5
$C_s$ is discharged to the point where the anti-parallel diode of S2 starts to conduct. This provides ZVS turn-on of S2. Also, the voltage potential of anode of Do increases high enough leading Do to be forward-biased in mode 6.

Mode 6
During mode 7, S2 is turned on with ZVS. Since it takes a long time interval before $i_{Lm}$ reduces to zero, ZVS of S2 is easily achieved.

Mode 7
The energy is transferred to the output with the resonant current $i_{Do}$. $D_0$ resonates to zero, $D_0$ turns off with ZCS. The voltage applied on $L_m$ is $V_{in} - V_{Cc}$, which decreases $i_{Lm}$ to a negative valley to provide a ZVS turn-on condition of $S_1$ in mode 8.

Mode 8

| TABLE 1 Design parameters of ZVS/ZVS DC-DC converter |
|---------------------------------|--------------|
| Parameters | Value        |
| $L_m$      | $5.6 \times 10^{-6}$ H |
| $L_{ik}$   | $4.8 \times 10^{-6}$ H |
| $C_r$      | $0.4 \times 10^{-6}$ F |
| $C_c$      | $10 \times 10^{-6}$ F |
| $C_o$      | $1000 \times 10^{-6}$ F |
| $R_o$      | 100 ohms     |
The Design parameters of ZCS/ZVS DC-DC converter is shown in the table 1.

IV CONTROL STRATEGY

The various controlling techniques for DC-DC boost converters discussed in this paper are VMC, CMC and HCMC. Output voltage is measured and compared to the reference voltage to generate the control voltage in VMC. The average voltage across the inductor is maintained by the duty ratio which is determined by the control voltage. To maintain constant voltage without any variation is maintained to bring out the output voltage to its reference value.

Figure 5 Hybrid controlling techniques of three stage boost converter

CMC contains two loops including voltage and current control loops which is more complex than VMC. The output voltage Vo with fixed reference voltage Vref is compared an error signal is produced and control signal is generated using error signal. To generate the duty cycle of particular frequency inductor current is sensed and compared with control signal to drive the switch of the converter. The output voltage becomes equal to reference voltage Vref where the inductor current is proportional to the control signal.

In HCMC method, when the inductor current goes below a certain value the main switch is switched on, and when the inductor current goes above a specified maximum value it is switched off. Thus, the amplitude of the current is bounded between these two limits. The main application in power inverters, motor drives, and power factor correction circuits; nevertheless, it can be used to control a switching current source by hysteresis control.

V RESULTS AND DISCUSSIONS

To ensure the feasibility of the proposed converter, the controller circuit is simulated using MATLAB Simulink software and verified through the simulation results. The MATLAB simulation software is used to analyze the control strategies for ZCS/ZVS DC-DC converter. The entire simulink model of closed loop ZVS/ZCS DC-DC converter using hybrid transformer with R-load is simulated for an input voltage of 12V and the output voltage obtained is 48V. The pulses for switches S1 and S2 are given through separate pulse generators. The converter is operated at the switching frequency of 20 kHz.

Proportional Integral (PI) controller is used in the ZVS/ZCS DC-DC converter using hybrid transformer to control the output voltage as we require. The reference voltage is given to the circuit through the constant block. The output and reference voltage are compared and the error signal is created. The error signal is processed by PI controller. The PI controller controls the circuit and gives the desired output. Here the input side has the disturbance of -5 V with the input voltage of 45 V. Even though the input side has the disturbance, the output obtained is constant.

The closed loop voltage waveform is shown in Figure 4.13. It is observed that even after the disturbance the system is able to maintain its steady state output.

Figure 6 Closed loop simulation of converter with R-load

Figure 7 Output voltage & current waveform under closed loop

Line regulation is a measure of the ability of the power supply to maintain its output voltage with variations in the input line voltage. Line regulation is expressed as percent of change in the output voltage relative to the change in the input line voltage. The output voltage is regulated for 17% as source disturbance by closing a feedback loop between the output voltage and duty-ratio signal.

Figure 8 Current Control of ZVS/ZCS DC-DC Converter with Line regulation
Hysteresis current control is a nonlinear current control method that has many advantages such as simple structures, fast dynamic response, robustness to the variance of load parameters, and being implemented easily. In hysteresis control, the source current is given as feedback to the relay, minimum and maximum limits are fixed in the relay and pulses are given to the switch as the switching pulses.

IV CONCLUSION

In this paper, a high boost ratio ZVS/ZCS DC-DC converter with hybrid transformer is presented. By incorporating resonant operation mode into traditional high boost ratio active-clamp coupled-inductor PWM converter, the proposed converter obtains the following features and benefits as ZVS turn-on of active switches and ZCS turn-off of diodes, reducing the switching losses and EMI noises, continuous input current with combined resonant and PWM waveforms reducing the RMS conduction losses, elimination of lossy snubber circuit for output diodes. Although an additional resonant diode and a small resonant capacitor are added, the total power device utilization is improved. Efficiency is improved compared to other converters by introducing hybrid control strategies.

REFERENCES