ANALYSIS, DESIGN AND SIMULATION OF ISOLATTED BIDIRECTIONAL DC-DC CONVERTERS

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ABSTRACT: This paper presents two cases of bidirectional isolated dc/dc converters.First one snubberless current fed half bridge converter and other one is 3 phase bidirectional DC-DC Dual Active bridge converter. By using snubberless current fed half bridge converter voltage clamping can be achieved on secondary side modulation which eliminates the need of snubber or active clamp also zero current switching is obtained at primary side .They provide smooth operation, the diodes across switches automatically turned off. So it can reduce switching transmission losses. voltage is increased to 5 times (Dmax=0.8) ,whereas active clamp converter can increase the voltage 4 times with the same value. This converter maintains Zero current Switching turn off of primary device and ZVS turn on of secondary device during the large variation in input voltage and output power conditions without using any extra circuitry .Also In this topology peak current through primary device and high frequency KVA rating of transformer voltage across primary devices can reduce. Another one is DAB. It consists of single phase and three phase and structure of half bridge or full bridge topology. Compared to other converters DAB has smooth power transfer capability and mostly used in high power applications. Advantages of DAB is bidirectional power flow, high power density, isolation and low component stress. These both cases can use in PV system

Index Terms -- Current fed converter(CFHB) ,soft switching, ZCS, ZVS, Dual active bridge (DAB), Photo voltaic (PV)

1. INTRODUCTION:

Fossil fuels decreased from last few decades[1,2]. To stabilize the usage of power requirement and limited conventional power, non conventional energy sources are used. Solar energy, wind energy ,tidal energy sources give unregulated and discontinuous power .We have to regulate and stabilize the power from renewable sources while also large amount of power can be extracted from the source. These sources can be combined and energy can be stored for reusing the power as a distributed generation system for long period usage.

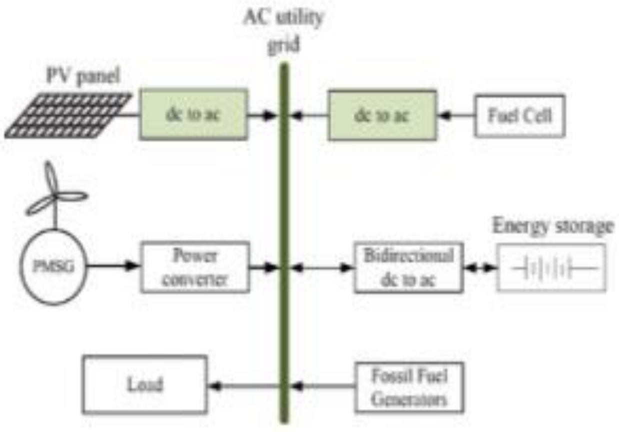


Fig. 1. Hybrid distributed power generation system.

Figure 1 shows the hybrid distributed generation(DG) system. DGs are near to end users. They consist of wind turbine, solar system and fuel cell. Solar PV generation is easy and it is used from low power applications to high power applications. High initial investment is the main disadvantage here. In order to convert unregulated dc output to regulated output , power electronic devices are used like inverters and frontend converter topologies for single phase converters. These are not preferred because they are of low power ,are bulky and have high cost .Now a days high frequency multistage converters are used for front end converters .They achieve maximum power point tracking and inverter will control the grid current and voltages[3].

The objectives outlined in this paper as follows .Introduction ,complete design procedure, analysis of current fed half bridge is explained with example and simulation results are given in section 2, Design ,simulation results of three phase DAB is given in section 3,conclusion given in section 4.

INTRODUCTION TO CFHB DC DC CONVERTER

Currently, isolated boost (current-fed) converters are used for such applications. The main limitations of such converters are hard switching and requirement of an active-clamp or passive snubber to absorb the switch turn-off voltage spike to limit the device voltage. Active-clamp-based ZVS topology proposed[4,5], analyzed, and designed is shown in Fig. 2. Though active-clamp assists in ZVS of switches, it dissipates around 2% of the output power along with increase in circulating current through the components, increasing their conduction losses, particularly at light load. It also increases the number of components and converter complexity.

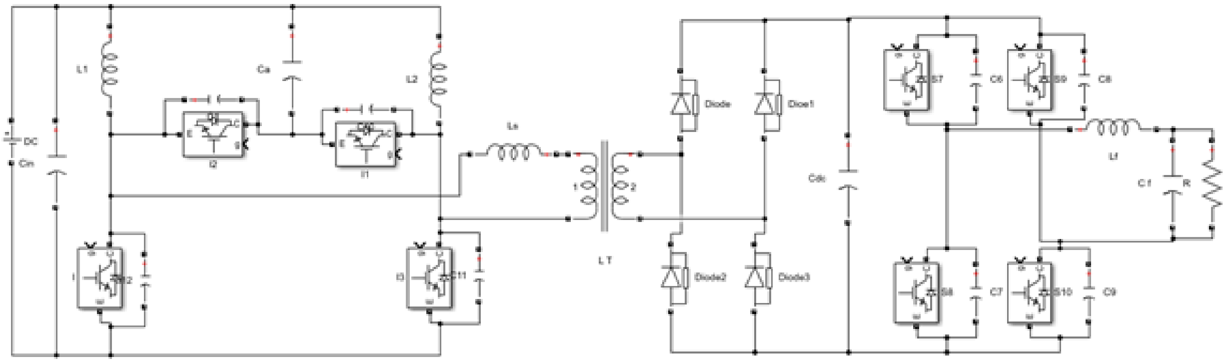


Fig 2. Inverter with active clamped current fed half bridge dc dc converter

In order to overcome these disadvantages , a new snubberless naturally clamped spft switching CFB converter is used[6,7],which is shown in fig 3.Secondary modulation diverts the current from primary switch into the transformer , causing transformer current to rise and the primary switch current to fall to zero naturally ,resulting in zero-current turn-off [zero-current switching] and reduce the voltage across the components without using additional activeclamp circuits.

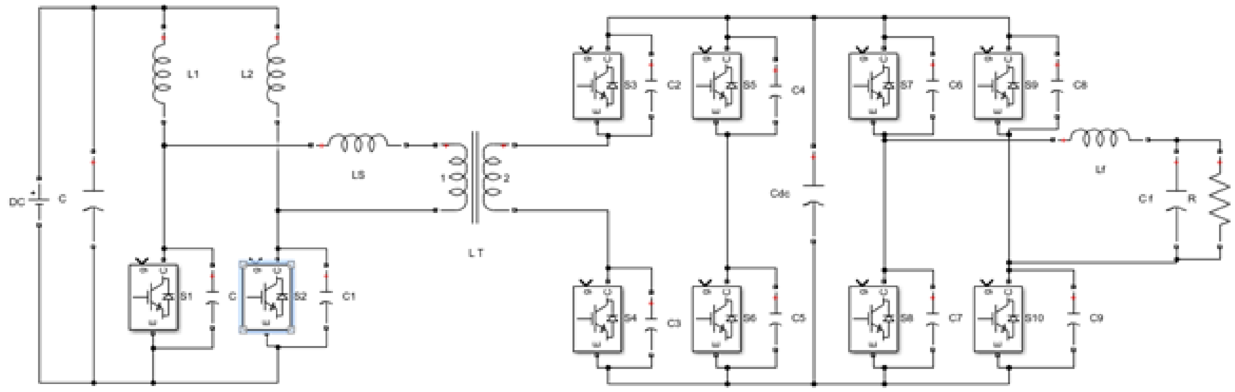


Fig.3 Snubberless current fed half bridge dc dc converter

2. OPERATION AND ANALYSYIS

2.1 Operation And Analysis Of CFHB Isolated DC-DC Converter

In this steady state operation and analysis of CFHB converter is explained. In this topology fixed frequency duty cycle technique is used for control. For easy operation some assumptions are taken : 1) inductor 1 and inductor 2 values are high to maintain current. 2) magnetizing inductance is high 3) all elements are taken ideal . the steady state operating wave forms are shown in fig.4 . the input switches are controlled by gate signals shifted by 180 degrees with an over lap. And duty cycle is more then 50%.

Interval 1 ($t_o < t < t_1$): it is shown in fig 5(a), in this period switch S1, Diodes D4 and D5 are operating, and the power is came to inverter through source and HF transformer. And switch S1 current is given by

$i_{s1} = I_{in,}\ i_{s2} = 0,\ i_{Ls} = \frac{-I_{in}}{2},\ i_{D4} = \frac{I_{in}}{2n}$.

And $V_{s2} = \frac{V_{DC}}{n}$

Interval 2 $\left(t_1 < t < t_2\right)$: This mode is in fig 5(b) , in this switch S2 is on, capacitor across the switch is discharged.

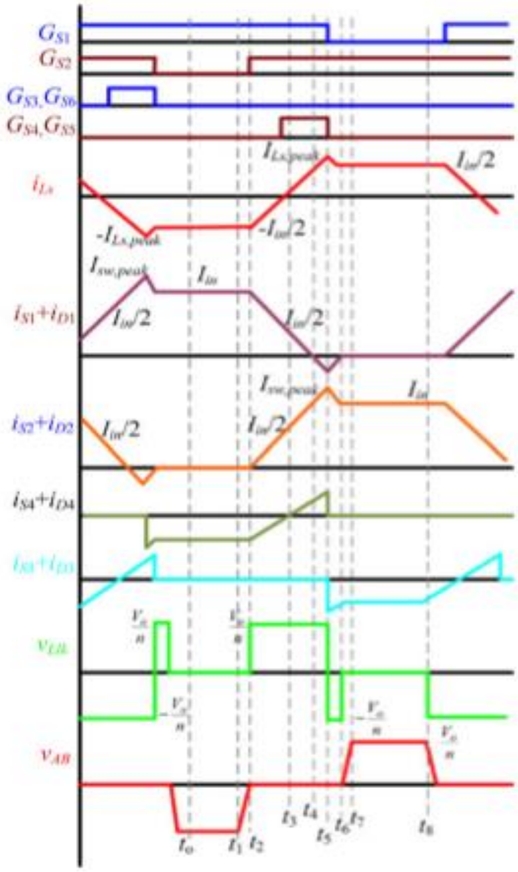


Fig. 4. Operating waveforms of the proposed ZCS two-inductor current-fed half-bridge isolated dc/dc converter shown in Fig. 3.

Interval 3 $\left(t_2 < t < t_3\right)$**:** shown in fig 5(c), switch S2 is conducting and current at different components are given below

$$i_{Ls} = -\frac{I_{in}}{2} + \frac{V_{DC}}{n.L_s}\left(t - t_2\right) \qquad (1)$$

$$i_{s1} = I_{in} - \frac{V_{DC}}{n.L_s}\left(t - t_2\right) \qquad (2)$$

$$i_{s2} = \frac{V_{DC}}{n.L_s}\left(t - t_2\right) \qquad (3)$$

$$i_{D4} = \frac{I_{in}}{2} - \frac{V_{DC}}{n^2.L_s}\left(t - t_2\right) \qquad (4)$$

at finishing of the mode t=t3 and i_{s1} is decreased to $I_n / 2$ and i_{s2} is increased to $I_n / 2$.

Interval 4 $\left(t_3 < t < t_4\right)$**:** shown in fig 5(d), because of ZCS switches S4 and S5 ON.

At end $t = t_4$ and i_{s1} is zero, $i_{s2} = I_{in,}$ $i_{Ls} = \frac{I_{in}}{2}$ and $i_{s4} = I_{in} / n$

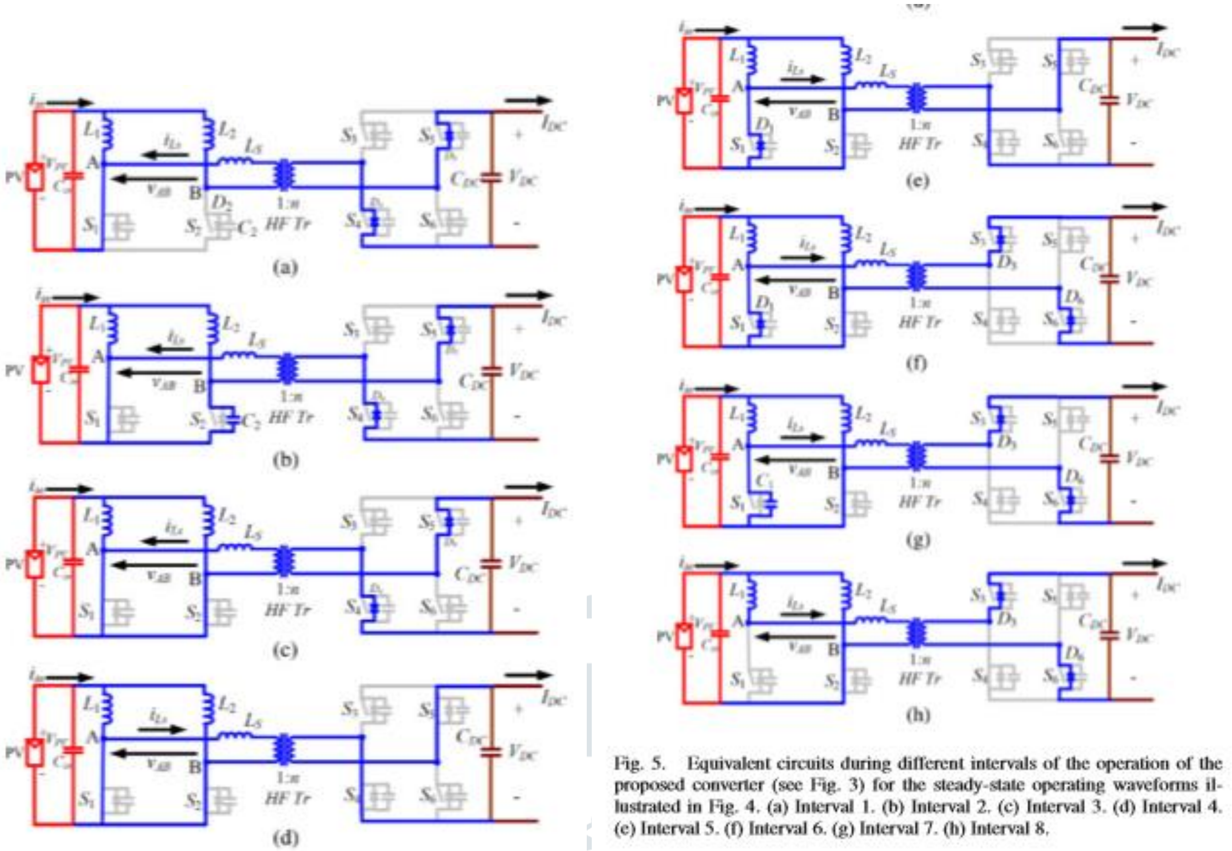


Fig. 5. Equivalent circuits during different intervals of the operation of the proposed converter (see Fig. 3) for the steady-state operating waveforms illustrated in Fig. 4. (a) Interval 1. (b) Interval 2. (c) Interval 3. (d) Interval 4. (e) Interval 5. (f) Interval 6. (g) Interval 7. (h) Interval 8.

Interval 5 $(t_4 < t < t_5)$**:** in this diode D1 conducted and S1 gets ZCS. Series inductance and switch S2 currents gets peak values.

$$i_{LS} = \frac{I_{in}}{2} - \frac{V_{DC}}{n.L_s}(t - t_4) \qquad (5)$$

$$i_{s2} = I_{in} - \frac{V_{DC}}{n.L_s}(t - t_1) \qquad (6)$$

Interval 6 $(t_5 < t < t_6)$ **:**Switches S4 and S5 are OFF.

$$i_{LS} = I_{LS,peak} - \frac{V_{DC}}{n.L_s}(t - t_5) \qquad (7)$$

$$i_{s2} = I_{s2,peak} - \frac{V_{DC}}{n.L_s}(t - t_5) \qquad (8)$$

Interval 7 $(t_6 < t < t_7)$**:** At this period capacitor across the S1 charges to VDC/n.

Interval 8 $(t_7 < t < t_8)$: constant current flows in switch S2, series inductance, and body diode of secondary switch. The cycle repeats.

2.2 Design of CFHB Isolated DC-DC Converter

For design purpose some specifications are taken: Maximum open circuit voltage Vocmax=50V, MPP Vpv=22V to 41V, MPP Iin=9A,Po=200W, Vdc=200V ,output voltage 110V, switching frequency 100KHz, and inverter switching frequency 20KHz, n=2.

1) Input current $I_{in} = \frac{P_o}{nV_{pv}} = \frac{200}{0.95 * 22} = 9.6A$

2) $V_{s1,sw} = \frac{V_{DC}}{n} = \frac{200}{2} = 100$

3) Input voltage and current of converter

$$V_{pv} = \frac{(1-d).V_{DC}}{n} = \frac{(1-0.8).200}{2} = 20$$

(d=0.8)

$$I_{DC} = \frac{(1-d).I_{in}}{n} = 0.9$$

4) Leakage inductance of transformer

$$L_s = \frac{(d-0.5).V_{DC}}{n.I_{in}.f_s} = 15.6\mu H$$

5) Primary switch rms current

$$I_{s1,rms} = I_{in}\sqrt{\frac{2-d}{3}} = 9.6\sqrt{\frac{2-0.8}{3}} = 6.1A$$

6) Primary winding rms current

$$I_{Ls,rms} = I_{in}\sqrt{\frac{5-4d}{12}} = 3.7A$$

7) Boost inductor values

$$L_1 = L_2 = \frac{V_{PV}.d}{\Delta I_{in} f} = 352\mu H$$

8) Average current through I_{s3} =0.5A

9) Secondary switch S3 rms current

$$I_{s3rms} = \frac{I_{in}}{2n}\sqrt{\frac{5-4d}{6}} = 1.3\mu H$$

$$I_{s3peak} = \frac{I_{in}}{2n} = 2.4A$$

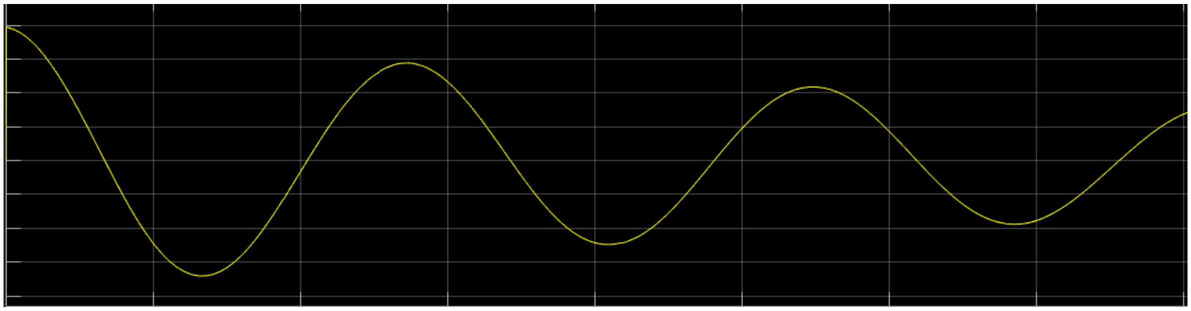
10) VA rating of high frequency transformer

$$VA_{x-er} = \frac{V_{DC}.I_{in}}{n}\sqrt{\frac{(5-4d)(1-d)}{6}} = 235\,VA$$

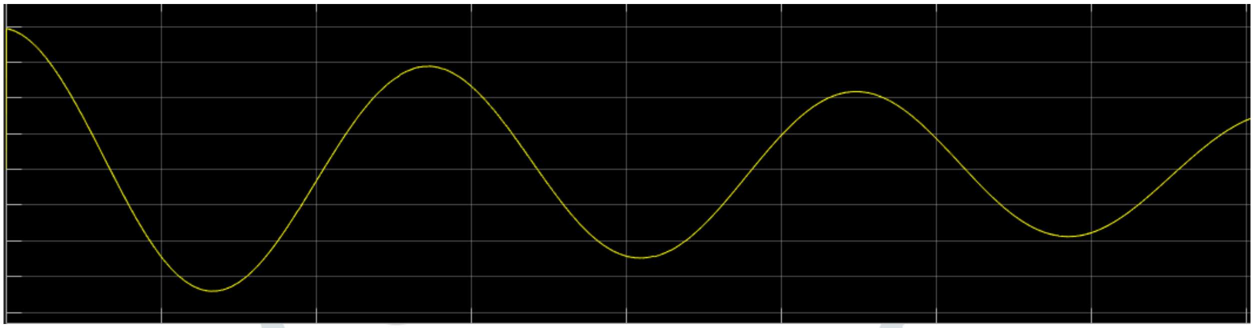
11) DC link capacitor

$$C_{DC} = \frac{I_{in}(d-0.5)}{2.n.\Delta V_{DC}.f_s} = 14.4\mu F$$

2.3 Current fed half bridge simulations Results



Out put voltage Vo



Out put current Io

TABLE 1

Values of the current fed half bridge converter

Input parameters		output		Simulation values
V_{PV}	22-44V	V_o	110V	Vo=98V
L_1,L_2	352 µH	C_{DC}	14.4µF	Io=1.8A
L_s	15.6µH	P_o	200W	
n	2	L_f	3.8µH	
f_S	100KHz	C_f	1.6µF	

Discussion: Design and simulation values of the output voltage and currents are approximately matched because of assumptions, and the graphs are shown above, on Y-axis output voltage, current are taken, on X-axis time period is taken

3. Three phase Dual Active Bridge

INTRODUCTION TO 3 PHASE DAB CONVERTER

Another topology is the 3phase DAB structure. This three-phase DAB circuit consists of two three-phase inverters that are tied together by a three-phase transformer as shown in Fig. 3.1even though the fact that the single-phase is considered to be more leading in research, the three-phase is poised to become more utilized. Unlike the single-phase, using three phase transformer leads to better apparent power thus a large energy density is possible[8]. Similar to the single phase, the upper and bottom switch in the three phase leg works at complementary 50% duty cycle. In each inverter, the legs are phase shifted by 120 degrees Also, the inverters on each side of the transformer are phase shifted to control the direction and the amount of power flow[8]

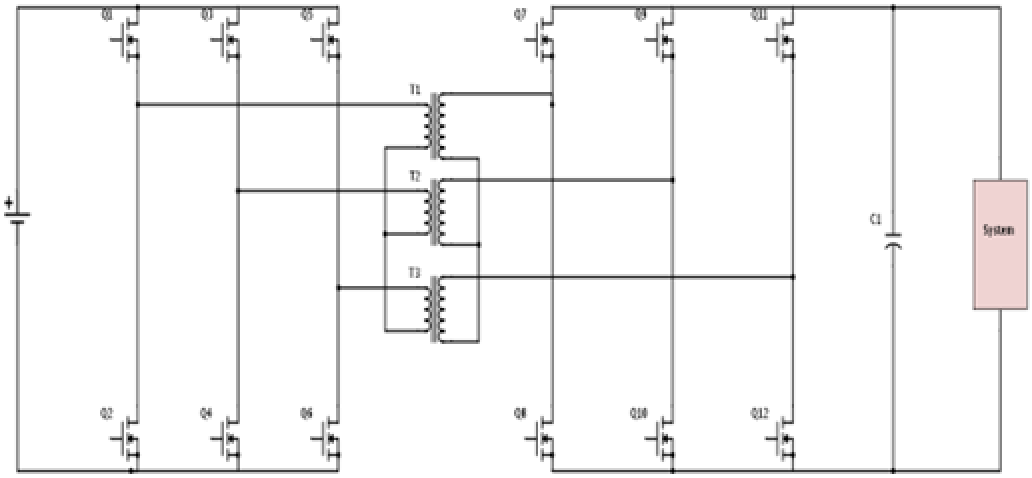


Fig 3.1 Three phase DAB topology

As mentioned before, the three-phase dc-dc DAB model consists of two three phase inverters connected together by a linear transformer. The input power supply is a constant DC voltage source and the output is also considered a DC voltage source that is smoothed by a capacitor.

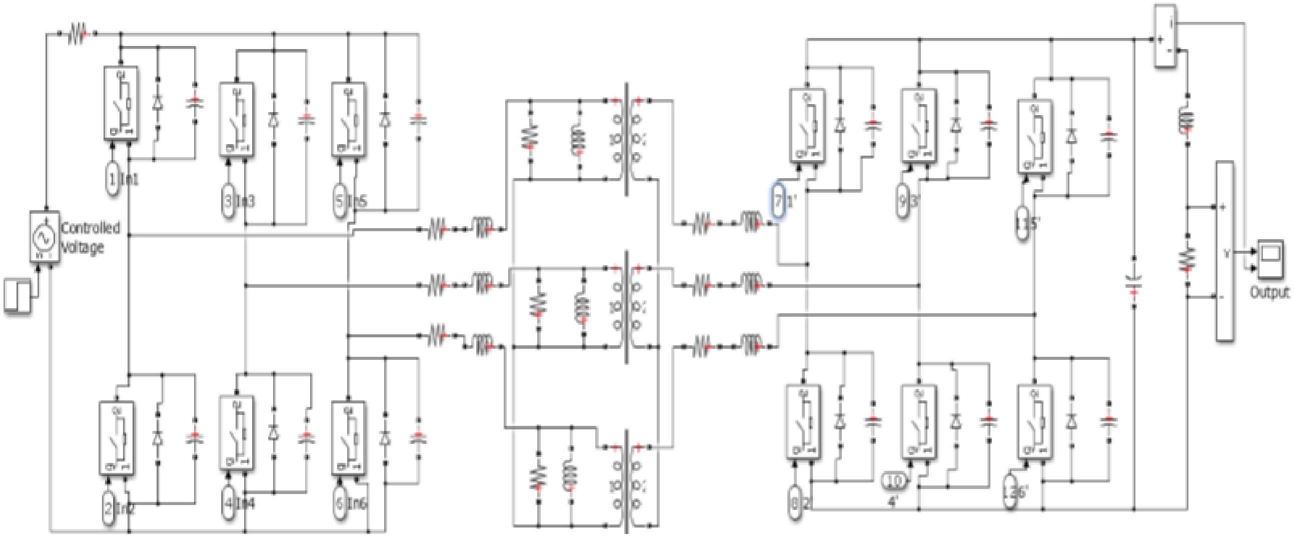


Figure 6. Three phase DAB model structure

Controls :

There are many ways to control a 3phase DAB but the working principle is always the same. In DAB topologies the switches usually activate at 50% duty cycle with a constant speed. Thus the two switches in one bridge will generate identical output. The output of one bridge will then be phase shifted from the previous bridge by 120 degrees. The energy will flow from the low voltage side to the high voltage side when the converter is working a boosting mode. The energy will reverse the direction when in buck mode. The energy flow can be controlled through the PH angle between the two inverters

3.1 Design of Three Phase DAB

At 100KHz

$$\text{Time } T = \frac{1}{f} = \frac{1}{100\text{kHz}} = 1e^{-5}$$

Then the counts per cycle is determined using the equation

$$\frac{T}{T_{\text{clock cycle}}} = \frac{1e^{-5}}{2e^{-5}} = 500\text{counts}$$

To prevent shoot through dead time has to chosen, 14 counts taken for 100kHz.

At zero phase-shift, the switches 1 and 2 are on when,

$1 \leq ON \leq 236$

$250 \leq ON \geq 486$

At 120° phase shift, switches 3 and 4 are on when

$168 \leq ON \leq 403$

$ON \geq 417$

$ON \leq 153$

At -120° phase shift, switches 5 and 6 are on when

$ON \geq 334$

$ON \leq 69$

$83 \leq ON \leq 319$

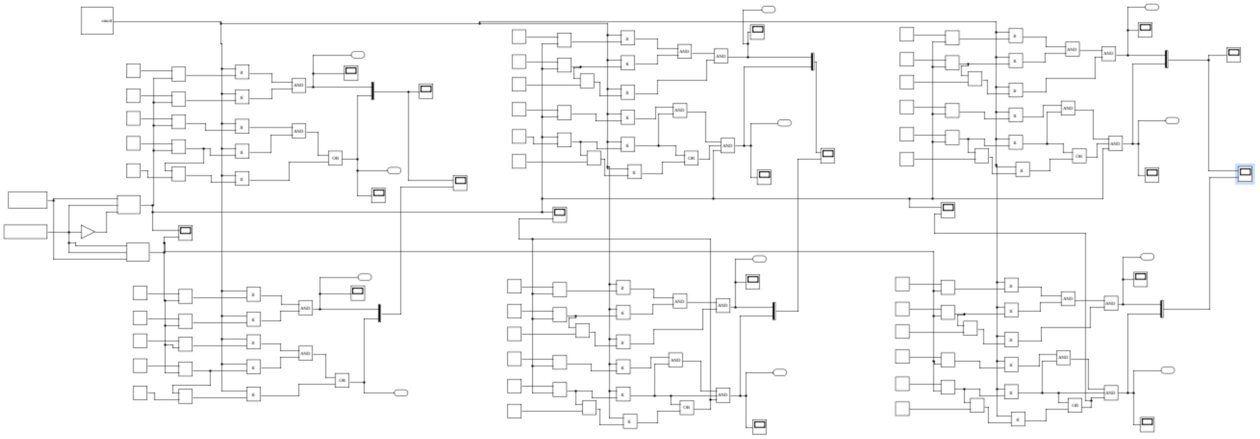
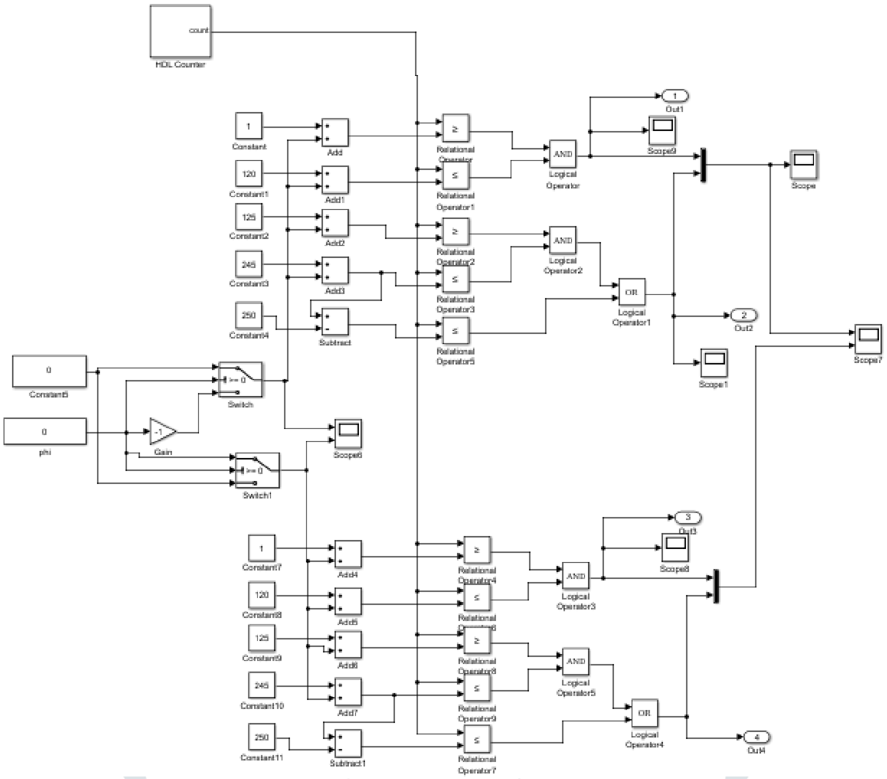
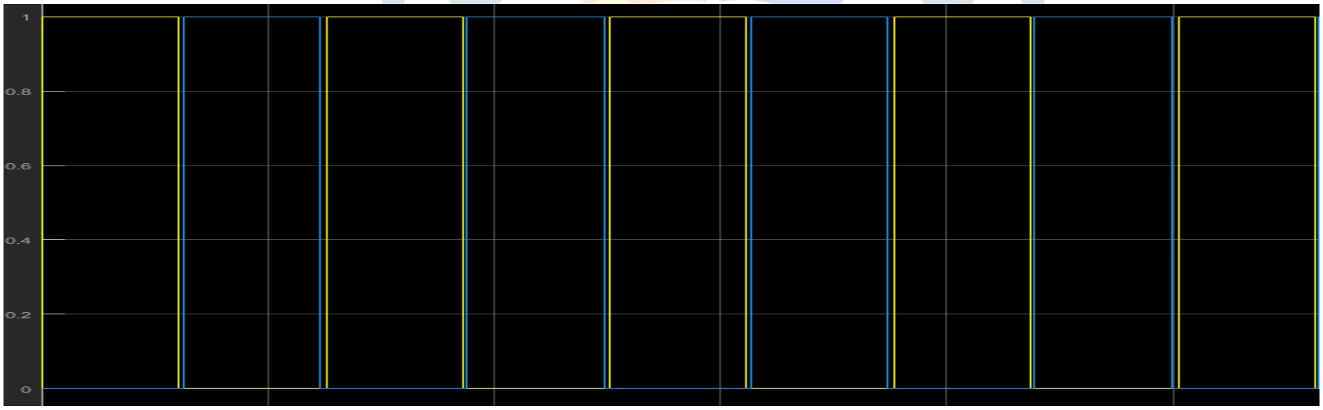


Fig 7.1Simulink model for the 100 kHz three-phase controls

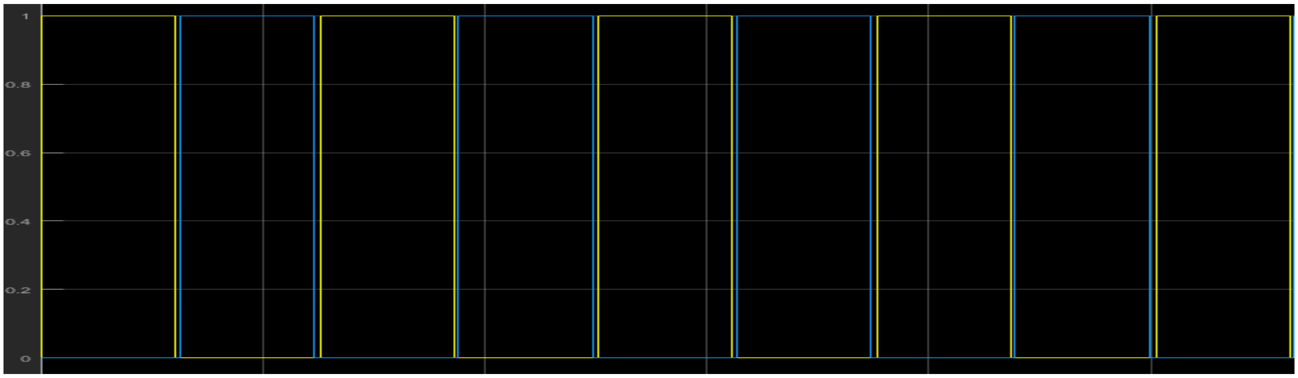


Fir 7.2 Simulink control schematic for one leg of the three-phase inverter at 100 kHz.

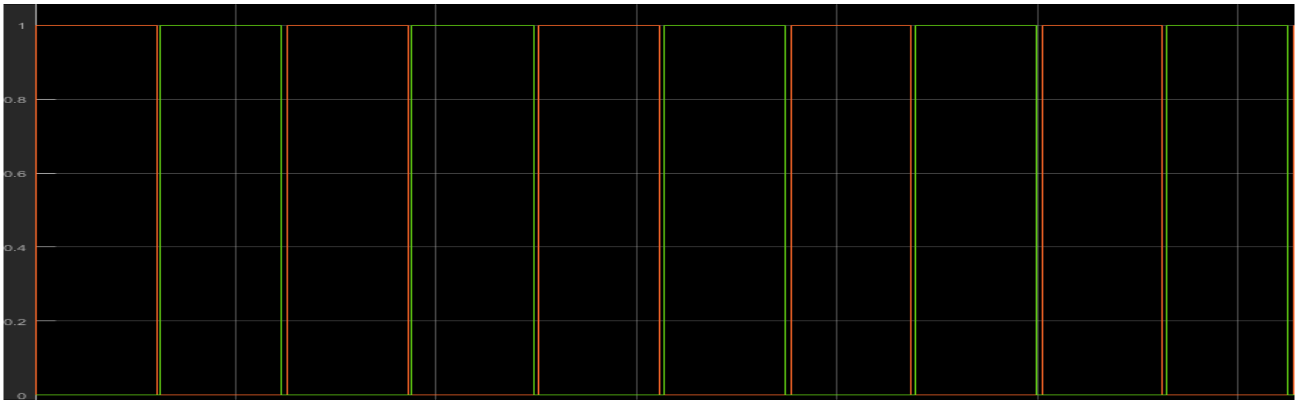
3.2 Simulation Results of Three phase DAB



Pulses at switch S1,S2



Pulses at switch S3,S4



Pulses at switch S5,S6

Fig. 7.3. Pulse Output of Switches 1,2,3,4,5,6

Discussion: From the above simulation switching pulses are came for 50% duty cycle at 100KHz frequency, correct pulses are obtained in simulation for switches S1,S2,S3,S4,S5 and S5.Time in X-axis, Y-axis shows output.

4. SUMMARY:

In this paper a new soft switching snubberless current fed half bridge converter and 3 phase DAB analysis ,design and simulations are presented . Both converters are applicable to photo voltaic (PV) applications. by using current fed half bridge converter voltage stress across devices can easily eliminated. There is no need of extra snubber circuit ,it provides ZCS to all devices as well as diodes can automatically switched off. So they can reduce switching transmission losses. voltage can be increased 5 times (Dmax=0.8) ,while active clamp converter can increased to 4 times with the same duty ratio. And coming to three phase DAB it provides isolation, high power density, low component stress.

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