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REALIZATION OF BATTERY CHARGER USING MULTILEVEL DC TO DC CONVERTER

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Abstract: This paper is about to Implementation of battery charger using Multilevel DC to DC converter for very high power applications such as Electric vehicle ranging from 10 to 60kW (BESS - Battery Energy Storage System),BEV – Battery Electric Vehicle. Multilevel DC to DC converter is also used to convert power from the very high voltage (HV) level bus to the 12V low voltage bus, which is mostly used to charge the LV battery and power the onboard electric devices. The multilevel DC to DC converter is designed by using full bridge modules with cascaded connection. The main advantage of using full bridge modules is to reduce the voltage stress across the switches.so that we can use the switches with low voltage ratings which is more convenient for us to use.as well as the conduction loss is reduced to half. The overall advantage is this multilevel DC to DC converter works in a more effective manner. The performance of multilevel dc to dc converter is verified by using the MATLAB simulation.

Index Terms **- Multilevel DC to DC converter, Battery energy storage system, Electric vehicle charging station, voltage balance technique.**

I. INTRODUCTION

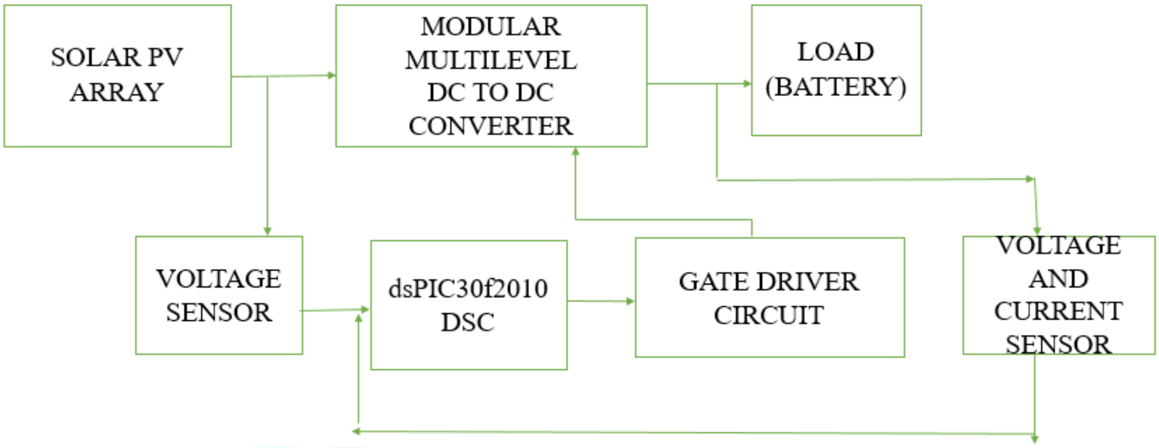
The advancement of smart grid technology is perfectly work well with transmission and distribution of DC network. On the other hand the emission of greenhouse gases, the consumption range of oil in internal combustion engine(ICE),cost of oil are very high those factors are triggered to reduce the overall function efficiency of ICE vehicle. Full bridge based modular multilevel dc to dc converter needs very high voltage and power ratings of MOSFET's and IGBT. Which leads to a more conventional losses. The SISR (series input with series rectifier) with transformer can reduce the voltage stress into one by third of the conventional fly back forward dc to dc converter. Unexpectedly the soft switching operation is not possible in this converter, so, the efficiency is keeps on decreasing. To obtain the maximum amount of efficiency push pull type converter with implementation of current doubles method is used. Because in this type of converter the conduction losses of the switches are reduced. Half bridge and series asymmetrical half bridge dc to dc converter also reduce the voltage stress across the all switches but in the meantime the transformer used for this kind of converter having additional winding compare to full bridge based converter. The better solution to reduce the voltage stress one third of the high input voltage is to connect the 3 pairs or six switches in the cascaded fashion. The main noticeable think is input auto balance mechanism when we move for high voltage level.in all the above mentioned converters auto balance mechanism is very difficult to implement.

II. IMPORTANCE OF MODULAR MUTILEVEL DC TO DC CONVERTER

For the high input voltage and high power applications the series input and output parallel is precisely used to get better operation on the output side. But when we move on to the low power and low voltage application ISOP modular multilevel converter is not going to work well. The duty cycle for the above mentioned converter is same for all type of modules so the voltage can be equally shared. This paper is described about the integration of full bridge converter with the special capacitor called as flying capacitor. The main role of the flying capacitor is to achieve the input voltage auto balance mechanism.

III. MULTILEVEL DC TO DC CONVERTERS

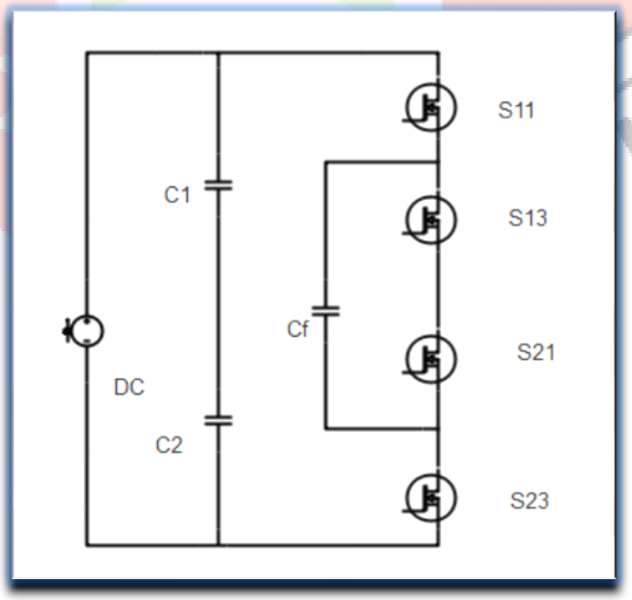
Integration of more than one converter is called the multilevel dc to dc converter. Implementation of multilevel dc to dc converter with transformers provides good isolation between input and output. Which gives the better production for the source when load is committing to the any kind of fault. In this paper, the modular multilevel dc to dc converter is implanted with the help of two full bridge converter with the help of input divider capacitor and also the flying-capacitor. Modular multilevel dc to dc converter is widely used for the case of step down condition electric vehicle charging purposes and high power rated applications. The insertion of flying capacitor provides the balanced condition for the charging and discharging purposes. The special feature of the input divider capacitor is to provide the auto balance condition for the high level of input voltage. Which is generally realized by the testing of hardware. Which is very useful to reduce the switch voltage stress behalf of that the efficiency is increased. More of dc based micro grid and dc based distribution and dc based high power applications are widely using the modular multilevel dc to dc converter. Phase shift control technique also included to the implementation of the modular multilevel dc to dc converter .which provides the additional advantage of SW (soft switching operation). The reduction of switching losses is also influenced by the soft switching character.so by implementation of phase shift control technique the switching losses are diminished by the half of the total switching losses.



Block Diagram of MMC Converter (Multilevel DC to DC converter)

IV. NEW NPC-(NEUTRAL POINT CLAMPED) CONVERTER TOPOLOGY

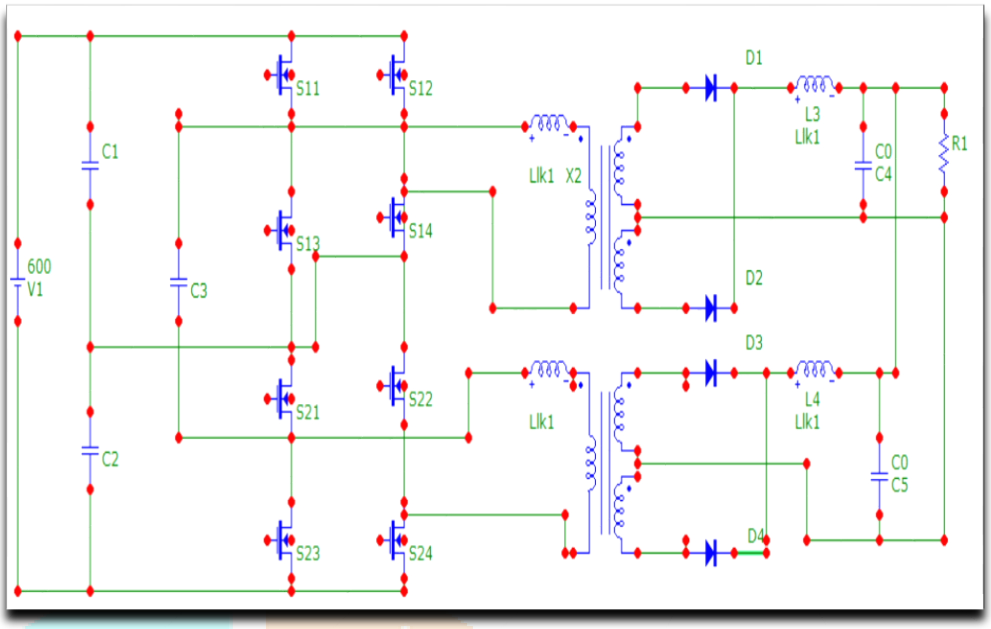
Neutral point clamped converter always works well with clamped capacitor or flying capacitor. Especially when we looking forward for high power and high voltage applications the NPC provides the desirable range of output power and desirable range of output voltage. Along with NPC phase shift control technique is used to achieve the input auto balance condition. Otherwise this system is not provide the balance condition for the input divider capacitors. But implementing the PSCT (Phase Shift Control Technique) is not a difficult task .so, it leads to the more switching loss across the each and every switches. On the other hand the other option is available with simple modification.by simply inserting one flying capacitor in parallel with diodes it share the equal amount of the voltages to the input divider capacitor.so the achievement of auto balance mechanism is easier by connecting a flying capacitor. Definitely it will reduce the cost of unnecessary auxiliary circuit to achieve the input auto balance mechanism. Furthermore it also reduces the switching loss of each and every switches. The additionally added input flying capacitor is alternatively parrallel with both input divider capacitor (C_1 and C_2)respectively.



NPC-(Neutral Point Clamped) Converter

V. POWER CIRCUIT DIAGRAM

The construction of multilevel DC to DC converter by combined the NPC(Neutral point clamped Converter) and flying capacitor reaches the better operating condition compare to all other conventional multilevel DC to DC converter.in this paper the multilevel converter is existing with SIOP (input Series and Output Parallel type along with the flying capacitor of having three levels. Which leads to the advancement of multilevel DC to DC converter. Selection of firing angle of upper leg switches are kept as a constant and the phase angle for the lagging leg switches are shifted carefully. Based on the duty ratio of each and every switches we get the desirable amount of output voltage. The flying capacitor provides the magnetism function such as it will provide the auto balance condition for the input dividing capacitor under all the condition and even under the very high voltage condition. The at most advantage of multilevel dc to dc converter with NPC(neutral point clamped converter) with flying capacitor is this topology can also implacable with N-stages or N-level of multilevel modular DC to DC converter. In the mean while the input supply voltage for the multilevel DC to DC converter from DC mirrored and DC distribution should have the stable value. If the input of input supply becomes unstable then we cannot able to achieve the input auto balance mechanism. Once the auto balance mechanism is failed then is is surely not possible to pick the desirable range of output voltage.



Circuit diagram of multilevel dc to dc converter

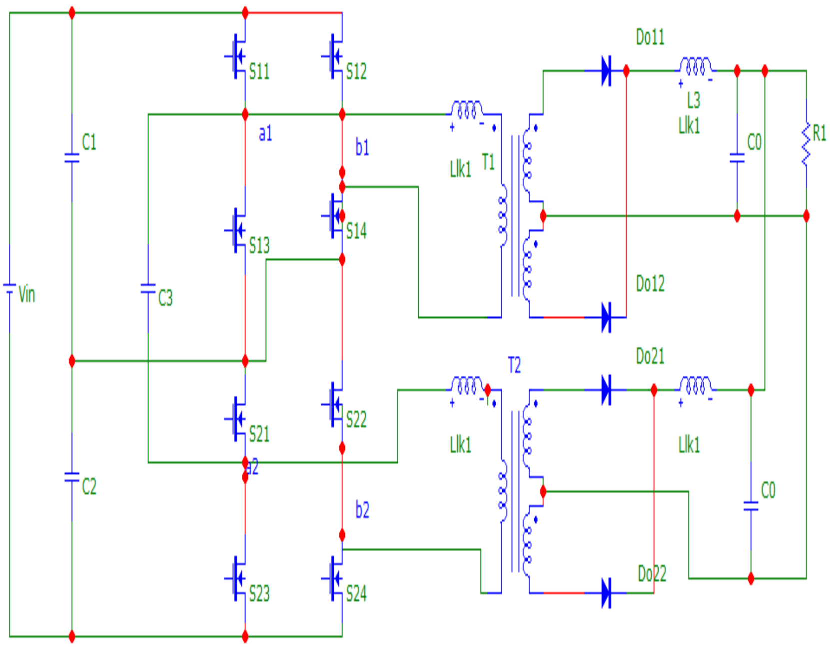
VI. OPERATION OF MMC (MODULAR MULTILEVEL CONVERTER):

The performance of the MMC is fully influenced by the the ZVS-(Zero Voltage Switching) technique.this ZVS is achieved for all the switches namelyS_{11} , S_{13} , S_{21} , S_{23} of upper leg switches. *and* S_{12} , S_{14} , S_{21} , S_{24} of lower leg switches. The firing angle of upper set switches are named as Θ_1, similarly the firing angle of lower leg set switches are called Θ_2. The autobalance condition of input voltage achieved under when $\Theta_1 = \Theta_2$. The conditions to reach the exact autobalance is $N_1 = N_2$. N_1 = is the turns ratio of primary transformer. N_2 is the secondary winding transformer. $L_{Lk1} = L_{Lk2}$ leakage inductance of primary and secondary winding of a transformer.

VII. OPERATING WITH DIFFERENT MODES:

MODE I:

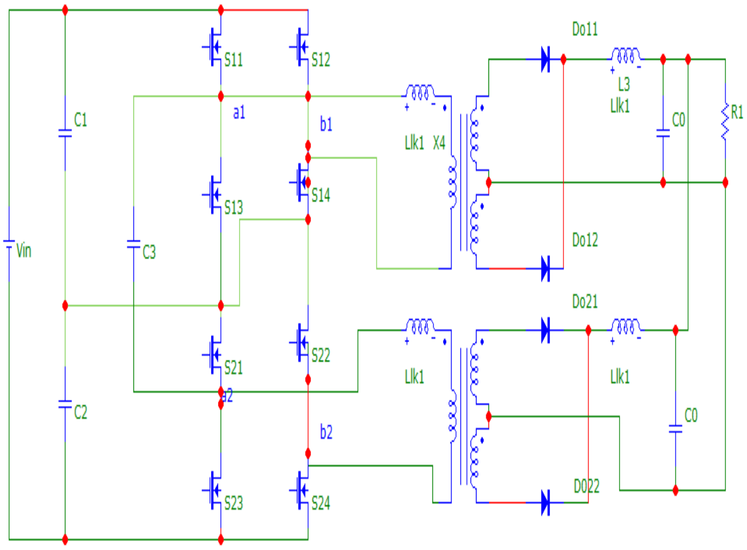
In mode I condition of MMC the voltage across the flying capacitor V_{cf} is exactly equal to the voltage of capacitor V_{c1} .because the switches S_{11} , S_{13} , S_{21} , S_{23} all are in conducting mode.so flying capacitor is parallel with V_{c1} .



Mode I Circuit Diagram

MODE II:

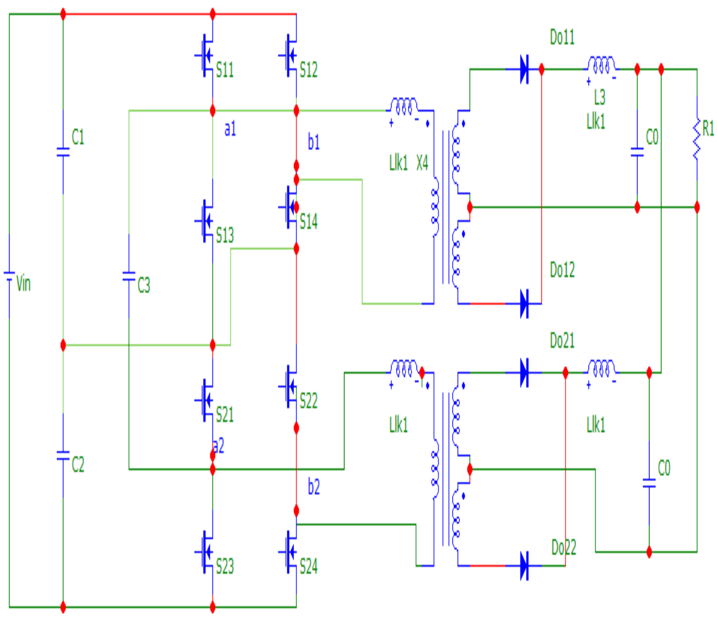
In mode II condition of MMC S_{11} and S_{21} are getting the turnoff signals.capacitor C_{s21} and C_{s11} are charged and C_{s23} and C_{s23} are discharged condition. In This mode ZVS is achieved for the switches S_{11} and S_{21} .



Mode II Circuit Diagram

MODE III:

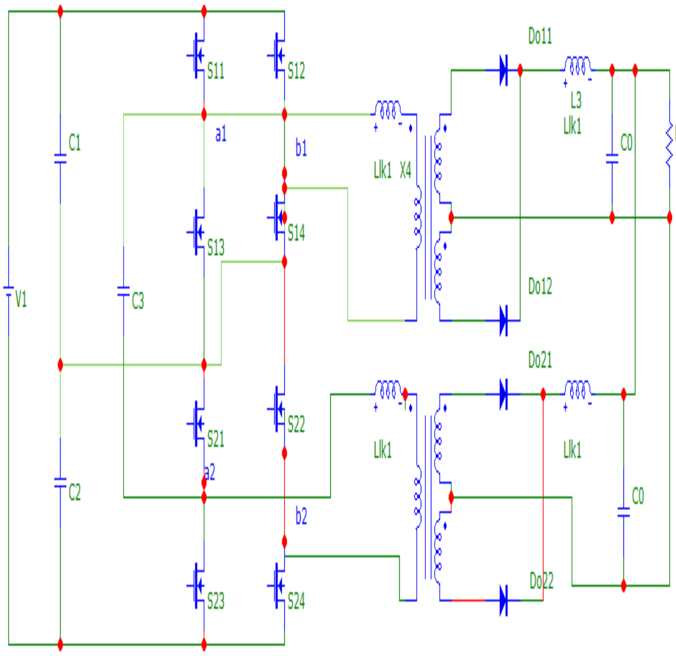
In mode III condition of MMC the ZVS turn on condition for the switches S_{13} and S_{23} are achieved by reaching the zero voltage across the capacitors namely C_{s13} and S_{s23} .



Mode III Circuit Diagram

MODE IV:

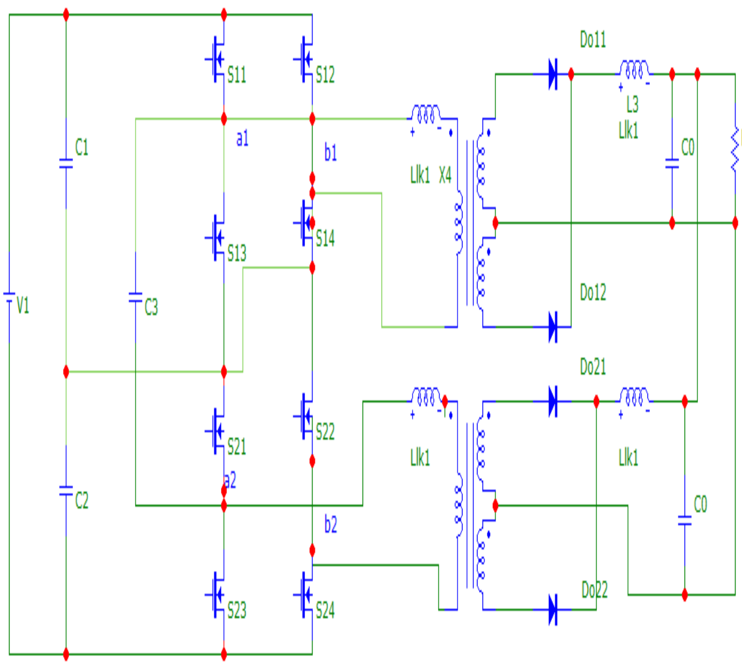
In mode IV condition of MMC the capacitor C_{s14} is charged this is quite enough to turn off the switch S_{13} with ZVS condition. Also in IV mode the capacitor C_{24} is discharged.



Mode IV Circuit Diagram

MODE V of MMC:

In mode V condition of MMC the switch S_{24} is getting the turn off signal. So switch S_{13} is turned off with ZVS condition.



Mode V Circuit Diagram

VIII. **DESIGNING OF MULTILEVEL DC TO DC CONVERTER**

Input capacitors $C_1 = C_2 = \frac{V_o((1-(2\times D_r))\times T^2}{\Delta V_{Cout}} = 210\ \mu\text{F}$

$L_{lk2} = \frac{V_o(1-D_{eff})\times T}{\Delta I_{L1}} = 9.48\mu H$

$output\ capacitors\ C_{01} = C_{02} = \frac{V_o((1-(2D_{eff}))\times T^2}{\Delta V_{Cout}} = 17.68\mu\text{F}$

Filter inductance $L_{f1} = \frac{V_o(1-D_{eff})}{\Delta I_{f1} *2*F_{sw}} = 29.84\mu H$

LC FILTER DESIGNING

- $L_f = \frac{V_o(1-D_r)}{\Delta I_{f2} * 2 * F_{sw}} = 47\mu H$
- $C_f = \frac{1}{(2\pi f_c)^2 L_f} = 4.575\mu F$
- Transformer turns ratio = 10 : 12 : 12
- S_{11} to S_{24} MOSFETs KGF25N(120KDA)
- D_{011} to D_{022} Secondary Diode Rectifier

Solar panel:

- The 100W solar system will generate one Kilowatt-hours per or 30kWh per month. Efficieny- 96%
- Voltage at maximum power V_{mp}- 18.6V
- Current at maximum power I_{mp}- 5.38A
- Open circuit voltage V_{oc}- 22.3V
- No of cells per module- 36
- Diamentions- 77.5cm$\times$ $66.5cm$ $\times$ 3.4cm

MOSFET:
Features :

- High speed switching
- High system efficiency
- Soft current turn-off waveforms
- Extremely enhanced avalanche capability

Bridge Rectifier:

- The KBPC3510 is a single-phase Bridge Rectifier with diffused junction and metal case.
- Low Power Loss and High Efficiency.
- Electrically Isolated Metal Case for Maximum Heat Dissipation. Case to Terminal Isolation Voltage of 2500V.

TLP250:
Features:

- Input threshold current: I_F= 5mA(max)
- Supply voltage: 10V-35V
- Output peak current: 2.0 A(max) Speed: 0.5 ms(max)

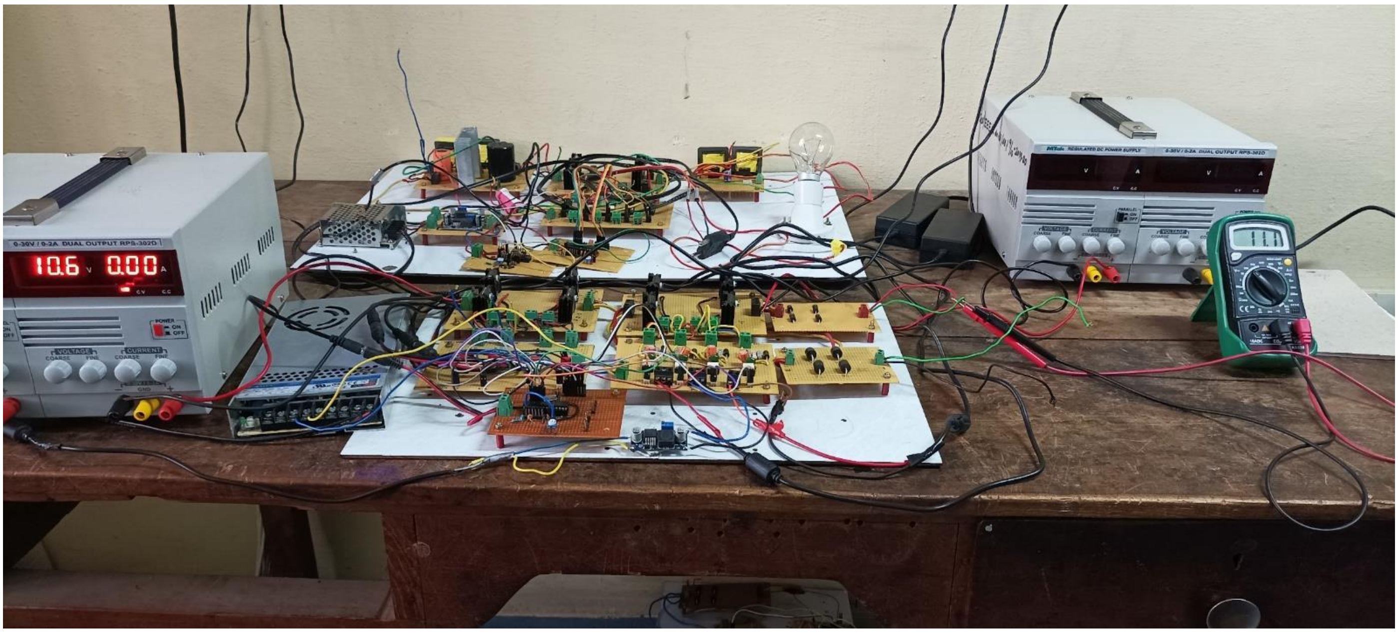
Applications:

- IGBT gate drive
- Power MOSFET gate drive
- Inverter
- Servo motor control

COMPONENTS	VALUES
MOSFET switches	$(S_{11}, S_{12}, S_{13}, S_{14}, S_{21}, S_{22}, S_{23}, S_{24})$ = KGF25N(120KDA) (1200V,25A)
Diode bridge rectifier	D = KBPC3510 (1200V, 35A)
Input capacitor (C_1, C_2) Output capacitor(C_{01}, C_{02} Flying capacitor (C_f)	$C_1 = C_2$ = 200µF, 450W C_{01} = 19.08μF, 450W, C_{02} = 19.08μF, 450W C_f = 4.95μF, 450W
Leakage Inductance (L_{LK1},L_{LK2}) Filter Inductor(L_f)	L_{Lk1}= 9.88μH, L_{Lk2}= 9.17μH L_{f1} = 27.84μH, L_{f2} =40μH
Load resistor	R =100Ω

IX. HARDWARE RESULTS:

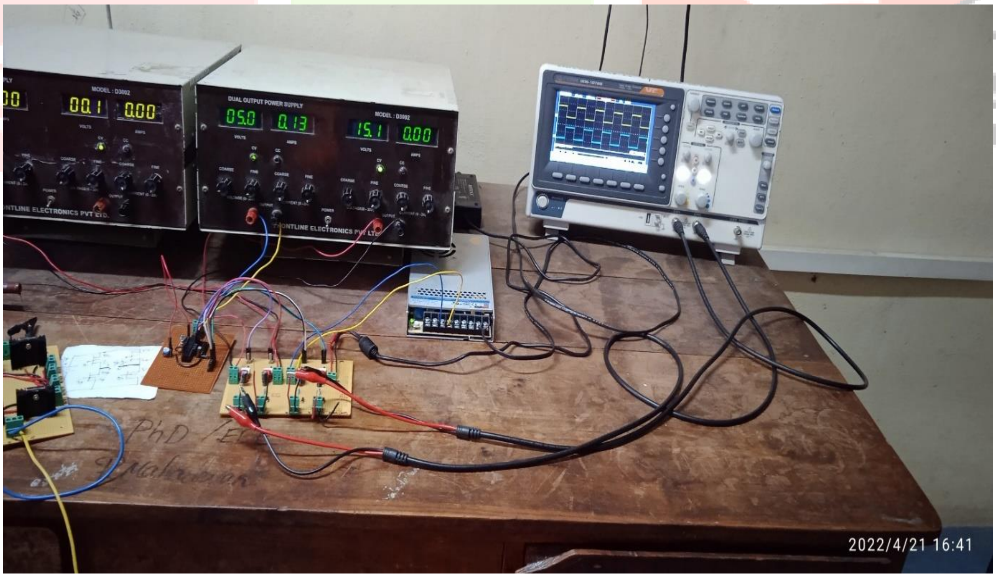
POWER CIRCUIT SETUP:



Power circuit setup

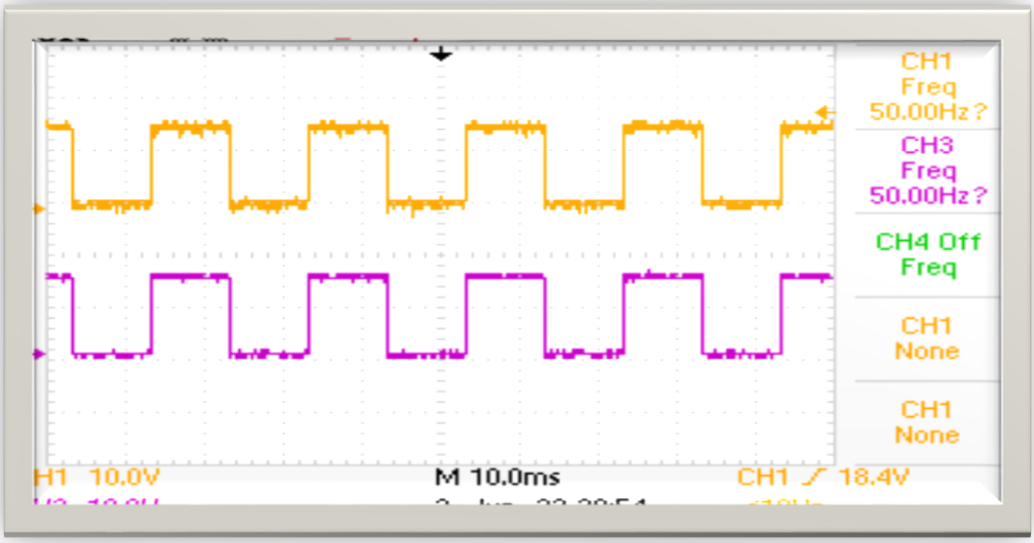
The above figure shows the complete setup of Multilevel DC to DC converter. This converter consisting of eight switches, first four switches connected in antiparallel model which provides the inverter operation and another four switches also connected as like a previous case. Which can also be act as inverter. Totally it contains two inverters. Output of each inverter is connected with rectifier to convert in the form of DC. This output of rectifiers connected parallel to share the equal voltage for each of the rectifier.

TESTING OF PWM SIGNAL



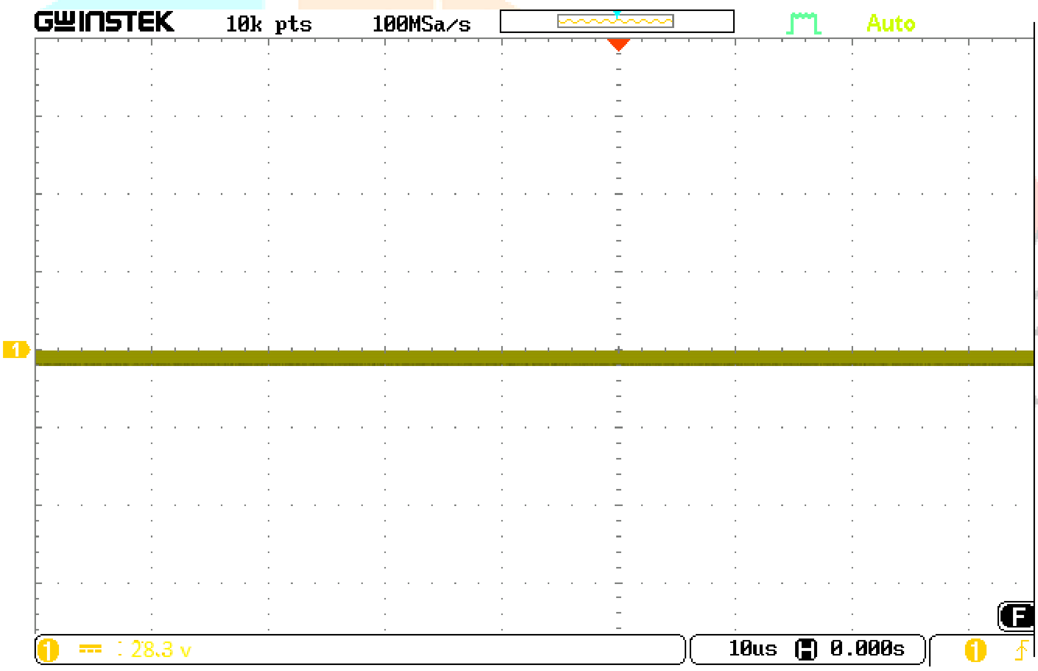
Testing of PWM signal

PWM SIGNAL:



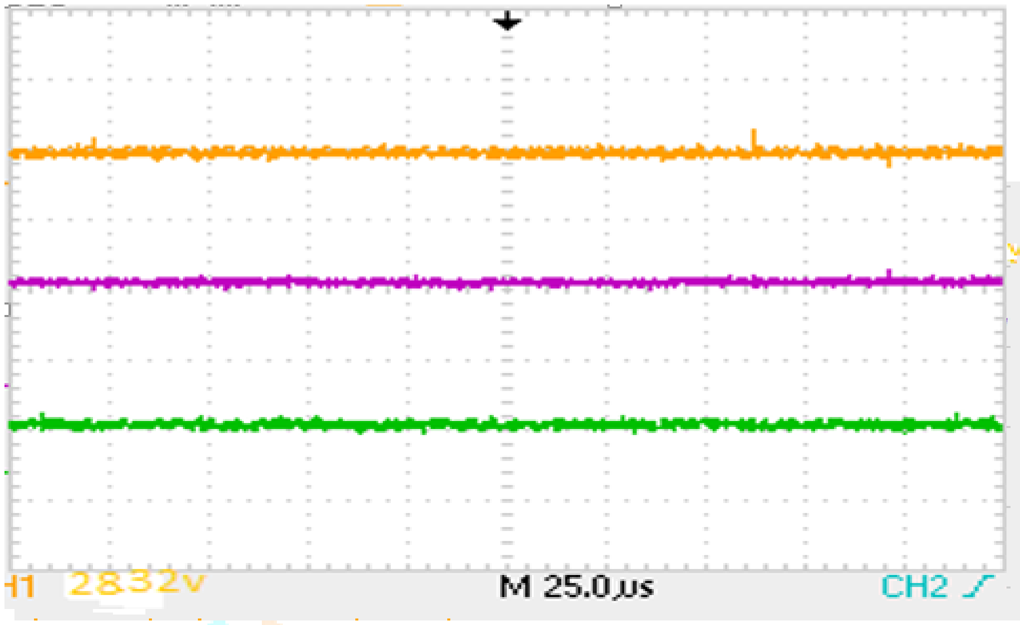
PWM Signal for Inverter circuit

OUTPUT VOLTAGE:



Output voltage waveform for upper converter

OUTPUT VOLTAGE AND CURRENT WAVEFORM:



Output voltage and current waveform

RESULT:

The Modular multilevel DC to DC converter is designed with the input of 800 V in a simulation model. Which is widely used for very high power and high voltage applications. Simulation is completed with 10kW output power and hardware will be implemented with less than 200W. The Multilevel inverter circuit with their controller and Driver circuit is designed. The PWM generation for the H- Bridge inverter is completed.

CONCLUSION:

In this paper the modular multilevel DC to DC converter topology is implemented by using the shifting thr firing angle of each of the switches. This multilevel converter can also possible to provide the isolation between the load and the source by inserting the small size transformer.it will increase the overall efficiency of the entire operation, as well as the safety. The flying capacitor brings the auto balance condition for the both input divider capacitors without adding any auxiliary circuit. It would be more economically convenient. Finally we get the better operating and high level efficiency.

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