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A 17 Level Back To Back T-Type Multilevel Inverter Module for Asymmetrical Dc Sources

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ABSTRACT: This paper presents a Back to Back T-Type module which produces 17 levels for asymmetrical non-similar DC sources with less number of switches. This paper also presents a topology to obtain higher number of output levels by cascading the proposed module(s). This module is designed in such a way that it creates both positive and negative voltages by itself, this is one of the principal characteristics of the module proposed. The module or its cascaded connected modules are suitable for renewable energy sources such as Photo Voltaic (PV) farms which leads to higher levels of output voltage thereby decreasing the harmonics in the power system compared to the standard multilevel inverter topologies.

Keywords: Multilevel inverter, T-Type, Back to Back T-Type, Bidirectional switch, Asymmetrical DC source

I. INTRODUCTION

Multilevel inverters (MLI's) are the array of power semiconductor devices, DC source voltages, capacitors and load. These multilevel inverter generates an output voltage in the form of the stepped waveform. These multilevel inverters can be designed for different power applications such as low/medium/high depending on the available DC input source(s) and the required load.

Applications of the Multilevel inverters can be observed in Electric vehicles, Drive systems, Interfacing with renewable energy sources, Power factor compensators etc.

Advantages of multilevel inverters are: (1)Higher output levels compared to the standard inverter which produces only two levels. (2) Lower harmonic component compared to the standard inverter. (3) Distributes stress on the switches, which reduces overall stress on the switches therefore reduces the chance of local hotspot on the switches, which also increases the life span of the switch. (4) Increases efficiency of the power system compared to the standard inverter.

Standard Multilevel inverter topologies [1] are mainly divided into three types and they are:
1) Diode-clamped multilevel inverter topology: This type of inverters consists of clamped diodes and capacitors to generate the ac voltage. This type of MLI's are also called as neutral-point clamped (NPC) multilevel inverters. These are extensively used in high power, medium voltage drives.
2) Flying-capacitor multilevel inverter: In this type of MLI's the switches are connected in series and the capacitors are clamped between the connecting points of the switches.
3) Cascaded H-bridge multilevel inverters:In this type of MLI's several H-Bridge units are connected in series.

These MLI's topologies do have several disadvantages. Such as, these MLI's require more number of semiconductor devices/switches due to which these MLI's requires a separate gate drive circuit to each semiconductor devices/switches to operate. This increases theoverall cost of the system.

To overcome this aT-Type topology [2] is introduced, which reduces the overall switch count for MLI's and the work efficiency for the MLI's can also be improved.Fig 1 shows the T-Type topology for MLI's. It is composed of two unidirectional switches (S1-S2) and one bidirectional switch (S3). The output voltages obtained from T-Type topology are0, $\pm V_{dc}$ and $\pm 2V_{dc}$.

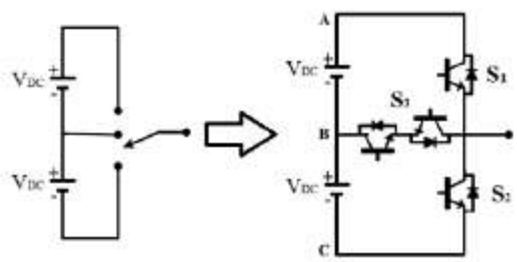

Fig 1: Generalized T-Type topology for MLI's

Where S1, S2, S3 are switches.
V_{dc} is the input DC voltage.
Back to Back T-Type module is derived from the above T-Type topology.

PROPOSED MODULE

A Back to Back T-Type module can be achieved by connecting two T-Type modules in adjacent to each other as shown in Fig 2. A Back to Back T-Type module has six unidirectional switches (S1-S6) and three bidirectional switches (S7-S9). Therefore the total switch count for the module proposed is twelve.

Bidirectional switches are composed of two unidirectional switches which enables the current to flow in both directions.

The presented module is having four DC sources, two are in the upper part of the module and the other two in the lower part of the module, which are represented byV_U (V_{U1}, V_{U2})and V_L(V_{L1}, V_{L2})respectively, which forms a non-similar (asymmetrical) multisource dc input voltages for the MLI's.

To obtain 17 levelsof output voltage, $V_U$and V_L are maintained in the ratio of $1V_{DC}$ and $3V_{DC}$ respectively where $V_U$and V_L are composed of two DC source voltages each.There are six unidirectional switches and three bidirectional switches in the presented module, therefore the total number of switching signals given to the module are nine.

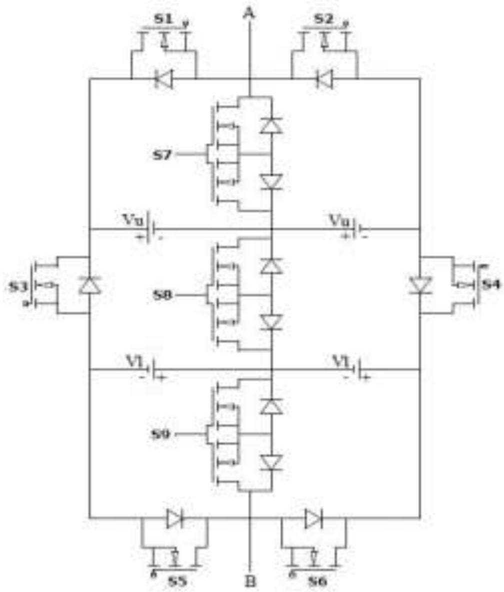

Fig 2: Back to Back T-Type module

The theory for the proposed module is to provide a different current paths to obtain both positive and negative output voltages with the non-similar DC sources provided to the module.

The diodes in the proposed module are placed in such a way that there are no positive side of DC voltage source is connected to the anode of diode.

MODES OF CONDUCTION

1. Modes Of Conduction To Obtain $+1V_{dc}$ and $+2V_{dc}$

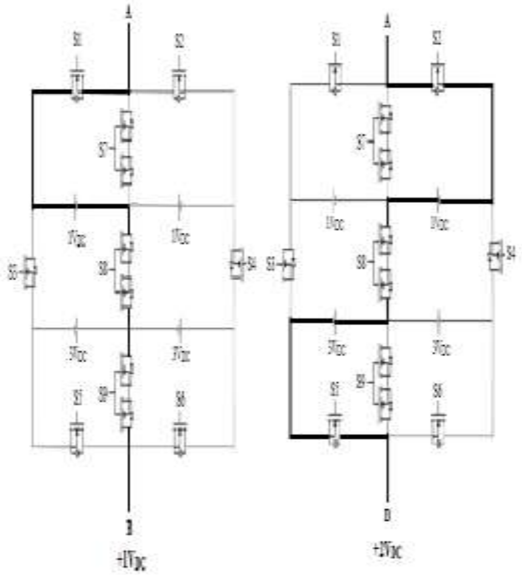

Fig 3(a): Modes of conduction to obtain $+1V_{dc}$ and $+2V_{dc}$

$+1V_{dc}$: To obtain $+1V_{dc}$ switches S1, S8, S9 will be closed and thus these switches only conduct and all other remaining switches will be open.

$+2V_{dc}$: To obtain $+2V_{dc}$ switches S2, S5, S8 will be closed and thus these switches only conduct and all other remaining switches will be open.

2. Modes Of Conduction To Obtain $+3V_{dc}$ and $+4V_{dc}$

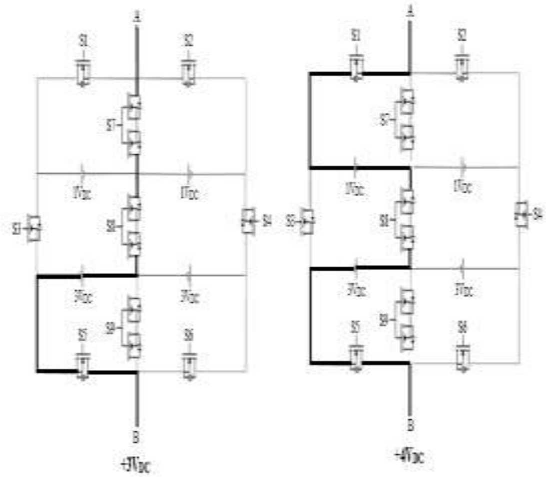

Fig 3(b): Modes of conduction to obtain $+3V_{dc}$ and $+4V_{dc}$

$+3V_{dc}$: To obtain $+3V_{dc}$ switches S5, S7, S8 will be closed and thus these switches only conduct and all other remaining switches will be open.

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+4V_{dc}: To obtain +4V_{dc} switches S1, S5, S8 will be closed and thus these switches only conduct and all other remaining switches will be open.

3. Modes Of Conduction To Obtain +5V_{dc} and +6V_{dc}

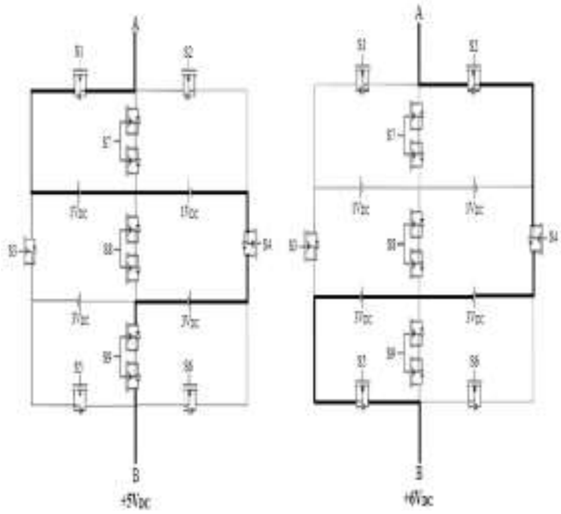

Fig **3(c):** Modes of conduction to obtain +5V_{dc} and +6V_{dc}

+5V_{dc}: To obtain +5V_{dc} switches S1, S4, S9 will be closed and thus these switches only conduct and all other remaining switches will be open.

+6V_{dc}: To obtain +6V_{dc} switches S1, S2, S5 will be closed and thus these switches only conduct and all other remaining switches will be open.

4. Modes Of Conduction To Obtain +7V_{dc} and +8V_{dc}

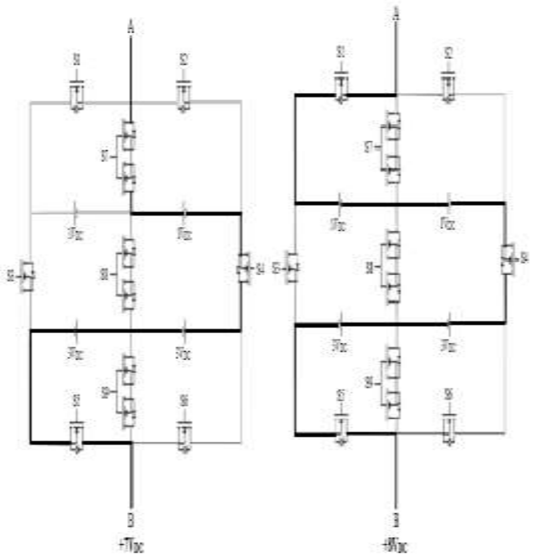

Fig 3(d): **Modes of conduction to obtain +7V_{dc} and** +8V_{dc}

+7V_{dc}: To obtain +7V_{dc} switches S4, S5, S8 will be closed and thus these switches only conduct and all other remaining switches will be open.

+8V_{dc}: To obtain +8V_{dc} switches S1, S4, S5 will be closed and thus these switches only conduct and all other remaining switches will be open.

5. Modes Of Conduction To Obtain -1V_{dc} and -2V_{dc}

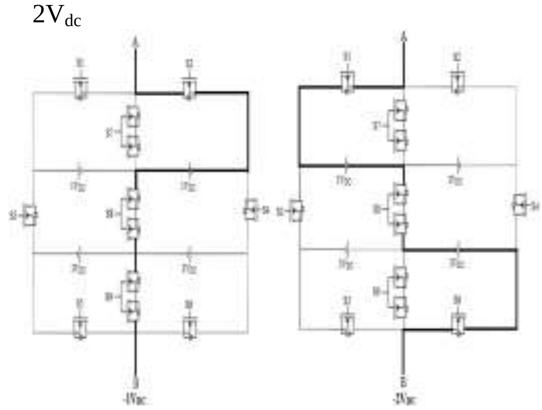

Fig 3(e): Modes of conduction to obtain -1V_{dc} and -2V_{dc}

-1V_{dc}: To obtain -1V_{dc} switches S1, S8, S9 will be closed and thus these switches only conduct and all other remaining switches will be open.

-2V_{dc}: To obtain -2V_{dc} switches S1, S6, S8 will be closed and thus these switches only conduct and all other remaining switches will be open.

6. Modes Of Conduction To Obtain -3V_{dc} and -4V_{dc}

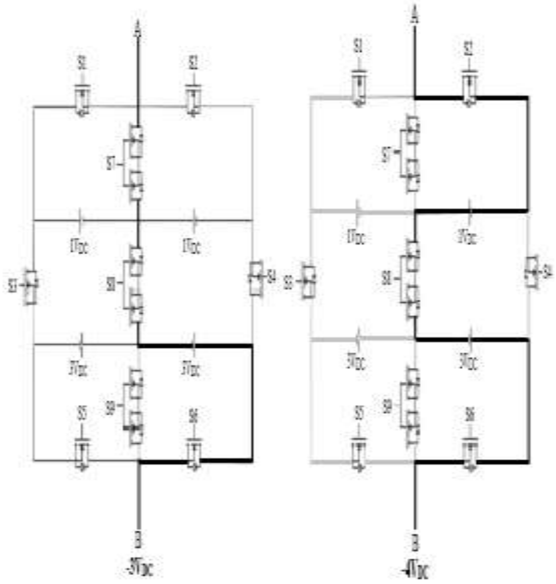

Fig 3(f): Modes of conduction to obtain -3V_{dc} and -4V_{dc}

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$-3V_{dc}$: To obtain $-3V_{dc}$ switches S6, S7, S8 will be closed and thus these switches only conduct and all other remaining switches will be open.
$-4V_{dc}$: To obtain $-4V_{dc}$ switches S2, S6, S8 will be closed and thus these switches only conduct and all other remaining switches will be open.

7. Modes Of Conduction To Obtain $-5V_{dc}$ and $-6V_{dc}$

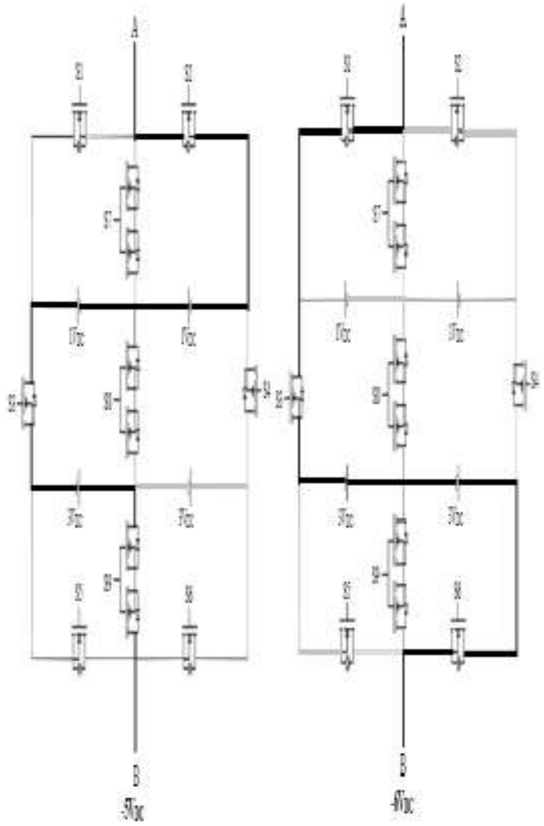

Fig 3(g): Modes of conduction to obtain $-5V_{dc}$ and $-6V_{dc}$

- $-5V_{dc}$: To obtain $-5V_{dc}$ switches S2, S3, S9 will be closed and thus these switches only conduct and all other remaining switches will be open.

$-6V_{dc}$: To obtain $-6V_{dc}$ switches S1, S3, S6 will be closed and thus these switches only conduct and all other remaining switches will be open.

8. Modes of conduction to obtain $-7V_{dc}$ and $-8V_{dc}$

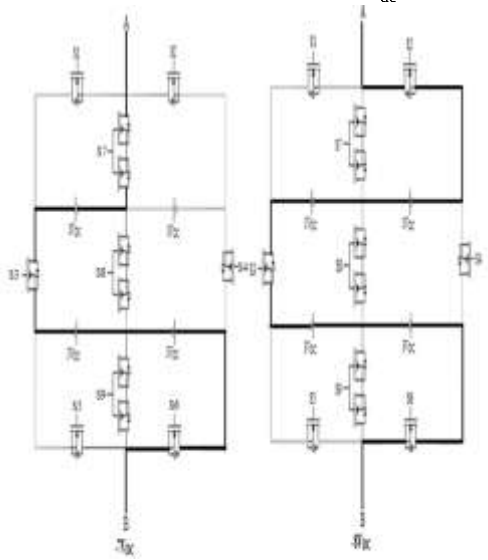

Fig 3(h): Modes of conduction to obtain $-7V_{dc}$ and $-8V_{dc}$

$-7V_{dc}$: To obtain $-7V_{dc}$ switches S3, S6, S7 will be closed and thus these switches only conduct and all other remaining switches will be open.

$-8V_{dc}$: To obtain $-8V_{dc}$ switches S2, S3, S6 will be closed and thus these switches only conduct and all other remaining switches will be open.

$0V_{dc}$: To obtain $0V_{dc}$switches S7, S8 and S9and thus these switches only conduct and all other remaining switches will be open.

Fig 3(a, b, c, d, e, f, g and h) shows the modes of conduction of switches for the module proposed, to obtain different output voltages. The signals for unidirectional and bidirectional switches are given in such a way that the short circuit should not occur in the module except for the zero level.

Since only three switches are required to get a specific output voltagein the proposed module, the proposed module can be said to be balanced.
Fig 4 represents the timing diagram of the switches for the Back to Back T-Type module

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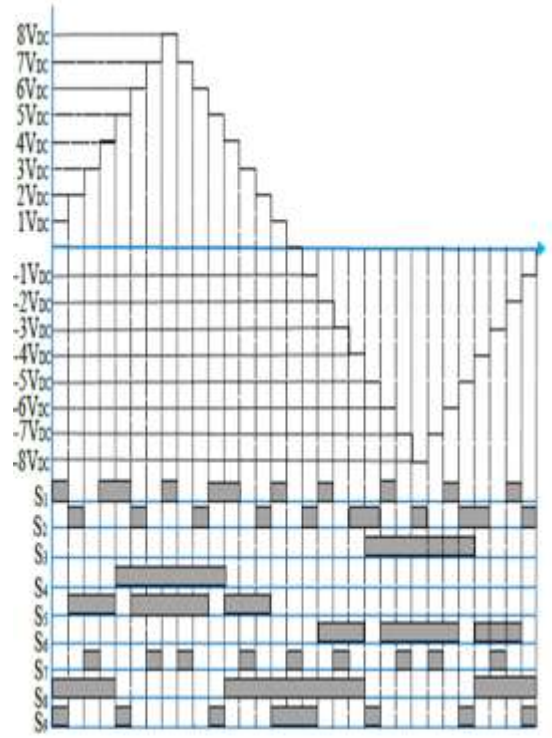

Fig 4: Timing diagram of switches for Back to Back T-Type module

CASCADING OF THE PROPOSED MODULE

Output voltage levels produced by the proposed module can even be achieved for much higher levels by cascading the module proposed.

On connecting the proposed module in series for twice, the output voltage levels obtained is of 33 levels. The circuit model for 33 levels is shown in Fig 5.

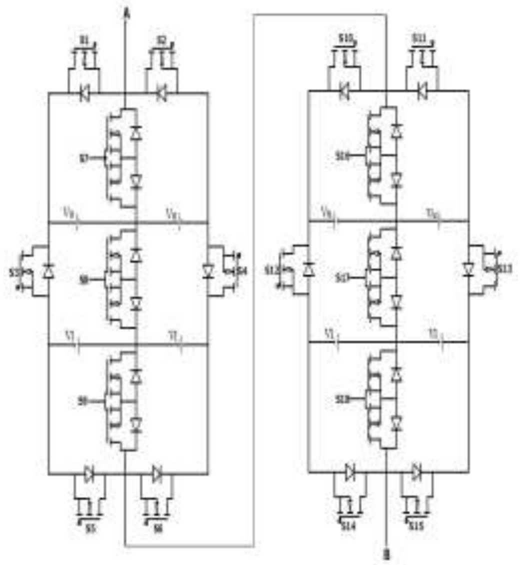

Fig 5: Cascaded Back to Back T-Type module to obtain 33 levels of output voltage

On connecting the proposed module in series for three times, the output voltage levels obtained is of 49 levels. The circuit model for 49 levels is shown in fig 6.

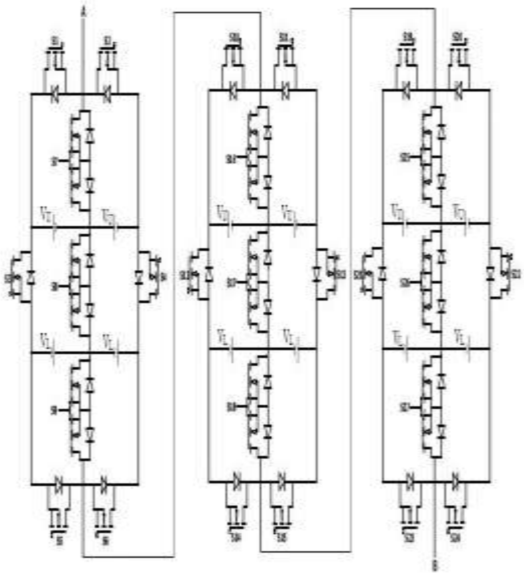

Fig 6: Cascaded Back to Back T-Type module to obtain 49 levels of output voltage.

Therefore the proposed module can be generalized to obtain 16n+1 output voltage levels, for which the proposed module requires 4n input DC voltage sources with 12n switches (6n unidirectional and 3n bidirectional switches) for which 9n switching signals are to be given. Where nindicates the numerical values. (1, 2, 3…., n).

COMPARISON OF PROPOSED MODULE WITH ITS CASCADE FORMS

Number of module (s)	Output levels	Switch count	Source count	Switching signals
1	17	12	4	9
2	33	24	8	18
3	49	36	12	27
n(generalized form)	16n+1	12n	4n	9n

Table 1: comparison of Back to Back T-Type module with its Cascade form

II. SIMULATION AND ITS RESULTS FOR PROPOSED MODULE

Simulation is carried out for the proposed module in MATLAB/Simulink.Voltmeter is connected across the load to measure the output voltage.Output of voltmeter is connected to the scope to observe the output voltage waveforms.

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Signals to the switches are provided by Phase disposition PWM signals.

Phase disposition signals for Back to Back T-Type module is shown the fig 7.

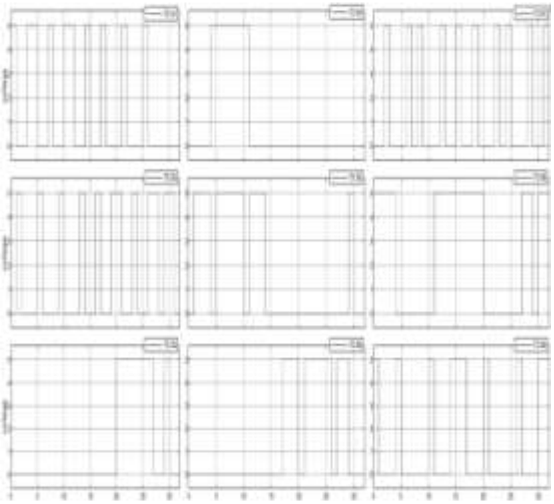

Fig 7: Phase disposition signals for the switches of

Back to Back T-Type module to obtain 17 levels

These signals are provided to the MOSFET Switches (S1-S9) as shown in the above figure.

1. SIMULATION for Back to Back T-Type module for 17 levels

Input voltage: $96V_{dc}$

V_U:V_L= $12V_{dc}$:$36V_{dc}$

Output voltage obtained is $96V_{dc}$

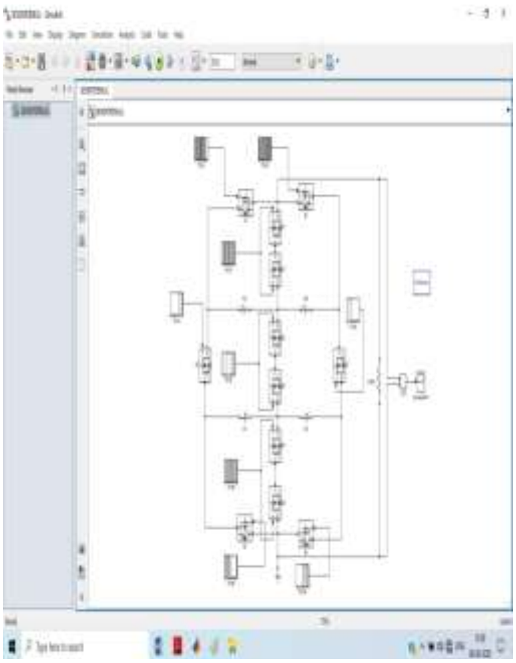

Fig 8: Matlab/Simulink model for 17 level Back to Back T-Type module

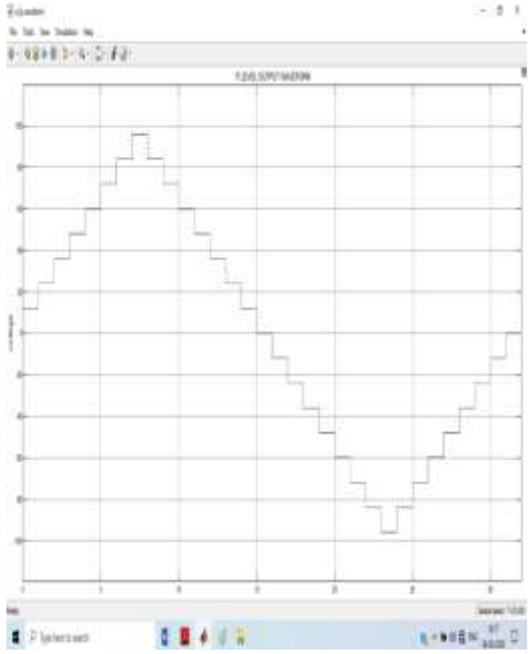

Fig 9: Simulation for the output voltage of 17 level waveform in Matlab/Simulink for Back to Back T-Type module

2. SIMULATION for Back to Back T-Type module for 33 levels

Input voltage: $96V_{dc}$

V_U:V_L= $6V_{dc}$:$18V_{dc}$

Output voltage obtained is $96V_{dc}$

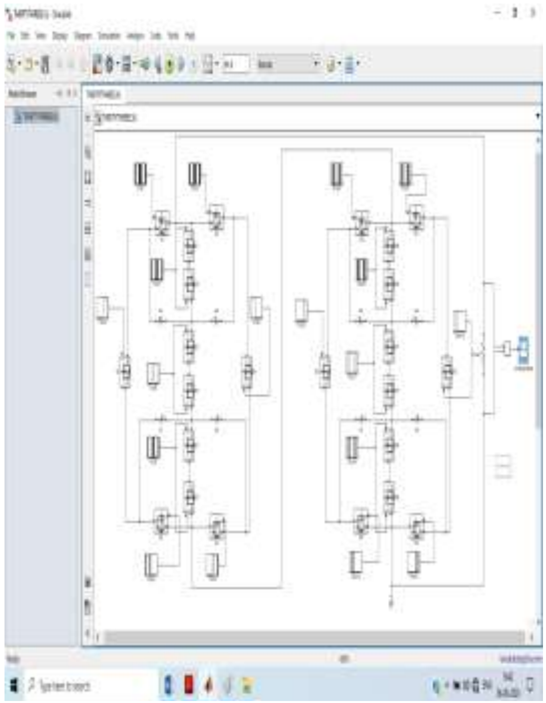

Fig 10: Matlab/Simulink model for 33 level Cascaded Back to Back T-Type module

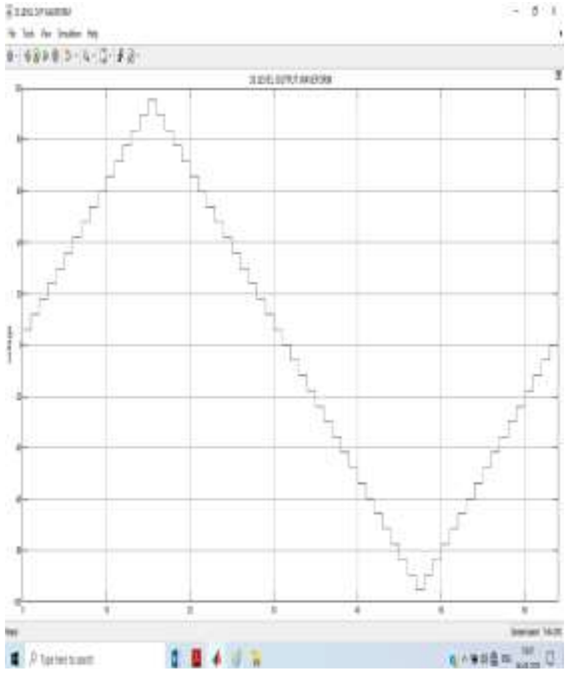

Fig 11: Simulation for the output voltage of 33 level waveform in Matlab/Simulink for cascaded Back to Back T-Type module

3. SIMULATION for Back to Back T-Type module for 49 levels

Input voltage: $96V_{dc}$
$V_U:V_L= 4V_{dc}:12V_{dc}$
Output voltage obtained is $96V_{dc}$

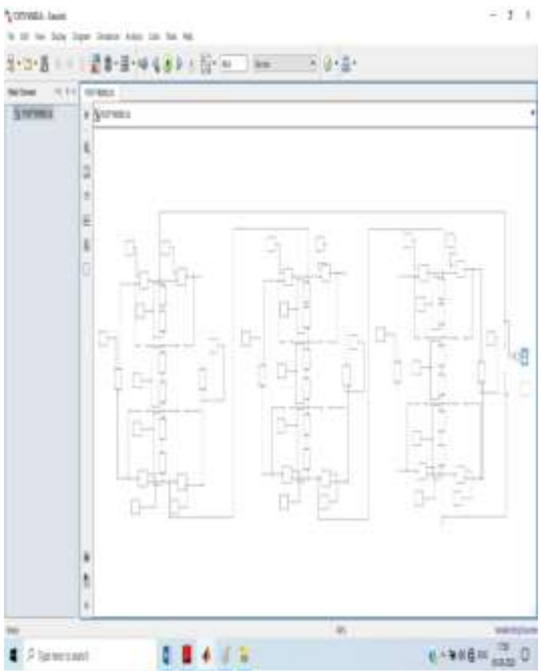

Fig 12: Matlab/Simulink model for 49 level Cascaded Back to Back T-Type module

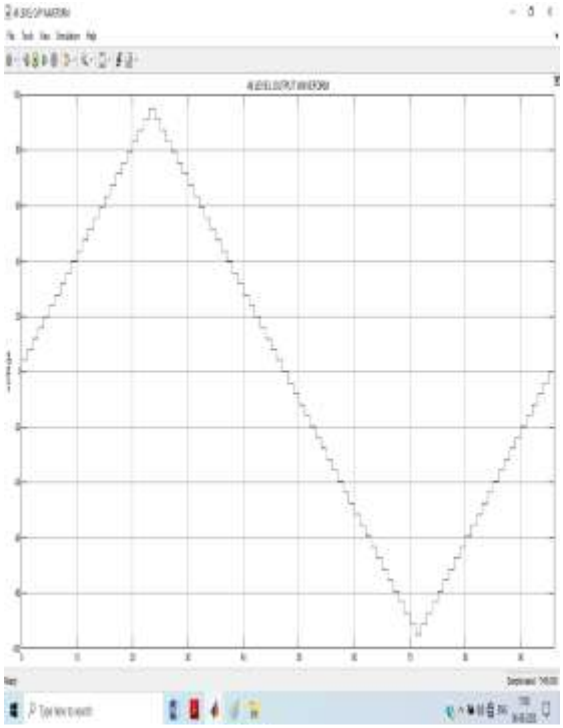

Fig 13: Simulation for the output voltage of 49 level waveform in Matlab/Simulink for cascaded Back to Back T-Type module

III. CONCLUSION

This paper presented new topology called as Back to Back T-Type module which generates 17 levels of the output voltage with the lesser switch count and lesser DC sources. This module can even be connected in series to obtain higher output levels. The advantage of the proposed module is that it produces both positive and negative voltage levels without any additional circuitry such as H-Bridge. This module can be easily implemented for non-similar DC sources in case of high power/voltage applications. This module decreases the stress on the switches thereby increases the lifespan of the switch due to which the module works efficiently thereby the harmonics system can be reduced significantly in the power system.

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