19 and 21-level Cascaded and Cross H-Bridge MLI Comparison

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Abstract - Present days renewable energy sources-based grids are developing which needs inverters to convert power from DC to AC. 2-level inverters were used for this purpose to overcome the drawbacks of 2-level inverters multilevel inverters are developed. Because of the combination of numerous devices in a series structure, multilevel inverters provide outstanding solutions to high voltage, high power applications. With the use of suitable simulations and mathematical analysis, this paper compares the performance of 19 and 21-level cascaded H-Bridges with cross H-Bridge MLI. Total Harmonic Distortion levels, switching device count, and inverter output voltage and current are all compared. The primary issues brought up in this study are limitations of a few switching devices that can support high voltage in the inverter. The benefit of this research is that it identifies the right inverter that can be utilised for real-time applications by taking the variables into account. The count of switching devices, output voltage, current, and harmonic distortion, among other factors. The Matlab/Simulink Platform is used to validate the analysis.

Index Terms – Cascaded H-Bridge, Cross H-Bridge, THD, Multilevel Inverter

I. INTRODUCTION

Conversion of power from DC to AC is one of the essential parts of the electrical power system. Initially 2-level inverters were employed for this purpose, but the major issues with 2-level inverters are low quality ouput voltage, high stress across the switches and large filter requirement. To mitigate these issues multilevel inverters(MLI) are invented. The primary premise of MLI is to spread the inverter's working voltage among switches in the circuit, which decreases voltage stress across the switches and allows low rating switches to be utilised in high voltage/power rating applications. As the level of output voltage rises, the level of harmonics falls at low switching frequencies, lowering the cost of filters. [1-2].

The diode clamped (NPC) MLI, capacitor clamped (FC) MLI, and cascaded H-Bridge (CHB) MLI are the conventional MLI topologies [3-5]. The key drawbacks of these traditional MLI topologies include an increase in the quantity of switches and auxiliary components, which increases the dimension and price of the inverter [6-8]. The capacitor voltage in the NPC and FC MLI topologies may be managed using redundant switching states, but as the voltage level grows, the quantity of capacitors and requirement of clamping diodes increases, as does the complexity of the control method.

The H-Bridge cells with DC sources are linked in series in a cascaded H-Bridge MLI. The CHB MLI is classed as symmetrical [9-11] or asymmetrical [12-14] based on the kind of DC sources. The symmetric topology provides high modularity and packing due to the same construction of each H - Bridge, but the number of switches grows fast as the output voltage level increases. With an asymmetric architecture, the output voltage may be raised with fewer switches, but the rating of some of the switches is almost equal to the maximum working voltage, making hardware circuit design more difficult. In recent years, several new topologies have been developed. MLI are gaining popularity due to their numerous uses. Multilevel output from a multi winding transformer [15-16] is not cost effective for high power/voltage applications.

This paper discusses about comparison exploration of sinusoidal PWM controlled 19-level and 21-level cross H-Bridge (CRHB) and CHB MLI topologies in terms of %THD, number of switches, voltage across the switches and total voltage stress of the inverter. The simulation is performed with MATLAB/SIMULINK.

II MATHEMATICAL ANALYSIS

CROSS H-BRIDGE

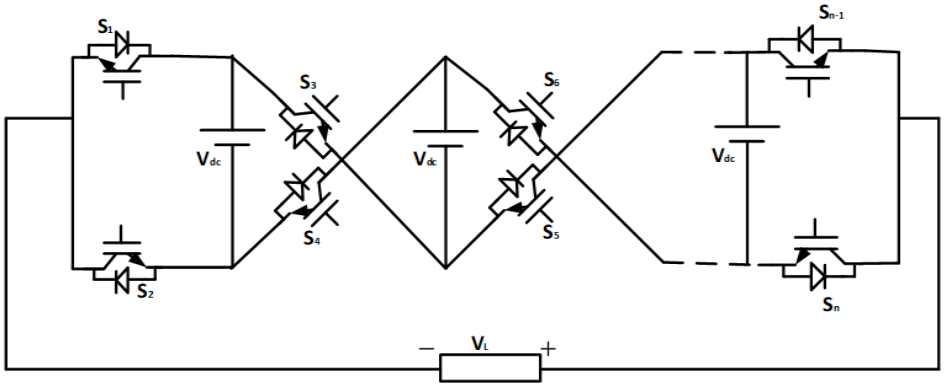

Fig. 1. Circuit representation of N-level single cross H-Bridge MLI

The CRHB MLI [17] is connected with particular cross connections with distinct DC sources as shown in fig.1.
The association between the output voltage level, the quantity of switches, and the quantity of voltage sources:

N_s=V_L+1 (1)

V_L=2*V_s+1 (2)

N_s=2(V_s+1) (3)

N_D=$\frac{V_L+1}{2}$ (4)

CASCADED H-BRIDGE

In CHB MLI, the H-Bridge cells with DC source are linked in series. Each H-Bridge consists of four controlled switches. The circuit configuration of CHB-MLI is represented in fig.2.

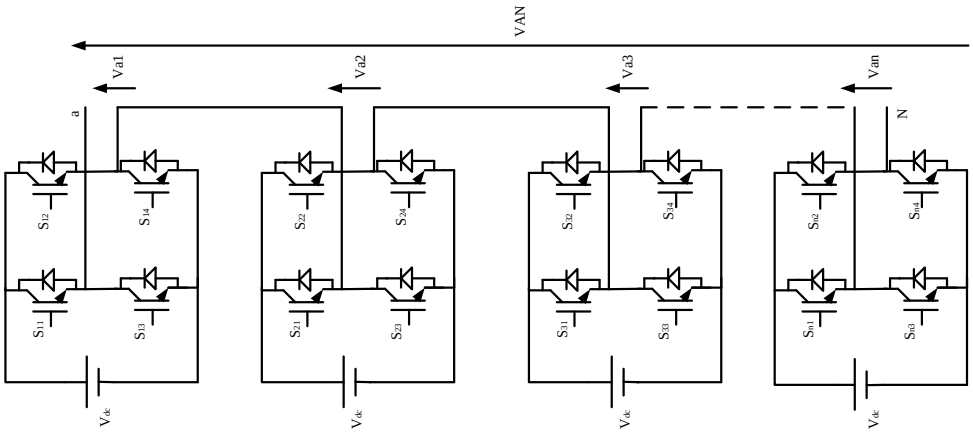

Fig. 2. Circuit representation of N-level single cascaded H-Bridge MLI

N_s=2*(V_L-1) (5)

V_L=2*V_s+1 (6)

N_s=4*V_s (7)

N_D=V_L-1 (8)

where
V_L is output voltage level,
N_s is quantity of switches,
V_s is quantity of voltage sources,
N_D=no. of switching devices in current path.

Switches Voltage rating:

In CRHB MLI the voltage stress across switches S_1, S_2, S_{n-1} and S_n is V_{dc} and other switches voltage stress is $2V_{dc}$ and the voltage stress of all switches in CHB MLI is V_{dc} [18-20]. The total voltage stress of CHB MLI and CRHB MLI is = $2*(V_L - 1)* V_{dc}$
where V_L is level of output voltage.

SWITCH LOSSES

The dominant losses of the power electronic switches are conduction and switching losses [21-23]. Conduction losses are due to conduction of switches. Switching losses are due to turn on and turn off of switches.

The transistor average conduction losses ($P_c, T(t)$) and diode ($P_c, D(t)$)can be represented as follows:

$$P_c, T=\frac{1}{2\pi}\int[V_T + R_T i^{\beta}(t)]\ i(t)d(\omega t) \quad (9)$$

$$P_c, D=\frac{1}{2\pi}\int[V_D + R_D i(t)]i(t)\ d(\omega t) \quad (10)$$

The per cycle conduction total conduction losses of MLI

$$P_c=(P_c, T + P_c, D)*N_D \quad (11)$$

The switching losses is given as

$$P(sw) = f * (T_{on} * E_{on} + T_{off} * T_{off} * E_{off}) \quad (12)$$

Where V_T and $V_D$are transistor and diode voltage drop respectively.
R_T and R_D are equivalent resistance of transistor and diode
f= frequency,
T_{on}= number of times the switch is turned on,
T_{off}= number of times the switch is turned off.

RESULTS AND DISCUSSION

The simulation of 19-level and 21-level cross H-Bridge and cascaded H-Bridge MLI is done in MATLAB/SIMULINK environment. The RL load is considered with R=10Ω and L-100mH. Results of voltage, current, and %THD are presented and compared.

19-LEVEL CASCADED H-BRIDGE MLI

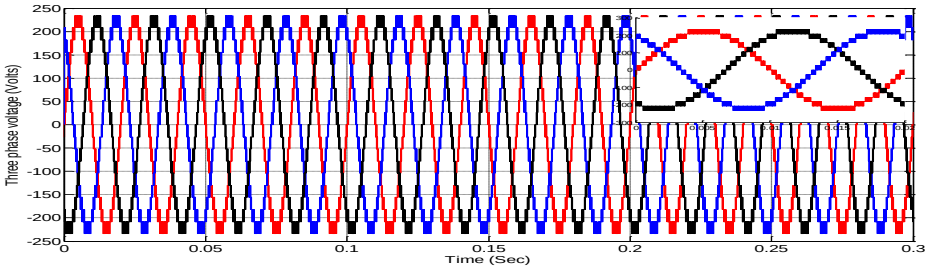

Fig. 3. Three phase voltage

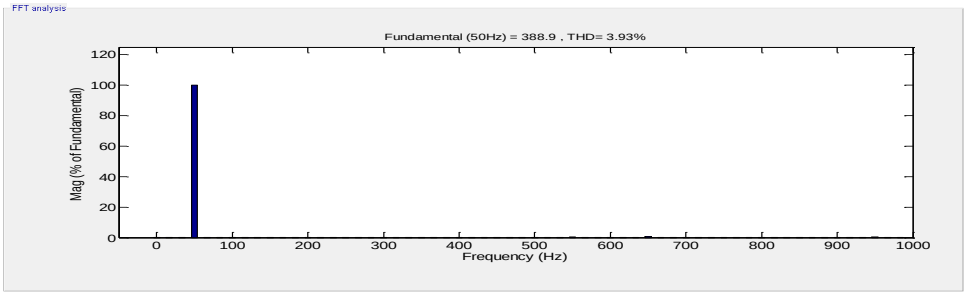

Fig. 4. %THD of voltage

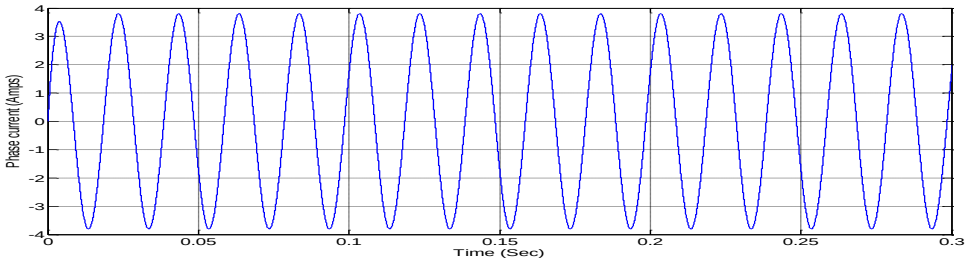

Fig. 5. Phase current

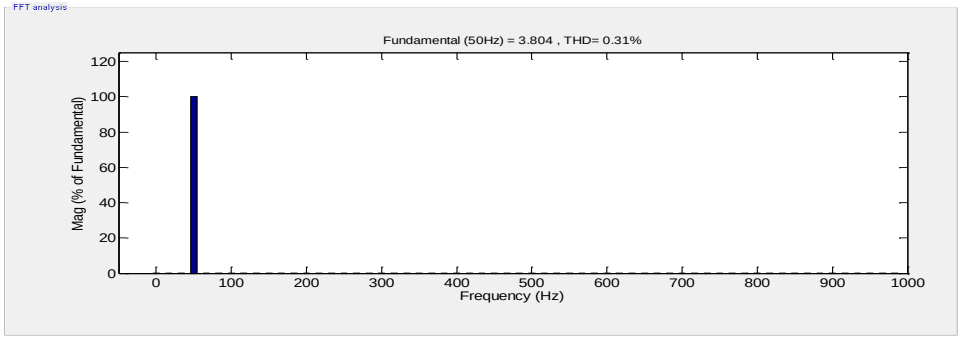

Fig. 6. %THD of current

Fig.3. represents three phase 19-level output voltage with 230V peak to peak, Fig.4. represents %THD of voltage which is recorded as 3.93, Fig.5. represents phase current with 3.8A peak to peak and Fig.6. represents %THD of current which is recorded as 0.31.

19-LEVEL CROSS H-BRIDGE MLI

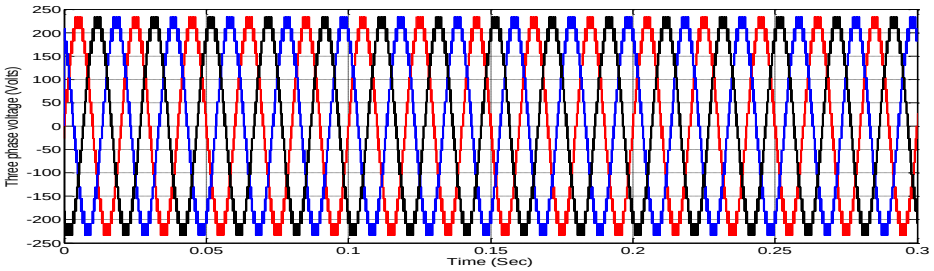

Fig. 7. Three phase voltage

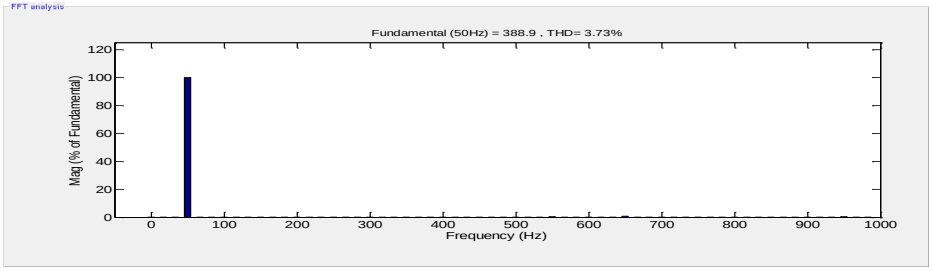

Fig. 8. %THD of voltage

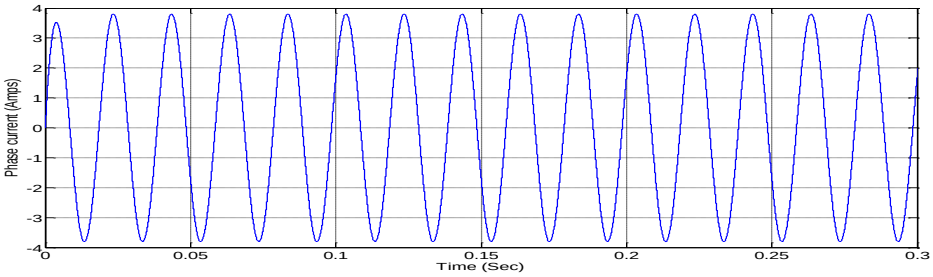

Fig. 9. Phase current

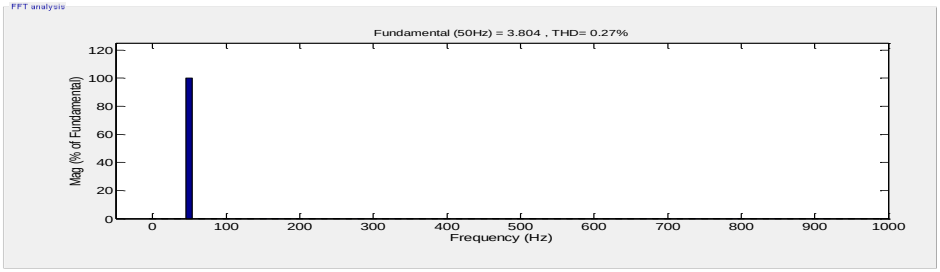

Fig. 10. %THD of current

Fig.7. represents three phase 19-level output voltage with 230V peak to peak, Fig.8. represents %THD of voltage which is recorded as 3.73, Fig.9. represents phase current with 3.8A peak to peak and Fig.10. represents %THD of current which is recorded as 0.27.

21-LEVEL CASCADED H-BRIDGE MLI

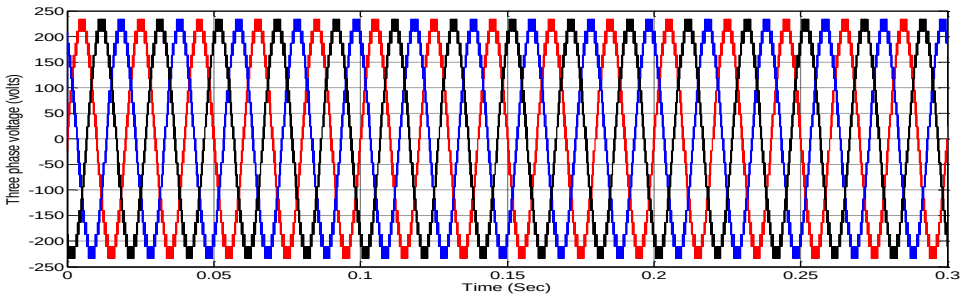

Fig. 11. Three phase voltage

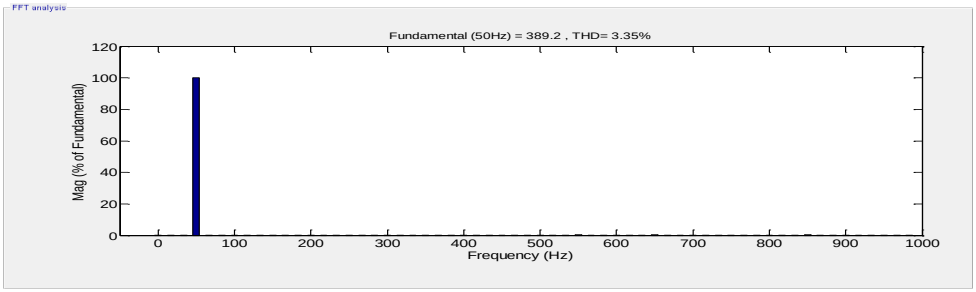

Fig. 12. %THD of voltage

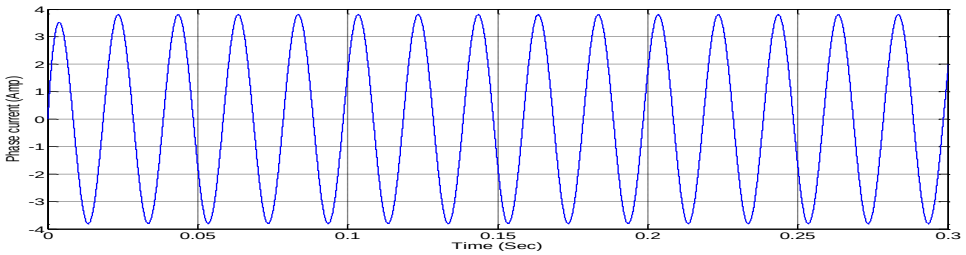

Fig. 13. Phase current

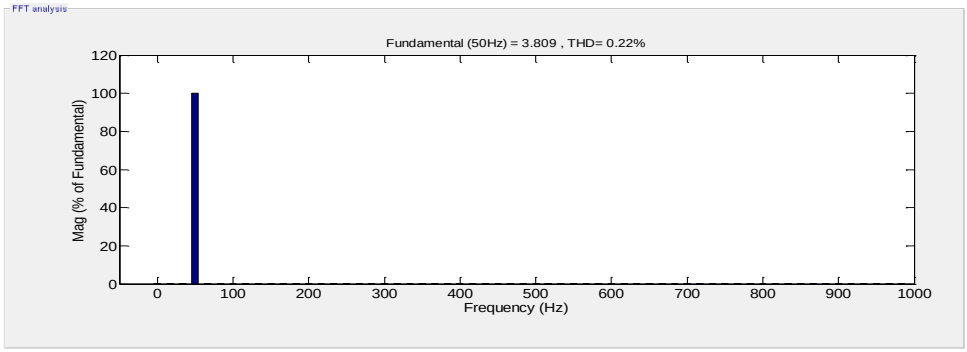

Fig. 14. %THD of current

Fig.11. represents three phase 21-level output voltage with 230V peak to peak, Fig.12. represents %THD of voltage which is recorded as 3.35, Fig.13. represents phase current with 3.8A peak to peak and Fig.14. represents %THD of current which is recorded as 0.22.

21-LEVEL CROSS H-BRIDGE MLI

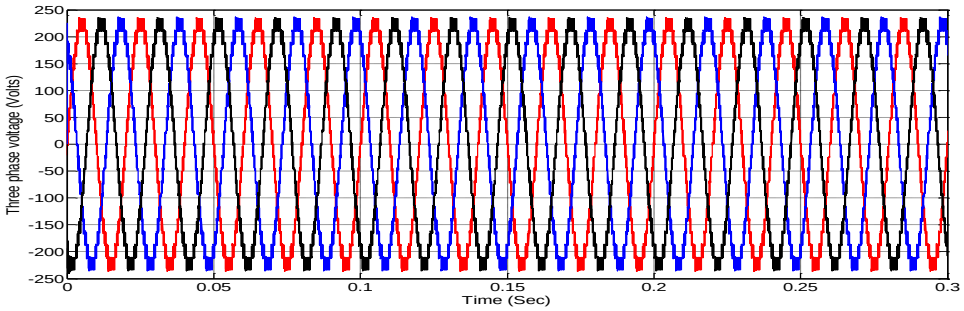

Fig. 15. Three phase voltage

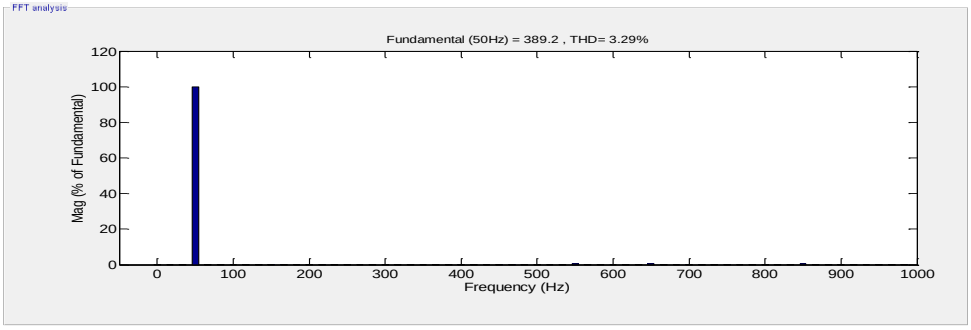

Fig. 16. %THD of voltage

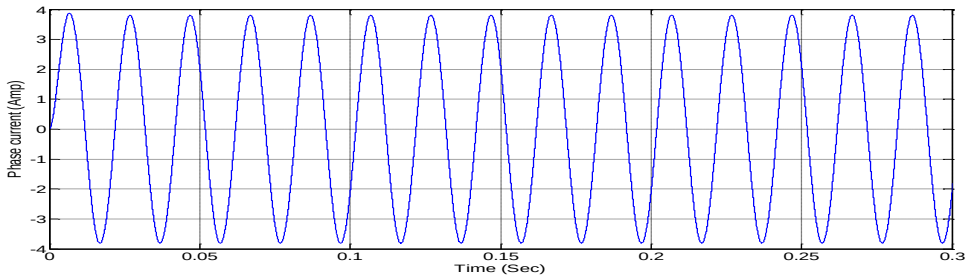

Fig. 17. Phase current

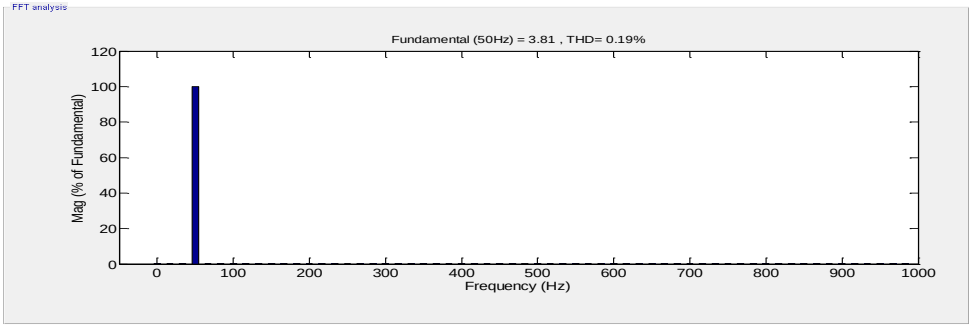

Fig. 18. %THD of current

Fig.15. represents three phase 21-level output voltage with 230V peak to peak, Fig.16. represents %THD of voltage which is recorded as 3.29, Fig.17. represents phase current with 3.8A peak to peak and Fig.18. represents %THD of current which is recorded as 0.19.

Table 1. represents the comparative analysis of number of switches for 19 and 21-level CHB and CRHB MLI topologies. From the table it is clear that number of switches required for CRHB MLI topology is reduced by 50 percent.

Table 1. Number of switching devices Vs O/P voltage levels

O/P VOLTAGE LEVELS	CHB MLI		CRHB MLI	
	1-Φ	3- Φ	1- Φ	3- Φ
19-level	40	120	20	60
21-level	44	132	22	66

Table 2. represents the comparative analysis of switch losses for 19 and 21-level CHB and CRHB MLI topologies. From the table it is clear that the losses with CRHB MLI topology are reduced by 24.19 percent with 19-level output and 24.9 percent with 21-level output. Table 3. represents the comparative analysis of %THD for 19 and 21-level CHB and CRHB MLI topologies. From the table it is clear that the %THD of voltage with CRHB MLI topology are reduced by 3.5 percent with 19-level output and 1.7 percent with 21-level output and the %THD of current with CRHB MLI topology are reduced by 12.9 percent with 19-level output and 13.6 percent with 21-level output.

Table 2. Total losses(w) of switches Vs O/P voltage levels

O/P VOLTAGE LEVELS	CHB MLI		CRHB MLI	
	1-Φ	3- Φ	1- Φ	3- Φ
19-level	21.41	64.23	16.23	48.69
21-level	23.32	69.96	17.51	52.53

Table 3. %THD Vs O/P voltage levels

O/P VOLTAGE LEVELS	CHB MLI		CRHB MLI	
	Voltage	Current	Voltage	Current
19-level	3.93	0.31	3.73	0.27
21-level	3.35	0.22	3.29	0.19

IV. CONCLUSION

Multilevel inverters are one of the essential parts of power systems to convert power from DC to AC. This paper discussed about comparative exploration of 19-level and 21-level CHB and CRHB MLI topologies. The comparison is done in terms of number of switches, %THD and total switch losses of inverter. From the results it is clear that the performance of CRHB topology is better in terms of number of switches, %THD and total switch losses of inverter compared to cascaded H-Bridge MLI topology.

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