Modeling of Multi level inverter with Hybrid switches and Fuzzy logic controller under less number of switches

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Abstract:
This paper presents multilevel H bridge inverter modeling with different switches as IGBT, MOSFET, power BJT and combination of IGBT MOSFET, MOSFET BJT and BJT IGBT. All results are compared and listed in the table. Ninth level inverter is taken to test improvement of THD and hence performance with hybrid switches. Finally, the percentage of THD is reduced with PI controller along with Fuzzy logic controller. Obtained results are taken from MATLAB/SIMULINK.

Keywords:
Multi level inverter, Hybrid switches, PI Controller, Fuzzy logic controller (FLC)

1. INTRODUCTION:

The faculty of Effective Efficient Energetic Engineering is always seeking for emerging trends in effective manner for society. The concept of multi level inverter also comes under the above. In the case of DC, there is no problem of frequency. In the case of AC, frequency is the big issue. To maintain frequency at required level, many techniques are involved. Major electrical appliances are AC only. There is no facility to store energy in AC. Hence DC is required. There is possibility to store energy in DC and then it can be converted to AC with the help of inverter. The problem of inverter is output voltage is not sinusoidal and THD.

The series connected H - bridge Multi Level Inverter vanish the drawbacks of existing two level inverter with the help of combination of two H-Bridge Multi level inverter module as its level increasing capability. The proposed model reduces the number of switches required for the same level as compared to conventional [1]. The H Bridge multilevel inverter is the combination series connected inverters to decrease the switches and to generate the electrical potential stages at output [2]. The voltage source inverter of multi level has been modeled to decrease the complexity of circuit by simplifying the utilization of bilateral electronic switches to the 3- phase, 6 switches, and bridge configuration [3]. The new approach was introduced, which consists minimum number of DC voltages and electronic switches that blocks great voltages hence reduce the criticalness of circuit [4-5]. The non symmetrical 27 stages Multi level inverter for 3-phase electrical system which contained different DC voltage sources is observed to get maximum electrical potential at the output [6]. The application of series connected H-Bridge multilevel DC-AC converter, which modeled 5 stages output inverter is observed in [7]. The application of fuzzy logic controller to uncontrolled converter (the switches are diodes) where the load is unbalanced inductive with parallel filter is observed in [8]. The proportional derivative tuning procedure is used on series combination of AC-DC converters which is also applicable for parallel case using different techniques and with different stage properties [9]. For medium electrical potential applications, a new technology is proposed which can be used for large electrical potential also [10]. In existing DC-AC converters, electrical potential stabilizing problem and criticalness of PWM problems are advantaged by multilevel DC-AC Converter

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[11]. To get minimum disturbance in the output voltage of H Bridge multilevel DC-AC converter, a new scheme is indicated [12]. To increase the ability of control which minimize the delay of switching operation, the modern power converter with different sampling procedures [13]. Emerging control scheme has been shown to decrease the fixed electrical potential sources and to parry huge ON/OFF frequency for different stages of inverter [14]. The five level inverter has been studied for different string inverter in solar applications with pulse width modulation technique also observed[15-16]. One more emerging summative Ferro electric Liquid Crystal device has been introduced with recent electrical power distribution procedure for back to back connected H bridge DC to AC converter for performance issues in connection with different stages [17]. A fixed electrical current sink changing translation indicator for different stage DC to AC convertor with Ferroelectric Liquid Crystal has been introduced for speed control of wind turbine system [18].

In this work, to get nine level inverter two H bridges are connected back to back. To decrease the harmonic distortion, the different carrier based LSPDPWM technique is proposed. By using MATLAB simulink, the results are verified and presented the same.

2. Nominated switching scheme for H-bridge Multi Level DC to AC Converter

The existing H bridge Dc to AC converter is giving the output electrical potential in three stages namely V, 0 and V only. But the nominated ON/OFF technical scheme provides FIVE stages in output voltage those are V/2, V, 0, -V/2 and –V. The operating principle and working strategy is as follows. The entire operation is explained in FIVE modes of operation of the circuit.

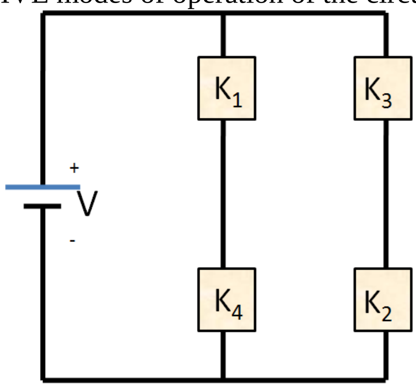

Fig 1: Nominated ON/OFF methodology for H bridge inverter

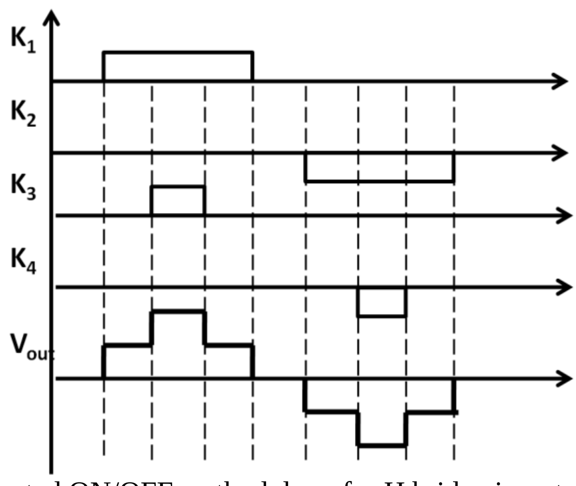

Fig 2: Nominated ON/OFF methodology for H bridge inverter waveforms

There are four switches in the circuit. Those are K1, K2, K3 and K4. When the switches K1 and K2 are ON, then respective output voltage is positive. Hence the switches K1 and K2 are called positive switches. Similarly, when the switches K3 and K4 are ON, then respective output voltage is negative. Hence the switches K3 and K4 are called negative switches.

- In the 1st mode of operation switch K1 only conducted and output voltage is V/2.

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- In the 2nd mode of operation, the switches K1 and K2 are turned ON and the respective output voltage is V.
- In the 3rd mode of operation the switch K3 is turned ON and the respective output voltage is –V/2
- In the 4th mode of operation the switches K3 and K4 are turned ON and respective output voltage is –V.
- In the 5th mode of operation all switches remain OFF that is those switches act as open circuit. Then the load is disconnected from the source. Hence the respective output voltage is ZERO.

2.1 Back-to-back H-bridge inverter (9 level)

Figure 1 is a simple circuit diagram of back to back H bridge 9 stage DC to AC converter. The figure 2 shows ON/OFF and output voltage waveforms of DC to AC 9 stages converter. K11, K12, K13 and K14 are the switches of DC to Ac converter 1 and K21, K22, K23 and K24 are the switches of DC to AC converter 2.

Mode 1: The switch K1 is turned ON. It is shown in figure 3. In the two converters switch K1 is turned ON as shown in figure 3. Then the current flows in the path as follows

I: V_1- K_{11}- R load – K_{22} – V_2 –K_{21}-K_{12}-V_1

Here, $V_1 = V_2 = V$

By applying the KVL to the figure 3,

-V1 – V2 + Vo = 0

Vo = 2V

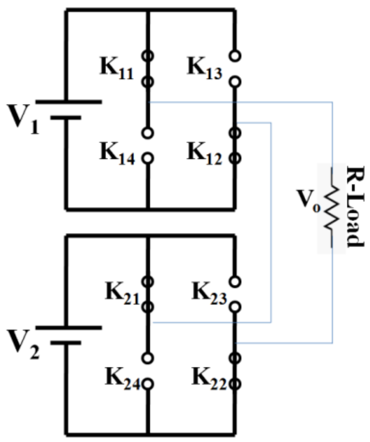

Fig 3: Circuit for Mode 1

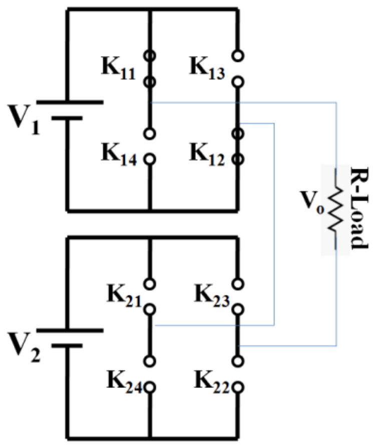

Fig 4: Circuit for Mode 2

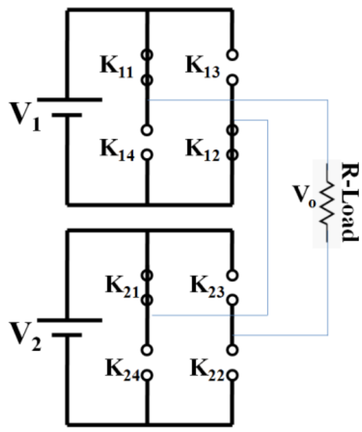

Fig 5: Circuit for Mode 3

Mode2:

The figure 4 has shown the circuit model for mode 2 operation of nine level multilevel inverter. The switches K11, K12 and K21 are turned ON. Then corresponding output voltages are V and V/2 i.e. from converter 1, V and from converter 2, V/2. Then the total output voltage is V+V/2=3V/2.

Mode3:

The figure 5 has shown the circuit model for mode 3 operation of nine level multilevel inverter. The switches K11 and K12 are turned ON. The corresponding output voltage is V.

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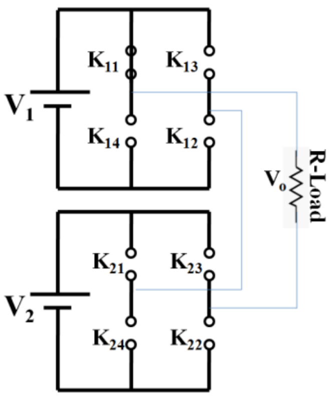


Fig 6: Circuit for Mode 4

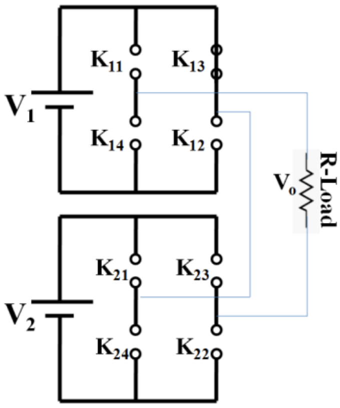


Fig 7: Circuit for Mode 5

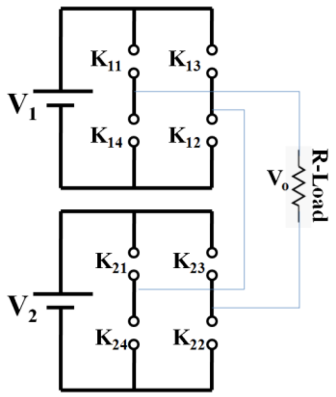


Fig 8: Circuit for Mode 6

Mode4:

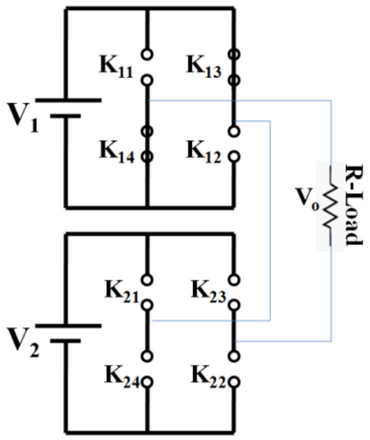
The figure 6 has shown the circuit model for mode4 operation of nine level multilevel inverter. The switch K11 alone turned ON. The corresponding output voltage is V/2.

Mode5:

The figure 7 had shown the circuit model for mode5 operation of nine level multilevel inverter. All switches are remained OFF. The corresponding output voltage is 0.

Mode6:

The figure 8 has shown the circuit model for mode6 operation of nine level multilevel inverter. The switch K13 alone turned ON. The corresponding output voltage is -V/2.



9: Circuit for Mode 7

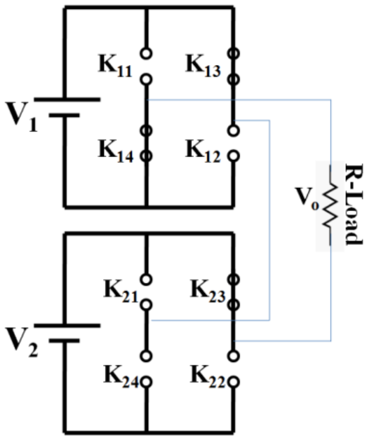


Fig 10: Circuit for Mode 8

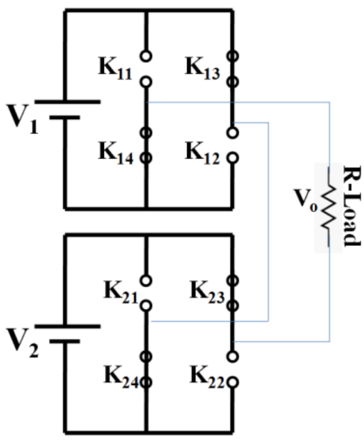


Fig 11: Circuit for Mode 9

Mode 7:

The figure 9 has shown the circuit model for mode7 operation of nine level multilevel inverter. The switches K13 and K14 are turned ON. The corresponding output voltage is -V.

Mode 8:

The figure 10 has shown the circuit model for mode8 operation of nine level multilevel inverter. The switches K13, K14 and K23 are turned ON. The corresponding output voltage is -3V/2.

Mode 9:

The figure 11 has shown the circuit model for mode9 operation of nine level multilevel inverter. The switches K13, K14, K23 and K24 are turned ON. The corresponding output voltage is -2V.

All the above is shown in table 1.

Switching of switches for different modes of operation									
Mode	**K11**	**K12**	**K13**	**K14**	**K21**	**K22**	**K23**	**K24**	**Vo**
1	ON	ON	OFF	OFF	ON	ON	OFF	OFF	**2V**
2	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	**3V/2**

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3	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	**V**
4	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	**V/2**
5	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	**0**
6	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	**-V/2**
7	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	**-V**
8	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	**-3V/2**
9	OFF	OFF	ON	ON	OFF	OFF	ON	ON	**-2V**

Table 1: Nine level inverter switching modes

The number of switches required in above cases is 8. When the level is increased, the required switches also increased. Hence for optimal case, the switches are reduced as listed in Table 3.

Level	**Existing topology Switches =p*2*(m-1) P=Phase, m=level**		**Nominated topology Switches = p(m-1) P=Phase, m=level**	
	1- phase	**3- phase**	**1- phase**	**3- phase**
7	12	36	6	18
9	16	48	8	24
15	28	84	14	42

Table 3: Comparison of number of switches required in existing topology and nominated topology

3. Transformation methodologies:

There are several procedures of transformation. The most commonly used procedure to generate the switching signal, the sine wave is compared with triangular wave as shown in figure 12.

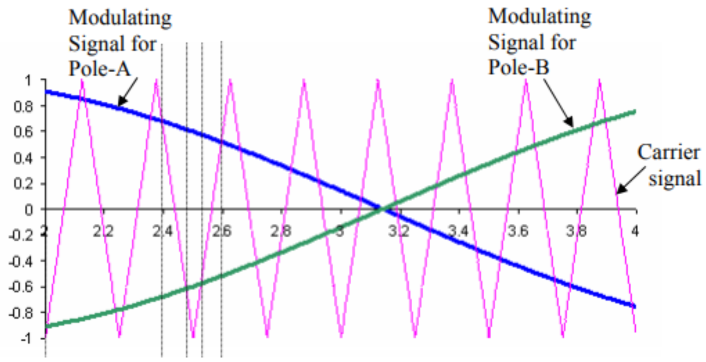

Fig 12.Pulse generation

For m-stage DC-AC converter, (m-1) triangles are used as carriers. The switches K1 and K3 uses the carriers to generate the positive output voltage that is V/2 and V. Similarly the switches K2 and K4 uses the carriers to generate the negative output voltages –V/2 and –V.

4. Control methodologies:

The control methodologies of the nominated back to back H bridge multi stage DC to AC converter are many. But proportional plus integral controller and Fuzzy logic Controllers are popularly used. In this paper, the comparison is made among both to validate DC to AC converter efficiency.

Proportional plus integral controller:

Due to good construction and better design for controlling the machines at industries. It is shown in figure 13.

The output equation of proportional plus integral controller is as follows

$$Vo = KVi + \int Vi\, dt$$

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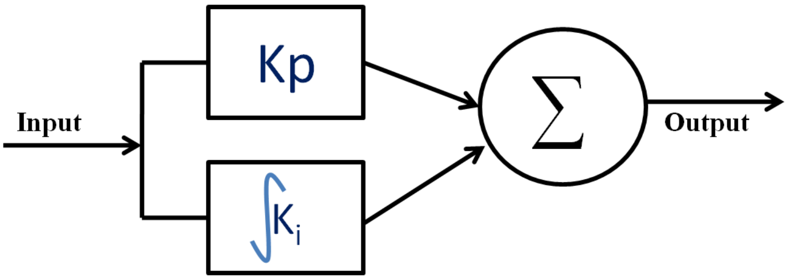

Fig 13: PI controller

Fuzzy logic controller: Figure 14 illustrate implementation of fuzzy logic controller. Figure 15 indicates members functions implementation. Figure 16 indicates Fuzzy space.

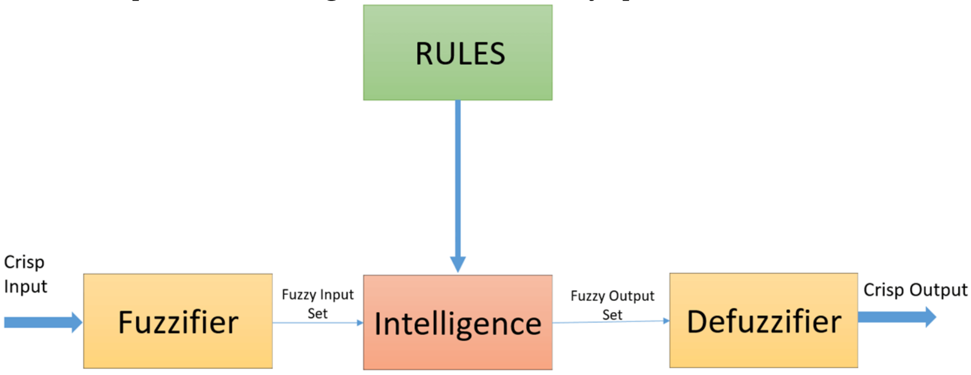

Fig 14: Implementation of Fuzzy logic controller

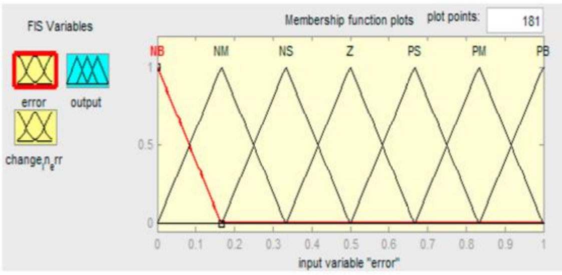

Fig 15a

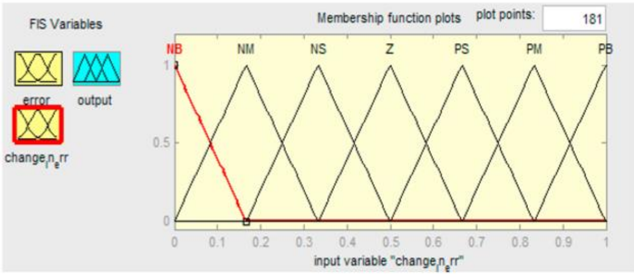

Fig 15b

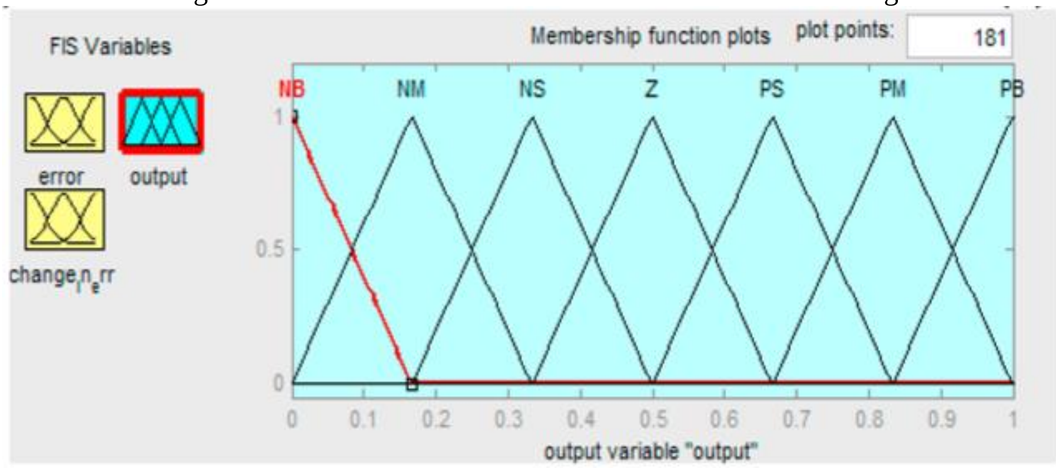

Fig 15c

Fig 15:
(a)Membership function plot of error, (b) Membership function plot of changein error, (c) Membership function plot of output.

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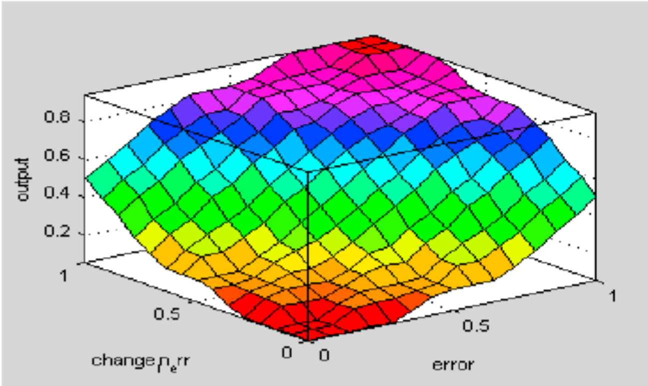

Fig 16: Fuzzy space

5. Simulation:

Now, the switches are replaced by MOSFET, IGBT and the combination of both MOSFET and IGBT. The simulation results are as follows

Components	Voltage	Frequency(HZ)	THD(%)	Fundamentals
MOSFET	-3.274	800	7.705	9.539
MOSFET&IGBT	-4.517	800	8.45	12.01
IGBT	-4.960	800	9.35	16.13

Table 2: Simulation results of nine level inverter with MOSFET, IGBT, MOSFET and IGBT

The table 2 has shown simulation results of 9 level H bridge multi level inverter. It is observed that, the MOSFET alone gives tolerable THD values compare to other cases.

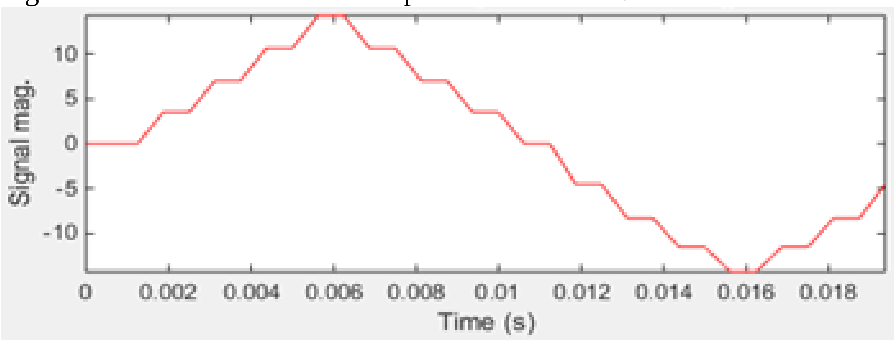

Fig 17: Nine level H bridge inverter output voltage without any controller

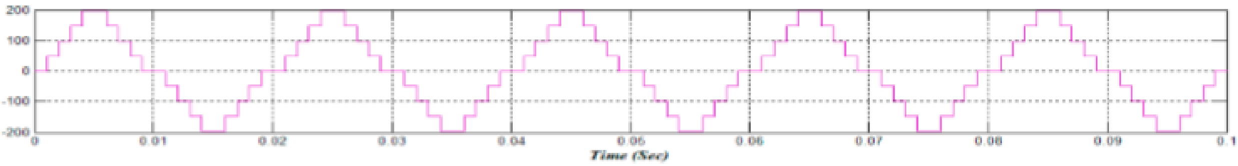

Fig 18: Output voltage with PWM controller

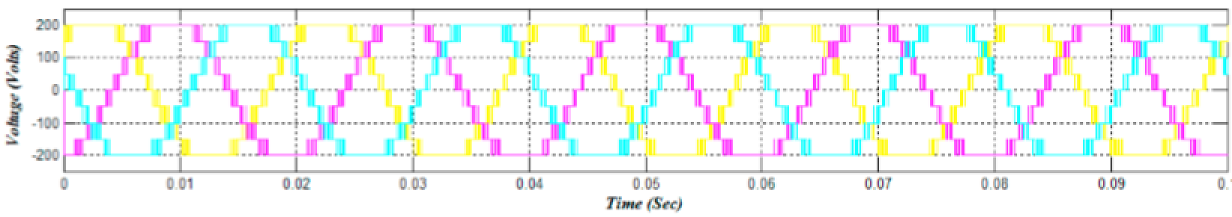

Fig 19: Output voltage with PWM and FLC

Inverter	THD (%)
Without controller	7.705
With PWM	6.204
With PWM + FLC	3.245

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Table 3

6. Conclusion:

With the results obtained from simulation, the following conclusions are made

i. From table 2, it is observed that with the use of MOSFET switch gives good THD

ii. From figure 17, it is observed that the shape of output voltage is not as per the requirements of inverter

iii. From figure 18, it is observed that when PWM controller is used the output voltage shape is modified as per the requirements of the inverter.

iv. From figure 19 and table 3, it is observed that, when Fuzzy logic controller is used, the total harmonic distortion value is reduced to as minimum as possible i.e. 3.245

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