INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

A New Hybrid Multilevel Inverter With Reduced Number Of Switches

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Abstract:

An inverter converts DC into AC symmetrical square wave output voltage. The symmetrical square wave contains infinite number of odd harmonics. When these square wave used for electrical equipments, life of the electrical equipment decreases. So, Multilevel inverter produces higher output voltage levels near the sine wave and corresponding magnitude of harmonics reduced. The conventional MLIs are Cascaded H-bridge five-level MLI and Multistring five-level MLIs, which used PWM techniques, the switching losses are high, efficiency decreases and also cost of switches high. The proposed topology is Hybrid Multilevel inverter with reduced number of switches, the switches operated with fundamental frequency then switching losses are low and efficiency increases. A Hybrid MLI produced higher output voltage levels are seven, nine, eleven, thirteen and fifteen. The THD reduces when increasing the higher output voltage levels. The simulation results shown in the Matlab/simulink 2009b.

Key words*: Multilevel Inverters, Sinusoidal phase shift carrier PWM, level shift Phase Dispose PWM, Pulse generation, THD analysis.*

I. Introduction

Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind and fuel cells can be easily interfaced to a multilevel converter system for a high power application [1-3].

The concept of multilevel converters has been introduced since 1975[4]. The term multilevel began with the three level converter [5]. Subsequently, several multilevel converter topologies have been developed [6-13]. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a stair case voltage waveform. Capacitors, batteries and renewable voltage sources can be used as the multiple dc voltage sources.

The cascaded H-bridge five-level multilevel inverter (MLI) has 8 switches. Sinusoidal phase shift carrier PWM used for Cascaded H-ridge five-level MLI, all the switches operated with carrier switching frequency, so the switching losses are high. The same five-level output voltage produced with 6 switches (Multistring five-level MLI), the level shift phase dispose PWM used. In these inverter, the 2 switches operated with fundamental frequency and remaining switches operated with carrier switching frequency, then switching losses are low compared with the Cascaded H-bridge five-level MLI [14].

The PWM techniques used in the MLIs, the switching losses are high and efficiency decreases and the switches capable of carrier switching frequency, the cost of switches are high.

In this paper the switches operated with fundamental switching frequency, which the switching losses are decreases and efficiency increases. The switches capable of fundamental switching frequency and then cost of switches are low. A Proposed New Hybrid MLI have 9 switches, two batteries and two capacitors. The proposed Hybrid MLI produced seven, nine, eleven, thirteen and fifteen level stair case output voltage with only 9 switches. The output voltage level increases corresponding THD decreases.

2.Multilevel Inverters

The basic Inverter converts DC into AC at desired output voltage and frequency. The inverter output produces two voltage levels $+V_{dc}$ and $-V_{dc.}$ The inverter output produces symmetrical square wave. The square wave output voltage contains infinite number of odd harmonics. The harmonics reduced by using Multilevel Inverters. Multilevel inverter is defined as level refers to the various voltage values in a cycle. The Multilevel inverter starting from three level output voltage. The basic inverter produces three voltage levels 0, $+V_{dc}$ and $-V_{dc}$. The three level output voltage contains the harmonic content reduced compared to the two level output voltage. The voltage levels are increasing, the harmonic content in the output voltage reduces and the easily sine wave output wave form produces from multilevel inverters.

2.1 Cascaded H-bridge Five-level Multilevel Inverter (MLI)

The One full H-bridge inverter produces three voltage levels. They are 0, $+V_{dc}$ and $-V_{dc}$. The five-level output voltage are producing from two full H-bridge inverters connected in cascaded form. They are 0, $+2V_s$, $+V_s$, $-2V_s$ and $-V_s$. The sinusoidal phase shift carrier pulse width modulation used for cascaded H-bridge five-level inverter. The carrier frequency used for carrier wave 1860Hz.

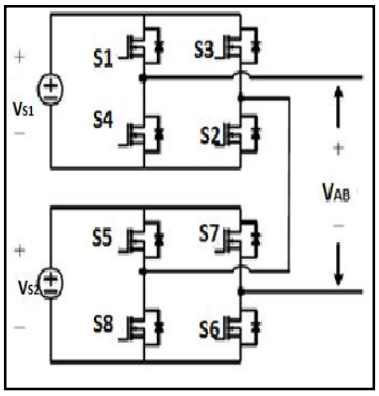

Figure 1: Cascaded H-bridge 5-level MLI

In the Table I shows, '1' means switch is ON and '0' means switch is OFF in the Cascaded H-bridge 5-level MLI. The $V_{S1}=V_{S2}=100V$ as the input voltage of inverter. The sinusoidal phase shift carrier PWM applied to the circuit, which PWM contains one reference waveform and four carrier wave forms. The phase shift of the carrier wave

form is $360^0/(n-1)$, the 'n' means number of voltage levels. The first carrier wave form operated with 0 degrees, the second carrier wave form shifted with 90degrees, third carrier waveform shifted with 180degress and fourth carrier waveform shifted with 270 degrees. All switches operated with carrier switching frequency, whose switching losses are high in the above circuit. The five level output voltage produced in the above circuit.

Output Voltage	**Switches in Cascaded H-bridge Five level MLI**							
	S1	S2	S3	S4	S5	S6	S7	S8
+2Vs	1	1	0	0	1	1	0	0
+Vs	1	1	0	0	1	0	1	0
+Vs	1	0	1	0	1	1	0	0
0	1	0	1	0	1	0	1	0
0	1	0	1	0	0	1	0	1
0	0	1	0	1	1	0	1	0
0	0	1	0	1	0	1	0	1
-Vs	0	0	1	1	1	0	1	0
-Vs	1	0	1	0	0	0	1	1
-2Vs	0	0	1	1	0	0	1	1

Table 1: Switching Sequence Of Eight Switches

2.2 Multistring Five-Level Multilevel Inverter (MLI) With Six Switches

The five-level output voltage produced by using two sources with six switches. They are 0, $+V_{dc}$, $-V_{dc}$, $+2V_{dc}$ and $-2V_{dc.}$ The level shift phase dispose pulse width modulation used in the Multistring five-level multilevel inverter with six switches, which compared to the Cascaded H-bridge Five-level Multilevel inverter then switching devices, circuit complexity, area required and also cost reduced. The V_{S1}= V_{S2}= 100V as the input voltage of this inverter. The carrier switching frequency 1860Hz used in the Multistring Five-level MLI for S1, S4, S3 and s6. The fundamental switching frequency used for S2, S4 switches.

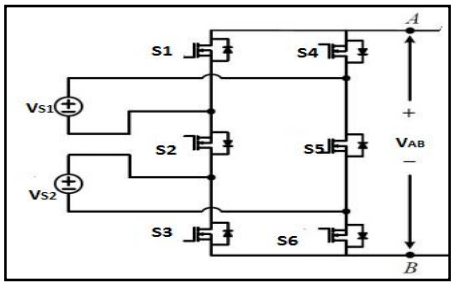

Figure 2: Multistring five-level MLI diagram

Output voltage	**Multi string five-level multilevel inverter with six switches**					
VAB	S1	S2	S3	S4	S5	S6
+2VS	0	1	0	1	0	1
+VS	0	1	1	1	0	0
+VS	1	1	0	0	0	1
0	1	1	1	0	0	0
0	0	0	0	1	1	1
-VS	1	0	0	0	1	1
-VS	0	0	1	1	1	0
-2VS	1	0	1	0	1	0

Table 2: Switching Sequence Of Six Switches

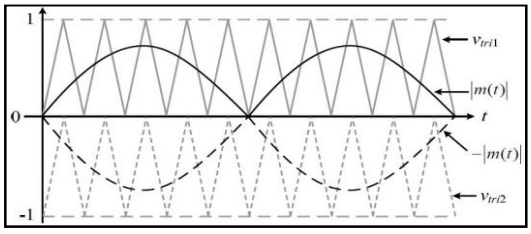

Figure 3: Modulation strategy of carrier/reference signals

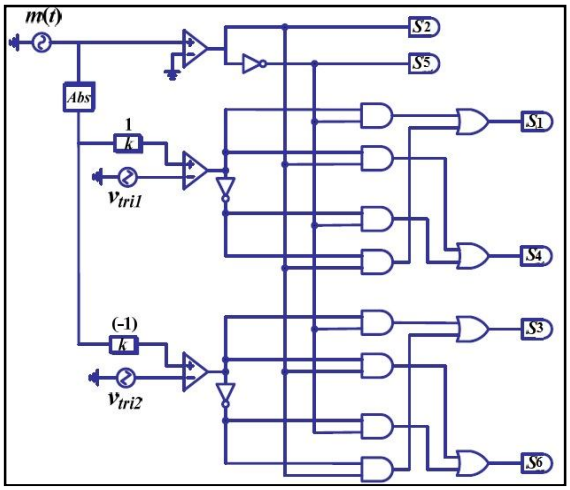

Figure 4: Modulation logic of Multistring5- level MLI diagram

In the table II shows '1' means switch is 'ON' and '0' means switch is 'OFF' in the Multistring five-level MLI diagram. In the above Fig.2 shown operated with level shift phase dispose PWM, which PWM contains two reference wave forms and two carrier waveforms in the Fig.3 shown and modulation logic of Multistring 5-level MLI in the Fig 4 shown. The above Fig.4 shown the middle switches operated with fundamental switching frequency (S2, S5) and remaining four switches operated with switching carrier frequency (S1, S3, S4, S6) of modulation logic applied to the multistring 5-level MLI (Fig.2 shown) compared to 5-level cascaded H-bridge MLI have one reference wave form and four carrier wave forms then switching losses are high in the cascaded H-bridge 5-level MLI. The switching losses decreases in the multistring 5-level MLI compared to the Cascaded H-bridge 5-level MLI.

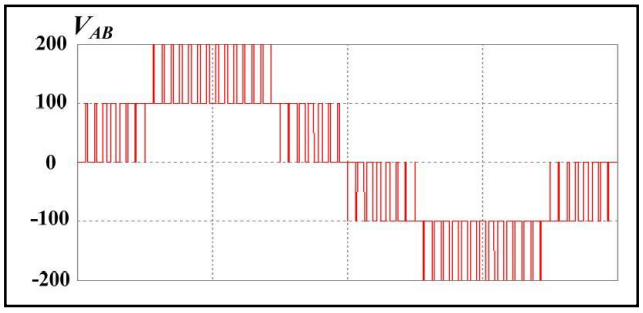

Figure 5: Five-level Multistring Multilevel inverter five level output phase voltage of simulation waveform V_{AB}

The above Fig.5 shown 5-level output voltage of 5-level multistring MLI. The same output voltage of 5-level cascaded H-bridge MLI.

Contents	Cascaded H-bridge MLI	Multistring MLI
Output voltage level	Five-level	Five-level
Number of switches	8	6
Pulse Width Modulation technique	Sinusoidal Phase shift carrier PWM used	Phase dispose PWM used
Carrier switching frequency	All switches operated with carrier switching frequency	S2,S5operated with fundamental switching frequency, S1,S4,S3,S6 Operated with carrier switching frequency
Switching losses	High	low
Cost	High	low

Table 3: Compare Between The Cascaded H-Bridge Mli And Multistring Mli

The above table shows comparison between the Cascaded H-bridge MLI and Multistring MLI. The PWM techniques used for MLIs, the switching losses are high. The cost is high because PWM techniques used in the MLI (the switches capable of carrier switching frequency, so the cost of switches are high).

The same five level output voltage produced with five switches. As the switches operated with fundamental switching frequency, the cost of switches is low. So, the switching losses are low and reduce the number of switches, complexity and control circuit. The Five-level inverter with five switches operation shown below.

2.3 Five level inverter with five switches

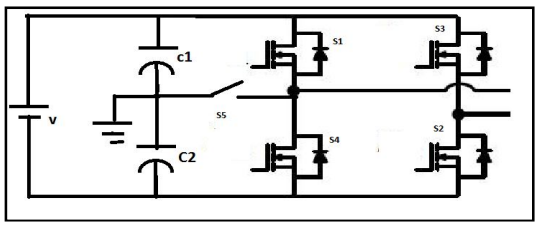

Figure 6: 5-level inverter with 5 switches diagram

S_1	S_2	S_3	S_4	S_5	V_0
1	**1**	**0**	**0**	**0**	$+2V_S$
0	**1**	**0**	**0**	**1**	$+V_S$
1	**0**	**1**	**0**	**0**	**0**
0	**1**	**0**	**1**	**0**	**0**
0	**0**	**1**	**0**	**1**	$-V_S$
0	**0**	**1**	**1**	**0**	$-2V_S$

Table 4: Switching Sequence Of 5 Switches

In the above Fig.6 shown, 5-level output voltage produced from five level inverter with five switches. In the above circuit contains 5 switches, two capacitors and one battery. The input supply voltage shared by the two capacitors. In the table IV shows the switching sequence '1' means switch is 'ON' and '0' means switch is 'OFF' in the 5-level inverter with 5 switches (above Fig 6 shown). The five switches operated with fundamental switching frequency. So the number of switching devices, cost and complexity reduces compared to the above two MLIs. The switching losses decreases compared to the above two MLIs. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

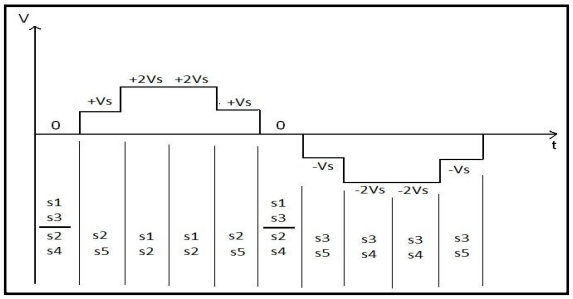

Figure 7: Five level output voltage of five level inverter with five switches

The five-level output voltage as shown above in Five-level inverter with five switches.

2.3 Proposing system of Hybrid Multilevel Inverter

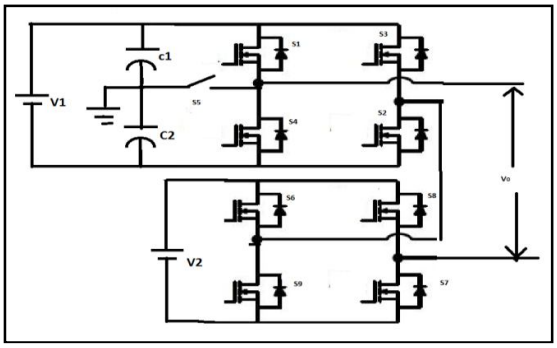

Figure 8: Proposing system of Hybrid Multilevel inverter diagram

In the above circuit Fig.8 has shown two batteries, two capacitors and nine switches. In this circuit, all switches operated with fundamental switching frequency. Hybrid Multilevel Inverter produces seven, nine, eleven, thirteen and fifteen level output voltage levels. In cascaded H-bridge MLI configuration seven, nine, eleven, thirteen and fifteen level output voltage corresponding switches are 12, 16, 20, 24 and 28 switches. So, seven, nine, eleven, thirteen and fifteen level output voltage levels produced from only nine switches. The Hybrid MLI operated by pulse generation of seven, nine, eleven, thirteen, fifteen level output voltage. So switching losses decreases and reduces the cost, number of switches, area required, complexity, protection circuit and driving circuit and finally the THD reduces corresponding voltage levels increases and also the switches operated with fundamental switching frequency (pulse generation).

2.3.1. Seven Level Hybrid MLI

In the above circuit shown (Fig.8), the input voltage V1=100V and V2=50V taken. The output voltage levels are $+1.5V_S$, $+V_S$, $+0.5V_S$, 0, $-0.5V_S$, $-V_S$, $-1.5V_S$. The Seven level output voltage is produced in the Hybrid MLI is called as Seven level Hybrid MLI. The all switches operated with fundamental switching frequency. Generally, the seven level output voltage produce with 12 switches in cascaded form but we obtained seven level output voltage by only nine switches. The seven level output voltage with switching sequence of 9 switches table V shown below. In the table '1' means switch is 'ON' and '0'means switch is 'OFF'.

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	V_0
1	1	0	0	0	1	1	0	0	$+1.5V_S$
1	1	0	0	0	1	0	1	0	$+V_S$
0	1	0	0	1	1	0	1	0	$+0.5V_S$
1	0	1	0	0	1	0	1	0	0
0	0	1	0	1	1	0	1	0	$-0.5V_S$
0	0	1	1	0	1	0	1	0	$-V_S$
0	0	1	1	0	0	0	1	1	$-1.5V_S$

Table 5: Seven Level Output Voltage With Switching Sequence Of 9 Switches

2.3.2. Nine Level Hybrid MLI

In the above circuit shown (Fig.8), the input voltage V1=100V and V2=100V taken. The output voltage levels are $+2V_S$, $+1.5V_S$, $+V_S$, $+0.5V_S$, 0, $-0.5V_S$, $-V_S$, $-1.5V_S$,$-2V_S$.The nine level output voltage produced in the Hybrid MLI is called as Nine level Hybrid MLI. The all switches operated with fundamental frequency. Generally, the nine level output voltage produce with 16 switches in cascaded form but we obtained nine level output voltage by only nine switches. The nine level output voltage with switching sequence of 9 switches table VI shows below. In the table '1' means switch is 'ON' and '0'means switch is 'OFF'.

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	V_0
1	1	0	0	0	1	1	0	0	$+2V_S$
0	1	0	0	1	1	1	0	0	$+1.5V_S$
1	1	0	0	0	1	0	1	0	$+V_S$
0	1	0	0	1	1	0	1	0	$+0.5V_S$
1	0	1	0	0	1	0	1	0	0
0	0	1	0	1	1	0	1	0	$-0.5V_S$
0	0	1	1	0	1	0	1	0	$-V_S$
0	0	1	0	1	0	0	1	1	$-1.5V_S$
0	0	1	1	0	0	0	1	1	$-2V_S$

Table 6: Nine Level Output Voltage With Switching Sequence Of 9 Switches

2.3.3 Eleven Level Hybrid MLI

In the above circuit shown (Fig.8), the input voltage V1=200V and V2=300V taken. The output voltage levels are $+5V_S$, $+4V_S$, $+3V_S$, $+2V_S$, $+V_S$, 0,$-V_S$,$-2V_S$,$-3V_S$,$-4V_S$,$-5V_S$. The

eleven level output voltage produced in the Hybrid MLI is called as Eleven level Hybrid MLI. The all switches operated with fundamental switching frequency. Generally, the eleven level output voltage produce by 20 switches in cascaded form but we obtained eleven level output voltage with only nine switches. The eleven level output voltage with switching sequence 9 switches table VII shown below. In the table '1' means switch is 'ON' and '0' means switch is 'OFF'.

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	V_0
1	1	0	0	0	1	1	0	0	$+5V_S$
0	1	0	0	1	1	1	0	0	$+4V_S$
1	0	1	0	0	1	1	0	0	$+3V_S$
1	1	0	0	0	1	0	1	0	$+2V_S$
0	1	0	0	1	1	0	1	0	$+V_S$
1	0	1	0	0	1	0	1	0	**0**
0	0	1	0	1	1	0	1	0	$-V_S$
0	0	1	1	0	1	0	1	0	$-2V_S$
1	0	1	0	0	0	0	1	1	$-3V_S$
0	0	1	0	1	0	0	1	1	$-4V_S$
0	0	1	1	0	0	0	1	1	$-5V_S$

Table 7: Eleven Level Output Voltage With Switching Sequence Of 9 Switches

2.3.4 Thirteen Level Hybrid MLI

In the above circuit shown (Fig.8), the input voltage V1=100V and V2=200V taken. The output voltage levels are $+3V_S$, $+2.5V_S$, $+2V_S$, $+1.5V_S$, $+V_S$, $+0.5V_S$, 0,$-0.5V_S$,$-V_S$,$-1.5V_S$,$-2V_S$,$-2.5V_S$,$-3V_S$. The thirteen level output voltage produced in the Hybrid MLI is called as Thirteen level Hybrid MLI. The all switches operated with fundamental switching frequency. Generally, the thirteen level output voltage produce with 24 switches in cascaded form but we obtained thirteen level output voltage by only nine switches. The thirteen level output voltage with switching sequence 9 switches table VIII shown below. In table '1' means switch is 'ON' and '0' means switch is 'OFF'.

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	V_0
1	1	0	0	0	1	1	0	0	+3Vs
0	1	0	0	1	1	1	0	0	+2.5Vs
1	0	1	0	0	1	1	0	0	+2Vs
0	0	1	0	1	1	1	0	0	+1.5Vs
1	1	0	0	0	1	0	1	0	+Vs
0	1	0	1	0	1	0	1	0	+0.5Vs
1	0	1	0	0	1	0	1	0	0
0	0	1	0	1	1	0	1	0	-0.5Vs
0	0	1	1	0	1	0	1	0	-Vs
0	1	0	0	1	0	0	1	1	-1.5Vs
1	0	1	0	0	0	0	1	1	-2Vs
0	0	1	0	1	0	0	1	1	-2.5Vs
0	0	1	1	0	0	0	1	1	-3Vs

Table 8: Thirteen Level Output Voltage With Switching Sequence Of 9 Switches

2.3.5 Fifteen Level Hybrid MLI

In the above circuit shown (Fig.8), the input voltage V1=100V and V2=250V taken. The output voltage levels are +3.5Vs, +3V_S, +2.5V_S, +2V_S, +1.5V_S, +V_S, +0.5V_S,0,-0.5V_S,-V_S,-1.5V_S,-2V_S,-2.5V_S,-3V_S, -3.5Vs. The fifteen level output voltage produced in the Hybrid MLI is called as Fifteen level Hybrid MLI. The all switches operated with fundamental switching frequency. Generally, the fifteen level output voltage produce with using 28 switches in cascaded form but we obtained fifteen level output voltage by only nine switches. The Fifteen level output voltage with switching sequence 9 switches table IX shown below. In table '1' means switch is 'ON' and '0' means switch is 'OFF".

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	V_0
1	1	0	0	0	1	1	0	0	$+3.5V_S$
0	1	0	0	1	1	1	0	0	$+3V_S$
1	0	1	0	0	1	1	0	0	$+2.5V_S$
0	0	1	0	1	1	1	0	0	$+2V_S$
0	0	1	1	0	1	1	0	0	$+1.5V_S$
1	1	0	0	0	1	0	1	0	$+V_S$
0	1	0	0	1	1	0	1	0	$+0.5V_S$
1	0	1	0	0	1	0	1	0	0
0	0	1	0	1	1	0	1	0	$-0.5V_S$
0	0	1	1	0	1	0	1	0	$-V_S$
1	1	0	0	0	0	0	1	1	$-1.5V_S$
0	1	0	0	1	0	0	1	1	$-2V_S$
1	0	1	0	0	0	0	1	1	$-2.5V_S$
0	0	1	0	1	0	0	1	1	$-3V_S$
0	0	1	1	0	0	0	1	1	$-3.5V_S$

Table 9:Fifteen Level Output Voltage With Switching Sequence Of 9 Switches

2.4.Different Voltages Are Taken As The Source Voltages Of The Hybrid MLI

No of levels	**No of Switches**	**V1**	**V2**	**Output Voltage in V**
7	**9**	V_S	$0.5V_S$	$1.5V_S$
9	**9**	V_S	V_S	$2V_S$
11	**9**	$2V_S$	$3V_S$	$5V_S$
13	**9**	V_S	$2V_S$	$3V_S$
15	**9**	V_S	$2.5V_S$	$3.5V_S$

Table 10: Different Voltages Taken As Hybrid Mli

The seven, nine, eleven, thirteen and fifteen levels output voltage got only from nine switches corresponding to respective voltage sources taken.

The above table X shows different voltages are taken for Hybrid MLI. The Hybrid MLI are simulated the different output voltage levels used by the table 9.

III MATLAB/SIMULATION RESULTS

3.1 Cascaded H-bridge Five-level MLI

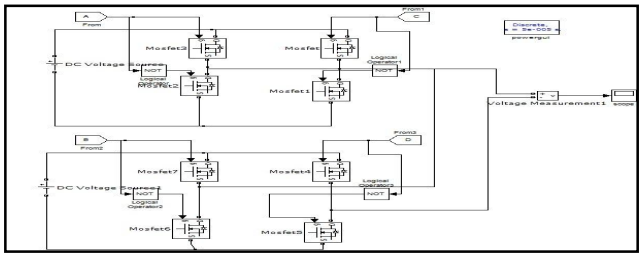

Figure 9: Cascaded H-bridge Five level MLI simulink diagram

The simulation diagram for cascaded H-bridge five level inverter diagram as shown above.

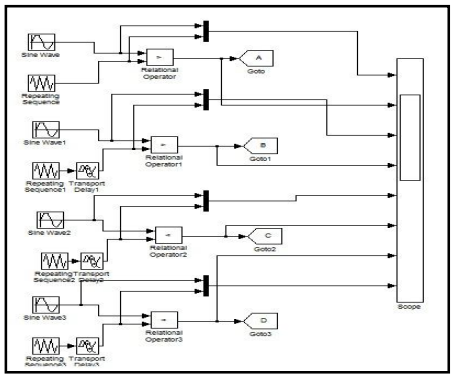

Figure 10 (a) sinusoidal phase shift carrier pwm simulink diagram

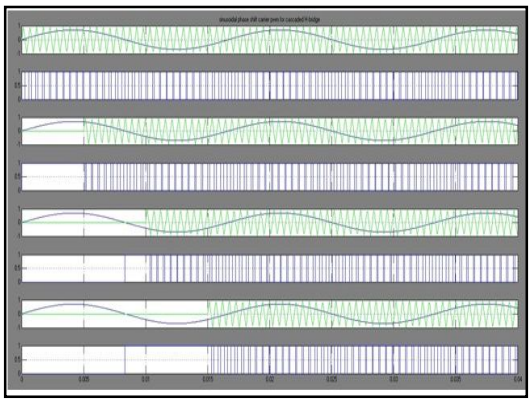

Figure 10 (b): reference and carrier waveforms of pwm generation

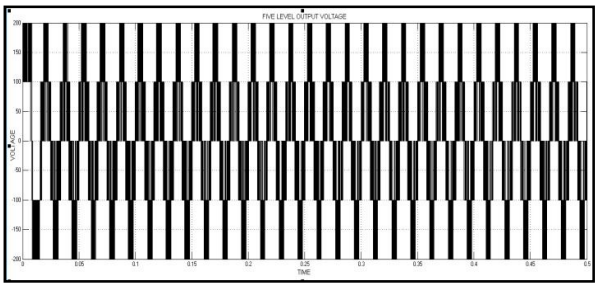

Figure 11: Five level output voltage of Cascaded H-bridge Five-level MLI

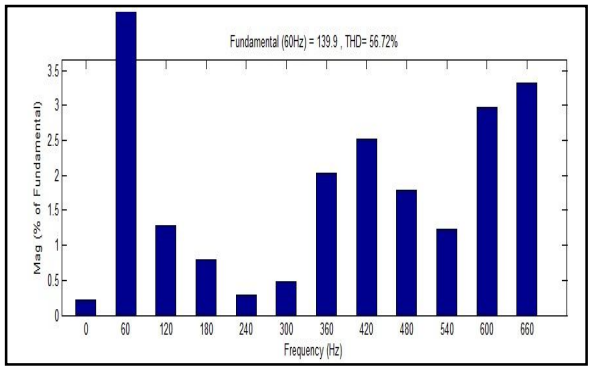

Figure 12: THD of Five-level output voltage of Cascaded H-bridge five-level MLI

3.2 Multistring Five-level MLI

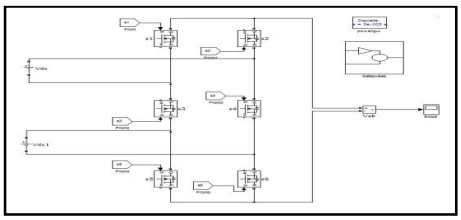

Figure 13: Mulstring Five-level MLI simulink diagram

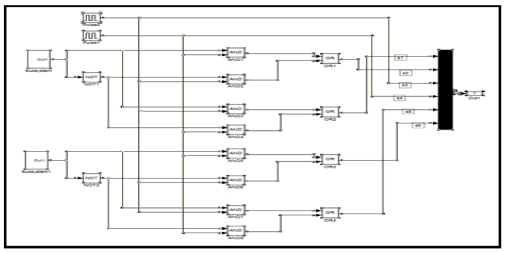

Figure 14 (a): subsystem2 of Phase dispose PWM

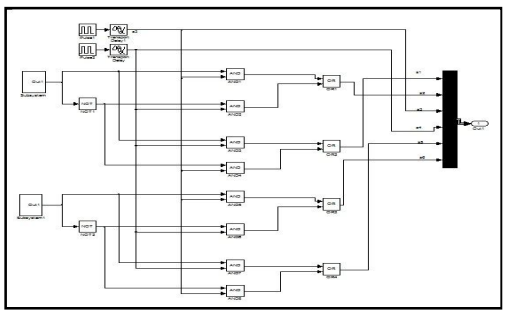

Figure 14(b) :Subsystem1 of Phase dispose PWM

The above Fig 14(a) shown subsystem2 of phase dispose PWM technique (Fig.15) and Fig.14(b) shown subsystem1 of phase dispose PWM technique(Fig.15).

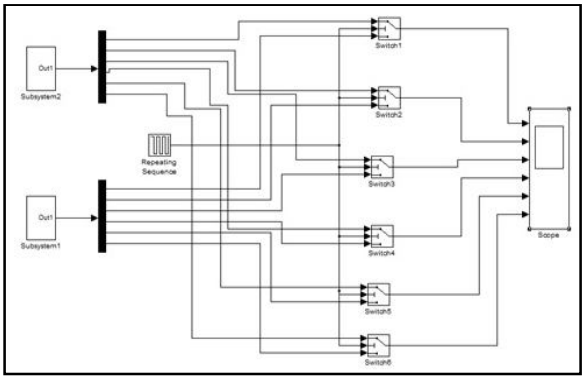

Figure 15 (a): Phase dispose PWM technique

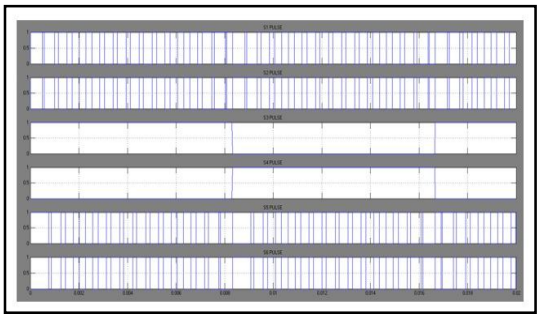

Figure 15(b): PWM generation of six switches

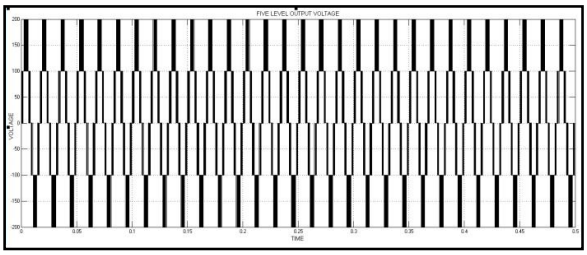

Figure 16: Five level output voltage of Multistring Five-level MLI

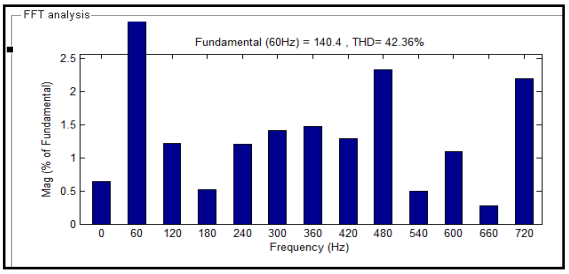

Figure 17: THD of Five level output voltage of Multistring Five-level MLI

The PWM techniques used in the Cascaded H-bridge five-level MLI and Multistring Five level MLI simulated as shown above. The THD value low (42.36%) in the multistring five level MLI compared with the Cascaded H-bridge five-level MLI (56.72%).

The switching losses are high, cost of switches high and efficiency decreases in the PWM techniques used for above two five level MLIs. The same five level output voltage produced with five switches as shown below. All the switches operated with fundamental switching frequency then switching losses decreases and efficiency increases and also cost of switches low.

3.3 Five-Level Inverter With Five Switches

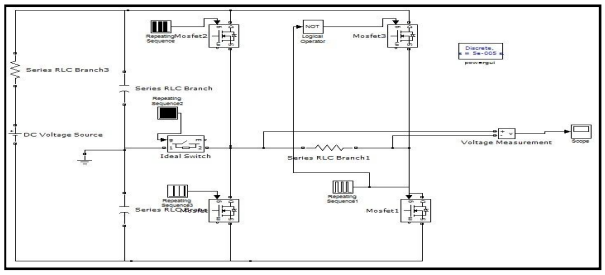

Figure 18: Five Level Inverter With Five Switches Simulink Diagram

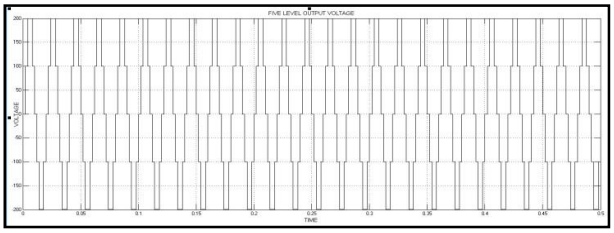

Figure 19: Five Level Output Voltage Of Five-Level Inverter With Five Switches

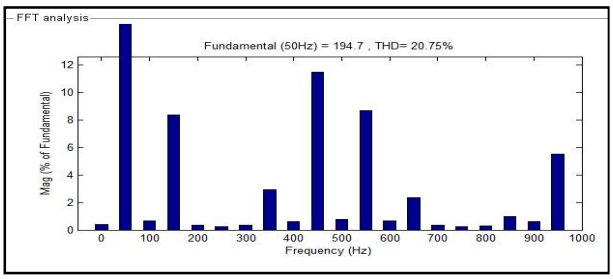

Figure 20: THD value of five level output voltage Five-level inverter with five switches

3.4 Proposing System Of Hybrid MLI

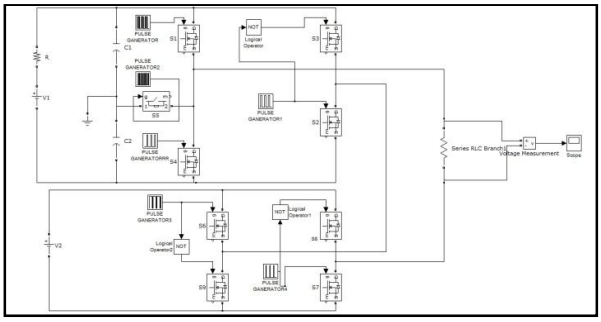

Figure 21: seven, nine, eleven, thirteen, fifteen level Hybrid MLI of simulink diagram

3.4.1. Seven Level Hybrid MLI

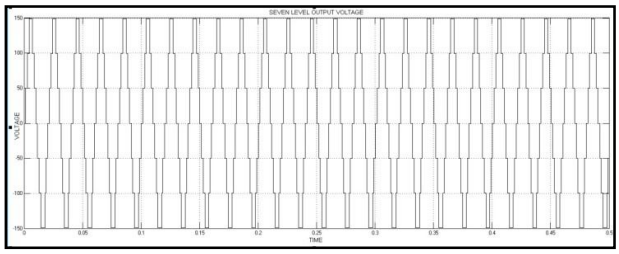

Figure 22: seven level output voltage of seven level Hybrid MLI

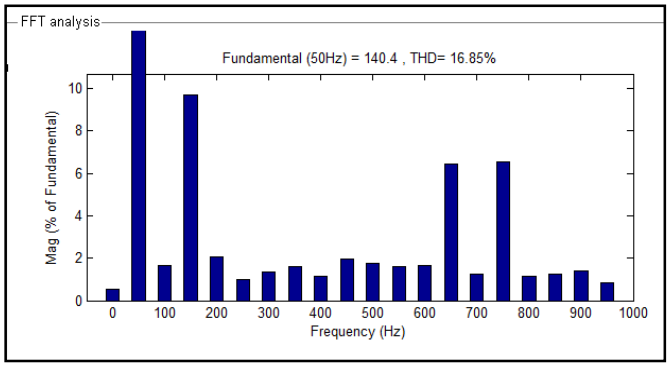

Figure 23: THD value of Seven level output voltage of Seven level Hybrid MLI

3.4.2.Nine Level Hybrid MLI

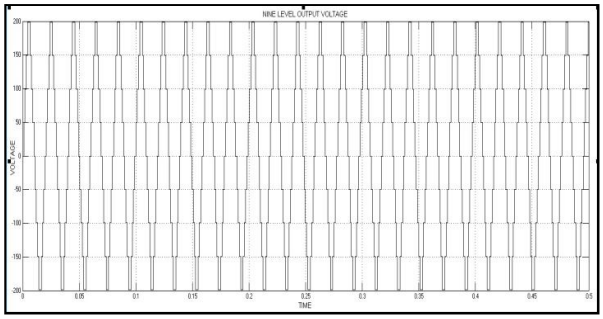

Figure 24: Nine level output voltage of Nine level Hybrid MLI

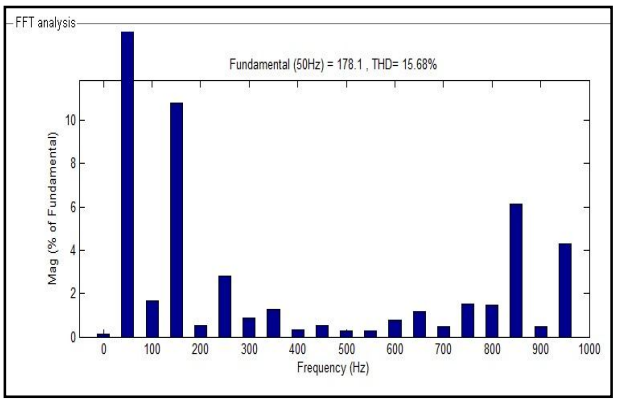

Figure 25: THD value of Nine level output voltage of Nine level Hybrid MLI

3.4.3.Eleven Level Hybrid MLI

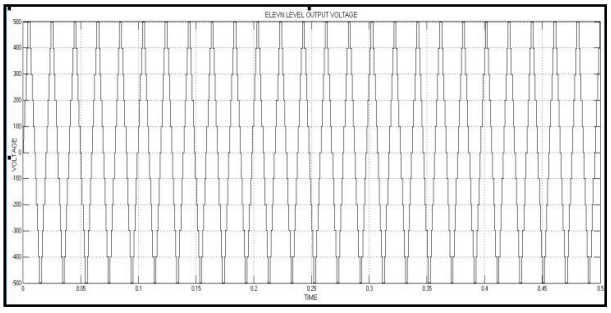

Figure 26: Eleven level output voltage of Eleven level Hybrid MLI

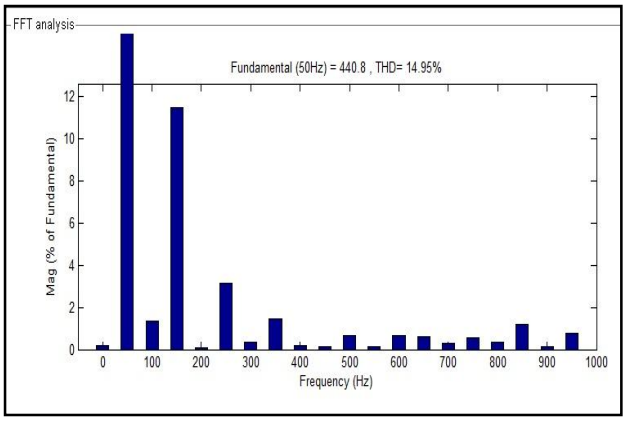

Figure 27: THD value of Eleven level output voltage of Eleven level Hybrid MLI

3.4.4. Thirteen Level Hybrid MLI

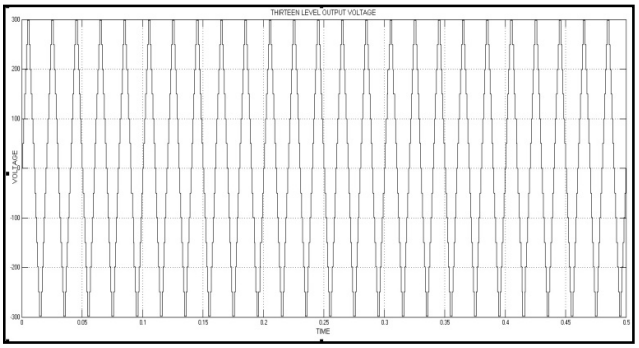

Figure 28: Thirteen level output voltage of thirteen level Hybrid MLI

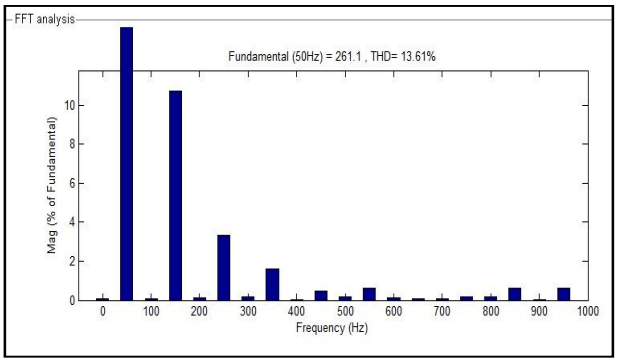

Figure 29: THD value of thirteen level output voltage of Thirteen level Hybrid MLI

3.4.5. Fifteen Level Hybrid MLI

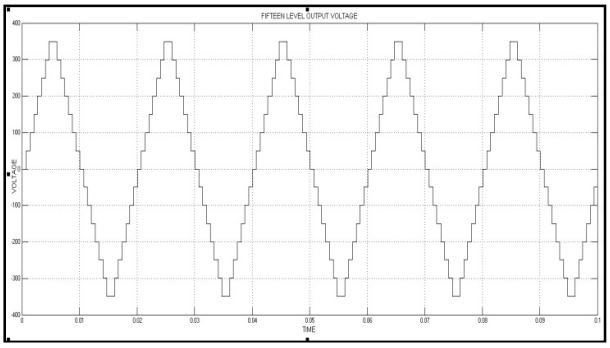

Figure 30: Fifteen level output voltage Fifteen level Hybrid MLI

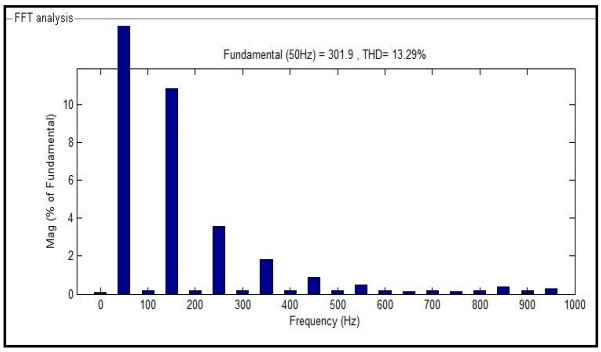

Figure 31: THD value of fifteen level output voltage of Fifteen level MLI

Output Voltage levels	Number of switches	
	Cascaded H-bridge MLI	Proposed Hybrid MLI
7level	12	9
9 level	16	9
11level	20	9
13level	24	9
15level	28	9

Table 11: Compare Between Cascaded H-Bridge Mli And Proposed Hybrid Mli

In the above table XI shows compare between Cascaded H-bridge MLI and Proposed Hybrid MLI, the switches in the cascaded form increases when increasing the output voltage levels. The cost of switches, reduce the number of switches, protection circuit, cooling equipment, control circuit increases in the cascaded form. But the Proposed Hybrid MLI produced higher output voltage levels are 7, 9, 11, 13, 15 level with nine switches only. So, the cost of switches reduce the number of switches, protection circuit, cooling equipment, control circuit decreases compared to the Cascaded H-bridge MLI.

Proposed Hybrid MLI		
Output voltage level	No of switches	THD of output voltage (%)
7 level	9	16.85
9 level	9	15.68
11 level	9	14.95
13 level	9	13.61
15 level	9	13.29

Table 12:Thd Comparison Of Different Voltage Levels

In the above table XII shows the output voltage increases corresponding the THD value decreases in the Proposed Hybrid MLI from 7 level to 15 voltage levels. The Hybrid Multilevel inverter operated with Fundamental switching frequency by using pulse generation, so the switching losses are low and efficiency is high.

4.Conclusion

In this paper "A New Hybrid Multilevel inverter with reduced number of switches" produced higher output voltage level consisting of seven, nine, eleven, thirteen, fifteen voltage levels. The THD value decreases, when increasing higher output voltage levels and also reduce the number of switches, cost, area required, protection circuit, cooling equipment, and driving circuit and also switching losses decreases, efficiency increases.

The Hybrid MLI is easily interfaced with DERs. They are photovoltaic arrays and fuel cells.

5.Reference

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