Cascaded Multi-level Inverters using different PWM techniques: Power Quality Analysis

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Abstract- As we know that the Multi-level inverters (MLI) are using in a broad way across the globe. Mainly industries are using this to design the machineries and other big equipment's. The rating of voltage and current are the major parameters which we need to control by optimize parameters. In this paper we propose the detail analysis of MLI for better performance of power qualities like total harmonic distortions (THDs) and power factor (PF). Normally, the inverter is used to convert the dc supply into ac supply but during the conversion of this supply there are too many losses present in the converted output and the waveform of the generated ac supply is not purely sinusoidal in its entire time period. For better performance, the PWM techniques are proposed here. Detail analysis is given in the paper.

I. INTRODUCTION

Normally, the inverter is used to convert the dc supply into ac supply but during the conversion of this supply there are too many losses present in the converted output and the waveform of the generated ac supply is not purely sinusoidal in its entire time period. It is quite identified that, the distorted parameter's waveforms in the ac supply, produce harmonic distortions, high frequency noise and power losses. The undesirable things affect the machine and other equipment like controllers and auxiliary systems. Thus, to overcome the losses and increase the performance of the machine, multi-level inverters came into existence. They are used to achieve the high-performance applications. Moreover, the benefits of using multi-level inverters are improved power quality, reduction in switching losses of the system and improved voltage capability. The MLIs generate common mode voltage (CMV). CMV reduces the voltage stress of the motor without damaging it. Lesser switching frequency basically means lower switching losses and vice versa. This ability of operation results in the higher efficiency of the operation. The combination of previous Technique and the multi-level topologies reduces the THD in the output. This reduces the requirement of filter circuit.

II. MULTI-LEVEL INVERTER (MLI)

An n-level inverter will generate an output voltage with n levels with respect to the -ve point of the Capacitor. Basically, the term multi-level begins with three levels, if we enhanced the defined levels in the inverter; the o/p waveform will be like a staircase waveform having different intermediate levels, which results in reduction in THD.

The requirement of an MLI is to generate a high- power output from minimum resources, low power wind turbines etc. MLIs have different topologies by arranging diodes and switches in different manner. In MLI, the arrangement of switches' angles is of utmost importance. Basically, the multi-level inverter is used to achieve the perfect sinusoidal waveform of the output and thereby reducing losses and thus increasing output. There are three different topologies of multi-level inverters.

1. Flying Capacitor

It is made up of a capacitors and cells for switching. These capacitors convert only a fixed voltage to provide to the energy. This topology also has the switching redundancy within phase, in order to balance the flying capacitors. Flying Capacitor topology has the ability to control the circuit well and the output parameters too.

1. Diode Clamp

The key working notion of Diode Clamped inverter is to use in optimized way by which on and off process can work proper for switch. The DC voltage that you need to apply at the input level needs to be twice the maximum output voltage that you desire. The problem is resolved by increasing quality equipment and

advance techniques. There exists a capacitor balancing issue, due to which these are limited only to three level multi-level inverters. Diode Clamp MLI provides improved performance and efficiency due to the use of frequency which is fundamental part for the circuitry.

3. Cascaded H-Bridge (CHB)

The Cascaded H-bridge MLI uses capacitors and switches. The power can be easily scaled.

As the levels increase, the control complexity increases and voltage imbalance problems are observed. There are several modulations and controlling techniques that have been developed for MLIs, out of which some of them are Multi-level Sinusoidal PWM and SVM. These are majorly known and used.

The main features due to which we used in our project are written below.

1. The output voltage of multi-level inverters is of low distortion with reduced dv/dt.
2. The input current that is drawn has reduced distortion.
3. The CMV generated is small. This helps in the reduction of tension and stress.
4. Cascaded H-Bridge MLI can operate with reduced switching frequency.

But apart from having large number of advantages multi-level inverter have some disadvantages and that are: -

The number of components used is high. The Cascaded H-Bridge inverter uses a combination of MOSFETs. The 5-steps MLI needs about many MOSFETS, with all gate drivers having the same number. The CHB MLI requires a large number of isolated dc supplies to run. It is usually used to provide the various DC supplies for the CHB inverter.

III MULTI-LEVEL INVERTER (MLI)

The cascaded inverter shown in the figure has five voltage levels. The output voltage that will be obtained can be 0, ±E, ±2E. It is observed that different voltage levels can obtain when two or more switches are in switching state. This MLI provides huge pliability for switching pattern design, mainly for SVM schemes. Generally, in the inverter we can defined level as below.

$$m= (2N+1)$$

where, N is defines as cells per phase leg and for CHB inverter the value of **m** should be odd. The Cascade H-Bridge MLI showed above, can be extended to any number of voltage levels. Let **Ns** be the final count of MOSFETs switches.

$$Ns = 6(m – 1)$$

where, **Ns** = Total count of switch
m= Set point of voltage

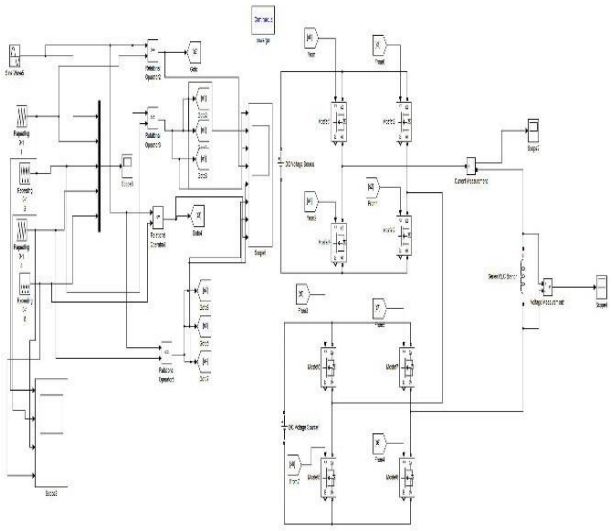


Fig 1: 1-phase 5-level CHB Inverter

In this diagram, total 8 MOSFETS are used and, it gives us the output of 5-level voltage. The output is then provided to a resistive load. Comparison of the triangular wave and the sinusoidal wave generates the pulses. For 5-level output, (n-1) triangular waves are taken. This means that 4 triangular Wave forms are required, which are compared to the sinusoidal waveform and thus each MOSFET is given a pulse with necessary time gap.

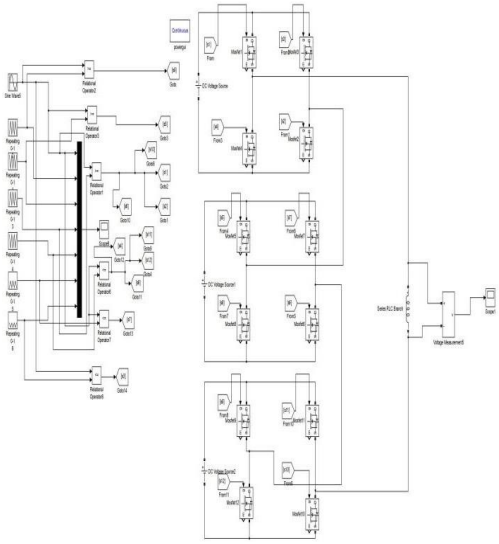


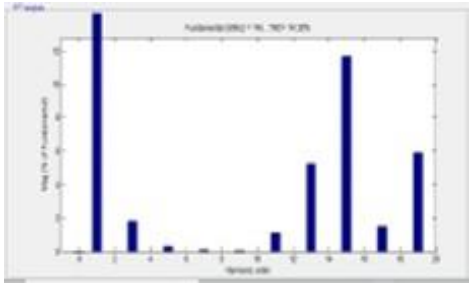
Fig 2: 1-phase 5- level CHB Inverter

IV SINGLE-PHASE 7-LEVEL CHB MULTI- LEVEL INVERTER

In figure 2, the 7-level CHB Multi Level Inverter has improved efficiency and better THD handling. It has reduced Harmonic Distortion than five-level MLI. This model is by far the best model which we made. It gave the best simulation results and least THD in the output.

V LEVEL SHIFTED MODULATION SCHEME: Multiple carrier pulse modulation

In the number of multi-level SPW, for '*n*' level inverter '*n*-1' carriers are used. These are following three types



1. IN- PHASE DIPOSITION (IPD)

In this all the carries are in phase with respect to each other.

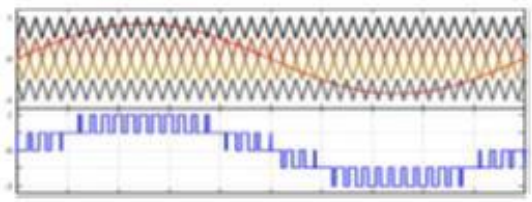


Fig 3: PD-PWM

2. PHASE OPPOSITIONDISPOSITION (POD)

From all the above technique, APOD TECHNIQUE has the least THD. So, the above simulations are done by using APOD technique.

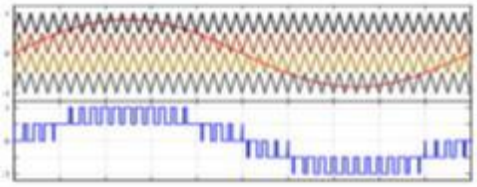


Fig 4: POD-PWM

3. ALTERNATE PHASE OPPOSITION DISPOSITION (APOD)

APOD technique needs every (x – 1) carrier waveform, for an x-level phase waveform, to be displaced by phase from each other by 180º alternately.

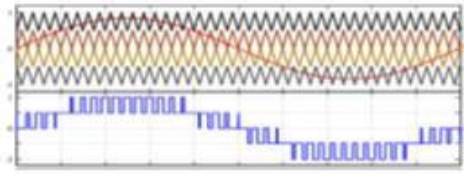


Fig 5: APOD-PWM

From all the above technique, APOD TECHNIQUE has the least THD. So, the above simulations are done by using APOD technique.

VI SIMULATION RESULTS

In this section we will be showing the simulation result of both the simulations. The output we get at the load side and the FFT analysis of both the simulation when we used APOD technique.

Fig 6: The First Fourier Transform Analysis of 7-level multi-level inverter with APOD

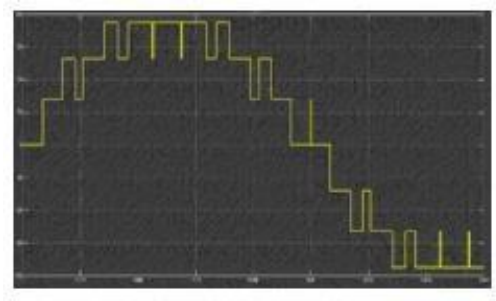


Fig 7: Image of the output waveform of a 7-level multi-level inverter with APOD

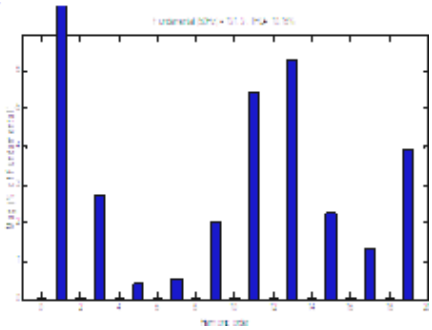


Fig 8: The First Fourier Transform Analysis of 5-level multi- level inverter with Alternate Phase Opposition Disposition

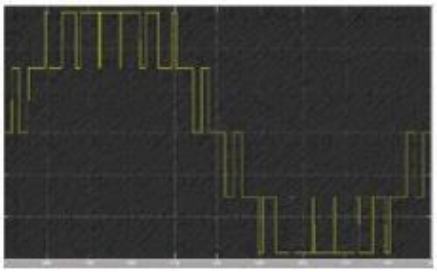


Fig 9: Image of the output waveform of a 5-level multi-level inverter with Alternate Phase Opposition Disposition

CONCLUSION

The Simulation results shows the performance and effectiveness of 1-Φ multi-level inverter and 7-step multi-level inverter of the proposed circuit for R- load, the result obtained is having 5-level and 7- level of voltage and current .form by using all the three PWM techniques like as:- IPD,POD,APOD. After the comparison of the THD values obtained from all the techniques we have concluded that APOD is much better than other two techniques for the practical approach.

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