A COMPARATIVE ANALYSIS OF THD IN FUZZY CONTROLLER BASED SYMMETRIC AND ASYMMETRIC MULTILEVEL INVERTER

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Abstract—The necessity of increasing power quality in the past years lead to the development of inverter. An inverter is a device which converts the direct current (DC) into an alternating current (AC) without changing the magnitude. In this project hybrid multilevel inverter is used, which is a combination of diode clamped MLI & H-bridge inverter. The 9 levels of symmetric and 31 level of asymmetric multilevel inverter is illustrated and the gate triggering pulse is given by fuzzy logic controller in the feedback. Fuzzy logic control technique enables better selective harmonic reduction in the output AC voltage. The results are compared between symmetrical & asymmetric MLI. The simulation is done using MATLAB/Simulink.

Keywords-Multilevel inverter (MLI), Fuzzy logic control (FLC)

I. INTRODUCTION

Power electronic inverters are widely used in various industrial drive applications. To overcome the problems of the limited voltage and current ratings of power semiconductors devices, some kinds of series and/or parallel connections are necessary. Recently, the multilevel inverters have received more attention in literature due to their ability to synthesize waveforms with a better harmonic spectrum and to attain higher voltages. They are applied in many industrial applications such as ac power supplies, static VAr compensators, and drive system, etc. One of the significant advantages of multilevel configuration is the harmonics reduction in the output waveform without increasing switching frequency or decreasing the inverter power output. These multilevel inverters, in case of \( m \)-level, can increase the capacity by \((m-1)\) times than that of two-level inverter through the series connection of power semiconductor devices without additional circuit to have uniform voltage sharing. Comparing with two level inverter system having the same capacity, multilevel inverters have the advantages that the harmonic components of line to line voltages fed to load, switching frequency of the devices and EMI problem could be decreased.

The output voltage waveform of a multi level inverter is composed of a number of levels of voltages starting form three levels and reaching infinity depending upon the number of the dc sources[3]. The main function of a multilevel inverter is to produce a desired ac voltage
waveform from several levels of dc voltage sources. These
dc voltages may or may not be equal to one another. The
dc sources can be obtained from batteries, fuel cells, or
solar cells. Conventionally, each phase of a cascaded
multilevel converter requires ‘n’ dc sources for 2n + 1
levels in applications that involve real power transfer.
These dc sources are assumed to have identical
amplitudes. The advantages of the multilevel inverters
(MLI) include: 1) they provide even voltage sharing, both
statically and dynamically 2) substantial reduction in size
and volume is possible due to the elimination of the bulky
coupling transformers or inductors and 3) multilevel
inverters can offer better voltage waveforms with less
harmonic content and, thus, can significantly reduce the
size and weight of passive filter components.

Several multilevel inverter topologies are
proposed over the past few years, the most popular
multilevel inverters which are mostly used are Diode-
clamped, Flying capacitor and the H-bridge multilevel
inverter. One aspect which sets the cascaded H-bridge
apart from other multilevel inverter is the capability of
utilizing different DC voltages on the individual H-bridge
cell which results in splitting the power conversion among
high voltage low frequency and low voltage high
frequency inverters. An alternate method of cascading
involves series connection of two three phase inverters
through the neutral point connection of the load.

The output of the MLI is controlled and changed
according to the desired level by the triggering pulse given
to the gate terminal of the semiconductor switches. This
method of controlling the output is known as modulation
technique. There are several types of PWM modulation
technique controlling the output voltage by changing
the pulse from the PWM modulation technique. The pulses
from the PWM technique is obtained by comparing the
carrier signal and the sampling signal. This pulse is given
as a triggering pulse to the gate terminal of the power
switching devices which is used to turn ON and OFF the
power devices.

There are several modulation techniques for
controlling the multilevel inverter topologies,

1. Step modulation

2. Sinusoidal PWM
3. Space vector modulation
4. Selective PWM harmonic
5. Modified sinusoidal PWM
6. Multiple pulses PWM.

II. CMLI USING HYBRID TOPOLOGY

Multilevel inverters are used to handle high power and
high voltage in power system applications. The symmetric
and asymmetric multilevel inverter with closed loop is used
to control the output voltage. The diode clamped multilevel
inverter is cascaded with the H-bridge forming a hybrid
topology. In symmetric multilevel inverter the dc sources
used is equal to Vdc. By using symmetric topology high
modularity is achieved. In asymmetric multilevel inverter
different dc sources are used. Asymmetric topology using
less number of switches to produce a high number of
voltage.

Both symmetric and asymmetric multilevel inverter
topology consists of two parts, the level creator part and
the H-bridge part. The level creator part produces the
output voltage which is always positive and the H-bridge is
used at the output to change the polarity. By using fuzzy
controller in the feedback to maintain the output voltage
constant.

III BLOCK DIAGRAM

![Fig.1 Block diagram of the system.](image-url)
The block diagram for the constant output of the multilevel inverter is shown in fig.1. In this diagram consists of converter, inverter, fuzzy logic controller, sinusoidal pulse width modulation.

By applying AC source voltage to the hybrid inverter which combines the diode clamped multilevel inverter and H-bridge inverter. By using twelve switches in hybrid multilevel inverter with each switch have one different voltage to generate the eleven step voltage of symmetrical output. The eleven step output is applied to fuzzy controller to maintain the constant output. A reference voltage is given to the fuzzy logic controller. The controller is used to check any difference in output voltage. Is there any deviation in output, the controller to compensate the output voltage and spwm signal for the switch is varied. The output of the inverter is in simulation diagram.

By applying AC source voltage to the hybrid inverter which combines the diode clamped multilevel inverter and H-bridge inverter. By using twelve switches in hybrid multilevel inverter with each switch have two different voltage to generate the twenty one step voltage of asymmetrical output. The twenty one step output is applied to fuzzy controller to maintain the constant output. A reference voltage is given to the fuzzy logic controller. The controller is used to check any difference in output voltage. Is there any deviation in output, the controller to compensate the output voltage and spwm signal for the switch is varied. The output of the inverter is in simulation diagram.

IV. SYSTEM CONFIGURATION

In sinusoidal PWM instead of maintaining the width of all pulses the same as in the case of multiple PWM, the width of each is varied in proportion to the amplitude of a sine wave evaluated at the same pulse. The distortion is reduced significantly compared to multiple PWM.

V. FUZZY LOGIC CONTROLLER

Fuzzy systems have attracted the interest of researchers in various scientific and engineering areas. The number and variety of applications of fuzzy logic have been increasing, ranging from consumer products and industrial process control to medical instrumentation, information systems and decision analysis. A fuzzy logic controller is designed to work with the structured knowledge in the form of rules and nearly everything in the fuzzy system remains highly transparent and easily interpretable. However, there exists no formal framework for the choice of various design parameters and optimization of these parameters generally is done by trial and error.

Fuzzy-logic control has the capability to control nonlinear, uncertain and adaptive systems with parameter variation. Fuzzy control does not strictly need any mathematical model of the plant. Its control rule can be
A comparative analysis of THD in fuzzy controller based symmetric and asymmetric multilevel inverter

V. FUZZY CONTROL RULES

In fuzzy control, we can distinguish two types of fuzzy rules: Mamdani rules and Sugeno rules. The Mamdani rules are the rules we have considered thus far in this thesis. The Sugeno rules are based on a different principle: the consequents of those rules are (linear) functions of the controller inputs.

MAMDANI FUZZY RULES:

The conjunction of fuzzified inputs is usually done by either min or product operation (we use product operation) and for generating the output max or sum operation is generally used for Defuzzification, we have used simplified reasoning method, also known as modified center of area method. For simplicity, triangular fuzzy sets will be used for both input and output. The whole working and analysis of fuzzy controller is dependent on the following constraints on fuzzification, Defuzzification and the knowledge base of an FLC, which give a linear approximation of most FLC implementations.

CONTRAINT 1: The fuzzification process uses the triangular membership Function.

CONTRAINT 2: The width of a fuzzy set extends to the peak value of each adjacent fuzzy set and vice versa. The sum of the membership values over the interval between two adjacent sets will be one. Therefore, the sum of all membership values over the universe of discourse at any instant for a control variable will always be equal to one. This constraint is commonly referred to as fuzzy partitioning.

CONTRAINT 3: The Defuzzification method used is the modified center of area method. This method is similar to obtaining a weighted average of all possible output values.

The conjunction of fuzzified inputs is usually done by either min or product operation (we use product operation) and for generating the output max or sum operation is generally used for Defuzzification, we have used simplified reasoning method, also known as modified center of area method. For simplicity, triangular fuzzy sets will be used for both input and output.
This type of fuzzy rule was used in the first reported applications of fuzzy control and has the following general Form:

$$r_k: \text{if } x_1 \text{ is } A_1^k \text{ and } \ldots \text{ and } x_N \text{ is } A_N^k, \text{ then } y_1 \text{ is } B_1^k, \ldots, y_N \text{ is } B_N^k$$

This is the same type of fuzzy rule considered thus far in this thesis. An example of such a fuzzy control rule is: if error is big and error change is small then control signal is big

Normally the min operator is used for conjunction and implication, the max operator for aggregation and max-min composition. This is known as the max-min inference method.

VII. SIMULATION RESULTS

1) RESULT OF SYMMETRIC MULTILEVEL INVERTER

In this symmetric multilevel inverter 12 IGBT is used. In this the diode clamped and H-bridge inverter is cascaded thus forming a hybrid topology. Basically the inverter operation is to convert the variable DC into an AC. The input dc source is given by using batteries or photo voltaic cells to the cascaded circuit. Here fuzzy logic controller is used to control the output voltage of the inverter. By using sinusoidal pulse width modulation technique the triggering pulse given to the switches are controlled.

By using the sinusoidal pulse width modulation control we can control the output by changing the magnitude and the modulation index value of the reference and carrier waveform. Mostly the carrier wave is triangular wave and the sampling wave is either we take DC signal as reference or we take sine wave. The gate triggering is very important in the IGBT device compared to many semiconductor power devices IGBT device has the fast switching characteristics and high speed applications, so this device is mostly used in the inverter circuits nowadays.

In this symmetric multilevel inverter it consists of two parts as level creator part and a H-bridge part. The input voltage to the dc source is 43V. The level creator part produces a output voltage which is always positive and the H-bridge part is to change the polarity of the output. The voltage at the output of the level creator part is about 170V. The output voltage at the output is 133V. The THD get reduced to 18.29%.

2) RESULT OF ASYMMETRIC MULTILEVEL INVERTER

In this asymmetric multilevel inverter the voltage given to the dc sources are different. The level creator part
produces a voltage which is positive. The output from the level creator part is given to the H-bridge part, thus the H-bridge changes the polarity of the output voltage. 12 IGBT is used to create the 31 level at the output. The frequency from the output voltage is given back to the input side by using a fuzzy logic controller. The input voltage given to the dc source are 180V, 90V, 45V, 23V. The output voltage at the level creator part is 220V and the output of the h-bridge is 269V. From the output voltage the frequency is feed back to the input by fuzzy logic controller. The THD get reduced to 11.51%.

VIII. CONCLUSION

The disturbances in power electronics equipment are often periodic and rich in higher harmonics. They have been frequencies and are often above the bandwidth of regulators used to control fundamental components. Therefore the ‘regular’ control can only partially reduce their effects on the distortion of control variables.

The cascade multilevel inverter with unequal DC sources and equal DC sources are illustrated and the gate triggering pulse is given by fuzzy logic controller in the feedback. Here the inverter power device circuit used is IGBT device and it has the better switching frequency and gate control compared to all other semiconductor switching devices such as power MOSFET, SCR, TRIAC etc. This fuzzy logic control technique enables us to obtain better selective harmonic reduction in the output AC voltage. Finally, we obtained the output AC voltage waveform and their frequency spectrums. Besides that, it realized better multilevel output and achieved desired results.

In this first phase, 9 levels of symmetric and 31 level of asymmetric multilevel inverter output voltage is obtained using fuzzy logic controller. The future work, the number of levels is increase in the cascaded multilevel inverter in order to reduce the selective harmonics elimination and to increase the voltage gain and power quality.

IX. COMPARISON BETWEEN SYMMETRIC & ASYMMETRIC MLI

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<th>INVERTEER</th>
<th>No. of switches</th>
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REFERENCES
