International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE) Vol 2, Issue 4, April 2016

Fuzzy Logic Based Harmonic Minimization In Cascaded Multilevel Inverter

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***Abstract*: There are numerous constraints in removing power from renewable vitality assets. To minimize the power shortage and to fulfill the power demand, power removing strategies must be progressed. Multilevel inverter is utilized to concentrate power from solar cells. The Cascaded H-Bridge (CHB) converter is one of the prominent sorts of Multi Level Inverter (MLI) as a result of its particular structure and high quantities of repetitive switching states. Harmonics in multilevel are because of shameful determination of switching angles to the entryways of the inverter switches. Nearness of harmonics prompts unintentional stumbling of transfers and inaccurate estimation of voltage and current by transformers. The proposed work manages particular selective harmonic elimination using fuzzy logic control to generate switching angle for the eleven levels cascaded h bridge controlled by five variable dc sources. The modulating switching angles are upgraded at every cycle of the yield crucial voltage. Results are checked utilizing MATLAB/SIMULINK environment.**

***Index Terms*- Multilevel inverter, selective harmonic elimination, switching angle, fuzzy logic controller.**

I. INTRODUCTION

Nowadays, multilevel inverters have become more attractive for their use in high-voltage and high-power applications. In multilevel inverters, the desired output voltage is achieved by suitable combination of multiple low dc voltage sources used at the input side. As the number of dc sources is increased, the output voltage becomes closer to a pure sinusoidal waveform. The required dc sources can be chosen from different of sources such as batteries, photovoltaic, fuel cells, capacitors, the rectified output voltage of wind turbines, and other similar dc sources.

Multilevel inverter is to synthesis a near sinusoidal voltage from several levels of dc voltages, typically obtained from battery sources. As the number of levels increases, the synthesized output waveform has more steps, which produce a staircase wave that approaches a desired waveform. Multilevel inverter is generally classified into to types, namely,

- Symmetrical inverter
- Asymmetrical inverter

In symmetrical inverter all the H bridges are provided with equal DC sources. Whereas, in asymmetrical inverter H bridges are provided with unequal dc sources. Following are the topologies of multilevel inverter.

1. Diode Clamped Multilevel Inverter
2. Capacitor Clamped Multilevel Inverter
3. Cascaded H-Bridge Multi level Inverter

The Cascaded H-Bridge (CHB) converter is one of the popular types of Multi Level Inverter (MLI) because of its modular structure and high numbers of redundant switching states, which are attractive features of this topology. On the other hand, the requirement of multiple isolated DC sources is considered the main drawback of this topology. However, in applications such as photovoltaic systems (PV) in which multiple DC sources are readily available, this drawback appears to be an advantage point.

II. CASCADED H BRIDGE MULTILEVEL INVERTER

A cascaded multilevel inverter made up of from series connected single full bridge inverter, each with their own isolated dc bus. Output voltage of an M level inverter is the sum of all the individual inverter outputs.

$$V_{dc} = V_{dc1} + V_{dc2} + V_{dc3} + V_{dc4} + V_{dc5} \quad (1).$$

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Each of the H-bridge's active devices switches only at the fundamental frequency, and each H-bridge unit generates a quasi-square waveform by phase shifting its positive and negative phase legs switching timings. Further, each switching device always conducts for 180˚ (or half cycle) regardless of the pulse width of the quasi square wave so that this switching method results in equalizing the current stress in each active device. IGBT or MOSFET can be used as power semiconductor switches. To form a single H bridge four semiconductor switches are needed which may be IGBT or MOSFET.

By connecting N cells in cascade 2N+1 levels in output voltage can be obtained. Each Cells triggers at different switching angle. There are different ways to control multilevel inverters. One of the general control methods is fundamental frequency switching scheme. Switching angle for each cell is calculated using selective harmonic elimination method. Fig 1 shows the eleven level cascaded H bridge Multilevel Inverter. And output of this Cascaded H bridge Multilevel inverter is shown in the Fig 2.

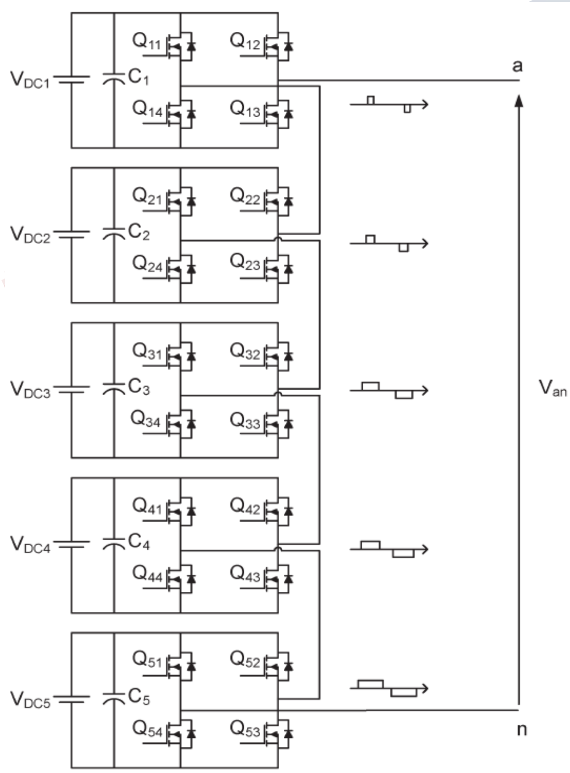

Fig.1 Cascaded H Bridge Multilevel Inverter

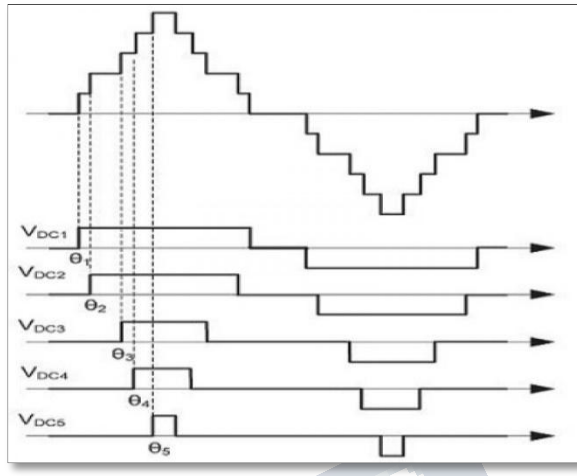

Fig. 2 Output waveform of Eleven level inverter

III. SELECTIVE HARMONICS ELIMINATION

One of the main challenges in the field of multilevel inverters is the control of switching angles in order to eliminate low order harmonics from output voltage. The principle of the SHEPWM is to compute the suitable switching angles so as provide an output waveform without certain lower harmonics order.

In our study the target is to cancel the 5^{th}, 7^{th}, 11^{th} and 13^{th} harmonics and to control as well as possible the fundamental voltage at the same time. Switching angle is calculated by solving the following equation. For the 11 level inverter five equations are needed to obtain the switching angles.

$$V_1\cos(\alpha1)+V_2\cos(\alpha2)+\ldots\ldots\ldots\ldots+V_5\cos(\alpha5)=(\pi*V_{fund}/4*V_{dc}) \quad (2)$$

$$V_1\cos(5\alpha1)+V_2\cos(5\alpha2)+\ldots\ldots\ldots V_5\cos(5\alpha5)=0 \quad (3)$$

$$V_1\cos(7\alpha1)+V_2\cos(7\alpha2)+\ldots\ldots\ldots V_5\cos(7\alpha5)=0 \quad (4)$$

$$V_1\cos(11\alpha1)+V_2\cos(11\alpha2)+\ldots\ldots V_5\cos(11\alpha5)=0 \quad (5)$$

$$V_1\cos(13\alpha1)+V_2\cos(13\alpha2)+\ldots\ldots V_5\cos(13\alpha5)=0 \quad (6)$$

Where α1, α2 will be the firing angle of the bridges respectively. The Newton-Raphson method, or Newton Method, is a powerful technique for solving equations numerically. Like so much of the differential calculus, it is based on the simple idea of linear approximation. The Newton Method, properly used, usually homes in on a root with devastating efficiency. In order to eliminate N harmonics N+ 1 equation are needed. The above equations are solved using Newton Raphson method. Numbers of iterations are used for solving above equations. Firing angle (or) switching angle is different for each bridge.

IV. FUZZY LOGIC CONTROLLER

The fuzzy logic controller (FLC) requires that each control variables which define the control surface be expressed in fuzzy set notations using linguistic labels. A fuzzy logic system consists of three main blocks: fuzzification, inference mechanism, and defuzzification. The following subsections briefly explain each block, and characterize them with regard to the type of fuzzy system we used. Figure 3 shows the block diagram of fuzzy logic control.

A. Fuzzification

Fuzzification is a mapping from the observed numerical input space to the fuzzy sets defined in the corresponding universes of discourse. For each input and output variable selected, we define two or more membership functions (MF), normally three but can be more. We have to define a qualitative category for each one of them, for example: low, normal or high. The shape of these functions can be diverse but we will usually work with triangles and trapezoids (actually usually pseudo-trapezoids) . For this reason we need at least three (for triangles) or four (for trapezoids) points to define one MF of one variable.

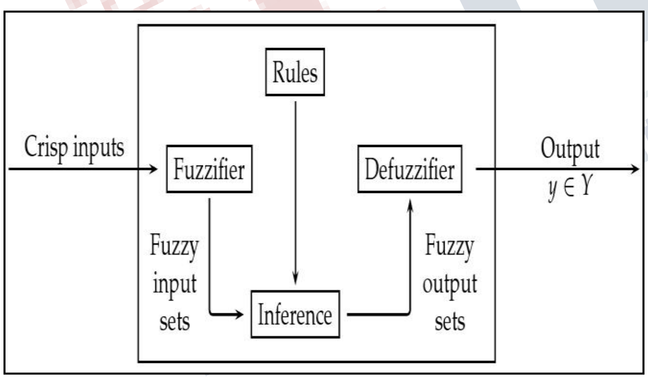

Fig.3 Block Diagram of Fuzzy logic control

B. Rule Base

Once the input and output variables and MF are defined, we have to design the rule-base (or decision matrix of the fuzzy knowledge-base) composed of *expert* IF <antecedents> THEN <conclusions> rules. These rules transform the input variables to an output that will tell us the risk of operational problems (this output variable, risk of a problem, also have to be defined with MF, usually low, normal and high risk). Depending on the number of MF for the input and output variables, we will be able to define more or less potential rules. The easier case is a rule base concerning only one input and one output variable.

C. Defuzzification

The fuzzy set representing the controller output in linguistic labels has to be converted into a crisp solution variable before it can be used to control the system. This is achieved by using a defuzzifier. Several methods of defuzzification are available. Of these, the most commonly used methods are i) Mean of Maxima (MOM) and ii) Centre of Area (COA). Most control applications use the COA method. This method computes the centre of gravity of the final fuzzy space (control surface) and produces a result which is sensitive to all the rules executed. Hence, the results tend to move smoothly across the control surface.

Various voltage levels of the h bridges are given as input to the fuzzy logic controller. Triangular membership function is used. If the number of membership function in output variable is more error to input- output is minimized..For each input and output number of membership functions can be defined. Switching angle is obtained as output in fuzzy logic controller. Output of the fuzzy controller is based on the IF – THEN rules. Various combination of membership function is used to create the rules

V. GATE PULSE GENERATION

In order to get gate pulse, selective harmonic elimination pulse width modulation (SHEPWM) is used. In this method Switching angle is compared with triangular wave. Switches of the bridges will be triggered when the gate pulse is applied. Switches 1 and 3 , or 2 and 4 can be triggered at time.

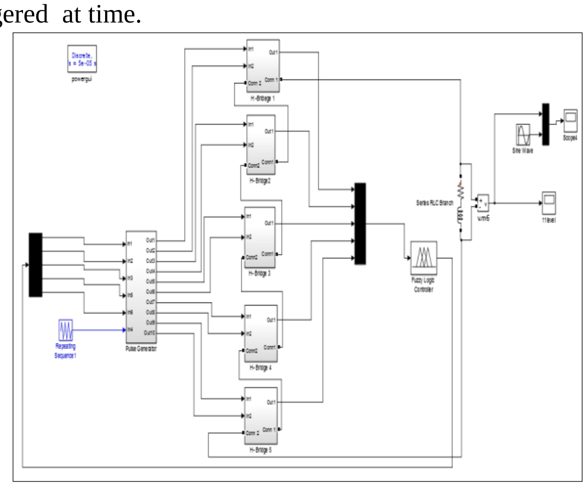

Fig. 4 Simulink diagram of the multilevel inverter with fuzzy logic

In the fig.4 five H bridges are connected in cascade. Fig.5 shows the subsystem of an H Bridge. All H bridges are made in similar manner. Output of the pulse generator is given as input to each H bridge.

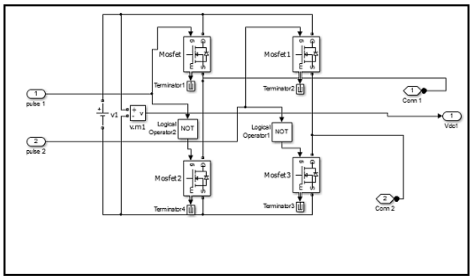

Fig.5 Subsystem of single H Bridge

Here NOT gate is used to invert the gate pulses. In the pulse generator magnitude of the triangular wave is chosen as 90 because switching angle of the switch varies between 0 to 90 degree**.**

VI. RESULT

A. Simulation Result

Fig. 6 shows the output waveform of the system. Harmonic analysis is done using FFT in MATLAB/ SIMULINK environment.

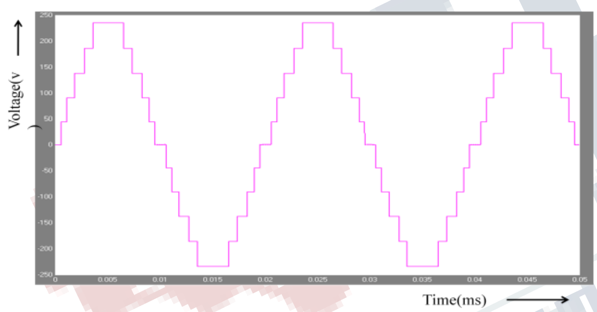

Fig. 6 Output Waveform

By FFT analysis magnitude of the 5,7,11 and 13th order harmonics is measured which is much lower than 9 level inverter. THD is measured as 9.59 which is shown in the fig 7.

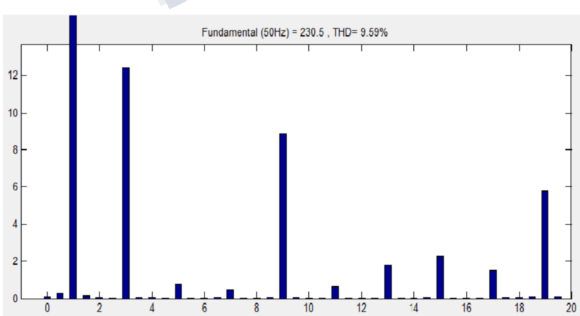

Fig 7 FFT analysis of output voltage

B. Hardware Implementation

While implementing the hardware of this project PIC 16F677A series is used to generate the gate pulse for the MOSFET. PIC microcontroller generates the gate pulse based on the variable DC source.

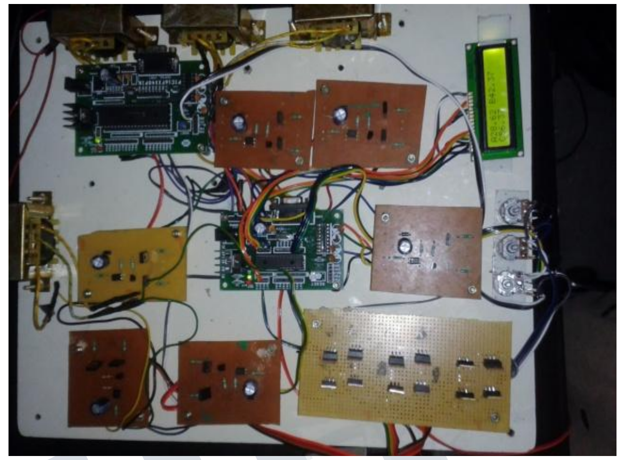

Fig. 8 Hardware setup

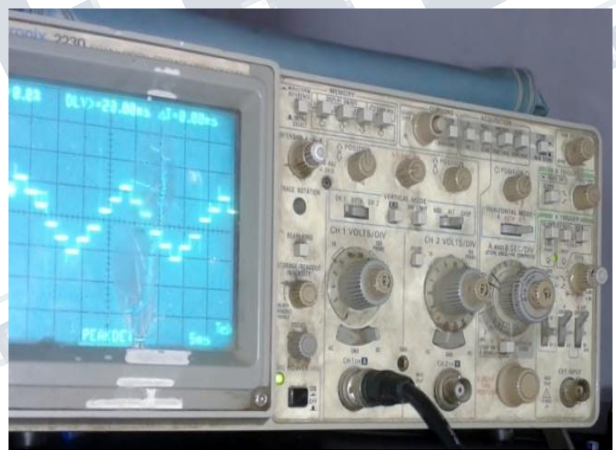

Fig. 9 Output waveform in DSO

Variable dc source is measured using voltage divider and given as input to the PIC microcontroller. Variable dc source can be given using solar panels and Regulated power supply. Firing angle is displayed using LCD display. Output of the multilevel inverter is shown in Digital Storage Oscilloscope. Figure 8 shows the hardware of multilevel inverter. Figure 9 shows the output in DSO.

VII. CONCLUSION

Different factors affect the values of dc voltage sources used in multilevel inverters and usually there is a percent of changes in the values of dc sources. Therefore, in this paper, the low order harmonics elimination method for multilevel inverters, considering dc sources variations is evaluated. From this viewpoint, the switching angles tuning based for the goal of low order harmonics elimination and maintaining the fundamental component at pre-specified value on modulation index variations in the presence of dc voltages variations is verified and confirmed its impracticability. A model For 11 level cascaded H bridge inverter using fuzzy logic has been presented in this paper. The main concept underlying the proposed technique is to reduce the harmonic. The developed model is implemented in MATLAB/SIMULINK software and Hardware.

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