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Power Quality Enhancement by Reduction of Harmoins using Fuzzy Logic

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Abstract: **-- In today's commercial world, multilevel inverters is playing a significant role from power failure. Harmonics is a major problem in power systems that have become serious recently owing to the wide use of power electronics related equipment. In this process, there is a possibility of generation of harmonic peaks because majority of the power utilities are non-linear loads. A high performance multilevel inverter should have a clean output voltage with low total harmonic distortion (THD) for both linear and non linear loads. Harmonic distortion is the most important power quality problem occurring in multilevel inverter, the harmonics can be eliminated by an optimal selection of switching angles. A hybrid evaluation technique evaluates the obtained optimal switching angles that are attained from the fuzzy inference system as well as neural network. The proposed technique is tested with a seven level cascaded H-bridge inverter. The proposed method will be implemented in MATLAB working platform and the harmonic elimination performance will be evaluated.**

Keywords:-- **Power quality, Harmonics, Switching angles, THD, Multilevel inverter.**

I. INTRODUCTION

Power electronic equipment usually introduces Current harmonics. These current harmonics result in problems such as a low power factor, low efficiency, power system voltage fluctuations and communications interference. Irrespective of variations in the input source or load condition, maintaining a constant voltage and constant frequency supply for critical loads. Harmonics are undesirable sinusoidal voltages or currents present in power systems that have frequencies which are integer multiples of the frequencies of the supply system [1]. By polluting the input supply of sensitive equipments harmonics introduced by non linear loads can cause faulty operation of the connected equipments [2]. Current is drawn in a non sinusoidal manner by the non linear loads that are connected to the sinusoidal supply voltage [3]. Harmonic current source and harmonic voltage source are the two types harmonic sources into which non linear loads can be categorized [4].

A Multilevel inversion known by the power conversion approach diminishes the total harmonic distortion (THD) by getting the output voltage in steps and taking the output nearer to sine wave [5]. Generating an estimated sinusoidal voltage from multiple stages of dc voltages usually got from capacitor voltage sources is the general objective of multilevel inverters [6].

In early APF designs, PWM based methods such as constant frequency control, sliding mode control, hysteresis control, and triangular waveform control are used to control the switches in the APF with time domain approach. The main shortcoming of this method is that, in order to obtain optimum results, relatively high switching frequencies are needed, which subsequently leads to high switching losses. Frequency domain methods include predetermined harmonic injection and PWM based techniques such as optimized injection method and adaptive frequency control are proposed as alternative to time domain approach. The switching frequencies for frequency domain methods can be much lower than time domain schemes, resulting in much lower switching losses. The main disadvantage of frequency domain method is longer computational time than time domain methods.

Nowadays high speed processor available to reduce computational time in practical. Whether it may be time domain or frequency domain approach, the conventional APFs are too complex and costly in practical, when the quantity to be controlled varies over a wide range. Hence an increasingly attractive alternative is to use artificial intelligent (AI) control schemes such as fuzzy logic, neural network, embedded system etc.

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The proposed hybrid technique reduces the harmonics by combining the fuzzy logic and the neural network. This technique can eliminate harmonics selectively by optimally and adaptively choosing the switching angles of the multilevel inverter. By selecting optimal switching angles, harmonics generation can be avoided in cascaded H-bridge multilevel inverter.

II. MULTILEVEL CONVERTERS

There are several types of multilevel converters. The three main types of multilevel converters are: diode-clamped multilevel converters, flying-capacitor (also referred to as capacitor-clamped) multilevel converters, and cascaded h-bridges multilevel converters**.**

At this point, it seems appropriate to discuss the difference between the terms "multilevel converter" and "multilevel inverter." The term "multilevel converter" refers to the converter itself. The main function of a multilevel inverter is to produce a desired ac voltage waveform from several levels of dc voltages. These dc voltages may or may not be equal to one another. The ac voltage produced from these dc voltages approaches a sinusoidal. The traditional two or three levels inverter does not completely eliminate the unwanted harmonics in the output waveform. Therefore, using the multilevel inverter as an alternative to traditional PWM inverters is investigated.

In this topology the number of phase voltage levels at the converter terminals is 2N+1, where N is the number of cells or dc link voltages. In this topology, each cell has separate dc link capacitor and the voltage across the capacitor might differ among the cells. So, each power circuit needs just one dc voltage source. The number of dc link capacitors is proportional to the number of phase voltage levels .Each H-bridge cell may have positive, negative or zero voltage. Final output voltage is the sum of all H-bridge cell voltages and is symmetric with respect to neutral point, so the number of voltage levels is odd.

Cascaded H-bridge multilevel inverters typically use IGBT switches. These switches have low block voltage and high switching frequency.

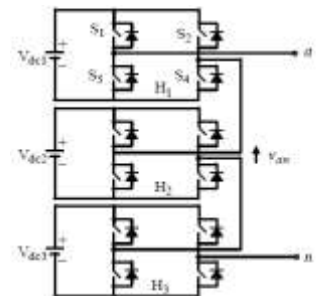

Fig 1. Cascaded h-bridge 7-level inverter

Consider the seven level inverter; it requires 12 IGBT switches and three dc sources. The power circuit of inverter is shown in the figure 1. A cascaded H-bridges multilevel inverter is simply a series connection of multiple H-bridge inverters. Each H-bridge inverter has the same configuration as a typical single-phase full-bridge inverter.

The output from the inverter is a periodically alternating staircase waveform, not a sinusoidal waveform as expected. The output waveform is far from an ideal sine waveform. The output waveform from the inverter contains harmonics. Mathematically, the waveform is a summation of an infinite series of harmonics. The magnitude of the harmonic number. Harmonics must always be limited below threshold levels.

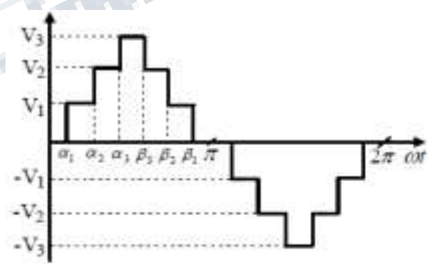

Fig 2. Output waveform

The cascaded H-bridges multilevel inverter introduces the idea of using Separate DC Sources (SDCSs) to produce an AC voltage waveform. Each H-bridge inverter is connected to its own DC source Vdc. By cascading the AC outputs of each H-bridge inverter, an AC voltage waveform is produced. By closing the appropriate switches, each H-bridge inverter can produce three different voltages: +Vdc, 0 and -Vdc. It is also possible to modularize circuit layout and packaging because each level has the same structure, and there are no extra clamping diodes or voltage balancing capacitors. The output waveform shown in fig 2.This circuit is simulated using the MATLAB software.

III. HYBRID EVALUATION OF SWITCHING ANGLES

The proposed technique performs a hybrid evaluation to determine the optimal switching angles, which can reduce the generation of harmonics in the multilevel inverter. The entire technique considers the requirement of eliminating the harmonics generation by selectively mitigating any of the harmonics. In other words, the technique can mitigate the selected harmonics and so the entire harmonics generation. Accordingly, the technique determines the voltage pattern that has minimum *Hth* order harmonics voltage. For instance, if the 5th order and 7th order harmonics are to be strictly mitigated in eliminating the harmonics generation, the harmonic voltage 5 *V* and 7 *V* should be very small. From the data set the switching angle pattern corresponding to the selected harmonic voltage pattern is determined. To perform the selective mitigation, the selection factors have to be given as input. Then, iterative approach is initiated with the generation of switching angles in their intervals. In the approach, a pool of arbitrary vectors are generated as follows

$$Z_a = [\alpha_0^{(a)}\ \alpha_1^{(a)} \dots\dots\dots \alpha_{N_l-1}^{(a)}]; \quad 0 \le a \le P_{size} - 1$$

where, Z_a is the a^{th} vector present in the pool and $\alpha_j^{(a)}$ is the jth switching angle of a^{th} vector. Every vector in the pool needs to satisfy the constraint,

$$\alpha_0^{(a)} < \alpha_1^{(a)} < \cdots < \alpha_{l-1}^{(a)}$$

The generated vector is evaluated by inputting vector to the trained FIS and the neural network. From the obtained output vectors, the evaluation factor is determined as follows

$$E_f^{(a)} = 0.3\left[\beta_1 THD_a^{net} + \beta_2 THD_a^{FIS} + (THD_a^{net} - THD_a^{FIS})^2\right]$$

where, $E_f^{(a)}$ is the evaluation factor for every arbitrary vector, THD_a^{net} and THD_a^{FIS} are the total harmonic distortion, when the a^{th} vector is the switching angle pattern estimated by the neural network and FIS, respectively and b1 and b2 are constants. The THD can be determined as follows

$$THD_a^{net} = \frac{1}{\left|V_{out\,1}^{(a)}\right|}\sqrt{\sum_{H=3,5..}^{N_H} \sigma_H \left|V_H^{(a)}\right|^2}$$

where, $V_{out\,1}^{(a)}$ and $V_H^{(a)}$ are the fundamental voltage estimated by the neural network for the a^{th} vector and the h^{th} order harmonics voltage respectively and σ_H is the selection factor for h^{th} order harmonics. From the pool, $P_{size}/2$ vectors that have minimum evaluation factor are selected and subjected to vector replacement. In the vector replacement operation, the vector that has the least evaluation factor is obtained. Based on the vector, the replacement of elements of the remaining vector are performed as follows

$$\alpha_j^{new} = \begin{cases} \dfrac{\alpha_j^2 + 1}{\alpha_j} \; ; \; \alpha_j < \alpha_j^{least} \\ \alpha_j \; ; \; \alpha_j = \alpha_j^{least} \\ \dfrac{\alpha_j^2 - 1}{\alpha_j} \; ; \; \alpha_j > \alpha_j^{least} \end{cases}$$

where, α_j^{new} is the j^{th} new switching angle and α_j^{least} is the j^{th} switching angle, which is obtained from the vector that has the least evaluation factor. Thus obtained new vectors are subjected to satisfy the constraint given in above equation. Once the vector elements replacement is done, $P_{size}/2$ vectors are obtained. They are placed in the pool along with the selected $P_{size}/2$ vectors so as to make the pool size to be *P size* . The entire process is repeated until the number of iterations reaches I_{max} . Once the maximum number of iterations is reached, the process is terminated and the vector which has the least evaluation factor is obtained from the pool. The resultant vector has the optimal switching angles that can prevent the generation of harmonics for the given multilevel inverter, by selectively mitigating the given harmonic elements.

IV. SIMULATION RESULTS AND DISCUSSION

The implementation of the proposed technique is performed in the working platform of MATLAB (version 7.10) and we have utilized the provided fuzzy and neural network toolboxes. In the evaluation phase, we have considered that the multilevel inverter type of H-bridge inverter, which is responsible for generating the harmonics affected voltage waveforms. The inverter

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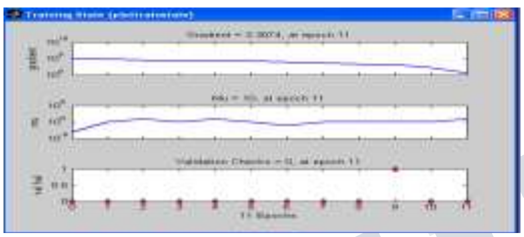
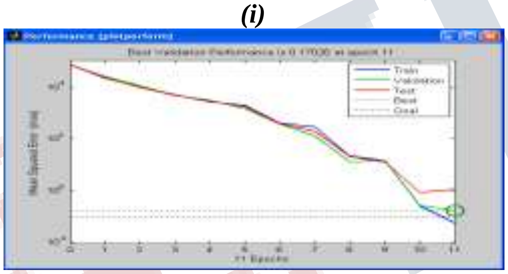
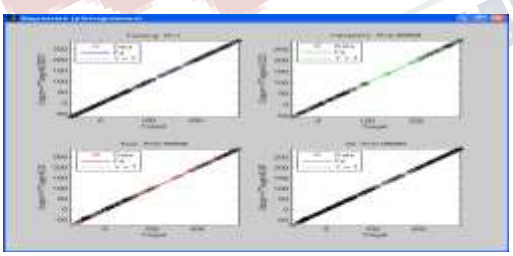
has 3 H-bridges and so 3 switching angles α_0, α_1 and α_2 are need to be selected optimally. The technique is implemented in such a way that it can eliminate the 3^{rd} order and 5^{th} order harmonics and so it can minimize the total harmonic distortion. During the generation of fuzzy rules, $N_l = 5$ is considered and accordingly the rules are generated for the corresponding $N_l = 5$ classes. Once the fuzzy rules have been generated, the network training process has also been performed. The performance of the network in its training stage is depicted in Fig.3. In the hybrid evaluation of switching angles, the iterative approach is tested for different number of iterations. The output voltage obtained for those attained optimal switching angles are given in Fig 8.



(i)



(ii)



(iii)

Fig3: The performance of the neural network training process in the proposed technique

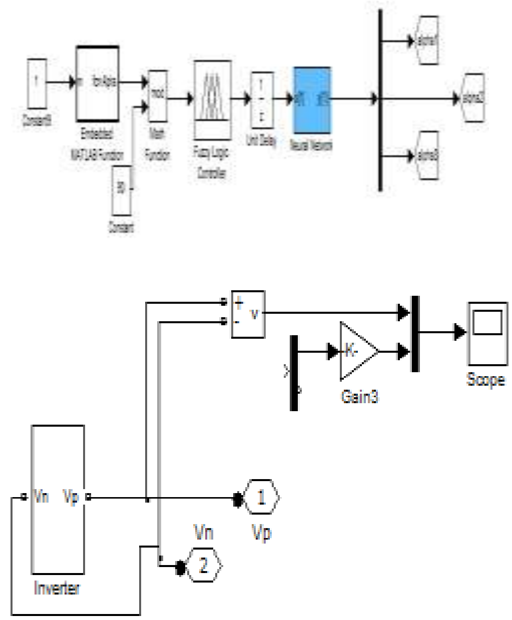


Fig4. Matlab simulation Circuit

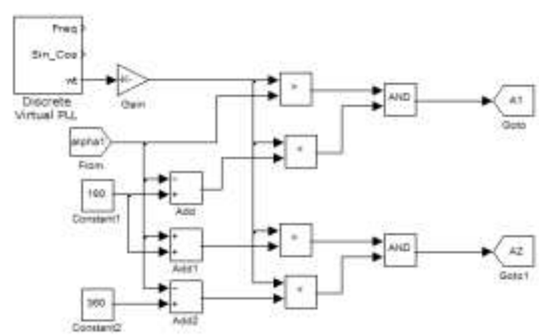


Fig 5. Switching angles for H_1

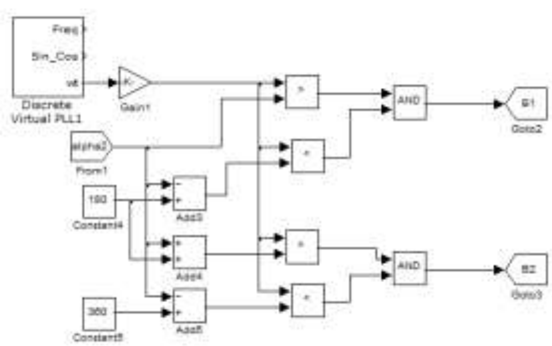


Fig 6. Switching angles for H_2

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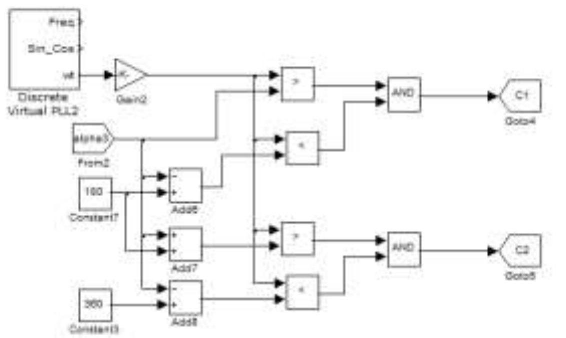
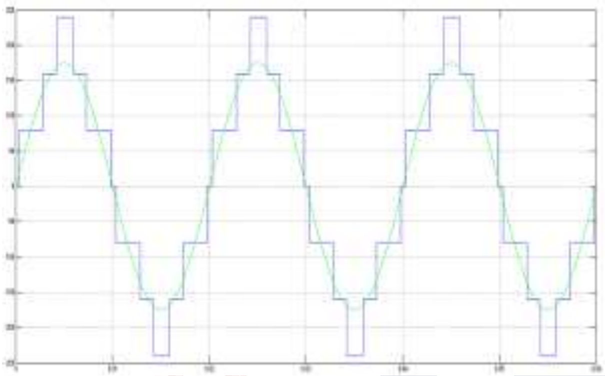
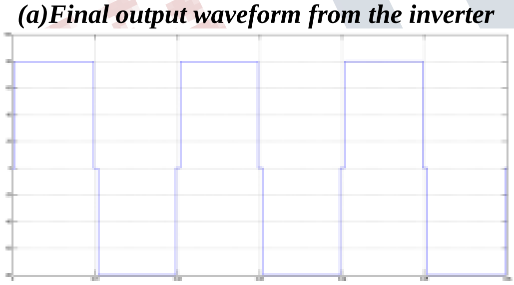


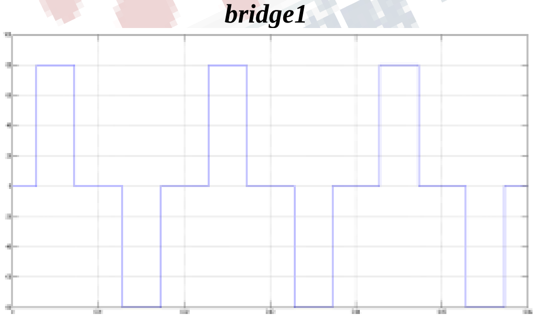
Fig 7. Switching angles for H_3



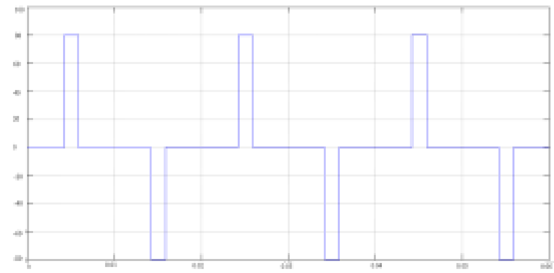
(a)Final output waveform from the inverter



(b)Output waveform switching angles of inverter bridge1



(c)Output waveform switching angles of inverter bridge2



(d)Output waveform switching angles of inverter bridge3

Fig 8.Output voltage obtained for optimal switching angles

From the obtained, we can visualize the effectiveness of the proposed technique. The final output obtained from multilevel inverter shows the harmonics less waveform. The generated waveform shows the harmless way to the nonlinear utilities.

IV. CONCLUSIONS

In this paper, a hybrid technique has been proposed to eliminate the harmonics that are generated from the cascaded H-bridge multilevel inverters. The technique was implemented to evaluate its performance in the elimination of harmonics in a 7-level 3 H-bridge inverter. The performance was evaluated in different iteration levels of the hybrid evaluation technique. From the results, it has been shown that the proposed technique can reach a remarkable level in harmonics elimination by mitigating the dominant odd order harmonics. The results analysis has shown that the suggested optimal switching angles can avoid the generation of harmonics and so the generated voltage waveform can maintain its harmonics free shape. By using the obtained switching angles, the harmonics generation can be avoided.

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BIOGRAPHY

G.N.Rao was born in Guntur, India. He received the (electrical) degree from the Institute ofEngin eers (India) and the M.Tech degree from Nagarguna University, Nambur,AP,India., and currently pursuing his Ph.d from J.N.T.University Kakinada .Working as Prof & H.O.D. Department of electrical and electronics engineering in Chalapathi institute of engineering and technology, Guntur. His areas of interest are in power systems, electrical machines, electromagnetic fields. Mr.Rao is a Life Member of the Indian Society for Technical Education (ISTE) and Associate Member of the Institution of Engineers (India)[IE(I)].

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