Mitigation of harmonics for five level multilevel inverter with fuzzy logic controller

Introduction. The advantages of a high-power quality waveform and a high voltage capability of multilevel inverters have made them increasingly popular in recent years. These inverters reduce harmonic distortion and improve the voltage output. Realistically speaking, as the number of voltage levels increases, so does the quality of the multilevel output-voltage waveform. When it comes to industrial power converters, these inverters are by far the most critical. Novelty. Multilevel cascade inverters can be used to convert multiple direct current sources into one direct current. These inverters have been getting a lot of attention recently for high-power applications. A cascade H-bridge multilevel inverter controller is proposed in this paper. A change in the pulse width of selective pulse width modulation modulates the output of the multilevel cascade inverter. Purpose. The total harmonic distortion can be reduced by using filters on controllers like PI and fuzzy logic controllers. Methods. The proposed topology is implemented with MATLAB/Simulink, using gating pulses and pulse width modulation methodology and fuzzy logic controllers. Moreover, the proposed model also has been validated and compared to the hardware system. Results. Total harmonic distortion, number of power switches, output voltage and number of DC sources are analyzed with conventional topologies. Practical value. The proposed topology has been very supportive for implementing photovoltaic based multilevel inverter, which is connected to large demand in grid and industry. References 17, table 4, figures 9.

Key words: cascade H-bridge multilevel inverters, fuzzy logic controller, selective pulse width modulation technique, total harmonic distortion.
bidirectional power switches will be magnified from a voltage perspective. Two IGBTs with dual anti-parallel diodes and a single driver circuit must be used to make a bidirectional switch. An anti-parallel diode is required for a unidirectional switch. It makes no difference which way a power switch is plugged in, whether it is a one-way or a two-way switch. Many asymmetric cascaded MLIs have been proposed to increase the number of output levels. As a primary drawback, these inverters require high-voltage DC power sources. Using a new basic unit, a greater number of output levels can be generated with fewer electronic devices. A cascaded MLI is put forward by connecting several of the basic units that have been proposed. An H-bridge will be added to the inverter's output because only positive and negative voltages can be generated. One of the proposed cascaded MLIs has been developed. H-bridge and diode-clamped MLIs, as well as flying capacitances and fly inducers, are examples of topologies that can reduce harmonic distortion. Clamping diode inverter voltage control becomes more difficult as the number of levels increases. Voltage regulation of a flying capacitor MLI becomes increasingly challenging with more levels. The cascade multilevel [17] is the most efficient of the three topologies. Cascade MLIs have better performance, but they still fall short of IEEE standards as the data presented above shows. Using cascading MLIs and controllers, as well as the selective pulse width modulation technique, reduces THD. Different carrier waveforms are designed for the third and fifth levels of the project to reduce THD.

2. System configuration for existing PI, PI with filter controller. Figure 1 illustrates about schematic diagram for MLI with closed loop control scheme. Figure 2 depicts the simulation diagram of five level MLI with single phase system. An example of a five-level MLI’s output can be seen in Figure 3. In order to get five level, six carrier signals and one reference signal has been used. Three levels are positive and the other three levels are negative and the left-over level is zero level and these voltages are obtained using different switching paths.

3. Results and discussion. Figure 4 shows MLI fast Fourier transform (FFT) analysis of five-level. Here the THD level obtained is 17.41 % for MLI with PI controller for a fundamental frequency of 50 Hz.

Proportional and integral (PI) and fuzzy logic controllers (FLC) with filters is being used to further reduce harmonic distortion below IEEE standards of 5 %. Using these controllers, it is possible to reduce THD more effectively.
Fuzzy logic is the application of conditional or rule-based logic to the transformation of an input space into an output space. It is a fuzzy set if the boundaries are ambiguous. The inclusion of elements with just a sliver of membership is permitted. It deals with difficult-to-define ideas (e.g., fast runner, hot weather). Being only a part of it is fine. Fudged set membership values range from 0 to 1, indicating the extent to which an object is a member of the collection. Input values in a fuzzy set range can be used to determine the appropriate membership value for a given membership functions. This type of multivalve logic is also known as a rule or condition because of the terminology used to describe the inputs and outputs of the multivalve devices. The schematic diagram of FLC is illustrated in Fig. 6.

![Fig. 6. Schematic diagram of FLC](image)

Weightings, which can be added to each rule in the rule base, can be used to control how much a rule affects the output values. A rule’s importance, reliability, or consistency can be assigned a numerical weighting. Depending on the results of other rules, these rule weightings can be either static or dynamic [14].

FLC in the fuzzy logic system is in charge of choosing the fuzzy rules that control it. Error ($E$) and error change ($\Delta E$), which are inputs to the FLC system, are shown in the following diagram. Distortion level of FLC and filter for three membership functions is shown in Fig. 7.

![Fig. 7. Distortion level of FLC and filter for three membership functions](image)

Figure 7 shows FFT analysis of five level MLI with FLC and filter for five membership functions. Here the THD level obtained is 3.43 %.

![Fig. 8. MATLAB/Simulink of FLC](image)

**Table 1**

<table>
<thead>
<tr>
<th>Change in error ($\Delta E$)</th>
<th>Ne</th>
<th>Zr</th>
<th>Pe</th>
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<tbody>
<tr>
<td>Ne</td>
<td>Sm</td>
<td>Me</td>
<td>Sm</td>
</tr>
<tr>
<td>Zr</td>
<td>Me</td>
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<td>Me</td>
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<tr>
<td>Pe</td>
<td>Sm</td>
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<td>Sm</td>
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![Table 2](image)

**Table 2**

<table>
<thead>
<tr>
<th>Change in error</th>
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<tbody>
<tr>
<td>NeB NeS ZO PeS PeB</td>
</tr>
<tr>
<td>NeB PeB PeB PeB PeS ZO</td>
</tr>
<tr>
<td>NeS PeS ZO ZO ZO NeS</td>
</tr>
<tr>
<td>ZO PeS ZO ZO ZO NeS</td>
</tr>
<tr>
<td>PeS PeS ZO ZO ZO NeS</td>
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<tr>
<td>PeB ZO NeS NeB NeB</td>
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If the value of error is negative and the error change is positive, the output will be small. System could get a medium output with no errors or errors changing in a negative direction. A large output would be possible with no errors or errors changing in a negative direction. If the error value is zero and the change in error value is positive, the output would be medium. If the error value is positive and the error change value is negative, the output will be small. It is considered medium-sized when the error rate is more than 10 %.

Table 3 shows the comparison of THD levels for different controllers. The results show that FLC gives the better response when compared with conventional PI controller. Although the distortion is reduced to some extent when PI controller is used, but it is greatly reduced when Fuzzy controller is used. Table 4 gives the specifications of various parameters used in the simulation.
The quality of multilayer output voltage waveform improves as the quantity of levels in a multilevel inverter grows. Different carrier waveforms are used for three and five levels of the project to reduce harmonic distortion. We used a multilevel inverter with a selective pulse width modulation technique to reduce harmonic distortion in five levels. PI and fuzzy logic controllers with filters have been added to the five-level multilevel inverter to further reduce the IEEE standards.

We can achieve from simulation results that total harmonic distortion can be done as a part of future work. We can achieve from simulation results that total harmonic distortion improves as the quantity of levels in a multilevel inverter grows. Different carrier waveforms are used for three and five levels of the project to reduce harmonic distortion. We used a multilevel inverter with a selective pulse width modulation technique to reduce harmonic distortion in five levels. PI and fuzzy logic controllers with filters have been added to the five-level multilevel inverter to further reduce the IEEE standards.

In the future, a sinusoidal pulse width modulation will be generated using other techniques for high-frequency applications by means of modified carriers using a fuzzy controller in order to reduce distortion as well as to improve the voltage. Then this proposed selective pulse width modulation will be applied to all types of inverters like voltage source and current source inverters. Previously only five level operations were done using the pulse width modulation technique. So, in the future, more than five-level operations will be achieved with other controllers. The verification of this inverter for lesser total harmonic distortion and higher frequencies can be done as a part of future work.

**Conflict of interest.** The authors declare that they have no conflicts of interest.

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