Development and Comparative Study of Two-input Fuzzy Controller over Single-input in 1-Φ PWM Inverter

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ABSTRACT
This paper presents the comparison between the two modes of PWM inverters for various load conditions. SPWM inverter has been modeled in this paper using two types of fuzzy logic controller depending upon the input to the FLC. Inverters are of great requirement for processes to provide the best and accurate results in different working condition such as for industrial, commercial, in drive power systems etc. So for their uninterrupted working in that field, there is need to deploy the device which works during the failure of power supply system but with high quality response. The method for generating pure sinusoidal voltage waveform at the PWM inverter output is described in this paper. Harmonics have been under the continuous research as these are the basic and old problem [1] which continues to affect the performance of the power systems in various applications depending upon the types of loads. In order to create best output of PWM inverter, fuzzy technique has been taken into consideration as it deals with non-precise inputs. All results are shown using MATLAB/Simulink simulation which shows that inverter output current is in sinusoidal waveform and in phase with line voltage, and current harmonics are in the limits of international (IEEE) standards (<5%)[2]. The ultimate goal is to yield output voltage with minimum distortion as low as possible.

Keywords: - Fuzzy Logic Controller, Membership functions, PWM (pulse width modulation) inverters, controllers' circuit design, TDH.

1. INTRODUCTION
The word quality has been discussed with certain definitions. Voltage quality is concerned with deviations of the voltage from the ideal. The ideal voltage is a single frequency sine wave of constant amplitude and frequency. Current quality is the complementary term to voltage quality. It is concerned with the deviation of the current from the ideal. The ideal current is again a single frequency sine wave of constant amplitude and frequency, with the additional requirement that the current sine wave is in phase with the voltage sine wave. The additional frequencies are termed as the "Harmonics" [2]. Voltage source inverters (VSIs) generate an AC supply from a DC source with some percentage of harmonics. In this paper, Matlab/ Simulink is used to model single-phase full-bridge VSI. This software package is designed for modeling, simulating and analyzing power systems. The desired output of the inverter must be pure sinusoidal but harmonic contents are there in high proportionate [3]. To control and eliminate the harmonics, various techniques and controllers can be deployed which are used to the gate current of the switching devices in the H-bridge circuit.

Fuzzy logic controllers have become the most popular controller since many years. In this paper, a controller based on fuzzy set theory [4] is designed for the harmonics reduction purpose. Dominance of FLC's over the conventional controllers has become tight as it can work with imprecise inputs, can handle nonlinearity and it is more robust than conventional nonlinear controllers [5]. In this paper, the comparative study has been carried out between the model using different kinds of FLC controllers. First controller is of SISO type and second one is TISO type. Both the controllers have shown the way to design the appropriate model for harmonic elimination in Sinusoidal PWM inverters. The first type of the controller is the part of the second type of controller. The compatibility of the system has been shown with various load conditions to demonstrate the increased working range of the system. Usage of FLCs is quiet easy due to quick maintenance processes, availability and explores the potential and feasibility of fuzzy logic control schemes that are suitable for harmonic current mitigation and inverter voltage control to improve the performances. The performance of fuzzy controller is evaluated through computer simulations. The results show that how TISO has become superior to SISO type FLC in this harmonic reduction model.

2. HARMONIC CONTENTS OF POWER SYSTEMS
SPWM inverters are the most commonly used inverters with capability of producing an ac voltage of variable magnitude as well as variable frequency. Output voltage has to be of good quality sinusoidal voltage waveform of desired fundamental frequency and magnitude. Lower order harmonics often cause problems in certain applications. In most power systems certain loading conditions can cause harmonic distortion to the associated voltage waveform, which may adversely affect certain types of connected load [6]. When an electrical load is connected to an AC electricity source, it will draw current and depending upon the load, different wave shapes are generated. The input current to the load carries a number of harmonics, analyzed by Fourier Transform [6].

In PWM techniques, it is not always possible to remove the lower order harmonics. The magnitudes of lower order harmonic voltages have to be reduced, often at the cost of increasing the magnitudes of higher order harmonic voltages, which theoretically is easier to filter out.

Now, in the present scenario different types of loads have been employed in industrial, commercial, residential area etc. like linear and non-linear loads. Linear load draws the current as sine wave [7]. For other types of load, however, the current drawn by the load may not be sinusoidal. In this paper the effects on the proposed model using inductive load are shown using two FLCs to determine functioning of the system.

3. FUZZY LOGIC & ITS CONTROLLER

Fuzzy concept has been into existence since 1965 when it was introduced by Lofti A. Zadeh [4]. Its implication inference is based on the compositional rule of inference for approximate reasoning. A member in a fuzzy set has a degree of membership to the set. Membership functions topologies can be of different kinds; the most common are triangular, trapezoidal, gaussian and sigmoidal [8]. The attributes of the membership function can be modified based on the desired input. FLC is a controller that does not require a precise mathematical modeling for designing. FLC basic configuration is comprised of four principle components: a fuzzification interface, a knowledge base, decision –making logic and a defuzzification interface. [9]

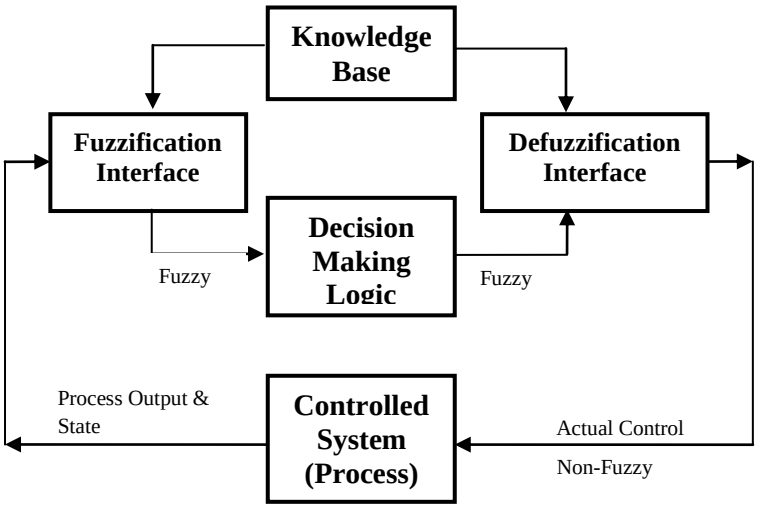

Figure 1: Basic configuration of FLC

There can be any number of inputs to a fuzzy system and each one of these inputs can have several membership functions. The output also has a set of membership functions. These membership functions define the possible responses and outputs of the system [9]. The fuzzy inputs are combined based on the rules and the degree of membership in each function set. The output membership functions are then manipulated based on the controller for each rule. All of the output member functions are then combined into one aggregate topology. The defuzzification process then chooses the desired finite output from this aggregate fuzzy set. There are several ways to do this such as weighted averages, centroids, or bisectors. The procedure of making fuzzy controller includes is described below:

1) The fuzzification interface involves the following functions:
   a) Measures the values of input variables,
   b) Performs a scale mapping,
   c) Fuzzification converts crisp data into suitable linguistic values known as fuzzy sets.
2) Knowledge base comprises data base and linguistic fuzzy control rule base:
   a) Data base provides defines linguistic control rules and fuzzy data manipulation in an FLC.
   b) Rule base (If- Then statements) characterizes the control goals by means of a set of linguistic control rules.
3) Decision making logic in an FLC has the capability of simulating human decision-making based on fuzzy concepts and of inferring fuzzy control actions employing fuzzy implication and the rules of inference in fuzzy logic.
4) Defuzzification interface performs scale mapping which converts output variables into corresponding universe of discourse and yields a non-fuzzy control action.

4. THE APPROXIMATION OF TWO FLC MODELS

The PWM fuzzy model for the harmonic distortion diagnostic is implemented in MATLAB/Simulink using the fuzzy logic toolbox. This toolbox allows for the creation of input membership functions, fuzzy control rules, and output membership functions [8]. As it is already explained, the models are implemented with two FLCs: one with single input as error voltage and another with two inputs as error voltage & rate of change of error voltage which is implemented using Simulink. The output is designated as the degree of correction. This degree of correctness is decoded into one of the output: small, average, large. A simple diagnostic system is created as shown in Figure 2.

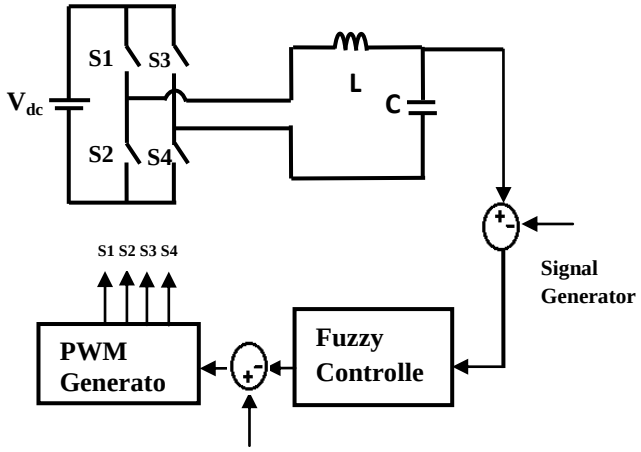

Figure 2: Sine-wave approximation using fuzzy logic controller

The modulating signal is a sinusoidal signal having amplitude in the range of -1 to +1 given in figure 3.

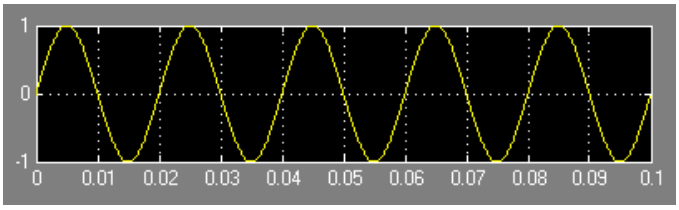

Figure 3: Voltage Input

The comparison between the two FLCs has been done to show that how important part is being played by the rate of change of error as one of the inputs. The fuzzy system used will be a mamdani system [9], and the centroids method for defuzzification is used. The input membership function for harmonic error will have three different membership functions: negative, zero and positive. Same membership functions are designed for differentiation of error with respect to time but with changed ranges.

Generally it is said to make the system perfect, it is necessary to use fine membership functions but here system is modeled using coarse type of membership functions for both inputs and output.

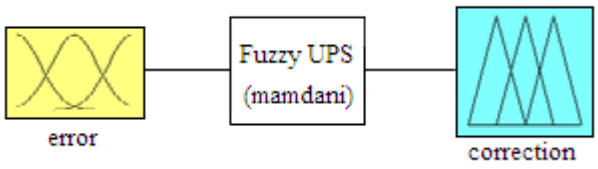

Figure 4: FLC_1

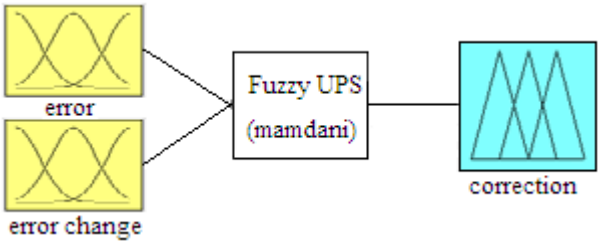

Figure 5: The FLC_2

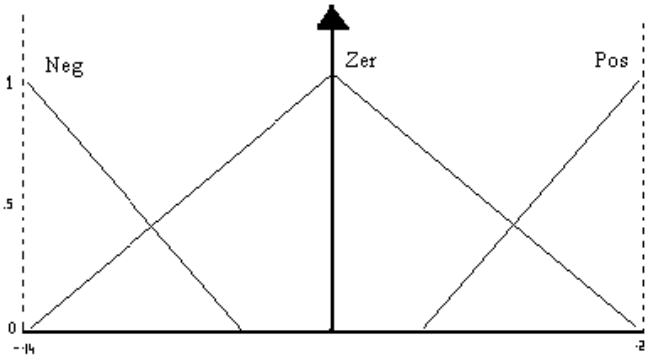

Figure 6: The Error Input Membership Functions

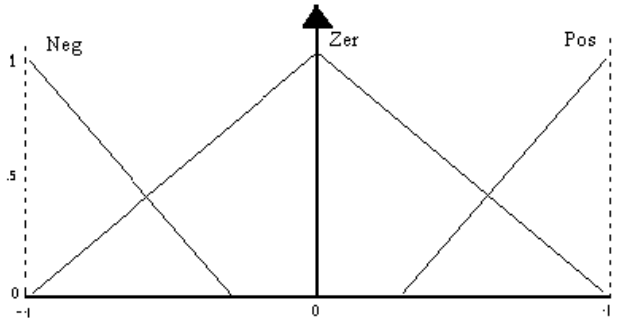

Figure 7: The Error Change Membership Functions

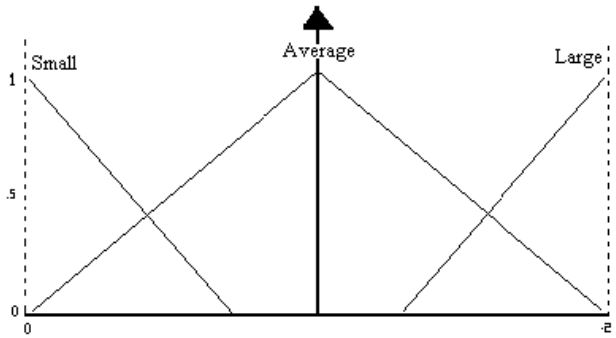

Figure 8: The System Correctness Output Membership Functions

The output has three membership functions: small, average & large. The fuzzy rules are in the form of if-then statements. These statements look at both inputs and determine the desired output. The rules defined for this system for two types of FLC which are shown in Table 1 & 2 below:

Table 1: Membership Rules for single input FLC

If error difference is :	**Then correction is :**
Negative	Small
Zero	Average
Positive	Large

Table 2: Membership Rules for double input FLC

ce / e	**N**	**Z**	**P**
N	S	A	L
Z	S	A	L
P	S	A	L

These rules are the defining elements of this system. They determine the output based on the input.

5. SIMULATION RESULTS

In this section, the comparison is made between the two FLC model results with the same system along with same category of load. PWM inverter output can be taken as both voltage and current depending upon the type of the source of the inverter as: voltage source inverter (VSI) or current source inverter (CSI). The Total Harmonic Distortion (THD) is calculated using FFT analysis tool which is the provided in simulink model in the form of powergui. Generally the best and worst cases counted for the Total harmonic Distortion is from 1% to 13%. But in this system tremendous results have been shown with RL (R= 10Ω, L= 0.1 mH) load. Firstly, the simulation results are shown for PWM inverter with single input FLC for RL load and secondly the same procedure is followed with double input FLC in terms of THD for both current and voltage across the load.

The results have been demonstrated for both the models along with LC filter. The filter parameters are L= 0.3 mH & C= 1000 μF

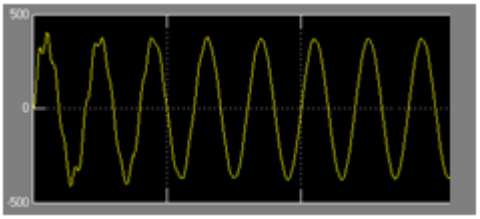

Figure 9: Output Voltage Waveform (FLC_1)

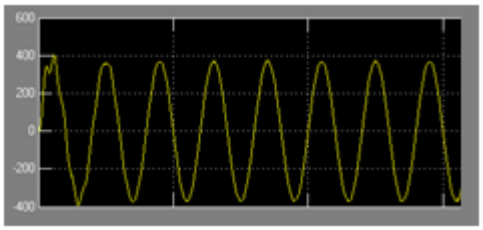

Figure 10: Output Voltage Waveform (FLC_2)

It can be clearly seen from the results that output voltage of FLC with only error input is having distortion in almost first four cycles but the model with two input FLC yields distorted wave mostly in first cycle. There THDs for voltages are also displayed for determining the exact values for both the FLCs.

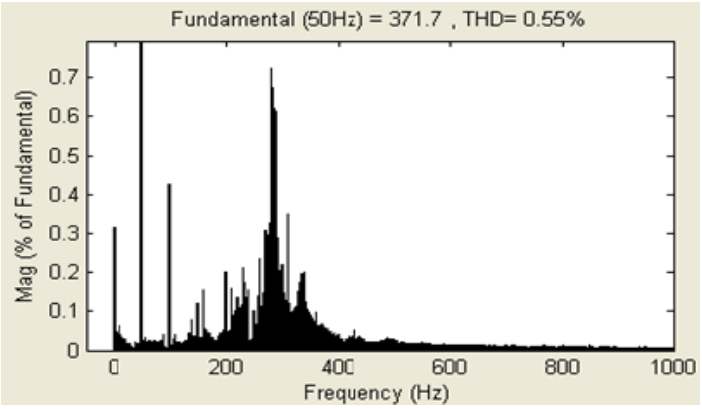

Figure 11: THD % for single input FLC

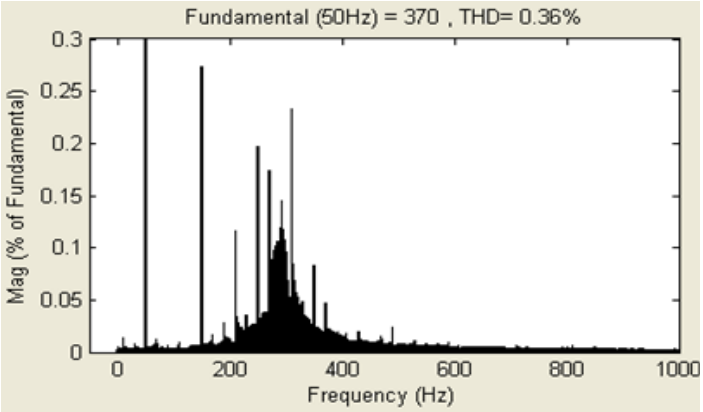

Figure 12: THD% for double input FLC

6. CONCLUSION

The above models have shown the ways to choose the better model for its working in this area which is carried out using a single phase pulse width modulated inverter along with two types of FLCs simulated using Matlab/Simulink software. The results have shown that how a firing circuit is made to work at its best and acceptable level for the control in the inverter output voltage. Tests have proved that the two inputs FLC in the inverter strategy, has reduced the low order harmonics are substantially.

This paper has presented that how the results presented in graphical format along with their THD% values, which gives the judgment that the distortion has been eliminated with TISO fuzzy logic controller up to the greatest level of 0.36% rather than 0.55% in case of SISO FLC and shows why two input FLC is superior to the Single input FLC.

7. REFERENCES

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