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MODELING AND SIMULATION OF MATRIX CONVERTER USING PI AND FUZZY LOGIC CONTROLLER

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ABSTRACT

The controlling and transforming methodd of electrical energy are the most important process in the field of electrical engineering.. The increased complexity of their control and usage of more number of elements led to work with of new type of converter called Matrix Converter which is very simple and compact. The Matrix Converter is an ac–ac power converter topology, mainly based on semiconductor switches with minimal requirements for passive components. In this paper the performance of such converter has been studied when driving linear load current using PI and Fuzzy Logic Controllers. Simulation results display the effectiveness of Matrix Converter with reduced THD values.

KEYWORDS: Matrix Converter, Modulation Methods, PI Controller, Fuzzy Logic Controller.

INTRODUCTION

Due to variations in the nature of supply voltage and frequency (source) and the varying requirements of modern applications (loads), power conversion is essential in order to ensure a proper and energy efficient operation of equipment. This thesis gives a brief overview on the power electronic technology, static AC/AC power frequency conversion structures and introduces the matrix converter (MC), which is the main topic of this work [2]. Among various modulation techniques of matrix converter like venturini modulation [3,4], optimum venturini modulation, space vector technique [6] and scalar method, mainly optimum venturini method is discussed in this work for the generation of duty cycle and to get the maximum output voltage. Pulse width modulation is used to generate the firing pulses for the control of switches of the matrix converter [5].

There are many electrical loads like linear loads, non-linear loads, lightning loads etc. But in this thesis linear passive resistance and inductance (RL) loads are considered to evaluate the performance of matrix converter. In order to get the desired response the output currents are compared with the reference current, which gives an error value from the difference of two currents. The closed loop control is used to suppress the error and finally the matrix converter gives the response with the reduction in harmonic content of output current waveforms [6].

For the proper regulation of matrix converter various controllers are discussed in this paper [7,8]. Firstly the performance of conventional PI controller fed matrix converter was observed and then followed by Fuzzy Logic Controller were connected to the matrix converter.

The Simulink Model was developed by using MATLAB Simulink software and to evaluate the effectiveness of matrix converter during balanced and distorted supply voltage conditions. The output waveforms of the matrix converter fed to linear RL load, during these conditions are observed.

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MODEL DESCRIPTION

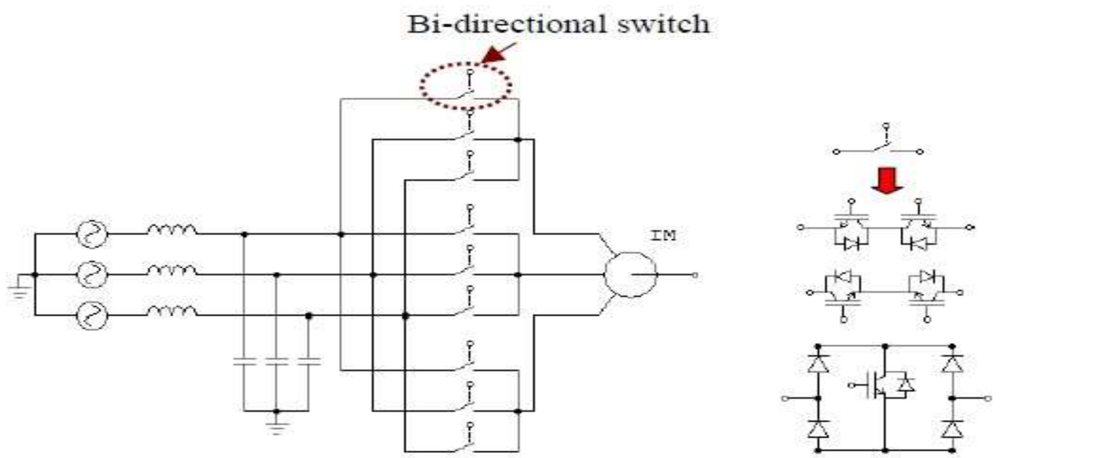
The direct AC/AC power frequency converter is a single stage power converter which consists of an array of semiconductor switches connected directly between the input and output terminals. The most common topology for an indirect AC/AC converter is the use of diode bridge rectifier at the supply side and a pulse width modulated voltage source inverter (PWM-VSI) at the load side. Although this type of AC/AC converter is very cost-effective and reliable, it has lots of drawbacks. Due to the uncontrolled operation of diode bridge rectifier, the input AC currents drawn by the rectifier contain a large amount of harmonics that produces distortion of the input line voltages, having a negative impact on the performance of sensitive loads and equipment connected to the same supply. [1] The matrix converter for 3 AC/AC power converter replaces the diode bridge with PWM rectifier resulting in a back-to-back converter .This converter overcomes the input harmonic problem of the former topology and offers improved total input power factor and bi-directional power flow.

The main theme of the control strategy is to design an ideal electronic transformer which is capable of varying the current, voltage, power factor and frequency. [2] Hulusi Karaca and Ramazan Akkaya [7] proposed a PI controller based compensation technique to get rid of the undesirable effects of the distorted input voltages for matrix converter controlled with Venturini modulation method. control for the load current. Hulusi Karaca and Ramazan Akkaya [8] designed Fuzzy Logic Controller fed to matrix converter. A FLC based novel compensation technique performs closed loop control of the output current to improve the output performance of the MC. Different types of membership functions of the linguistic variables and output/input characteristics are analyzed.

A. Boukadoum, T. Bahi, S. Oudina, Y. Souf A, and S. Lekhchine [9] designed adaptive fuzzy controller which is a hybrid controller to suppress the harmonics caused by nonlinear loads when connected to matrix converter.

The matrix converter is most versatile without any limits on the output frequency and amplitude. It replaces the multiple conversion stages and the intermediate energy storage element by a single power conversion stage and uses a matrix of semiconductor bidirectional switches.

Matrix converter topologies can be divided into two types: the direct matrix converter and the indirect matrix converter (also referred to as “dual bridge matrix converter”, “sparse matrix converter” or “two-stage matrix converter”). The circuit configuration of a conventional direct matrix converter with an array of 3 x 3 bidirectional switches is shown in Figure 2(a). By applying appropriate modulation strategy, such as optimum Venturini method or space vector modulation, the direct matrix converter is able to generate high quality sinusoidal input and output waveforms. The indirect matrix converter topology is the physical implementation of the indirect modulation method. As shown in Figure 2(c), the indirect matrix converter consists of a four-quadrant current source rectifier and a two-level voltage source inverter.



(a) Direct matrix converter (b) Typical bi-directional switches

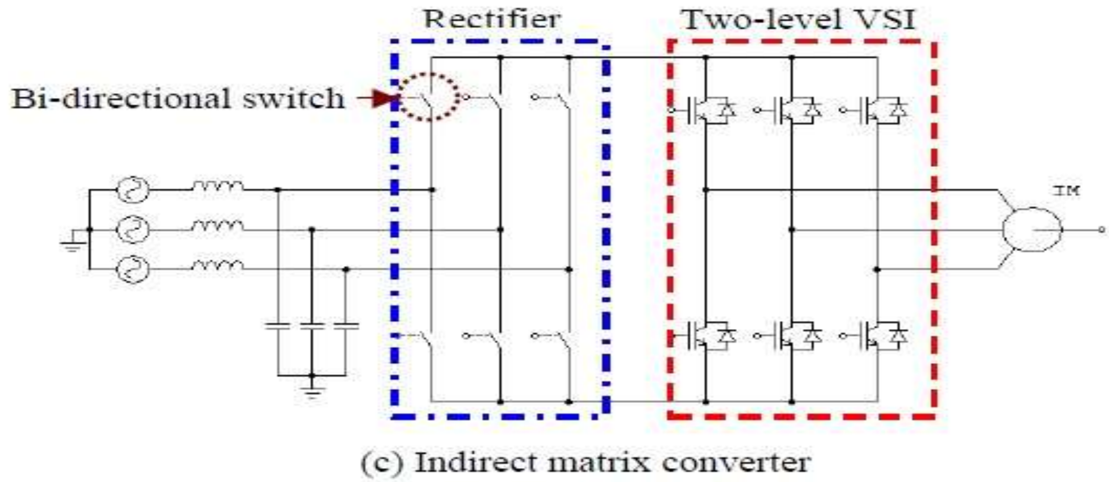


Fig2.1: (a) Direct matrix converter (b) Bi-directional Switches (c) indirect matrix converter

2.1 DIRECT MATRIX CONVERTER

The Matrix Converter is a single stage converter which has an array of m × n bidirectional power switches to connect, directly, an m-phase voltage source to an n-phase load. The power circuit diagram of the most practical three-phase to three-phase (3×3) matrix converter is shown in Figure 3, which uses nine bidirectional switches so arranged that any of three input phases can be connected to any output phase. Thus, the voltage at any input terminal may be made to appear at any output terminal or terminals while the current in any phase of the load may be drawn from any phase or phases of the input supply. The circuit is called a matrix converter as it provides exactly one switch for each of the possible connections between the input and the output [2]. The switches should be controlled in such a way that, at any time, one and only one of the three switches connected to an output phase must be closed to prevent ‘‘short-circuiting’’ of the supply lines or interrupting the load-current flow in an inductive load.
Compared to a traditional AC-DC-AC converter, the matrix converter offers the significant advantages [1] have encouraged extensive research into solving the practical difficulties in the implementation of the matrix converter in industrial applications.

2.2 POWER CIRCUIT AND WORKING PRINCIPLE OF THE MATRIX CONVERTER

In the basic topology of the MC shown in Figure 2.2, are the source voltages, are the source currents,, are the load voltages with respect to the neutral point of the load *n*, and, are the load currents. Additionally, other auxiliary variables have been defined to be used as a basis of the modulation and control strategies:, are the MC input voltages,, are the MC input currents, and, are the load voltages with respect to the neutral point N of the grid.

The filter (C_f, L_f, R_f), located at the input of the converter has two main purposes:1]It filters the high-frequency components of the matrix converter input currents, (i_A, i_B, i_C) generating almost sinusoidal source currents(i_{sA}, i_{sB}, i_{sC}). [2] It avoids the generation of overvoltage produced by the fast commutation of currentsi_A, i_B, i_C, due to the presence of the short-circuit reactance of any real power supply. It should be noted that R_f is the internal resistance of inductorL_f, not an additional resistor [3].

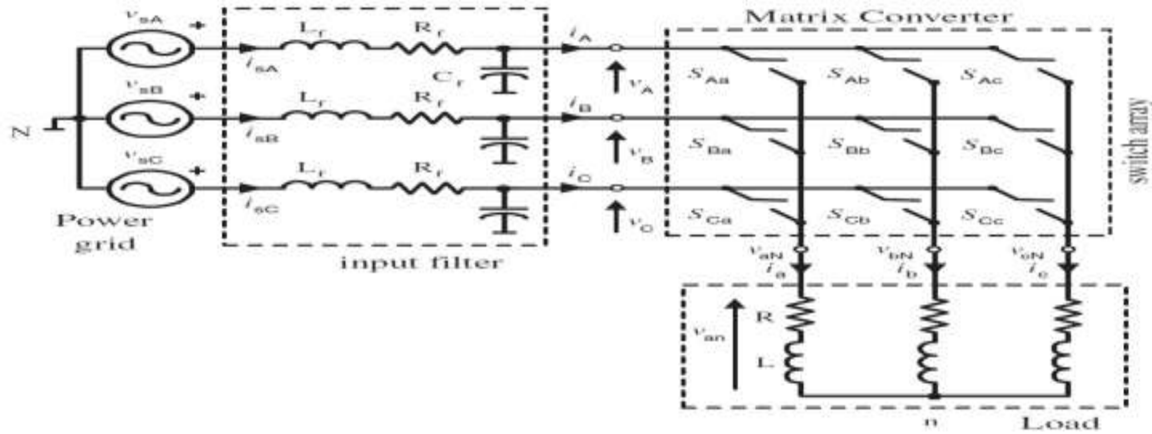


Fig2.2: Matrix Converter circuit

In the basic topology of the MC shown in Figure 2.2, $v_{si}, i = \{A, B, C\}$ are the source voltages, $i_{si}, i = \{A, B, C\}$ are the source currents, $v_{jn}, j = \{a, b, c\}$, are the load voltages with respect to the neutral point of the load *n*, and, $i_j, j = \{a, b, c\}$ are the load currents.

2.3 MODULATION OF THE MATRIX CONVERTER

In this section, the basic Venturini Modulation Strategy for the MC will be presented. Modulation is the procedure used to generate the appropriate firing pulses to each of the nine bidirectional switches (S_{ij}) in order to generate the desired output voltage. In this case, the primary objective of the modulation is to generate variable-frequency and variable-amplitude sinusoidal output voltages (v_{jN}) from the fixed-frequency and fixed-amplitude input voltages (v_i). The easiest way of doing this is to consider time windows in which the instantaneous values of the desired output voltages are sampled and the instantaneous input voltages are used to synthesize a signal whose *low-frequency component* is the desired output voltage. If t_{ij} is defined as the time during which switch S_{ij} is on and *T* as the sampling interval (width of the time window), the synthesis principle described above can be expressed as where $\bar{v}_{jN}(t)$ is the low-frequency component (mean value calculated over one sampling interval) of the *j*th output phase and changes in each sampling interval. With this strategy, a high-frequency switched output voltage is generated, but the fundamental component of the voltage has the desired waveform. The method described in previous section can be improved. This improvement can be achieved by modifying the target output voltage matrix $\bar{v}_o(t)$ to include third harmonics of the input and output frequencies. This new strategy is known as Venturini's optimum method. The target output voltages are modified in order to include the third harmonics.

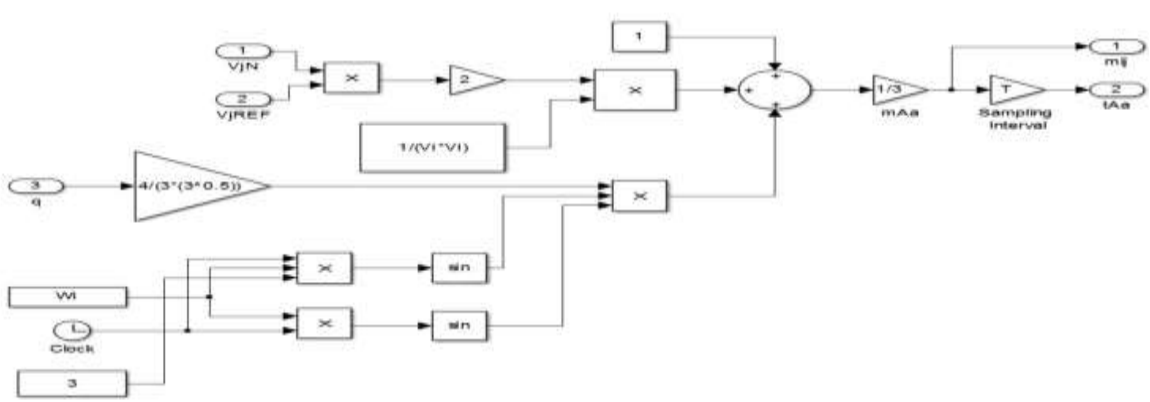


Fig 2.3: Simulink model of matrix converter to generate duty cycle for one output phase

CONFIGURABLE CONTROLLERS

3.1. PI CONTROLLER

The proportional controller is a device that produces an output signal which is proportional to the input signal. It improves the steady state tracking accuracy, disturbance signal rejection and relative stability. It also decreases the sensitivity of the system to parameter variations. The pi controller produces an output signal consisting of two terms- one proportional to input signal and the other proportional to the integral of input signal. The concerns of PI controller in the system are to reduce the steady state error and increased the order and type of the system by one which is shown in Fig.3.1.

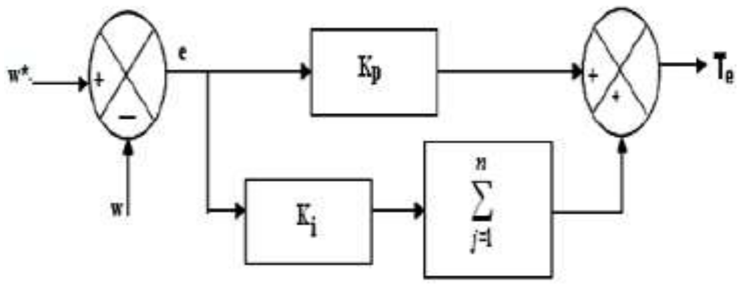


Fig 3.1: Block diagram of PI controller

Command Torque is the output signal of controller where K_p is the proportional gain and K_i is the integral gain.

PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller.

3.2 FUZZY LOGIC CONTROLLER

Fuzzy logic does not need any mathematical model of the plant.It is based on plant operator experience and easy to apply.It is basically an adaptive and nonlinear control, which gives robust performance for a linear or nonlinear plant with parameter variation.The results of our work have showed a very lowtransient response and a non-oscillating steady stateresponse with excellent stabilization.

SIMULATION OF MATRIX CONVERTER

The PI and Fuzzy logic controllers are connected to matrix converter for controlling the voltage transfer ratio "$\boldsymbol{q}$" and a set of simulations have been performed, using Matlab/Simulink. Bidirectional switches MOSFET are considered ideal and ode23tb simulation solver was used. The system parameters are listed below

System Parameters: Input voltage phase to neutral RMS: V_i=*220V*Input frequency f_i=*50 Hz* Input filter: $R_f = 0.8\Omega$, $L_f = 0.5mH$, $C_f = 80\mu F$.

Switching frequency: f_s=*5 kHz* Linear Load: $R_l = 10\Omega$, $L_l = 30mH$

The below figure shows the Simulink model of matrix converter fed to linear RL load and its voltage transfer ratio "$\boldsymbol{q}$" is modified by closed loop controller.

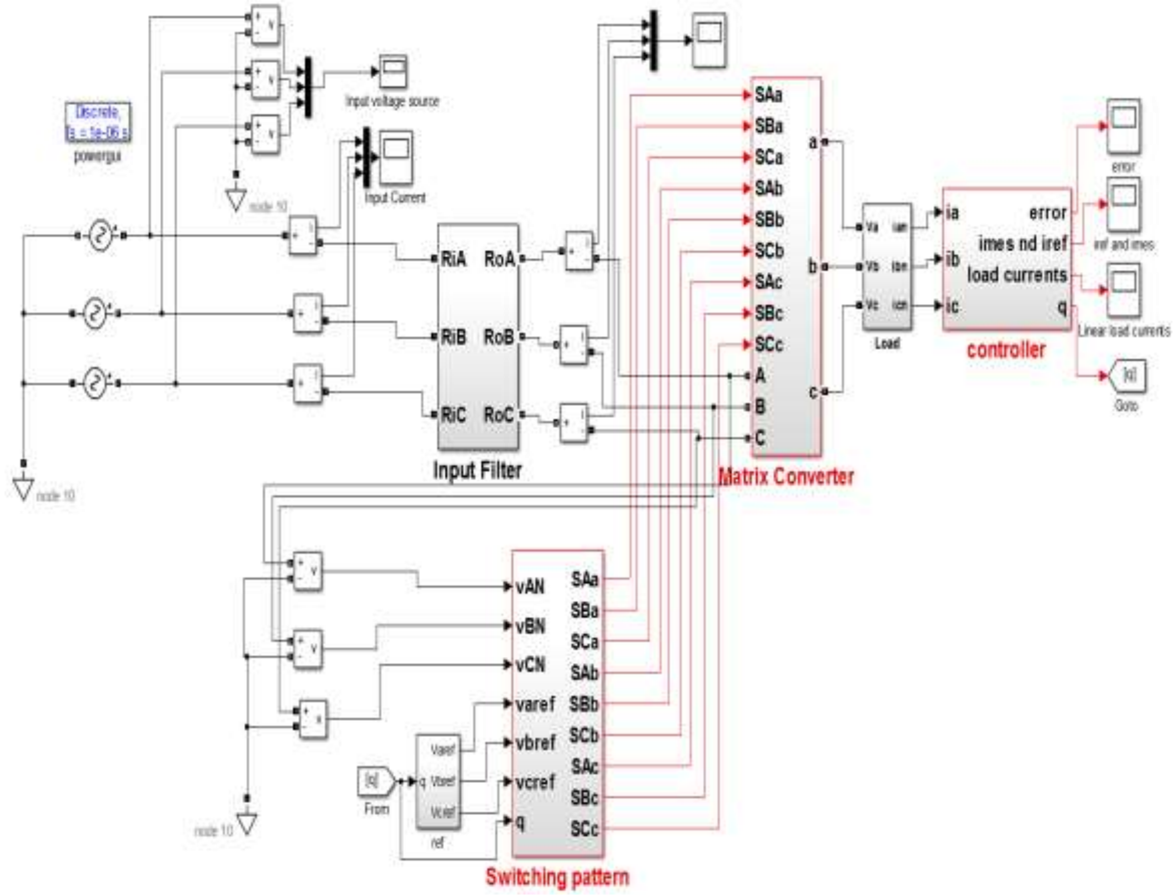


Fig 4.1: Simulink Model Of Controllers Fed To Matrix Converter

4.1 SIMULINK MODEL OF PI CONTROLLER

The simulink model of PI controller is shown below. The PI controller outputs the desired voltage gain value q by adjusting the error between measured and reference currents [7].

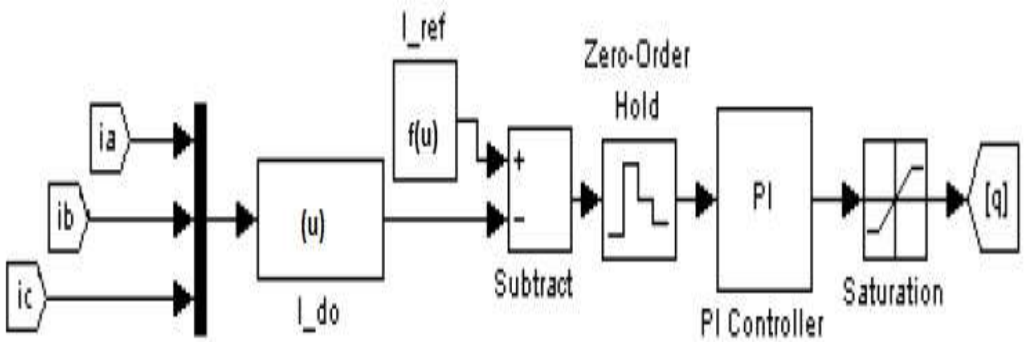


Fig 4.2: Simulink diagram of PI controller based feedback system

4.2 SIMULINK MODEL OF FUZZY LOGIC CONTROLLER

The output of the FLC system is the change of voltage gain (Δq) and its value is between -1 and +1 according to rule base in Table I. Actual voltage gain is calculated by adding the previous value and the change of the voltage gain.

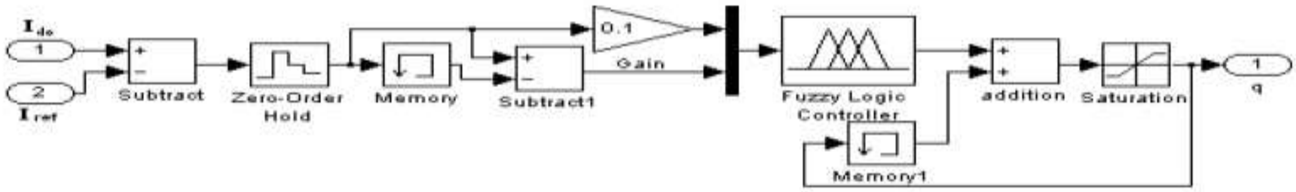


Fig 4.3: Simulink diagram of FLC based feedback system

Table 1: Fuzzy rules of inference

Δe/e	NB	NS	Z	PS	PB
N	PB	PS	PS	Z	NB
Z	PB	PS	Z	NS	NB
P	PB	Z	NS	NS	NB

SIMULATION RESULTS AND DISCUSSION

CASE:1. Balanced Grid Condition

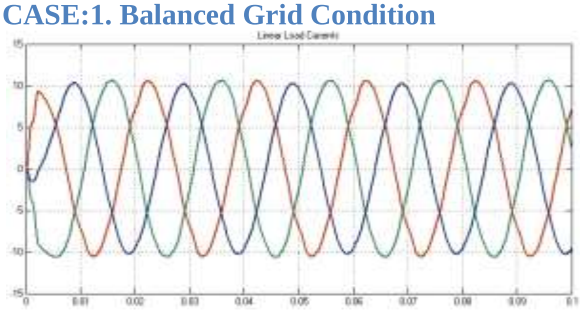


Fig 5.1: Linear load current PI Controller

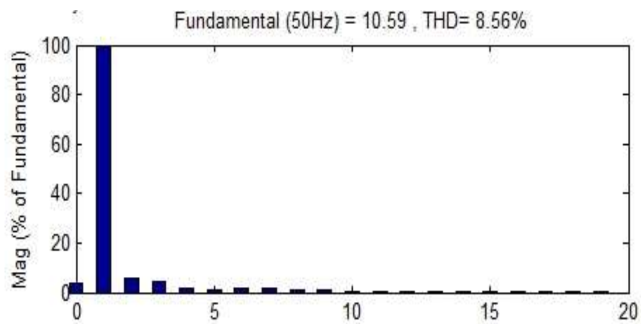


Fig 5.2 : Harmonic spectrum analysis of linear load current (PI controller)

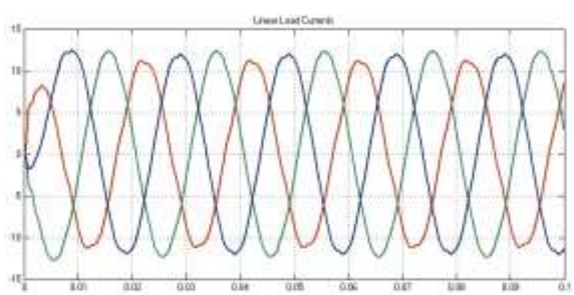


Fig. 5.3: Linear load current (Fuzzy Logic Controller)

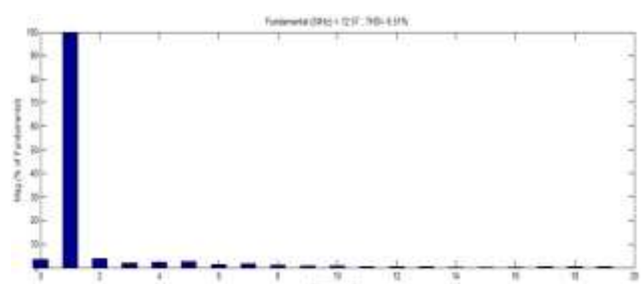


Fig 5.4: Harmonic spectrum analysis of linear load current (Fuzzy Logic Controller)

CASE:2. DISTORTED GRID CONDITION

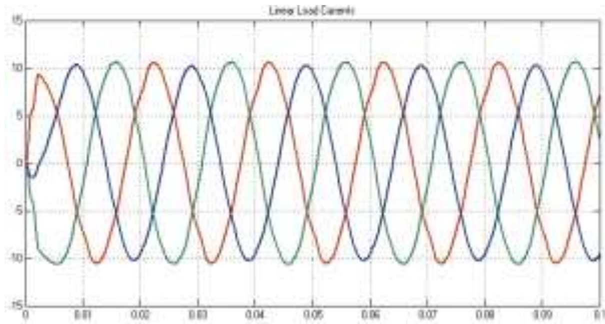


Fig.5.5: Linear load current (PI controller)

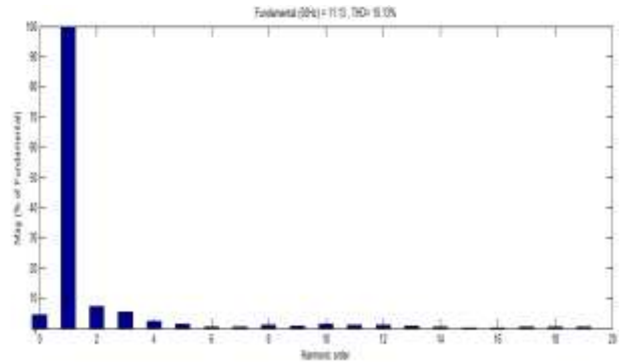


Fig.5.6: Harmonic spectrum analysis of linear load current (PI controller)

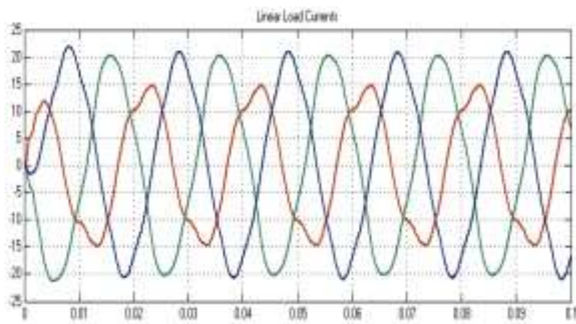


Fig.5.7: Linear load current (Fuzzy Logic Controller)

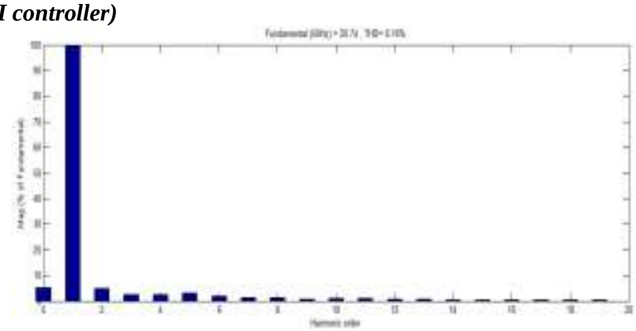


Fig.5.8: Harmonic spectrum analysis of linear load current (Fuzzy Logic Controller)

COMPARISION AND CONCLUSION

The above simulation results obtained in all the cases for RL load shows that the sinusoidal nature of linear load currents are preserved in any condition and the Fuzzy Logic Controller continuously adjusts to both normal and abnormal conditions much better than PI controller. At the same time FLC controller shows the better performance in suppressing the harmonics of linear load currents in terms of THD, which is compared with the PI under balanced and distorted grid conditions

Table 2: Comparison of the Controllers

	Linear Load Current (THD)	
System Condition	**PI Controller**	**Fuzzy Logic Controller**
Grid Balanced	8.56%	6.51%
Grid Distorted	10.13%	8.16%

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