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Control of PET Based On Fuzzy Logic for Power Quality Improvement

P Sravanthi*, T Srinivasa Rao**, P Anil Kumar***
**(PG Student Scholar, Department Of Electrical & Electronics Engineering, Avanthi Institute Of Engineering & Technology, Narsipatnam, Andhra Pradesh, India, E-Mail ID:sravanthinaidu243@gmail.com)*
*** (Associate Professor, Department Of Electrical & Electronics Engineering, Avanthi Institute Of Engineering & Technology, Narsipatnam, Andhra Pradesh, India, E-Mail ID:srinivasarao_tegala@yahoo.co.in)*
**** (Assistant Professor, Department Of Electrical & Electronics Engineering, Avanthi Institute Of Engineering & Technology, Narsipatnam, Andhra Pradesh, India, E-Mail ID:anilkumar.pappala@gmail.com)*

ABSTRACT

During the past several years, fuzzy control has emerged as one of the most active and fruitful areas for research in the applications of fuzzy set theory, especially in the realm of industrial process, which do not lend of quantities data regarding the input-output relations. This paper presents a power electronic transformer with fuzzy controller. In the design process converters and high frequency transformers have been used. One matrix converter operates as AC/AC converter in power electronic transformer. The proposed AC/AC converter can generate desired output voltage from square input voltage. The main point of proposed PET is reduction of the stage and components of the three-part PETs. The reliability and power quality of distribution system can be significantly improved by using proposed PET. To verify the performance of the proposed PET, computer-aided simulations are carried out using MATLAB/SIMULINK.

Keywords: Power electronic transformer (PET), AC/AC Matrix converter, Power Quality, High Frequency Transformer, Space vector Technique, fuzzy control.

I. INTRODUCTION

Nowadays by the improvement of the semiconductor and power electronics transformers are widely used in electrical power system to perform the primary functions of the transformers. Transformer [1] is most expensive device in an electrical system.

A new type of transformers based on Power Electronics (PET) has been introduced, which realizes voltage transformation, galvanic isolation, and power quality improvements in a single device. Different topologies have been presented for realizing the PET, in recent years [2]-[7]. In [2] the AC/AC buck converter has been proposed to transform the voltage level directly and without any isolation transformer. This method would cause the semiconductor devices to carry very high stress.

In this a three-part design that utilizes an input stage, an isolation stage, and an output stage [6]-[10]. These types enhance the flexibility and functionality of the electronic transformers owing to the available DC links. This approach can perform different power quality functions and provide galvanic isolation but they need whether too many power electronic converters and DC-link electrolytic capacitors. Thus they result in a rather cumbersome solution. Custom power devices are introduced in the distribution system to deal with various power quality problems faced by industrial and commercial customers due to increase insensitive loads such as computer and adjustable speed drives and use of programmable logic control in the industrial process[11],[12].

In this work two control methods are used, one is PI and another one is Fuzzy logic controller (FLC), The proposed AC/AC converter can generate desired output voltage from square input voltage. The main point of proposed PET is reduction of the stages and components of the three-part PETs. The reliability and power quality of distribution system can be significantly improved by using proposed PET. To verify the performance of the proposed PET, computer-aided simulations are carried out using MATLAB/SIMULINK.

II. CONVENTIONAL PET'S

Fig. 1 shows the basic block diagram of a PET with DC link capacitor which includes three stages. First stage is an AC/DC converter which is utilized to shape the input current, to correct the input power factor, and to regulate the voltage of primary DC bus. Second stage is an isolation stage which provides the galvanic isolation between the primary and secondary side. In the isolation stage, the DC voltage is converted to a high-frequency square wave voltage, coupled to the secondary of the HF (MF) transformer and is rectified to form the DC link voltage. The output stage is a voltage source inverter which produces the desired AC waveforms [4]-[9].

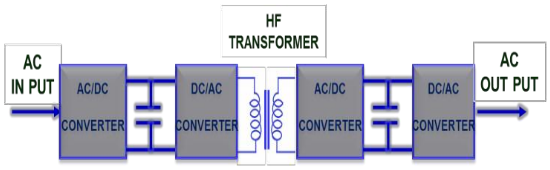


Figure1: Block Diagram of proposed PET with DC link

III. PROPOSED PET

The block diagram of the proposed PET is shown in Fig. 2. As can be seen from the Fig. 2 this is a three-stage design that includes an input stage, an isolation stage and an output stage. In the input stage converts the input AC voltage to DC voltage. The second part of the converter is formed by a DC/AC converter. This part of the converter contains the MF transformer with the high insulation capability. In the output part, the high frequency voltage is revealed as a power-frequency voltage. In this paper, a three part design is introduced. It is a new configuration based on the matrix converter with new function shown in Fig. 3. It can provide desired output voltage. In addition, it performs power quality functions, such as sag correction, reactive power compensation and is capable to provide three-phase power from a single phase system.

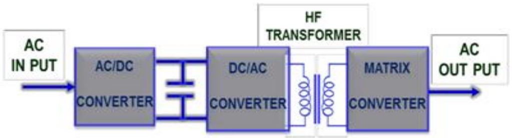


Figure 2: Diagram of electronic transformer using High Frequency AC link

Fig. 3 shows three phase rectifier with input inductances. A three phase PWM rectifier is used in thispaper, which operates same as input stage of conventional PET [8]-[9]. As can be seen from Fig. 4, the reference for the active current is derived from the DC voltage outer loop. The reference for the reactive current is set to zero to get unity power factor. The current error signals are input the current regulators and then form the modulation signals. If the d axis of the reference frame is aligned to the grid voltage, we obtain Vinq=0.

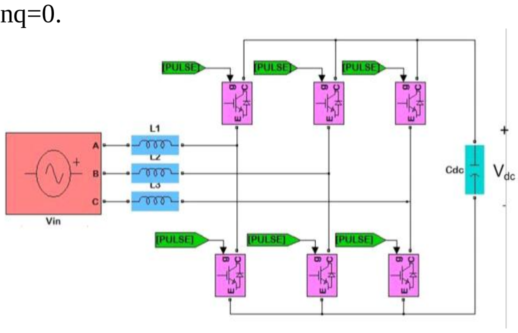


Figure 3: Structure of the proposed input stage

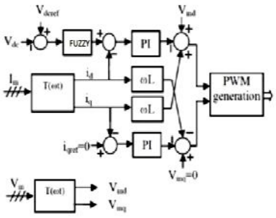


Figure 4: Input stage control diagram

Fig. 5 shows a matrix converter with novel function for square to sinusoidal voltage converter. Matrix converter topology employs six bidirectional switches to convert high frequency single-phase input directly to a power frequency (50/60 Hz) three- phase output. The output stage with LC filter and permanent magnet synchronous machine [12].

The proposed converter generates desired output voltage with suitable shape and frequency. Several modulation strategies have been proposed for traditional inverters. Among these methods, space vector pulse width modulation (SVM) became a standard for the switching power converters. This has some advantages, such as immediate comprehension of the required commutation processes, simplified control algorithm, and maximum voltage transfer ratio without adding third harmonic components. They provided both mathematical treatment and a physical description and understanding of the drive transients even in the cases when machines are fed through electronic converters.

Space Vector Pulse Width Modulation identifies each switching state of a two- or multilevel converter as a point in complex space. Then a reference phasor rotating in the plane at the fundamental frequency is sampled within each switching period, and the nearest three converter switched states are selected with duty cycles calculated to achieve the same volt-second average as the sampled reference phase . This directly controls the converter line-to-line voltages, and only implicitly develops the phase leg voltages an analytical expression is derived for the optimal apportioning factor that results in minimum THD[10]-[11].Comparing with pulse width modulation space vector modulation has more switching paterns. In proposed PET, space vector modulation technique applied to a matrix converter is employed. The main point of switching is, with changing of polarity in input sources on switches are turned off and other switches in arms are turned on.

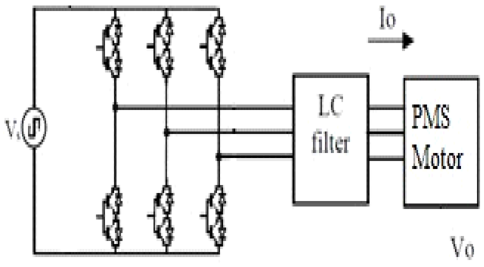


Figure 5: Circuit of output stage

Comparing with conventional PET with DC-link, in proposed converter power delivery stages and power electronic converters have been reduced. The reliability and power quality of distribution system can be significantly improved by using proposed PET.

IV. FUZZY LOGIC CONTROLLER

The Fuzzy Logic Controller (FLC) is used as controller in the proposed model. The Fuzzy Logic tool was introduced in 1965, also by Lotfi Zadeh, and is a mathematical tool for dealing with uncertainty

The fuzzy theory provides a mechanism for representing linguistic constructs such as 'many' 'low' 'medium' 'often' 'few'. In general, the fuzzy logic provides an inference structure that enables appropriate human reasoning capabilities. In fuzzy logic, basic control is determined by a set of linguistic rules which are determined by the system. Since numerical variables are converted into linguistic variables, mathematical modeling of the system is not required. The fuzzy logic control is being proposed for controlling the inverter action.

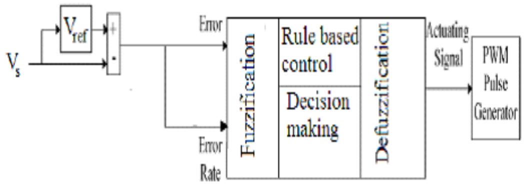


Figure 6: Block diagram of proposed control system

A. Error Calculation:

The error is calculated from the difference between supply voltage data and the reference voltage data. The error rate is the rate of change of error.

B. Fuzzification:

Fuzzification is an important concept in the fuzzy logic theory. Fuzzification is the process where the crisp quantities are converted to fuzzy. Thus Fuzzification process may involve assigning membership values for the given crisp quantities. This unit transforms the non-fuzzy (numeric) input variable measurements into the fuzzy set (linguistic) variable that is a clearly defined boundary, without a crisp (answer). In this simulation study, the error and error rate are defined by linguistic variables such as negative big (NB), negative medium (NM), negative small (NM), zero (Z), positive small (PS), positive medium (PM) and positive big (PB) characterized by membership functions given in Fig. 7.

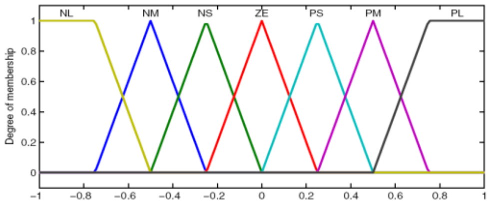


Figure 7: Membership function of Fuzzy Controller

C. Decision Making:

Fuzzy process is realized by Mamdani method. Mamdani inference method has been used because it can easily obtain the relationship between its inputs and output [11]. The set of rules for fuzzy controller are represented in Table II. There are 49 rules for fuzzy controller. The output membership function for each rule is given by the Min (minimum) operator. The Max operator is used to get the combined fuzzy output from the set of outputs of Min operator .The output is produced by the fuzzy sets and fuzzy logic operations by evaluating all the rules. A simple if-then rule is defined as follows: If error is Z and error rate is Z then output is Z.

Table I

Ce\e	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NM	NM	NS	Z
NM	NB	NB	NM	NM	NS	Z	PS
NS	NB	NM	NM	NS	Z	PS	PM
Z	NM	NM	NS	Z	PS	PM	PM
PS	NM	NS	Z	PS	PM	PM	PB
PM	NS	Z	PS	PM	PM	PB	PB
PB	Z	PS	PM	PM	PB	PB	PB

D. Defuzzification :

It is the process of converting the controller outputs in linguistic labels represented by fuzzy set to real control (analog) signals. Defuzzification means the fuzzy to crisp conversions. The fuzzy results generated cannot be used as such to the applications, hence it is necessary to convert the fuzzy quantities into crisp quantities for further processing. This can be achieved by using

Defuzzification process. Centroid method is used for Defuzzification in the present studies.

E. Signal Processing:

The outputs of FLC process are the control signals that are used in generation of switching signals of the PWM inverter by comparing with a carrier signal.

V. SIMULATION RESULTS

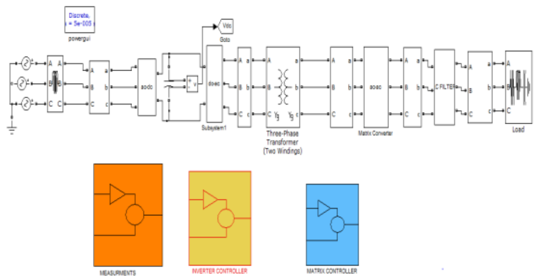
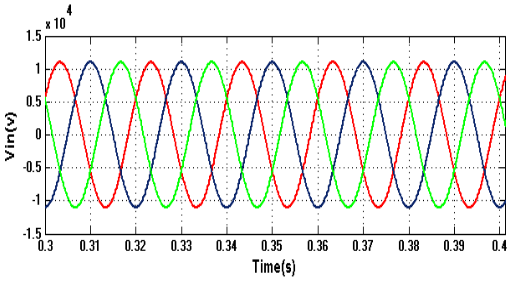


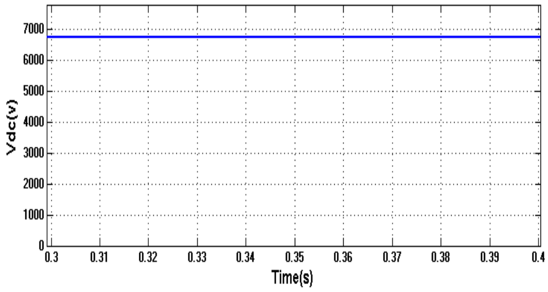
Figure 8: MATLAB / SIMULINK Modeling of Proposed Power Electronic Transformer

In the fig 8 shows MATLAB / SIMULINK modeling of proposed power electronic transformer. At the output stage a permanent magnet synchronous motor is connected. For voltage sag and Swell the output and speed torque of synchronous machine are at constant.

To evaluate the expected performance of the PET, the design was simulated to predict steady state performance. A prototype based on the proposed topology is simulated using MATLAB/SIMULINK. Operation of proposed PET is described by Fig. 9. Fig. 9(a) shows input line voltage of PET. As it can be seen in Fig. 9(b), the DC-link voltage of input stage is 6800 V. Fig. 9(c) depicts the output voltage of VSC in isolation stage that transforms DC voltage to medium frequency AC voltage as the transformer primary voltage. In the output stage, the medium frequency voltage is revealed as a 50 Hz waveform by AC/AC matrix converter, and synchronous machine in connected after the filter 9(f) shows rotor current, speed and torque of the Permanent Magnet Synchronous machine.



(a)



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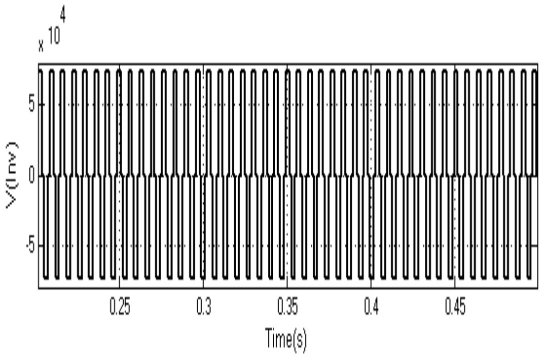
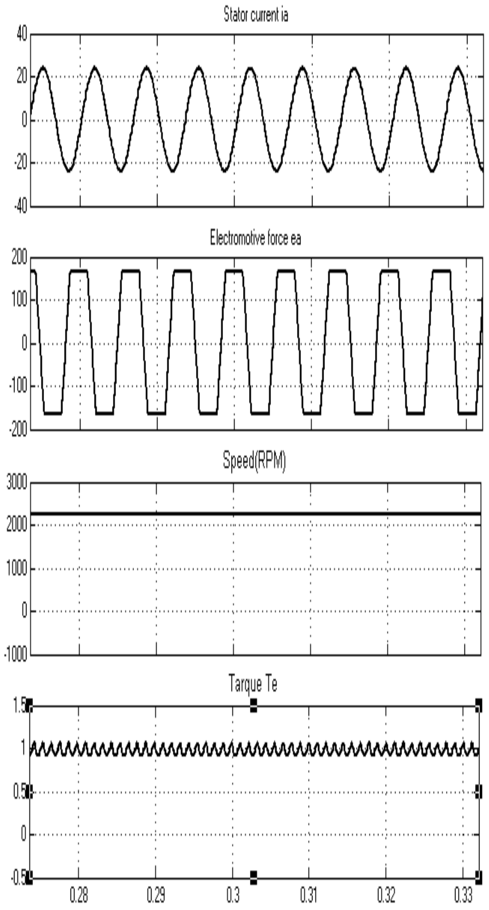


(C)



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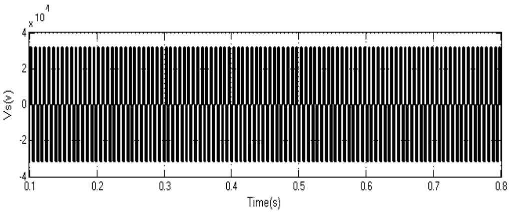
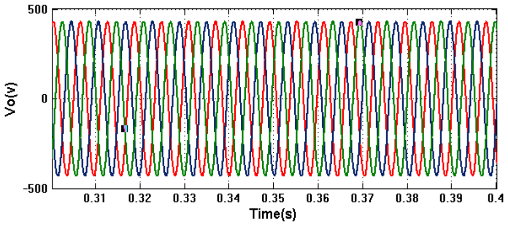


(e)

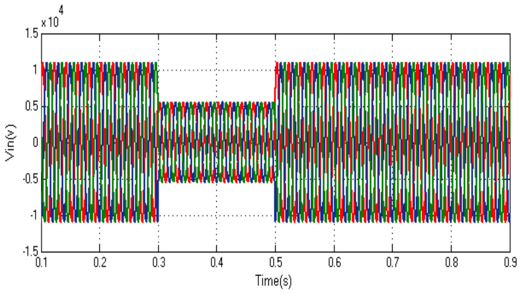


(f)

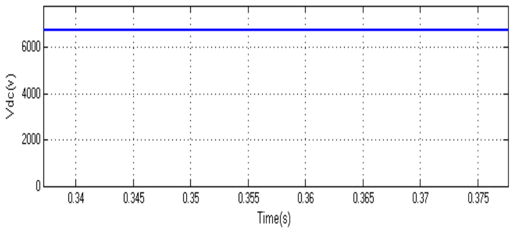
Figure 9: (a) Input voltage **(b)** DC-link voltage **(c)** MF transformer primary voltage **(d)** outputs of synchronous machine **(e)** MF Transformer secondary voltage and **(f)** output voltage

TABLE-2

Parameters	**Value**
Input phase-phase voltage	11KV
Power frequency	50Hz
MF transformer	10:1, 1000 Hz,30 kVA
Output voltage	415V
Matrix converter switching frequency	2050Hz
Load	20 kW+j10 kVAR
LC filter	2 mH, 220 µF
L, Cdc	3 mH, 2000 µF



(a)



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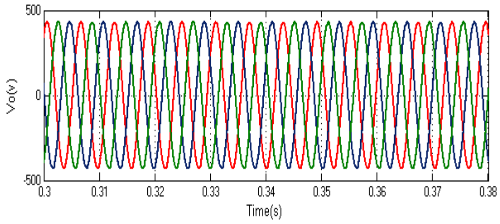
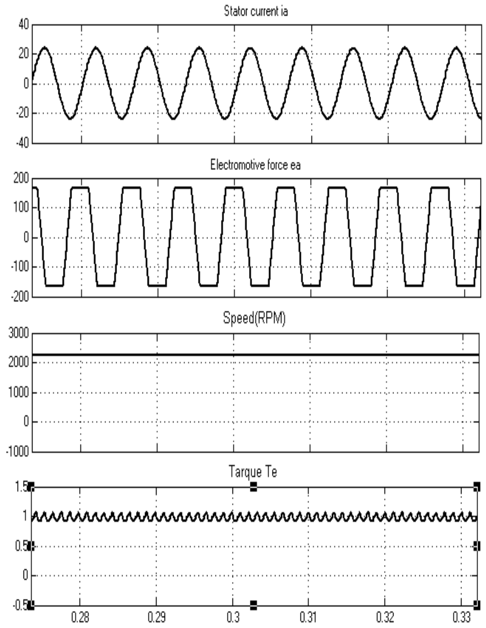


(c)

Figure 10: (a) Input voltage sag **(b)** DC-link voltage **(c)** Load voltage before filter and **(d)** load voltage



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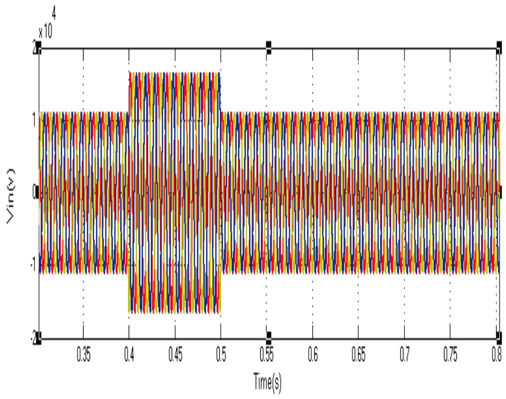

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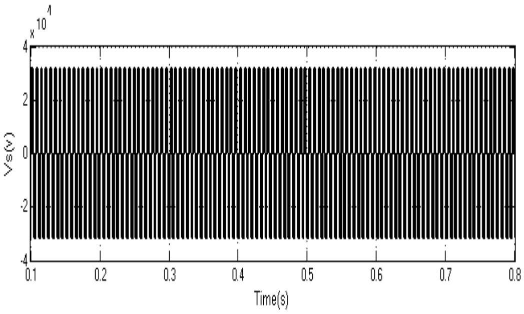

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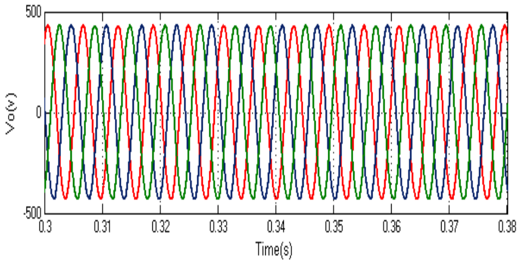

(d)

Figure 11: (a) Torque speed characteristics of synchronous machine when sag & swell occurred **(b)** Input voltage swells **(c)** DC-link voltage **(d)** Load voltage before filter and **(e)** load voltage.

VI. CONCLUSION

In this paper a new configuration of power electronic transformer with fuzzy logic controller has been proposed. To reduce the voltage fluctuations and to maintain the power quality within the limits PET has been developed.The control block consists of fuzzy logic controller.This controller will perform efficiently with reduced errors.Matrix converter plays a vital role in this paper,it converts high switching frequency in to supply frequency.Harmonics are also eliminated.If there are any disturbances such as voltage sag,voltage swell in supply side,these are not carried forwarded to load side.These disturbances are nullified by fuzzy logic controller.The proposed topology is verified through the Matlab/Simulink platform.

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