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Fuzzy Controlled Neutral Point Clamped Active Power Filter for Power Quality Improvements

P.Shyam Kumar
M-tech Student Scholar
Department of Electrical & Electronics Engineering,
Scient Institute of Technology & Science,
Telangana, India.
Email:shyamkumar.pitta29@gmail.com

K. Sreepal Reddy
Associate Professor
Department of Electrical & Electronics Engineering,
Scient Institute of Technology & Science,
Telangana , India.
Email: Sreepalpid@gmail.com

Abstract- In this concept, we revise new kind of continuous-alternating converter, a seven-level neutral point clamping (NPC) voltage source inverter (VSI). We intend this inverter for applications in high voltage and high power fields. In the foremost part, we develop the knowledge and the control models of this inverter using the connections functions of the semi-conductors. After that, we present pulse width modulation (PWM) to control this converter using its control model. Active power filter continues to draw considerable attention. Because of sensitivity of consumers on power quality and advancement in power electronics. Active power filter technology is the most efficient way to compensate reactive power and cancel out low order harmonics generated by nonlinear loads. An active power filter is a device that is connected in parallel to and cancels the harmonic currents from the group of nonlinear loads so that the resulting total current drawn from the ac main is sinusoidal. The shunt active power filter was considered to be the most basic configuration for the APF. Finally simulation results show that power quality of the power system network has been increased with the Seven level NPC based active power filter and its performance has studied under 1) balanced non-linear load, 2) Un balanced non-linear load and 3) variable non-linear load. Based upon the theoretical analysis it is proven that proposed control technique will effectively controls the NPC based Active power filter to improve the power quality.

I. INTRODUCTION

In general power electronic devices are mostly used in our day by day applications. As we know that these are non linear in nature, disturbances occur on the electrical supply network. These will establish harmonics in the power system thus causing equipment overheating, damage and EMI associated problems etc. Active Power Filters (APF) is expansively used to reimburse the current harmonics and load unbalance. Power quality is one of the most significant topics that electrical engineers have been noticed in recent years. Current harmonics is one of the problems associated to power quality. This phenomenon happens continuously in distribution systems. The existence of harmonics does not mean that the industry cannot run accurately. Like other power quality phenomena, it depends on the "stiffness" of the power distribution system and the susceptibility of the equipment. As shown below, there are a owner of different types of equipment that can have malfunction or failures due to high harmonic voltage and/or current levels. This harmonic effluence is often carried back onto the electric utility distribution system, and may influence facilities on the same system which are more liable. Some typical types of equipment susceptible to harmonic pollution include: extreme neutral current, resulting in overheated neutrals.

Generally, current controlled voltage source inverters are used in distributed system. Recently, a few control strategies for grid connected inverters incorporating PQ solution have been proposed. In [3] an inverter functions as active inductor at a certain frequency to absorb the harmonic current. But the literal calculation of network inductance in real-time is complex and may deteriorate the control performance. A similar approach in which a shunt active filter acts as active conductance to damp out the harmonics in distribution network is proposed in [4]. In [5], a control strategy for renewable interfacing inverter based on theory is proposed. In this tactic both load and inverter current sensing is required to compensate the load current harmonics. Here, the main idea is to control the inverter at intense loading conditions. It is shown in this paper that the grid-interfacing APF concert is tested under:

1) Balanced non-linear load,
2) Un-balanced nonlinear load; and
3) Variable non-linear load.

The principle of operation and block diagram of proposed concept is shown in fig.1.

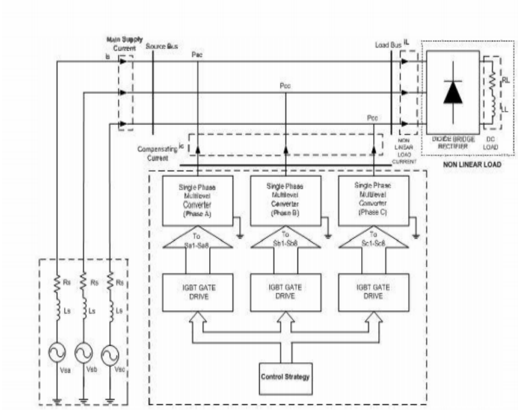

Fig 1 NPC based APF for power quality improvement in power system network

II. PROPOSED NPC CONVERTER TOPOLOGY

Two level voltage source is the mostly used converter power system with APF [4],[5], this inverter is limited for low power applications. Now a day's multilevel inverters are playing a major role in industrial applications because of its numerous characteristics and advantages. Advantages of multilevel inverters include minimum dv/dt, minute number of harmonics, stair case wave form, low THD etc. In general multilevel inverters are of three types. They include flying capacitor, neutral point clamped and cascaded H-bride multilevel inverter.

Flying capacitor type multilevel inverter having some draw backs like balancing of voltage and more capacitors. Hence in this we use a neutral point clamped multilevel inverter concept. The seven-level Neutral-point diode-clamped (NPC) active power filter has been playing an important role for Medium and high power applications shown in fig.2. It provides less voltage stress for semiconductor switches increases the power handling capability, reduces current/voltage harmonics and interference. The controller is the main part of the active power filter operation and has been a subject of many researches in recent years; among the various current control techniques, hysteresis current control is the most extensively used technique. It is easy to realize with high accuracy and fast response. In the hysteresis control technique the error function is centred in a preset hysteresis band.

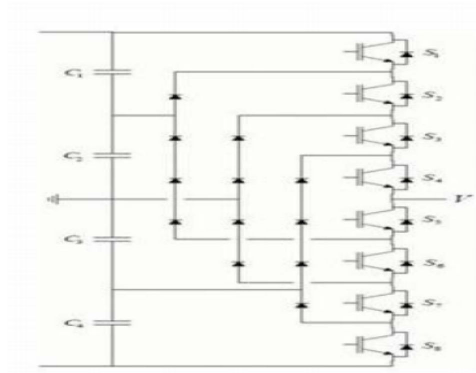

Fig 2 Seven level NPC configuration

TABLE-1
Shows Switching Configuration of Seven level NPC

level	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
3Vdc	1	0	0	1	1	0	0	1	1	0	0	1
2Vdc	1	0	0	1	1	0	0	1	1	0	1	0
1Vdc	1	0	0	1	0	1	0	1	1	0	1	0
0	1	0	1	0	0	1	0	1	1	0	1	0
-1Vdc	0	1	1	0	0	1	1	0	1	0	0	1
-2Vdc	0	1	1	0	0	1	1	0	0	1	0	1
-3Vdc	0	1	1	0	0	1	1	0	0	1	1	0

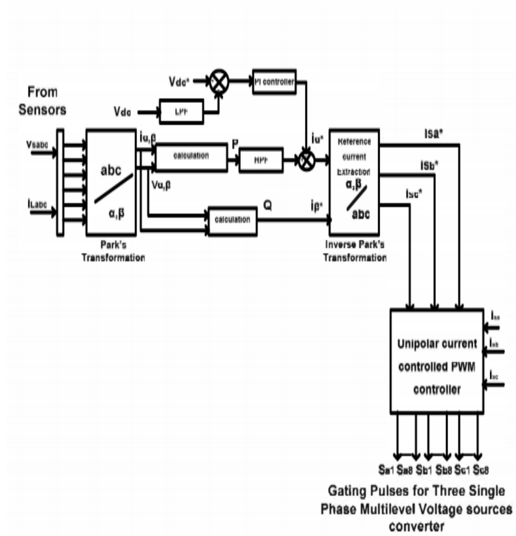

Fig.3 Control circuit of proposed NPC based APF

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III. REFERENCE CURRENT GENERATION

The reference current generator block generates the reference current to be injected into the grid upon sensing the voltage at the Point of Common Coupling (VPCC) and load currents using instantaneous active and reactive power (p-q) theory. For the computation of p and q, the three phase voltages at the point of common coupling (PCC) and load currents must first be transformed to the stationary two axis coordinates. The instantaneous real and reactive power p and q are determined using equations

$$p = V_\alpha \times I_\alpha + V_\beta \times I_\beta \quad (1)$$

$$q = V_\alpha \times I_\beta - V_\beta \times I_\alpha \quad (2)$$

Both instantaneous power quantities p and q consists of dc and ac components. While the dc components p and q arise due to the fundamental, the ac components p and q are a result of harmonic components. To provide harmonic as well as reactive power compensation as per the load demand, the reference for active and reactive power is generated. The ac component f5 is determined by first extracting using a very low cut off low pass filter and then subtracting it from p obtained using. Finally, the reference currents are generated as per (3) and (4).

$$\begin{bmatrix} i_\alpha{}^* \\ i_\beta{}^* \end{bmatrix} = \begin{bmatrix} v_{s\alpha} & v_{s\beta} \\ -v_{s\beta} & v_{s\alpha} \end{bmatrix}^{-1} \begin{bmatrix} p^* \\ q^* \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} i_{ca}{}^* \\ i_{cb}{}^* \\ i_{cc}{}^* \end{bmatrix} = [C]^T \begin{bmatrix} i_\alpha{}^* \\ i_\beta{}^* \end{bmatrix} \quad (4)$$

A. Hysteresis Current Controller

The hysteresis current controller compares the three phase reference currents (ica*, icb*, icc*) generated using with the actual inverter currents (ica, icb, icc) and generates the switching pulses as per the logic given below:

$$\text{if } (i_{ca} > i_{ca}{}^* + hb)$$

leg-a upper switch is OFF and lower switch is ON

$$\text{if } (i_{ca} < i_{ca}{}^* - hb)$$

leg-a upper switch is ON and lower switch is OFF Where, hb is the hysteresis band around the reference current which is usually 5 % of the maximum current to be injected by the inverter. Similarly, control signals for leg-b and leg-c of the inverter switches are generated.

IV. FUZZY LOGIC CONTROLLER

In recent years, the number and variety of applications of Fuzzy Logic (FL) have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. To understand why use of Fuzzy Logic has grown, it must be first understood as what is meant by Fuzzy Logic.

Fuzzy Logic has two different meanings. In a narrow sense, Fuzzy Logic is a logical system, which is an extension of multivalve logic. However, in a wider sense Fuzzy Logic is almost synonymous with the theory of Fuzzy sets, a theory which relates to classes of objects with un sharp boundaries in which membership is a matter of degree. In this perspective, Fuzzy logic in its narrow sense is a branch of Fuzzy Logic. Even in its more narrow definition, Fuzzy logic differs both in concept and substance from traditional multivalve logical systems.

a) Importance of Fuzzy Logic:

Fuzzy logic is all about the relative importance of precision: use as Fuzzy Logic Toolbox software with MATLAB technical computing software as a tool for solving problems with fuzzy logic. Fuzzy logic is a fascinating area of research because it does a good job of trading off between significance and precision something that humans have been managing for a very long time. In this sense, fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concept of fuzzy logic relies on age-old skills of human reasoning.

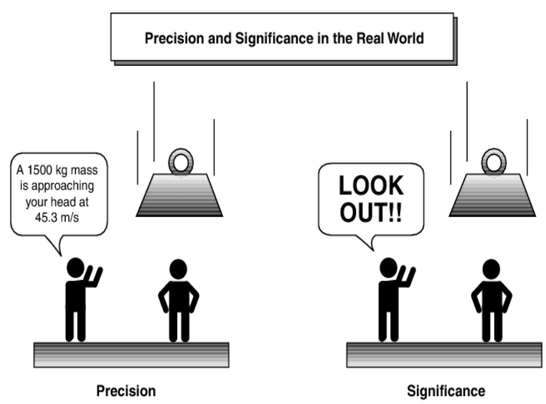

Fig 4 Fuzzy Description

b) Usage of Fuzzy Logic:

Fuzzy logic is a convenient way to map an input space to an output space. Mapping input to output is the starting point for everything. Consider the following examples:

- With information about how good your service was at a restaurant, a fuzzy logic system can tell you what the tip should be.
- With your specification of how hot you want the water, a fuzzy logic system can adjust the faucet valve to the right setting.

- With information about how far away the subject of your photograph is, a fuzzy logic system can focus the lens for you.
- With information about how fast the car is going and how hard the motor is working, a fuzzy logic system can shift gears for you.

To determine the appropriate amount of tip requires mapping inputs to the appropriate outputs. Between the input and the output, the preceding figure shows a black box that can contain any number of things: fuzzy systems, linear systems, expert systems, neural networks, differential equations, interpolated multi dimensional lookup tables, or even a spiritual advisor, just to name a few of the possible options. Clearly the list could go on and on. Of the dozens of ways to make the black box work, it turns out that fuzzy is often the very best way. As Lotfi Zadeh, who is considered to be the father of fuzzy logic, once remarked: "In almost every case you can build the same product without fuzzy logic, but fuzzy is faster and cheaper".

c) Convenience of Fuzzy Logic:

Fuzzy logic is not a cure-all. When should you not use fuzzy logic? The safest statement is the first one made in this introduction: fuzzy logic is a convenient way to map an input space to an output space. Fuzzy logic is the codification of common sense; use common senses when you implement it and which will probably make the right decision. Many controllers, for example, do a fine job without using fuzzy logic. However, it take the time to become familiar with fuzzy logic, it can be a very powerful tool for dealing quickly and efficiently with imprecision and nonlinearity.

The Fuzzy Logic Concept:

Fuzzy logic arose from a desire to incorporate logical reasoning and the intuitive decision making of an expert operator into an automated system [14]. The aim is to make decisions based on a number of learned or predefined rules, rather than numerical calculations. Fuzzy logic incorporates a rule-base structure in attempting to make decisions. However, before the rule-base can be used, the input data should be represented in such a way as to retain meaning, while still allowing for manipulation. Fuzzy logic is an aggregation of rules, based on the input state variables condition with a corresponding desired output. A mechanism must exist to decide on which output, or combination of different outputs, will be used since each rule could conceivably result in a different output action.

Fuzzy logic can be viewed as an alternative form of input=output mapping. Consider the input premise, x, and a particular qualification of the input x represented by Ai. Additionally, the corresponding output, y, can be qualified by expression Ci. Thus, a fuzzy logic representation of the relationship between the input x and the output y could be described by the following:

R1: IF x is A1 THEN y is C1
R2: IF x is A2 THEN y is C2
. . . .
. . . .
. . . .
Rn: IF x is An THEN y is Cn

where x is the input (state variable), y is the output of the system, Ai are the different fuzzy variables used to classify the input x and Ci are the different fuzzy variables used to classify the output y. The fuzzy rule representation is linguistically based. Thus, the input x is a linguistic variable that corresponds to the state variable under consideration. Furthermore, the elements Ai are fuzzy variables that describe the input x. correspondingly, the elements Ci are the fuzzy variables used to describe the output y. In fuzzy logic control, the term ''linguistic variable'' refers to whatever state variables the system designer is interested in. Linguistic variables that are often used in control applications include Speed, Speed Error, Position, and Derivative of Position Error. The fuzzy variable is perhaps better described as a fuzzy linguistic qualifier. Thus the fuzzy qualifier performs classification (qualification) of the linguistic variables. The fuzzy variables frequently employed include Negative Large, Positive Small and Zero. Several papers in the literature use the term ''fuzzy set'' instead of ''fuzzy variable'', however; the concept remains the same. Table 30.1 illustrates the difference between fuzzy variables and linguistic variables. Once the linguistic and fuzzy variables have been specified, the complete inference system can be defined. The fuzzy linguistic universe, U, is defined as the collection of all the fuzzy variables used to describe the linguistic variables. I.e. the set U for a particular system could be comprised of Negative Small (NS), Zero (ZE) and Positive Small (PS). Thus, in this case the set U is equal to the set of [NS, ZE, PS]. For the system described by Eq. (30.1), the linguistic universe for the input x would be the set Ux . .A1A2 . . . An.. Similarly,

TABLE 3 .1 Fuzzy and linguistic variables

Linguistic Variables		Fuzzy Variables (Linguistic Qualifiers)	
Speed error	(SE)	Negative large	(NL)
Position error	(PE)	Zero	(ZE)
Acceleration	(AC)	Positive medium	(PM)
Derivative of position error	(DPE)	Positive very small	(PVS)
Speed	(SP)	Negative medium small	(NMS)

the linguistic universe for the output y would be the set Uy . .Ca C2 . . . Cn.

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The Fuzzy Inference System (FIS) The basic fuzzy inference system (FIS) can be classified as: Type 1 Fuzzy Input Fuzzy Output (FIFO)
Type 2 Fuzzy Input Crisp Output (FICO)
Type 2 differs from the first in that the crisp output values are predefined and, thus, built into the inference engine of the FIS. In contrast, type 1 produces linguistic outputs. Type 1 is more general than type 2 as it allows redefinition of the response without having to redesign the entire inference engine. One drawback is the additional step required, converting the fuzzy output of the FIS to a crisp output. Developing a FIS and applying it to a control problem involves several steps:

1. Fuzzification
2. Fuzzy rule evaluation (fuzzy inference engine)
3. Defuzzification.

The total fuzzy inference system is a mechanism that relates the inputs to a specific output or set of outputs. First, the inputs are categorized linguistically (fuzzification), then the linguistic inputs are related to outputs (fuzzy inference) and, finally, all the different outputs are combined to produce a single output (defuzzification). Figure 30.1 shows a block diagram of the fuzzy inference system.

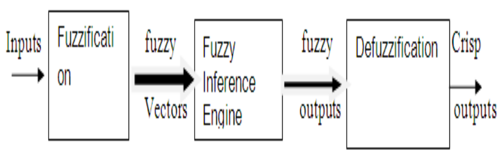

Fig 5 Fuzzy inference system

V MATLAB/SIMULATION RESULTS

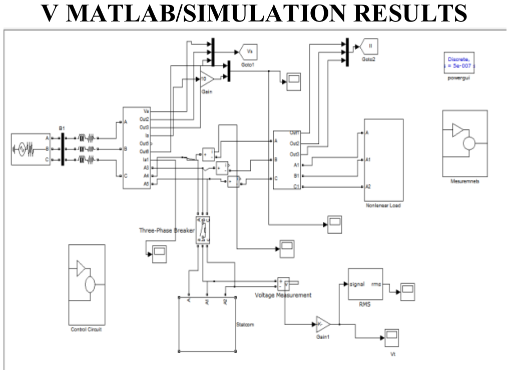

Fig 6 Simulation model of power system network with 5 level NPC based APF under balanced Non-linear load

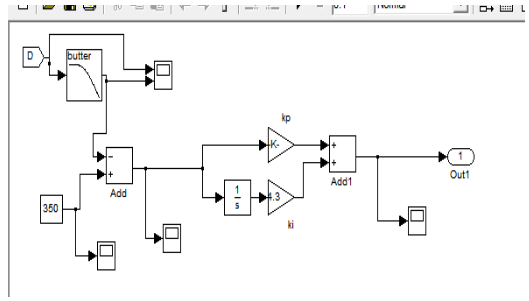

Fig 7 Simulation model of control circuit

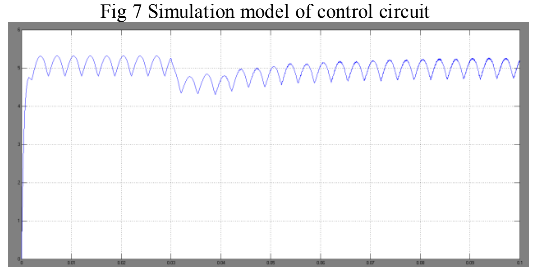

Fig 8 Simulation waveform of output current at non linear load

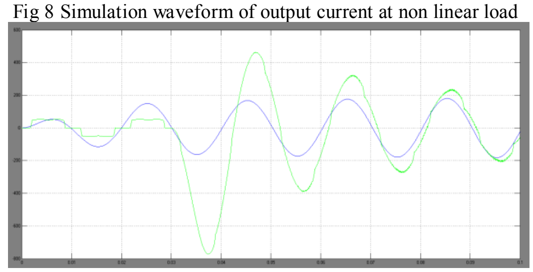

Fig 9 Simulation waveform of source voltage and current

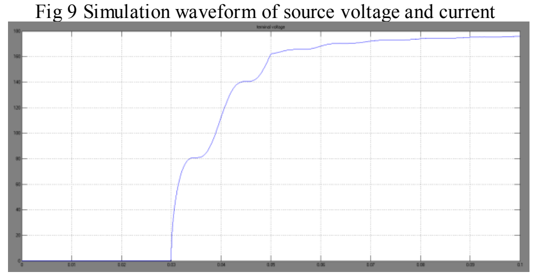

Fig 10 Simulation waveform of terminal voltage

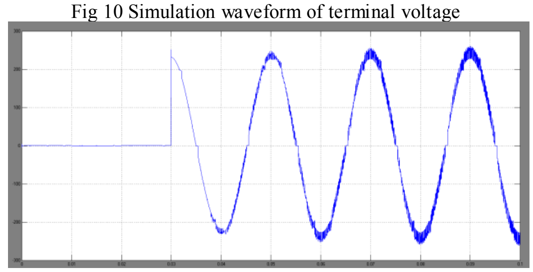

Fig 11 Simulation waveform of terminal voltage gain

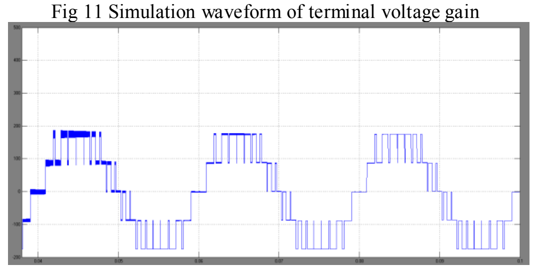

Fig 12 Simulation waveform of diode clamped inverter output voltage

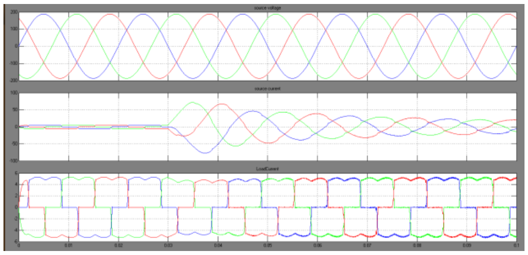

Fig 13 Simulation waveform of Source voltage, source current and load current

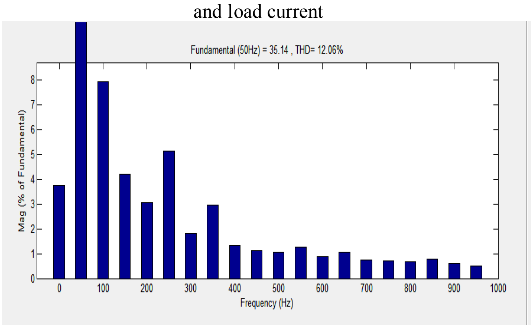

Fig 14 Simulation waveform of harmonic analysis of NPC based APF

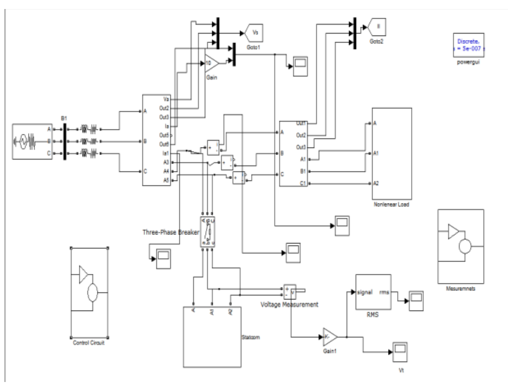

Fig 15 Simulation model of power system network with 5 level NPC fuzzy based under balanced Non-linear load

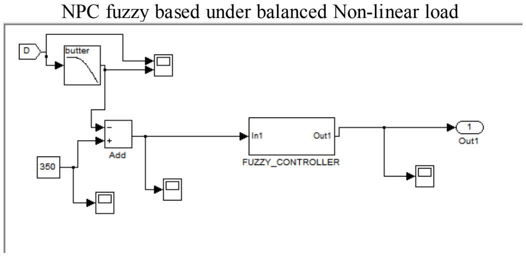

Fig 16 Simulation waveform of fuzzy logic controller

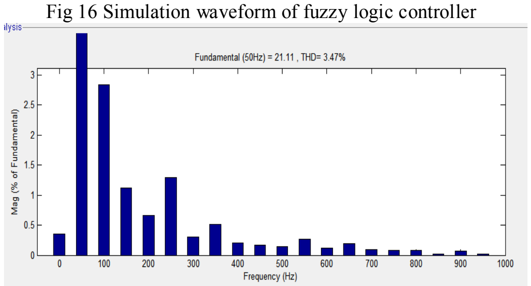

Fig 17 Simulation waveform of harmonic analysis of NPC based fuzzy logic controller

IV. CONCLUSION

The aim is to make decisions based on a number of learned or predefined rules, rather than numerical calculations. Fuzzy logic incorporates a rule-base structure in attempting to make decisions. Finally simulation results show that power quality of the power system network has been increased with the Seven level NPC based active power filter and its performance has studied under 1) balanced non-linear load, 2) Un-balanced non-linear load and 3) variable non-linear load. The fuzzy variable is perhaps better described as a fuzzy linguistic qualifier. Thus the fuzzy qualifier performs classification (qualification) of the linguistic variables. Based upon the theoretical analysis it is proven that proposed control technique will effectively controls the NPC based Active power filter to improve the power quality. The harmonic analysis shows the main difference between fuzzy and APF with connecting NPC. Fuzzy logic based NPC will be have better THD value.

REFERENCES

[I] J. Rocabert, A. Luna, F. Blaabjerg, and P. Rodriguez, "Control of power converters in AC microgrids," iEEE Trans. Power Electron., vol. 27, no. 11, pp. 4734-4749, Nov. 2012.

[2] M. Aredes, J. Hafner, and K. Heumann, "Three-phase fourwire shunt active filter control strategies," iEEE Trans. Power Electron., vol. 12, no. 2, pp. 311-318, Mar. 1997.

[3] S. Naidu and D. Fernandes, "Dynamic voltage restorer based on a fourleg voltage source converter," Gener. Transm. Distrib., iET, vol. 3, no. 5, pp. 437-447, May 2009.

[4] N. Prabhakar and M. Mishra, "Dynamic hysteresis current control to minimize switching for three-phase four-leg VSI topology to compensate nonlinear load," iEEE Trans. Power Electron., vol. 25, no. 8, pp. 1935- 1942, Aug. 2010.

[51 V. Khadkikar, A. Chandra, and B. Singh, "Digital signal processor implementation and performance evaluation of split capacitor, four-leg and three h-bridge-based three-phase four-wire shunt active filters," Power Electron., iET, vol. 4, no. 4, pp. 463- 470, Apr. 2011.

[6] F. Wang, J. Duarte, and M. Hendrix, "Grid-interfacing converter systems with enhanced voltage quality for microgrid application;concept and implementation," iEEE Trans. Power Electron., vol. 26, no. 12, pp. 3501- 3513, Dec. 2011.

[71 X.Wei, "Study on digital pi control of current loop in active power filter," in Proc. 2010 into Con! Electr. Control Eng., Jun. 2010, pp. 4287-4290.

[14]

[81 R. de Araujo Ribeiro, C. de Azevedo, and R. de Sousa, "A robust adaptive control strategy of active power filters for powerfactor correction, harmonic compensation, and balancing of nonlinear loads," Ieee Trans.Power Electron., vol. 27, no. 2, pp. 718-730, Feb. 2012.

[9] J. Rodriguez, J. Pont!, C. Silva, P. Correa, P. Lezana, P. Cortes, and U. Ammann, "Predictive current control of a voltage source inverter," iEEE Trans. ind. Electron., vol. 54, no. 1, pp. 495-503, Feb. 2007.

[10] P. Cortes, G. Ortiz, J. Yuz, J. Rodriguez, S. Vazquez, and L. Franquelo, "Model predictive control of an inverter with output LC filter for UPS applications," iEEE Trans. ind. Electron., vol. 56, no. 6, pp. 1875-1883, Jun. 2009.

[11] R. Vargas, P. Cortes, U. Ammann, J. Rodriguez, and J. Pont!, "Predictive control of a three-phase neutral-point-clamped inverter," iEEE Trans. ind. Electron., vol. 54, no. 5, pp. 2697-2705, Oct. 2007.

[12] P. Cortes, A. Wilson, S. Kouro, J. Rodriguez, and H. AbuRub, "Model predictive control ofinultilevel cascaded H-bridge inverters," iEEE Trans. ind. Electron., vol. 57, no. 8, pp. 2691-2699, Aug. 2010.

P. Shyam kumar pursing M.Tech (2016) in the stream of Electrical power system From the Scient Institute of Technology.

[13] P. Lezana, R. Aguilera, and D. Quevedo, "Model predictive control of an asymmetric flying capacitor converter," iEEE Trans. ind. Electron., vol. 56, no. 6, pp. 1839-1846, Jun. 2009.

K. SREEPAL REDDY received B.TECH degree from SRR Engineering College, karepally, Khammam (JNTUH) in the year 2006 and recived M.Tech in the stream of Power & Industrial Drives at JNTU Ananthapur Campus (JNTUA). Currently working as a Associate Professor in Scient Institute of Technology since 6years. And his areas of interest are Power Electronics, Power Systems, Electrical machines, Electrical Circuits and Control Systems.

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