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Developing Efficient Power System with Shunt Filter with FACTS Device and Fuzzy

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Abstract - In the proposed model a joint approach of FACTS device with filter bank is used to power quality enhancement facilitated with fuzzy logic controller. The Facts devices gives facility to control and manages the power quality of any power system but the proposed compensation needs extra logic to be implemented with the existing FACTS devices application, and the filter banks filter out the distortions created by the source and the transmission media itself. The active filter bank arranged in shunt with power line is the combination of a small-rating active power filter (APF) and a fifth-harmonic-tuned LC passive filter. The tuned passive filter and Thyristor controlling form a shunt passive filter (SPF) to compensate DC voltage. The distortions in the DC voltage affects the overall power quality of the system.

Keywords- ***Harmonics, Shunt power filter, Thyristor-controlled reactor, reactive power compensation.***

I. INTRODUCTION

Early equipment was designed to withstand disturbances such as lightning, short circuits, and sudden overloads without extra expenditure. Current power electronics (PE) prices would be much higher if the equipment was designed with the same robustness. Pollution has been introduced into power systems by nonlinear loads such as transformers and saturated coils; however, perturbation rate has never reached the present levels. Due to its nonlinear characteristics and fast switching, PE creates most of the pollution issues. Most of the pollution issues are created due to the nonlinear characteristics and fast switching of PE. Approximately 10% to 20% of today’s energy is processed by PE; the percentage is estimated to reach 50% to 60% by the year 2010, due mainly to the fast growth of PE capability. A race is currently taking place between increasing PE pollution and sensitivity, on the one hand, and the new PE-based corrective devices, which have the ability to attenuate the issues created by PE, on the other hand. Increase in such non-linearity causes different undesirable features like low system efficiency and poor power factor. It also causes disturbance to other consumers and interference in nearby communication networks. The effect of such non-linearity may become sizeable over the next few years. Hence it is very important to overcome these undesirable features. Classically, shunt passive filters, consist of tuned LC filters and/or high passive filters are used to suppress the harmonics and power capacitors are employed to improve the power factor. But they have the limitations of fixed compensation, large size and can also exile resonance conditions. Active power filters are now seen as a viable alternative over the classical passive filters, to compensate harmonics and reactive power requirement of the non-linear loads. The objective of the active filtering is to solve these problems by combining with a much-reduced rating of the necessary passive components. Various topologies of active power filters have been developed. The shunt active power filter based on current controlled voltage source type PWM converter has been proved to be effective even when the load is highly non-linear. Most of the active filters developed are based on sensing harmonics and reactive volt-ampere requirements of the non-linear load [1] and require complex control. A new scheme has been proposed in [10], in which the required compensating current is determined by sensing load current which is further modified by sensing line currents only.

Power Quality

The PQ issue is defined as “any occurrence manifested in voltage, current, or frequency deviations that results in damage, upset, failure, or misoperation of end-use equipment.” Almost all PQ issues are closely related with PE in almost every aspect of commercial, domestic, and industrial application. Equipment using power electronic devise are residential appliances like TVs, PCs etc. business and office equipment like copiers, printers etc. industrial equipment like programmable logic controllers (PLCs), adjustable speed drives (ASDs), rectifiers, inverters, CNC tools and so on. The Power Quality (PQ) problem can be detected from one of the following several symptoms depending on the type of issue involved.

- *Lamp flicker*
- *Frequent blackouts*
- *Sensitive-equipment frequent dropouts*
- *Voltage to ground in unexpected*
- *Locations*
- *Communications interference*
- *Overheated elements and equipment.*

PE are the most important cause of harmonics, inter harmonics, notches, and neutral currents. Harmonics are produced by rectifiers, ASDs, soft starters, electronic ballast for discharge lamps, switched-mode power supplies, and HVAC using ASDs. Equipment affected by harmonics includes transformers, motors, cables, interrupters, and capacitors (resonance). Notches are produced mainly by converters, and they principally affect the electronic control devices. Neutral currents are produced by equipment using switched-mode power supplies, such as PCs, printers, photocopiers, and any triplets generator. Neutral currents seriously affect the neutral conductor temperature and transformer capability. Inter harmonics are produced by static frequency converters, cyclo-converters, induction motors & arcing devices. Equipment presents different levels of sensitivity to PQ issues, depending on the type of both the equipment and the disturbance. Furthermore, the effect on the PQ of electric power systems, due to the presence of PE, depends on the type of PE utilized.

II. SYSTEM MODEL

Design Procedures

Active power filter Configuration Fig. 6 shows concept of active power filter. The load may be rectifier or other nonlinear load.

Assuming the mains voltage is a pure sine-wave, it is represented as

$$V_s(t) = V_p \sin(wt) \qquad (3.1)$$

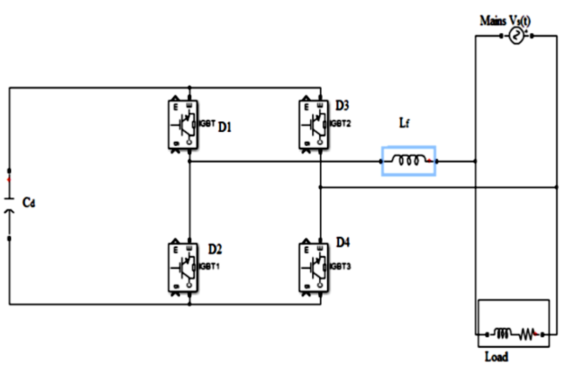

Fig.1 Circuit of Active Power Filter

The nonlinear load current can be represented as

$$I_L(t) = \sum_{n=1}^{\infty} I_n \sin(nwt + \theta_n) \qquad \textbf{(3.2)}$$

Therefore,

$$I_L(t) = I_1 \sin(wt + \theta_1) + \sum_{n=2}^{\infty} I_n \sin(nwt + \theta_n)$$

Assuming a reference sinusoidal signal is represented as

$$I_r = \sin(wt) \qquad \textbf{(3.3)}$$

The amplitude of real part of fundamental load current be,

$$I_x = 1/T(\int I_L(t) I_r(t)\, dt)$$

$$= I_1 \cos\theta_1 \qquad \textbf{(3.4)}$$

$$Now,\ \mathrm{I_{sc}}\ (\mathrm{t}) = \mathrm{I_x}\, \mathrm{I_r}(\mathrm{t})$$

$$= I_1 \cos\theta_1 \sin(wt) \qquad \textbf{(3.5)}$$

Hence, calculated compensation current be,

$$I_{cr}(t) = I_L(t) - I_{sc}(t) \ \textbf{(3.6)}$$

Component Functions

The inductor shown in Fig.6 is used to ensure that the compensation current generated by the convertor is smooth current; an inductor is required to filter out the switching ripple current. For a good dynamic response, the size of this inductor must be as small as possible. If the inductor is too small, it cannot suppress the switching ripple current. It may cause the problem of multi-crossing phenomenon because the change rate of the convertor output current is larger than the slope of the triangle carrier signal. This has the result that the switching frequency is higher than the carrier signal frequency. In addition, the gain of the error amplifier can affect this phenomenon. A PI controller is used to provide approximate amplitude to the mains current. Square wave generator and then sine wave is generated from source for synchronization. Now, the error signal is send to PWM modulator which is required to give the gate pulses for compensation current. To PWM modulator carrier waveform given is triangular wave and through this frequency of gate pulses can be controlled. The load here should be non-linear.

Component Calculations

In order for the circuit to function properly, the external components need to be calculated carefully. Voltage across the capacitor should be maintained more than 1.41 times of V_{mains} . For the PI controller,

$$K_i = (L + L_0).wc\ /\ (2 * V_{dc}) \qquad (3.7)$$

$$K_p = wc^* \ K_i \qquad (3.8)$$

This equations stands for triangular wave of amplitude 1 peak to peak.

Where, L + L0 = Total inductance,

Wc = Triangular wave frequency

Vdc= Capacitor voltage

III. PROBLEM FORMULATION

Power filter topologies

Depending on the particular application or electrical problem to be solved, active power filters can be implemented as shunt type, series type, or a combination of shunt and series active filters (shunt-series type). These filters can also be combined with passive filters to create hybrid power filters. The shunt-connected active power filter, with a self-controlled dc bus, has a topology similar to that of a static compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal-but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase-shifted by 180°. Series active power filters were introduced by the end of the 1980s and operate mainly as a voltage regulator and as a harmonic isolator between the nonlinear load and the utility system.

IV. PROPOSED METHODOLOGY

Fuzzy Algorithm

In a fuzzy logic controller, the control action is determined from the evaluation of a set of simple linguistic rules. The development of the rules requires a thorough understanding of the process to be controlled, but it does not require a mathematical model of the system. The internal structure of the fuzzy controller is shown in Fig. 2.

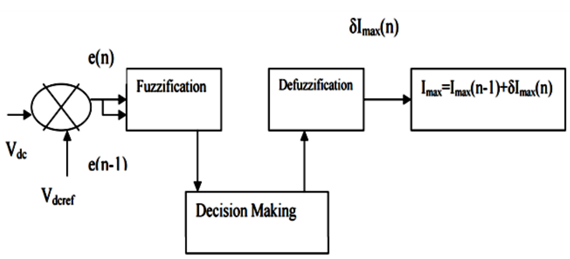

Fig 2. Internal structure of fuzzy logic controller.

A fuzzy inference system (or fuzzy system) basically consists of a formulation of the mapping from a given input set to an output set using fuzzy logic. This mapping process provides the basis from which the inference or conclusion can be made. A fuzzy inference process consists of the following steps:

Step 1: Fuzzification of input variables

Step 2: Application of fuzzy operator (AND,OR,NOT) in the IF(antecedent) part of the rule

Step 3: Implication from the antecedent to the consequent(THEN part of the rules)

Step 4: Aggregation of the consequents across the rules

Step 5: Defuzzification

The crisp inputs are converted to linguistic variables in fuzzification based on membership function (MF). An MF is a curve that defines how the values of a fuzzy variable in a certain domain are mapped to a membership value μ (or degree of membership) between 0 and 1. A membership function can have different shapes, as shown in figure 3. The simplest and most commonly used MF is the triangular-type, which can be symmetrical or asymmetrical in shape. A trapezoidal MF has the shape of a truncated triangle. Two MFs are built on the Gaussian distribution curve: a simple Gaussian curve and a two-sided composite of two different Gaussian distribution curves. The bell MF with a flat top is somewhat different from a Gaussian function. Both Gaussian and bell MFs are smooth and non-zero at all points.

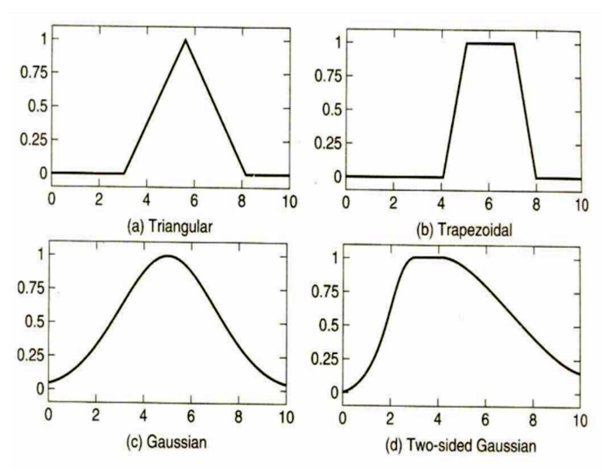

Fig. 3 Different types of membership functions.

The basic properties of Boolean logic are also valid for Fuzzy logic. Once the inputs have been fuzzified, we know the degree to which each part of the antecedent of a rule has been satisfied. Based on the rule, OR or AND operation on the fuzzy variables is done. The implication step helps to evaluate the consequent part of a rule.

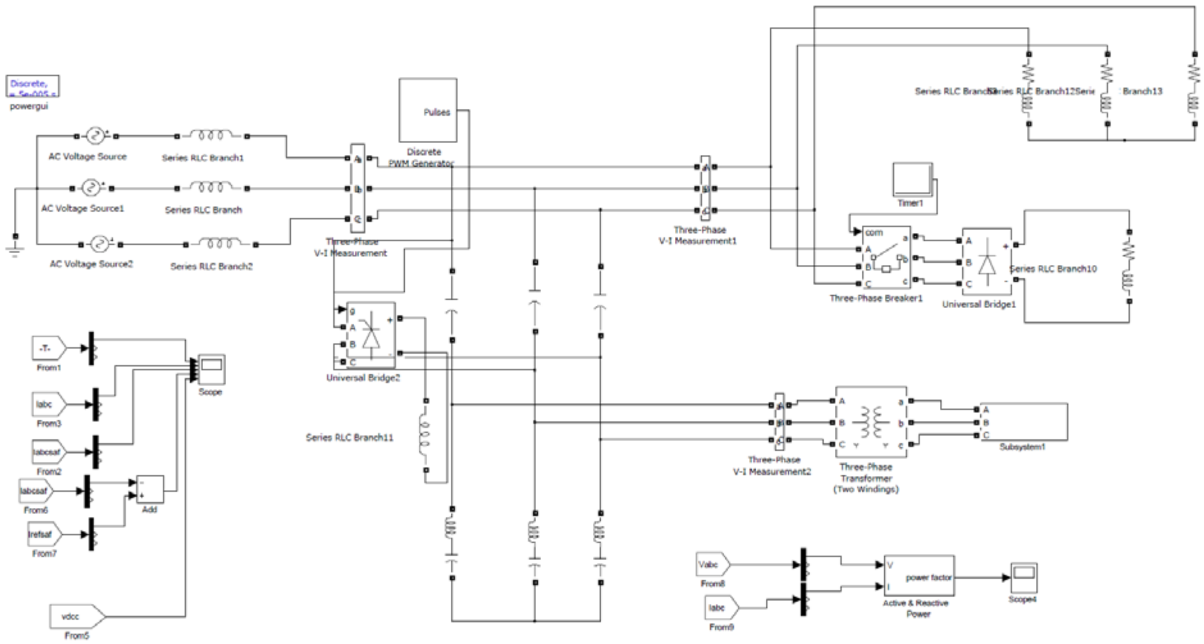

Fig. 4 Power System Model with Filter Bank in Shunt and Thyristor Control Unit

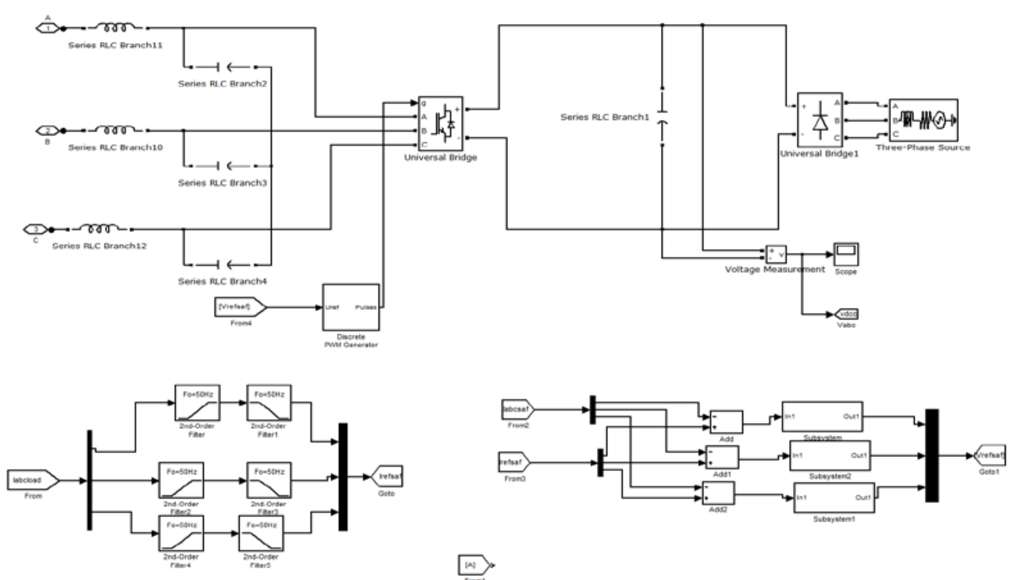

Fig. 5 Sub System Module

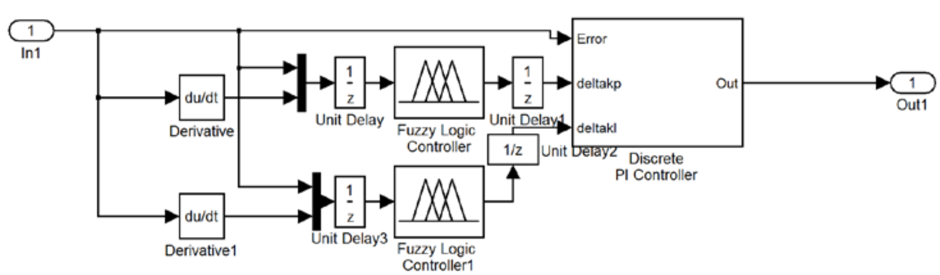

Fig. 6 Proposed Fuzzy Module

V. RESULTS

The proposed model mentioned in the previous section is designed and simulated in the MATLAB SIMULINK R2009b and the after simulation the outcomes of the various parameters are shown in the below figures. The Figure 7 shows the source voltage/current, DC voltage. The DC voltage at the load does not have any distortion means the power is delivering to the load side is better than the previous work.

In the Fig. 8 the FFT analysis of the system is also shown.

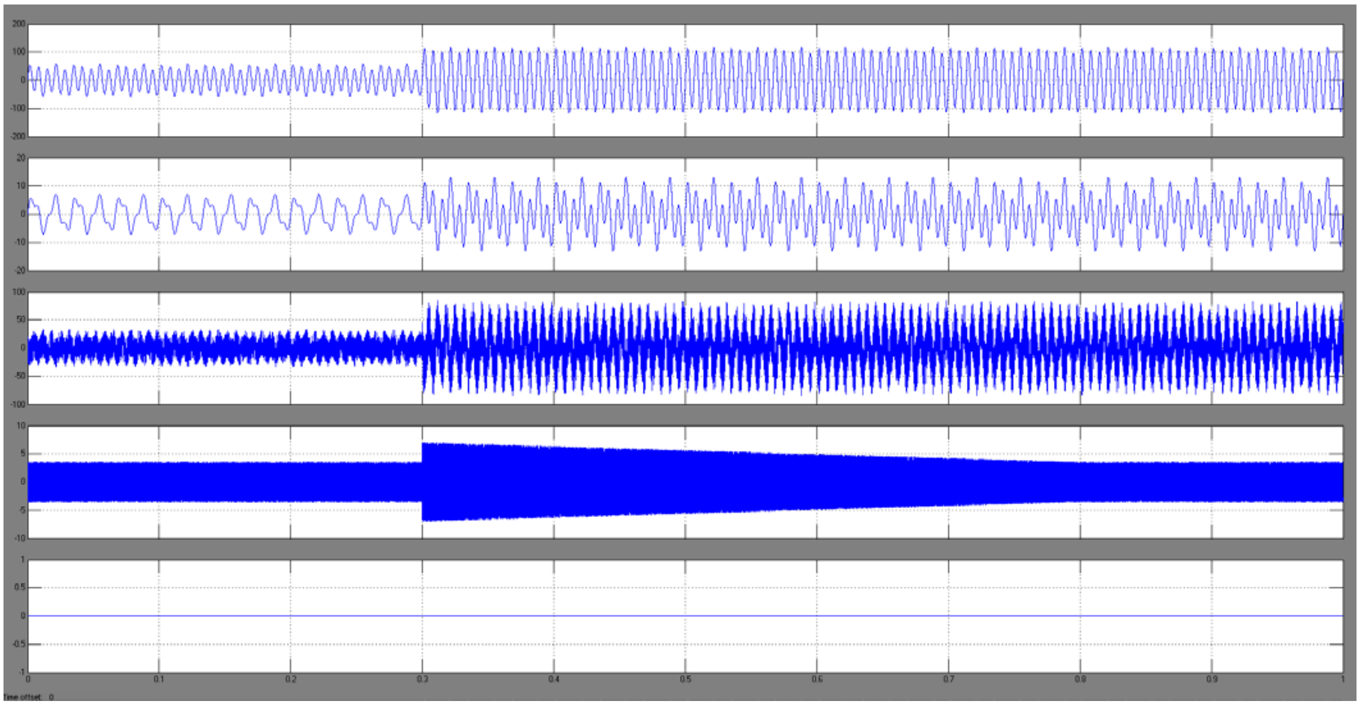

Fig. 7 Result Waveforms of Load Current and DC Voltage

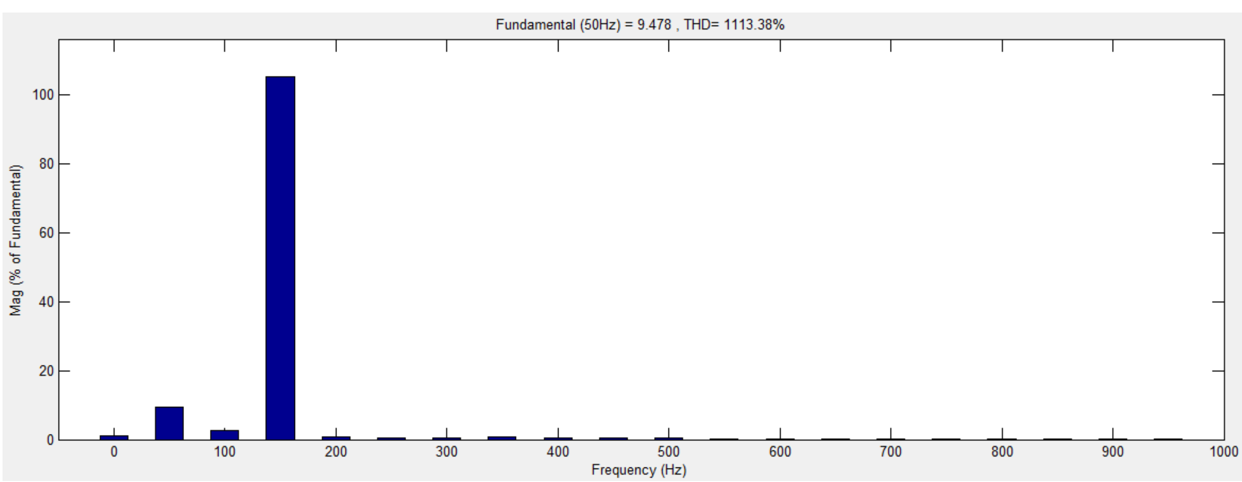

Fig. 8 FFT Analysis

VI. CONCLUSION AND FUTURE SCOPE

In modern electrical power system, numerous power electronics equipment had been introduced. Wide range of power conversion units, power electronic equipment and nonlinear loads such as adjustable speed drives, domestic appliances, transformer saturation cause increase in harmonics at the ac mains. Due to continuous development in technology and electronics equipment number of non-linear loads are increasing exponentially, due to this production of characteristics and non-characteristic harmonics occur in the power system. Around two decades the development of thyristors has brought the flexibility in the control but on the darker side it has brought harmonics to the system also. These loads draw non-sinusoidal current from ac mains and degrade the system performance. Characteristics harmonics can be eliminated using tuned filters whereas to eliminate non-characteristics harmonics is the major problem. From the above proposed methodology of the system the power quality has been improved and it is visible in the simulation results. The DC voltage has become smooth that better than previous work.

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