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Developing an Efficient Power System Using a Shunt Filter and a Fuzzy FACTS Device

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Abstract — *A hybrid method of a FACTS device and a filter bank is used in the suggested model to provide quality enhancement using a fuzzy logic controller. The FACTS devices provide the ability to control and manage the power quality of any power system, but the proposed compensation necessitates additional logic to be implemented with the existing FACTS devices application, and the filter banks filter out the distortions caused by the source and transmission medium itself. A small-rating active power filter (APF) and a fifth-harmonic-tuned LC passive filter make up the active filter bank arranged in shunt with power line. To compensate for DC voltage, a shunt passiv filter (SPF) is formed using a tuned passive filter and Thyristor control.*

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

I. INTRODUCTION (SIZE 10 & BOLD)

Early technology was built to endure unforeseen events such as lightning, short circuits, and sudden overloads without incurring additional costs. If current power electronics (PE) equipment was designed with the same robustness, current power electronics (PE) prices would be significantly higher. Nonlinear loads such as transformers and saturated coils have introduced pollution into power systems; nonetheless, the perturbation rate has never reached the present levels. PE is responsible for the majority of pollution problems due to its nonlinear characteristics and rapid switching. The majority of pollution problems are caused by the nonlinear characteristics and rapid switching of PE. PE processes around 10% to 20% of today's energy; the percentage is expected to reach 50% to 60% by the year 2010, due mainly to the fast growth of PE capability [1]-[3].

A struggle is currently going place between increasing PE pollution and sensitivity, on the one hand, and emerging PE-based corrective devices, which have the power to mitigate the issues caused by PE, on the other. Non-linearity increases, resulting in a variety of undesirable characteristics such as low system efficiency and low power factor [4]. Other consumers are irritated, and nearby communication networks are disrupted. Over the next few years, the impact of such non-linearity might be significant. Because of this, it is crucial to overcome these unfavourable characteristics. Shunt passive filters, consisting of tuned LC filters and/or high passive filters, are traditionally used to support harmonics, with power capacitors used to improve the power factor [5]. They do, however, have the limitations of fixed compensation, a large size, and the ability to exile resonance situations. To compensate for harmonics and reactivate the power demand of non-linear loads, active power filters are increasingly seen as a viable alternative for conventional passive power filters [6]-[8]. The goal of active filtering is to solve these issues by combining it with a significantly lower rating of the necessary passive components. Active power filters have been designed in a variety of topologies.

Even when the load is very non-linear, the shunt active power filter based on current controlled voltage source type PWM converter has proven to be effective. Most active filters are based on sensing harmonics and reactivating non-linear load volt-ampere requirements [9] and necessitate complex control. [10]–[12] proposes a new scheme in which the required compensating curve is determined by sensing load curves, which are then further modified by sensing line currents solely.

Power Quality

Any occurrence manifested in voltage, current, or frequency deviations that results in damage, upset, failure, or misoperation of end-use equipment," according to the PQ problem definition. In nearly every aspect of commercial, domestic, and industrial use, practically all PQ issues are closely related to PE. Residential appliances such as TVs, PCs, and so on; business and office equipment such as copiers, printers, and so on; and industrial equipment such as programmable logic controllers (PLCs), adjustable speed drives (ASDs), rectifiers, inverters, and CNC tools, among other things. Depending on the type of issue involved, the

Power Quality (PQ) problem might be detected by one of many symptoms.

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

Harmonics, internal harmonics, notches, and neutral currents are all caused by PE. Harmonics are generated by rectifiers, ASDs, soft starters, electronic ballasts for discharge lights, switched-mode power supplies, and HVAC systems that use ASDs. Transformers, motors, cables, interrupters, and capacitors (resonance) are among the equipment affected by harmonics. Converters are the major source of notches, which mostly affect electronic control devices. Equipment that uses switched-mode power supplies, such as PCs, printers, photocopiers, and any triplets generator, produces neutral currents. The neutral conductor temperature and transformer capacity are seriously affected by neutral currents. Static frequency converters, cyclo-converters, induction motors, and arcing devices all produce inner harmonics. Equipment has varying levels of sensitivity to PQ issues, depending on the kind of equipment and the type of disturbance. Furthermore, the impact of PE on the PQ of electric power systems varies depending on the type of PE used.

II. SYSTEM MODEL

Design Procedures

Configuration of the active power filter Figure 6 depicts the concept of an active power filter. It may be a rectifier or another nonlinear load. Assuming the mains voltage is a pure sine-wave, it is represented as

$$V_s(t) = V_s \sin wt \tag{1}$$

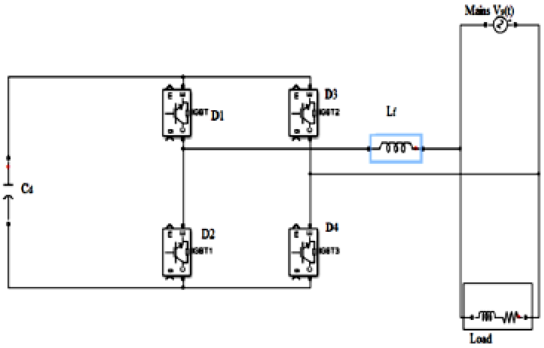

Fig. 1 Circuit of Active Power Filter

The nonlinear load current can be represented as

$$I_L(t) = \sum_{n=1}^{\infty} I_n \sin(nwt + \theta_n) \tag{2}$$

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

$$I_r = \sin(wt) \tag{3}$$

The amplitude of real part of fundamental load current be,

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

$$= I_1 \cos \theta_1 \tag{4}$$

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

$$= I_1 \cos \theta_1 \sin(wt) \tag{5}$$

Hence, calculated compensation current be,

$$I_{cr}\,(t) = I_L(t) - I_{sc}\,(t) \tag{6}$$

A. Component Functions

The inductor in Fig. 6 is utilised to ensure that the compensation curve generated by the converter is smooth; an inductor is required to filter out the switching ripple curve. This inductor's size must be as tiny as possible to provide a good dynamic response. The switching ripple current cannot be sustained if the inductor is too tiny. The change rate of the converter output current is larger than the slope of the triangle carrier signal, which might cause the multi-crossing phenomenon. The switching frequency is thus higher than the carrier signal frequency. This phenomenon can also be influenced by the gain of the error amplifier. To provide approximate amplitude to the mains current, a PI controller is used. For synchronisation, a square wave generator is used, followed by a sine wave generator. The error signal is now sent to the PWM modulator, which is required to generate the gate pulses for compensation. The waveform sent to the PWM modulator carrier is a triangle wave, and the frequency of the gate pulses may be controlled using this frequency. Non-linear loads should be used here.

B. 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,

$$\mathrm{K_i} = (\mathrm{L} + \mathrm{L_0}) \cdot \mathrm{wc} / (2 * \mathrm{V_{dc}}) \tag{7}$$

$$\mathrm{K_p} = \mathrm{wc}^{*}\, \mathrm{K_i} \tag{8}$$

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

Active power filters can be implemented as shunt type, series type, or a mix of shunt and series active filters (shunt-series type) depending on the application or electrical problem to be solved. These filters can be used with passive filters to make hybrid power filters. The architecture of a shunt-connected active power filter with a self-controlled dc bus is similar to that of a static compensator (STATCOM), which is used for reactivating power compensation in power transmission systems. Shunt active power filters compensate for load harmonics by injecting an equal-but-opposite harmonic compensating current. In this situation, the shunt active power filter acts as a current source, injecting the load's harmonic components but 180° phasing them. By the end of the 1980s, a series of active power filters had been introduced, and they primarily serve as a voltage regulator and harmonic isolator between the nonlinear load and the utility system.

IV. PROPOSED METHODOLOGY

Fuzzy Algorithm

The control action of a fuzzy logic controller is determined by the evaluation of a set of simple language rules. The creation of the rules necessitates a deep understanding of the process to be controlled, but not a mathematical model of the system. Figure 2 depicts the fuzzy controller's internal structure.

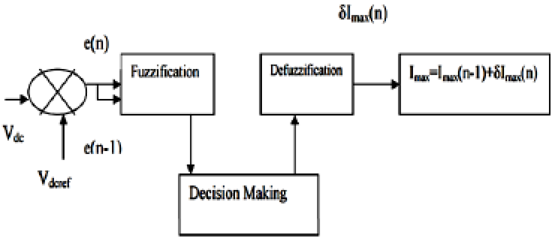

Fig. 2 Internal structure of fuzzy logic controller.

A fuzzy inference system (also known as a fuzzy system) is essentially a fuzzy logic formulation of the mapping from a given input set to an output set. This mapping procedure provides the foundation for drawing inferences or conclusions. The steps in a fuzzy inference procedure are as follows:

Step1: Fuzzification of input variables
Step2: Application of fuzzy operator (AND,OR,NOT) in the IF(antecedent) part of the rule
Step3: Implication from the antecedent to the consequent(THEN part of the rules)
Step4: Aggregation of the consequents across the rules
Step5: Defuzzification

In fuzzification based on membership function, the crisp inputs are turned to linguistic variables (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 (or degree of membership) that is between 0 and 1. Figure 3 depicts the various shapes that a membership function can take. The triangular-type MF, which can be symmetrical or asymmetrical in shape, is the simplest and most widely used. The shape of a trapezoidal MF is that of a truncated triangle. A simple Gaussian curve and a two-sided composite of two different Gaussian distribution curves are based on the Gaussian distribution curve. A Gaussian function differs from a bell MF with a flat top in certain ways. Both Gaussian and bell MFs are smooth and non-zero at all points.

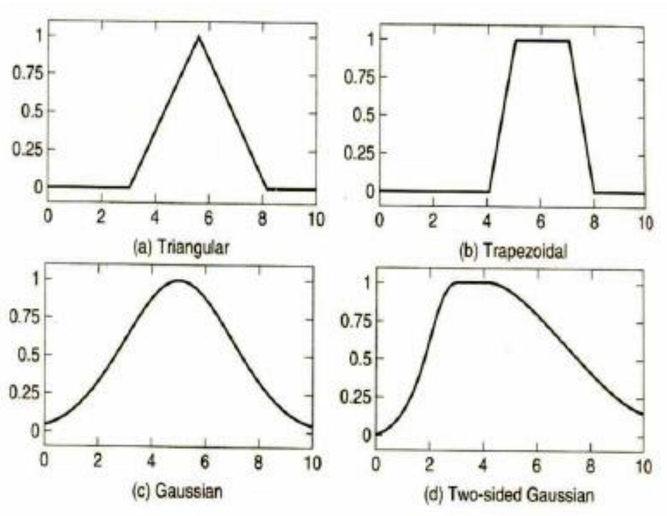

Fig. 3 Different types of membership functions.

The essential characteristics of Boolean logic apply to Fuzzy logic as well. We know the degree to which each portion of the antecedent of a rule has been satisfied after the inputs have been fuzzified. OR or AND operations on the fuzzy variables are performed based on the rule. The implication step aids in the evaluation of a rule's consequential element.

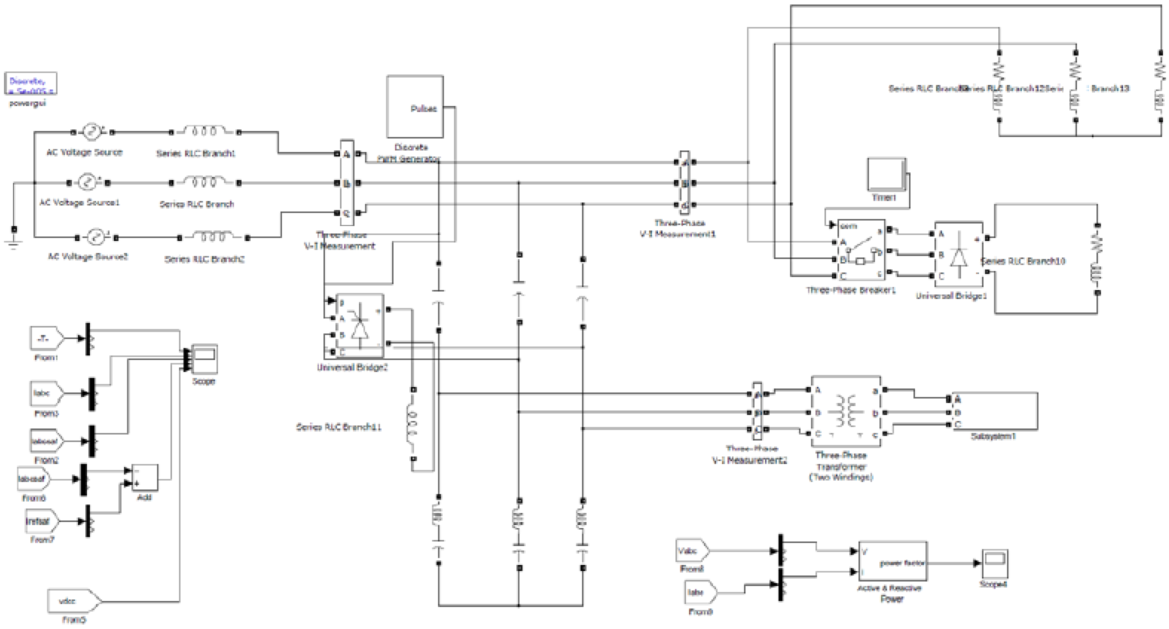

Fig. 4 : Power System Model with Filter Bank in Shunt and Thyristor Control Unit

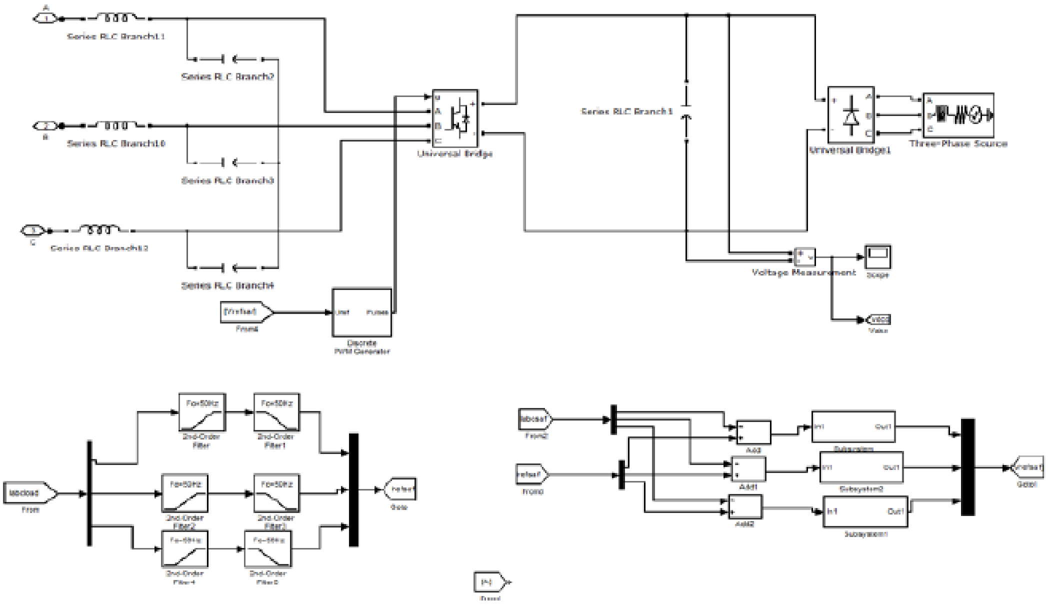

Fig. 5 : Sub System Module

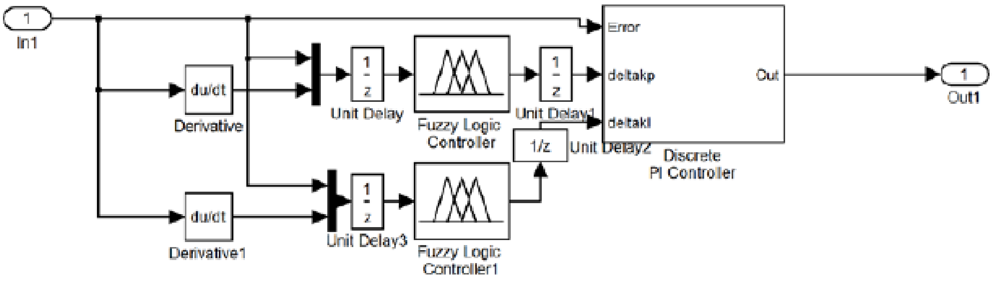

Fig. 6 : Proposed Fuzzy Module

V. RESULT

The suggested model from the previous section is designed and simulated in MATLAB SIMULINK R2009b, and the results of the various parameters are displayed in the following figures. The source voltage/current, DC voltage, is shown in Figure 7. The DC voltage at the load has no distortion, which means the power delivered to the load side is better than before.

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

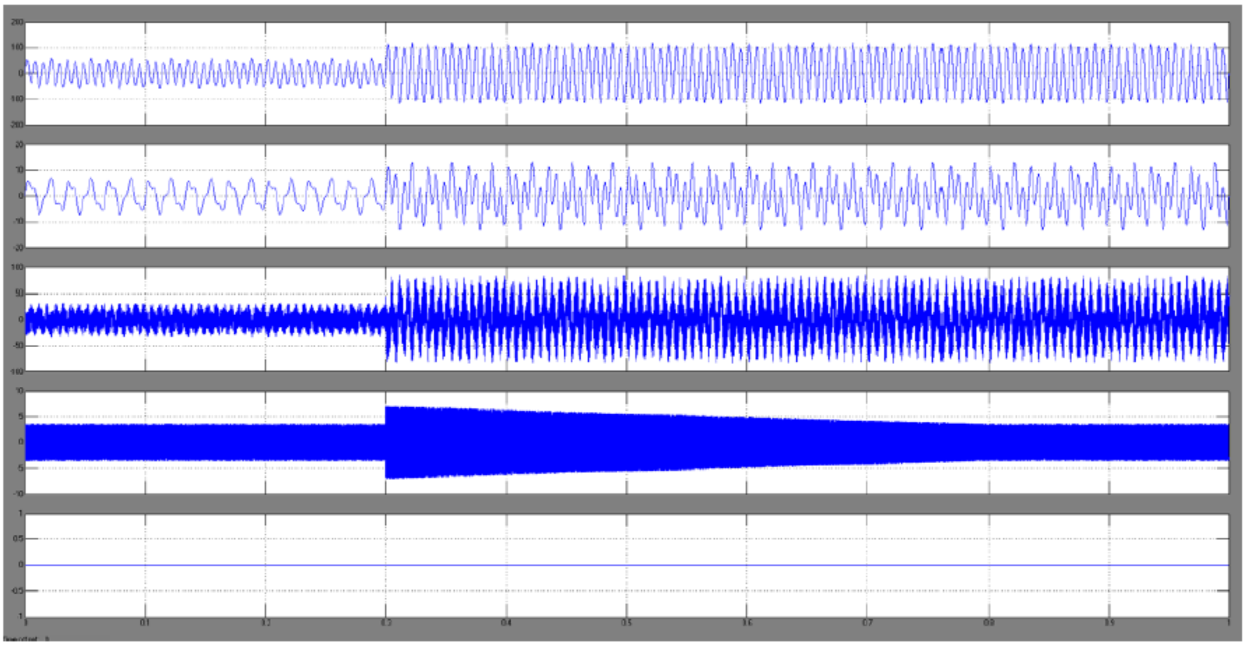

Fig. 7 : Result Waveforms of Load Current and DC Voltage

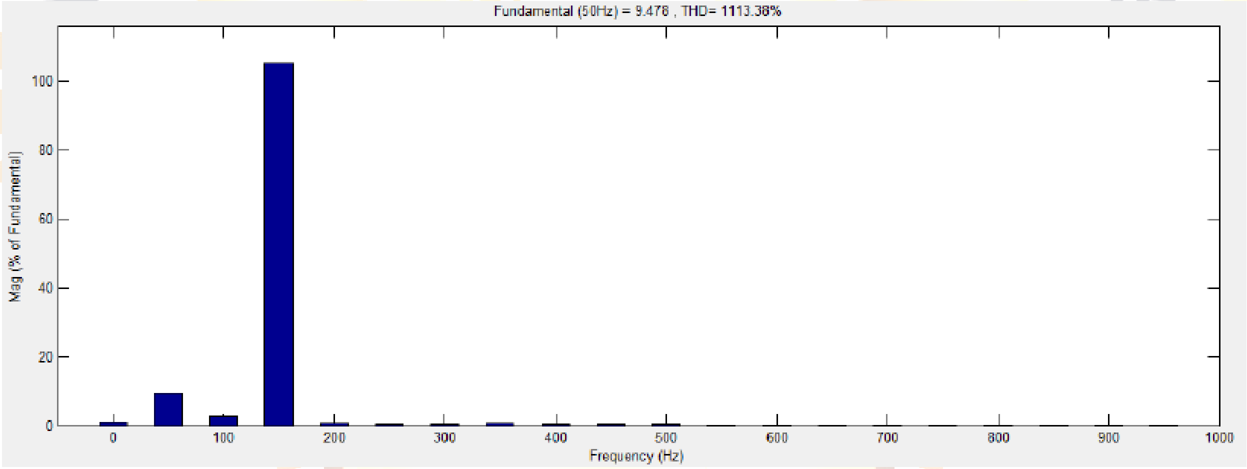

Fig. 8 : FFT Analysis

VI. CONCLUSION

Numerous power electronics equipment have been included into current electrical power systems. Nonlinear loads such as adjustable speed drives, domestic appliances, and transformer saturation cause an increase in harmonics at the ac mains. The number of non-linear loads is increasing exponentially as technology and electronic equipment advance, and as a result, characteristic and non-characteristic harmonics are produced in the power system. Thyristor development during the last two decades has offered control flexibility, but it has also contributed harmonics to the system. These loads degrade system performance by drawing non-sinusoidal current from ac mains.

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