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Power Quality Improvement using a Novel Filter

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ABSTRACT

Due to common power quality problems like harmonics or current imbalances, the reliability must generally decline as electrical power demand rises. We require a common LC filter to increase its overall quality and dependability. However, there are certain drawbacks to this kind of filter, namely the fact that it cannot be used for high power applications. This research suggests a hybrid cascaded shunt active filter-based thyristor- controlled reactor as a solution. This SPF nonlinear control approach included current tracking and voltage regulation. The SPF's filtering properties are enhanced by the small-rating APF, which is also employed to prevent resonance between the SPF and line inductances. To control the TCR, a proportional-integral controller was employed, and a triggering alpha was retrieved using a lookup table. This work suggested the idea of a fuzzy logic controller to achieve better results than a traditional PI controller. The advantage of this controller is that it reduces steady state error and enhances system responsiveness.

KEY WORDS: Harmonics, Shunt Active Filter. Thyristor Controlled Reactor, PI controller, Total Harmonic Distortion, FLC controller.

1. INTRODUCTION

For the purpose of correcting harmonic and reactive power, this proposal provides a system that combines a thyristor-controlled reactor (TCR) and a shunt hybrid power filter (SHPF). The SHPF is made up of a small-rating active power filter and an LC passive filter tuned to the fifth harmonic (APF) [1-3]. A shunt passive filter that takes into consideration reactive power is produced by combining the tuned passive filter with the TCR (SPF). To enhance the SPF's filtering properties and avoid resonance between the SPF and line inductances, the small-rating APF is used. The latter presupposes that the managed system may be divided into two loops, one fast and one sluggish, and is based on a decoupled control approach. As a result, the outside voltage loop was subject to a nonlinear feedback control rule, while the inner loop was subject to perfect linearization control. Integral compensators were added to the current and voltage loops to eliminate steady-state errors brought on by the uncertainty of system parameters.

Active filters, on the other hand, are quite expensive for large-scale systems and require high power converter ratings [4-5]. Hybrid filters efficiently mitigate the drawbacks of both passive and active filter solutions while also providing cost-effective harmonic compensation, especially for high-power nonlinear systems. A variety of control methods, including instantaneous reactive power theory, synchronous rotating reference frames, sliding- mode controllers, neural network methods, nonlinear control feedforward control, Lyapunov function-based control, and others, have been used to enhance the performance of active and hybrid filters. When employed in a multi-converter conditioner architecture created by an active conditioner working in tandem with a hybrid conditioner, multiple filter topologies for minimising harmonics and reactive power have been documented in the literature. The hybrid conditioner combines a low-rated active power filter with one or more passive filters connected in series (APF).

In order to suppress current harmonics and mitigate the reactive power issues caused by the load, a new combination of a shunt hybrid power filter (SHPF) and a TCR (SHPF-TCR compensator) is developed in this study. The small-rated active filter and the fifth-tuned LC passive filter are connected in series to create the hybrid filter. The passive filter and the TCR support the majority of the compensation in the suggested topology, while the APF is intended to enhance filtering properties and dampen resonance that may arise between the passive filter, the TCR, and the source impedance. The high kilovolt ampere rating of the inverter, which necessitates a significant amount of energy held at high dc-link voltage, hurts the shunt APF when utilised alone.

To compensate for reactive power and harmonics, A. Hamadi, S. Rahmani, and K. Al-Haddad suggest an unique topology for a three-phase hybrid passive filter (HPF). The HPF is made up of a series passive filter and a variable- impedance shunt passive filter based on a thyristor-controlled reactor (SPF). The series passive filter inductance rating is reduced using a mutual-inductance design idea. The suggested HPF system's distinct features are as follows: 1) resistance to source impedance variations; 2) absence of problems with serial or parallel resonance; 3) rapid dynamic response; and 4) significant size reduction in an SPF capacitor. Simulation and experiments are used to validate the proposed HPF system's performance under various load circumstances.

The proposal by P. Flores, J. Dixon, M. Ortuzar, R. Carmi, P. Barriuso, and L. Moran is as follows: A 27-level inverter was used to build an active power filter and static var compensator with active power generating capacity. This inverter's three phases are made up of three ldquo Hrdquo bridges, all of which are coupled to the same dc link and have output transformers scaled in the power of three. During prolonged electricity outages, its hybrid construction enables active power generation and even load feeding. The simulation outcomes for this application are shown, along with a few tests using a 3-kVA device.

2. SHUNT ACTIVE POWER FILTER

By introducing equal-but-opposite harmonic compensatory currents into the grid with a shunt active power filter, current harmonics are reduced. The shunt active power filter serves as a current source in this case, injecting the load's harmonic components but 180° out of phase. This technique can be applied to any load that is regarded to be a harmonic source. Furthermore, the active power filter may correct the load power factor with the right management scheme. In this method, the non-linear load and active power filter are viewed as perfect resistors by the power distribution system. Figure 1 depicts the shunt active power filter's structure [7-9].

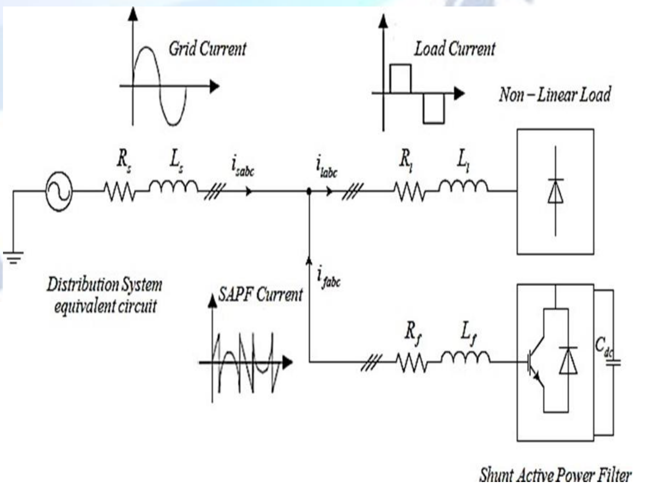

Figure 1: Structure of Shunt Active Power Filter

2.1 Direct control method

The load currents are monitored, and the harmonic currents are extracted from the load currents using this method. The direct control method is depicted in Figure 2. The SAPF injects harmonic currents without any knowledge of grid currents using this mechanism. All system errors, such as parameter uncertainty, measurement, and control problems, will appear as unfiltered harmonic contents in the grid current. The system stability is the key benefit of this technology. This strategy, however, necessitates a more complex control algorithm with a huge number of sensors.

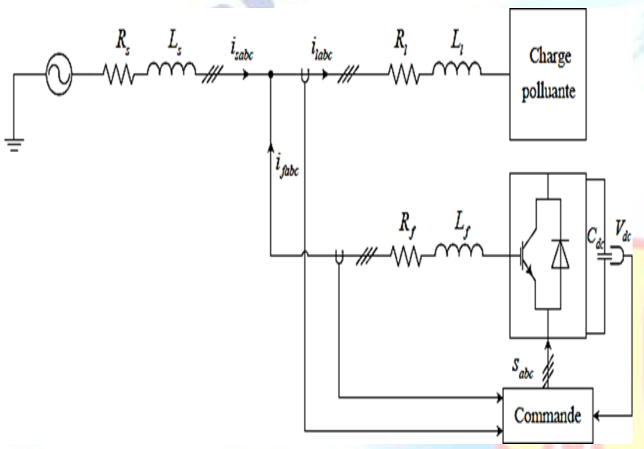

Figure 2: Direct Control Method Diagram

2.2 Indirect Control Method

This approach is based on measuring the source currents before applying the sinusoidal shape to them. Compared to direct control, the control algorithm is less complex and requires fewer sensors. The SAPF's indirect control method is depicted in Figure 3.

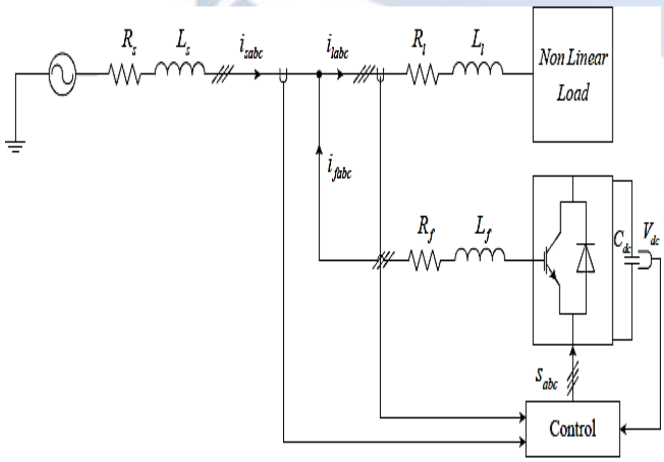

Figure 3: Indirect Control Method

2.3 Instantaneous Active and Reactive Power Theory

The instantaneous active and reactive power theory (dq), first put forth by Akagi et al. in 1983, is the foundation for the majority of APFs [6]. Watanabe and Aredes later made improvements to it for three-phase four- wire power systems after it was initially created for three-phase systems without a neutral wire. The method involves converting distorted currents from a three-phase frame abc to dq stationary frame. The essential premise is that nonlinear regulated loads can compensate for harmonic currents induced by nonlinear loads in the power system. The dq theory is built around a set of time-domain instantaneous powers given in Eq. (1a) to (1d).

V_q and V_d is estimated using equations

$$V_q = \frac{2}{3}(V_a - \frac{1}{2}V_b - \frac{1}{2}V_c)$$

$$V_d = \frac{2}{3}(-\frac{\sqrt{3}}{2}V_b - \frac{\sqrt{3}}{2}V_c)$$

i_q and i_d is estimated using equations

$$i_q = \frac{2}{3}(i_a - \frac{1}{2}i_b - \frac{1}{2}i_c)$$

$$i_d = \frac{2}{3}(-\frac{\sqrt{3}}{2}i_b - \frac{\sqrt{3}}{2}i_c)$$

The instantaneous reactive power q(t) represents more than just reactive power, which is a crucial distinction to make. While the habitual reactive power just takes into account the basics of current and voltage, the instantaneous reactive power takes into account all current and voltage harmonics.

3. FUZZY LOGIC CONTROLLER

A mathematical system entirely based on fuzzy logic is called a fuzzy control system. The fuzzy rules are used directly by fuzzy controllers. Conditional statements that describe the relationship between all fuzzy variables are known as fuzzy rules. The fuzzy controller's logic is capable of handling ideas that cannot be represented as true or false. A block diagram of a fuzzy logic controller is illustrated in the image below.

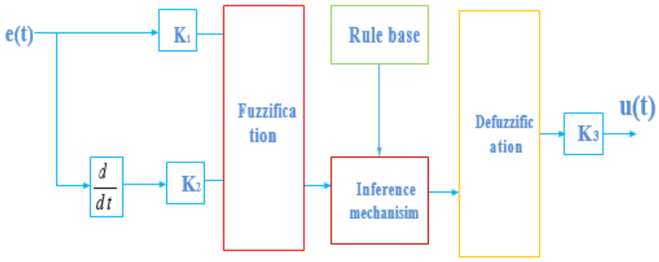

Figure 4: Fuzzy Logic Controller

A function that converts items from a domain of interest to the set's membership value defines the fuzzy set. This type of function is known as a membership function and is typically identified by the Greek letter "." In order to design FIS, Figure 4, illustrates the selection of a number of inputs and outputs in the form of membership functions.

4. SIMULATION RESULTS

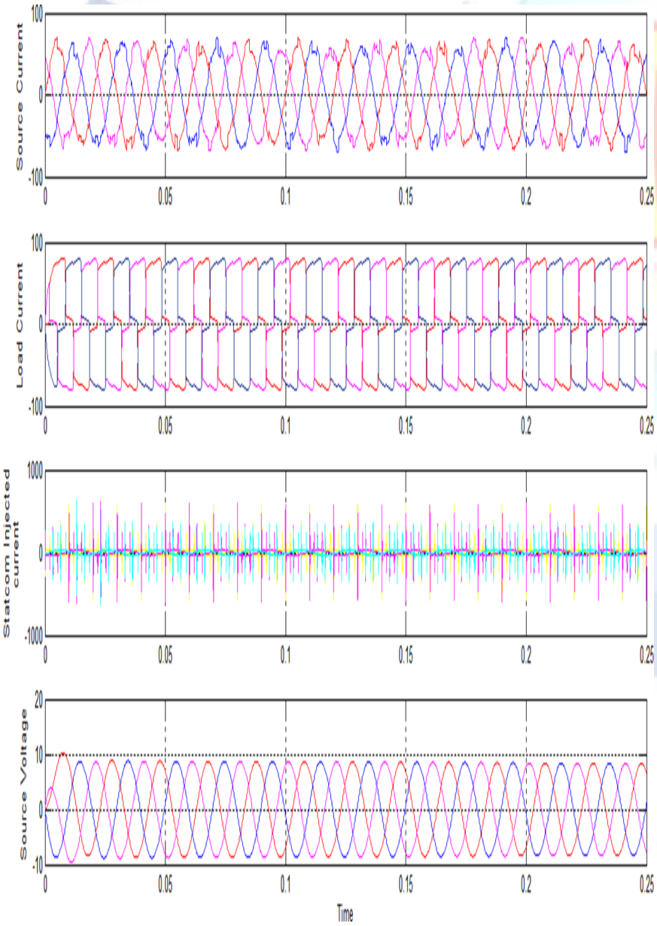

Figure 5: Source current, Load current, static injected current, source voltage of APF converter system

Fig. 5 (a-d) represents source current, load current, static injected current and source voltage of APF converter system is connected to a non-linear load. And Fig. 6 (a-d) represents source current, load current, static injected current and source voltage of APF converter system is connected to a non-linear load. It is observed that the load current has considerable nonlinearities when connected to the classical APF converter system. And they are going to be minimized when connected to the FLC converter system.

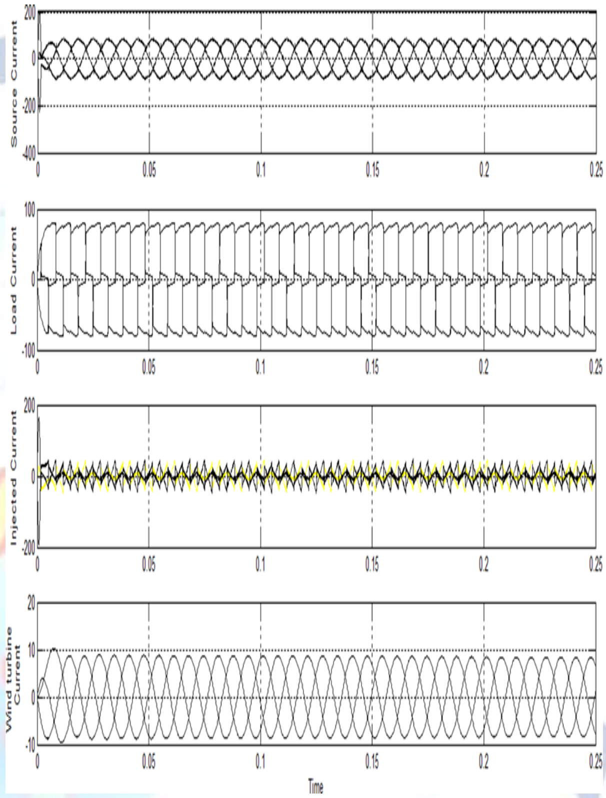

Figure 6: Source current, Load current, static injected current, source voltage of FLC converter system

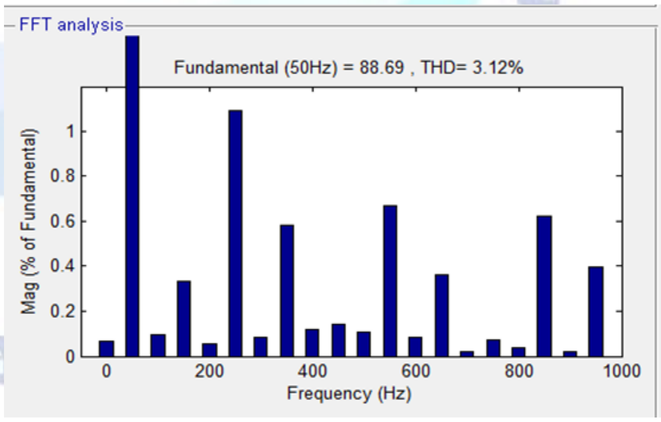

Figure 7: THD in Classical APF converter system

Figure 7 and Figure 8 shows the Total harmonic distortion of Classical APF converter system and THD in FLC Coveter system. The THD is reduced from 3.12% to 2.03% with the proposed novel filter.

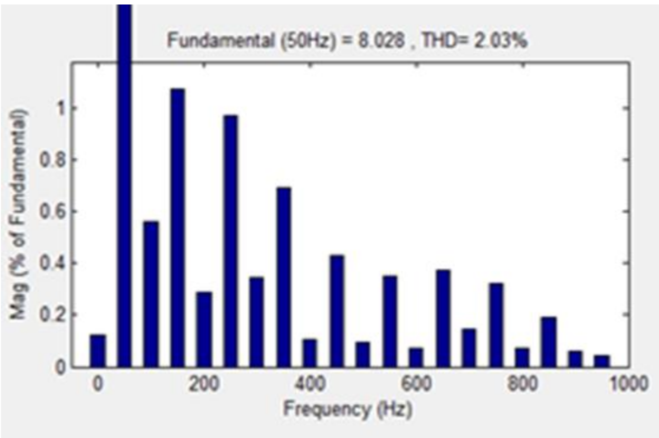

Figure 8: THD in FLC Coveter system

5. CONCLUSION

In this paper, a thyristor controlled switch with a combination of SHPF on the TCR working and fuzzi logic controlled operating for the current configuration is established, simulation results in steady state and dynamic response is analysis, and circuit is implemented using power electronics and circuit analysis is graphically in function in every and THD total harmonic distortion is analysed with the help of Past Fourier transient analysis and result show in Dynamic condition the SHPF-TCR compensator has been found to effectively eliminate current harmonics and reduce total harmonic distortion (THD). The THD is reduced from 3.12% to 2.03% with the proposed novel filter.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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