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FLC Based on a Performance Analysis of Direct Power Control with SVPWM for Shunt Active Power Filter

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Abstract
This paper presents a proposal for a fuzzy controlled shunt active power filter that aims to minimise the harmonics produced by the "non-linear load connected to the three-phase grid." This study proposes a remedy for the limitations of conventional DPC control by integrating direct power control with space vector modulation, a technique often used in shunt active power filters. From here on, the main objective will be to develop a control mechanism that efficiently reduces the current total harmonic distortion (THD) and power ripple, resulting in the best possible results. This method is based on the substitution of switching tables and hysteresis controllers with a vector modulator and PI controllers to provide a constant switching frequency throughout operation. A comparison study is conducted between a PI controller and a fuzzy logic controller, with additional measures taken to reduce harmonics. The researcher conducts a series of simulations using the Matlab / Simulink environment. The simulations produce graphs that show the outcomes over time.

Keyword: Shunt Active Power Filter (SAPF), Direct Power Control (DPC), Space Vector Modulation SVM, Total Harmonic Distortion (THD), Fuzzy logic controller.

INTRODUCTION

Power electronic equipment, especially static power converters, has been widely used for decades, and as a result, electrical power quality has significantly declined. Sometimes, people may refer to these electrical devices as "deforming charges." Dimmers, computer peripherals, air conditioning and lighting systems that employ fluorescent tubes, diode and thyristor rectifiers, and other non-linear loads use currents that are not sinusoidal. They may cause harmonic pollution in electrical distribution networks by absorbing non-sinusoidal currents, even when fed a sinusoidal voltage. [1]

Traditional compensatory methods, such as capacitor banks and passive filters, are one way to deal with this scenario. This technique, unfortunately, has significant drawbacks, such as the possibility of a resonance between the supply network's inductance as well as the capacitor bank's inductance. Therefore, for a long time, researchers looked into alternative methods that made use of various compensatory approaches, such as active power filters. The capacity to adapt to changes in the load, decrease the chance of resonance, and balance line currents in the event of unbalanced loads are just a few of the many benefits that active filters provide over traditional compensation systems. Various strategies for controlling the APF have been given in the literature, the most often utilized of which is the HCC (Hysteresis Current Controller), which is simple and precise. The main disadvantage is that the inverter components must operate at a high switching frequency. Researchers have been focusing on direct power control technique (DPC) in recent years due to its notable characteristics: no internal current loops, good dynamics, & efficiency. [2]

This study demonstrates how to use the DPC-SVM command to create a fuzzy logic driven active power filter. The research is done in MatLab/Simulink and tested on a test bench.

Active Power Filters

Active power filters were created to improve harmonic compensation dynamic management. In this field of harmonic filtering, advancements in solid state switching devices as well as their control mechanisms had a key influence. Active power filters (APF) are classed according to the type of converter and connection utilised in their circuit (i.e. Shunt or Series). As indicated in the diagram shown in figure, APFs can be classed as shunt, series, or hybrid. [3]

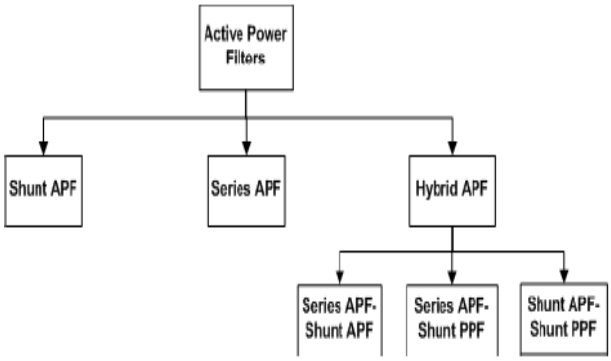

Figure 0 Classification of active power filters configurations

The generalised block diagram as shown in figure represents a typical APF configuration, comprising components and their interconnections. The reference current estimator receives the transmitted harmonic current in the main line, which is created by the nonlinear load. This pattern uses an appropriate interface to regulate the power circuit. As described in APFs classification, the power circuit in the generalised block diagram can be connected in series or shunt. [4]

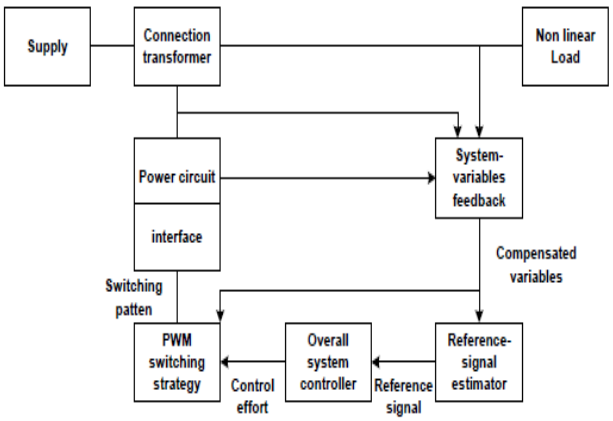

Figure 2 Generalized block diagram for Active Power Filters

Fuzzy Logic Controller based SAPF

Fuzzification, defuzzification, as well as a decision-making unit make up the fuzzy control system depicted in the diagram. The inputs are the error and the change in error, and the signal is obtained by delivering the output to the drive circuit. Prior to being sent to the decision-making block, which employs the data sets and rule base to produce the output, the inputs undergo fuzzification in the fuzzification block. The defuzzification block receives the output and returns clean values. The signal will be sent to the drive circuit to be determined.

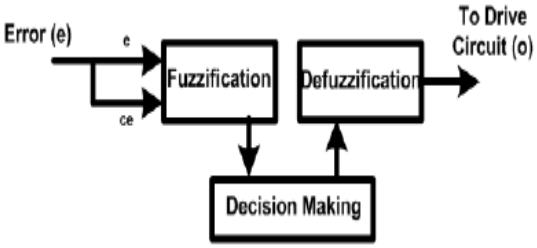

Figure 3 Fuzzy Control System

Figure 4, seen below, illustrates the fuzzy inference system, which comprises membership functions and the Mamdani technique of decision making. Error (e), change in error (ce), and output of FLC (o) are the membership functions in this case. *Vdc* minus dc, where *V* is the voltage differential, is the error. From *dc V*, we get the derivative of the change in error.

To get the membership function FLC as an output, we need these two as inputs. Figure shows the membership functions of three variables: Output, Change in Error, and Error. It shows the range of membership functions, including their minimum and maximum values. Using just small, medium, and large membership functions simplifies the structure of fuzzy inference systems across all membership functions. This information pertains to the system's behaviour. Because of this, some kind of memory device, like a flip-flop, is required. [7]

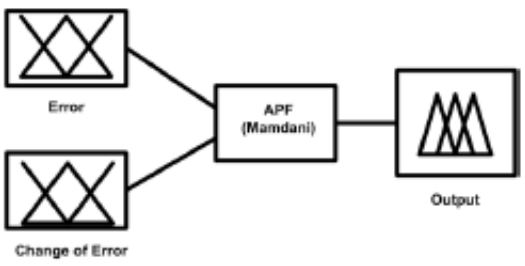

Figure 4 Fuzzy Inference System

Space vector modulation

"Space Vector Modulation (SVM)" has gone through numerous researches and is currently establishes as a standard for the "switching power converters. In the previous ten years, research reports as well as patents have been created, and the idea of Space Vector Modulation has been well developed. Various implementation methods were explored, as well as some dedicated computer pieces based on this notion were built. Space Vector Modulation has been used for a variety of novel three-phase topologies, including three-phase voltage-source inverters, AC/DC matrix converters, resonant three-phase converters, and AC/DC or DC/AC current source converters, among others. [8]

One way to regulate pulse width modulation (PWM) is by space vector modulation, or SVM. Its main function is to generate alternating current (AC) waves, which are then used to drive three-phase AC motors at varying speeds from direct current (DC) via a series of class-D amplifiers. There are many varieties of support vector machines (SVMs), and they all have different computing requirements and quality metrics. One area of ongoing study is the reduction of total harmonic distortion (THD), which is produced by the fast switching inherent in these algorithms.

METHODOLOGY

Fuzzy Logic Controller

To use the control algorithm of a shunt active filter, one must measure the voltage on the DC side of the capacitor and compare it to a reference value. Fuzzy processing has two inputs: error and error change. A fuzzy controller uses a language-based set of rules to decide how to operate as a controller. It has the advantage of not requiring a mathematical model and working with erroneous inputs.[33]

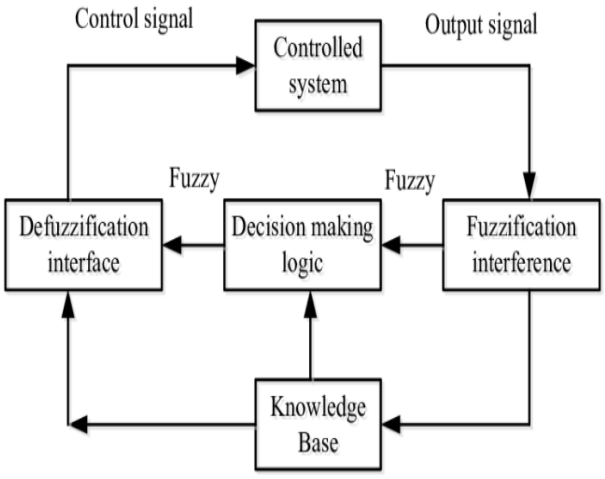

Figure 5 Block diagram of Fuzzy Logic Controller

Fuzzification

Instead of numerical variables, language variables are used in fuzzy logic control. "Positive small (PS), Positive Medium (PM), Positive Big (PB), Negative Small (NS), Negative Medium (NM), Negative Big (NB), as well as Zero are the different types of errors between the reference and output signals (ZE)." The fuzzification process makes use of a triangle membership function. A numerical variable may be "fuzzed" by changing its representation to a "verbal variable". [34]

Rule Elevator:

Instead of numerical variables, fuzzy logic makes use of linguistic variables. The following are the fuzzy set rules that govern the system:

Defuzzification:

By using fuzzy logic principles, the linguistic variables are transformed into crisp values, and the outcome is then shown. You have to decide between processing power and accuracy. Consequently, defuzzification of the fuzzy control action (i.e., the calculated output of the fuzzy control method) is necessary.

Rule Base:

When using rule elevator, it is necessary to store the linguistic control rules in rule base. The table below shows the rules utilised by the controller.

Advantages of Fuzzy Logic Controller

When compared to other adaptive control approaches, fuzzy control has the following advantages:

- It permits more accurate system design by sharing output to input without being too cognizant of all the variables.
- Because of the emphasis on words instead of numbers, the procedure is quite similar to how humans think.
- They can handle more operating scenarios than PI controllers, making them more robust.
- "FLC is cost-effective"
- "FLC is adaptable"
- "FLC is a trustworthy company"
- "FLC is more efficient"
- "It improves stability"

Despite its superior performance, the Mamdani fuzzy controller requires more fuzzy sets and rules than the PI

controller. Additionally, in order to surpass the typical PI controller, all of the coefficients must be increased. The fuzzy control system requires less time to settle than the PI control system.

RESULTS AND DISCUSSION

The algorithm that has been suggested is implemented using MATLAB (R2016a). We may utilise functions for a range of approaches, including Windows, scaling, and shifting, among others, in the signal process toolbox in the MATLAB Library.

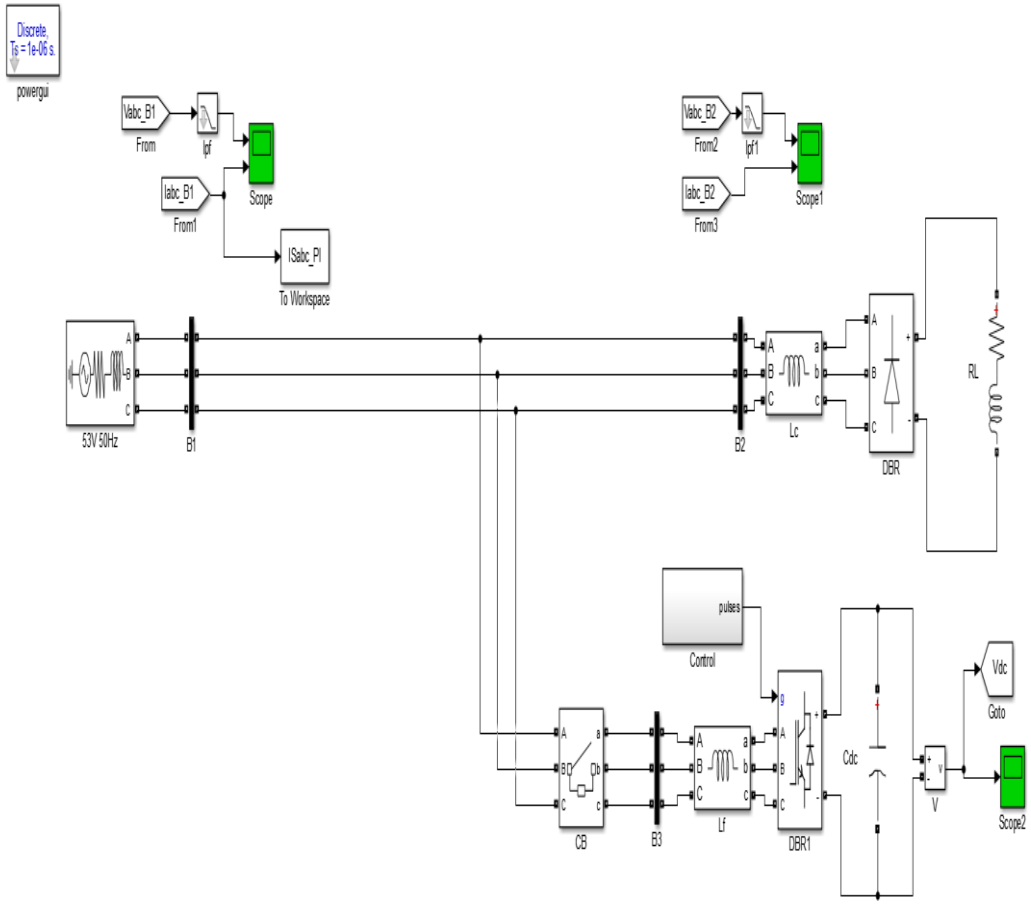

Figure 6 Proposed system

The above figure represents the experimental setup with the non-linear load and the three-phase conventional power supply. The system's rating is 53V 50Hz. To compensate for harmonics in the source current, a shunt active power filter is connected at PCC.

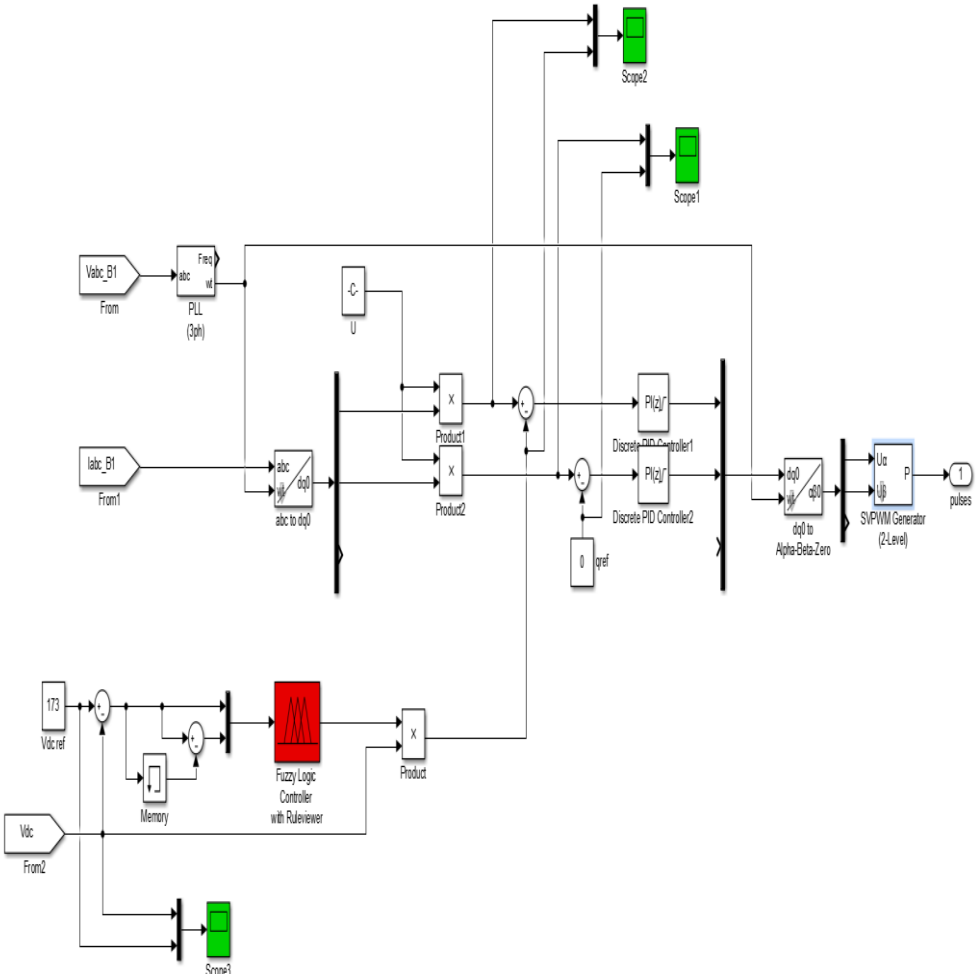

Figure 7 Control structure modelling with Fuzzy logic controller

Both the controller use SVPWM technique to control the shunt APF for reduction of harmonics. The simulation is run for 1sec with shunt APF connected at 0.2sec and the results of the model are observed. The below is the three phase source voltages and currents as per the given simulation time and changes to the system. The voltage is maintained at 1pu throughout the simulation without and with shunt APF. The source current harmonics are reduced after 0.2sec with small transient at the initial stage.

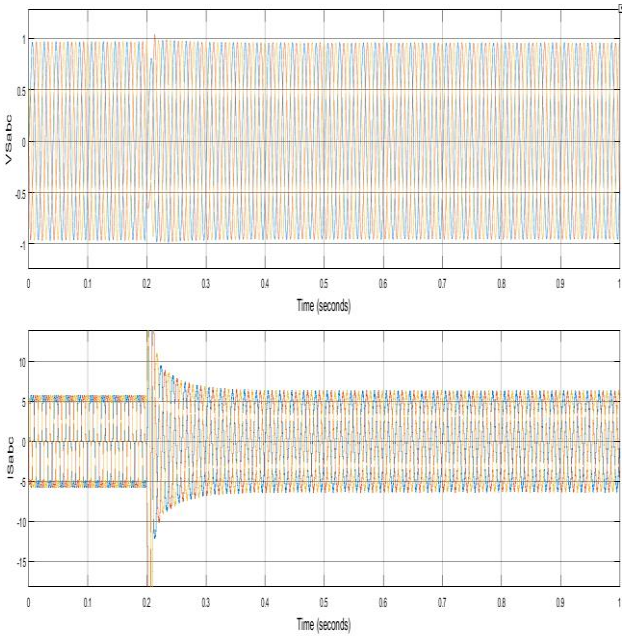

Figure 8 Source voltages and currents

The below are the "three phase load voltages and currents" before and after connecting shunt APF.

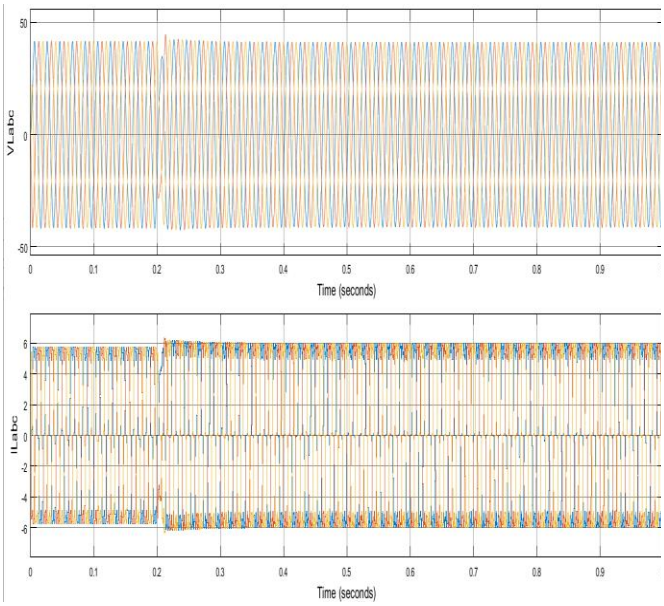

Figure 9 Load voltages and currents

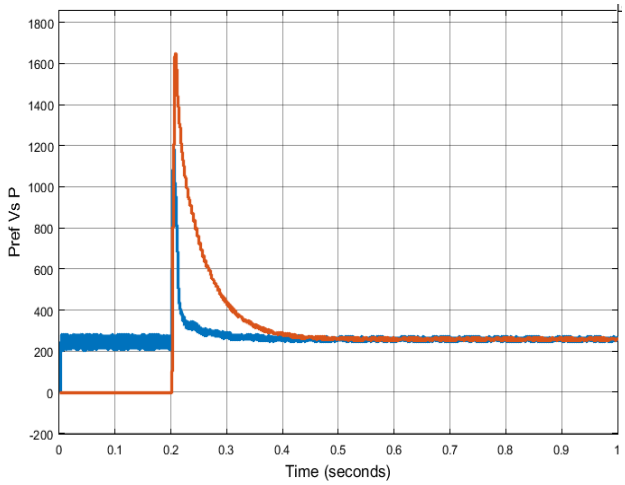

Figure 10 Active power reference and measured comparison

The above graph is the comparison of reference active power to measured active power and below is the comparison of reactive power reference and measured components.

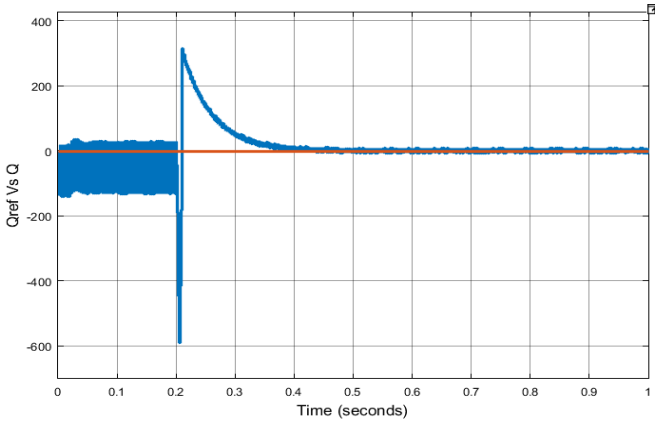

Figure 11 Reactive power reference and measured comparison

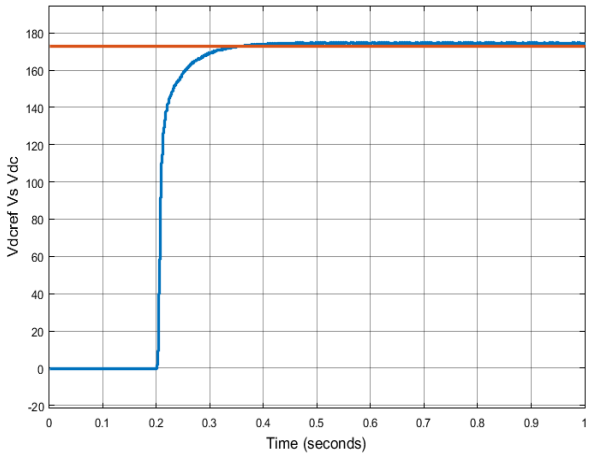

Figure 12 DC link voltage reference and measured comparison

The above graph exhibits a comparison of the DC link voltage at the shunt active power filter with a reference voltage, as measured at the DC link. After the shunt APF is connected at 0.2 seconds, the value climbs to the reference value.

CONCLUSION

In this study, a "shunt active power filter" was explored and designed for reducing overall harmonic reduction in the source current utilizing PI and Fuzzy logic controller. By eliminating harmonics in the load current, a shunt active power filter improves the power quality. An active power filter based on fuzzy logic controller outperforms a PI controller. To overcome the limitations of conventional DPC control, the DPC-SVM system integrates vector modulation with conventional DPC control. The results of the experiments and the models both point to the practicability of the suggested control technique. These results are similar

and hence acceptable, validating the simulations and confirming the efficiency of the proposed control mechanisms.

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