Direct Power Control with SVPWM for Shunt Active Power Filter: A Review

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Abstract: Harmful effects of harmonic currents have sparked intense interest in studying ways to mitigate them in the electrical grid. There is consensus that a shunt active power filter (SAPF) is the gold standard for this purpose. Harmonic currents are discovered in a power system that has been contaminated by harmonic currents, and then corrective mitigation current is generated and injected back into the power system to cancel out all the identified harmonic currents. That means it's more important to make sure the SAPF can operate in phase with the operational power system so that the mitigation current can be injected properly than it is to make sure the SAPF can generate corrected mitigation current on its own. Accordingly, the control algorithms of SAPF need suitable synchronisation technology to be implemented. In this study, we examine and evaluate the characteristics, working principle, implementation, and performance of a wide range of current phase synchronisation approaches used to govern SAPF operation.

Keywords: APF's, SAPF's, power quality, harmonics mitigation, grid-tied

I. INTRODUCTION:

Distribution networks now often incorporate power electronic instruments that introduce nonlinear loads into the system. Poor power factor, decreasing efficiency, overheating motors and transformers, malfunctioning sensitive equipment, etc. are all the consequence of power quality disruptions induced by nonlinear loads, such as harmonics pollution, unbalanced load currents, and reactive power issues.[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. As a result, other solutions involving different compensating techniques like active power filter have been studied for many years. Active filters have various advantages over conventional compensation techniques, including the ability to adjust to changes in the load, reduce the likelihood of resonance, as well as balance line currents in the case of imbalanced loads. 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]

A. Space vector modulation:

Space Vector Modulation (SVM) has become a standard for switching power converters, and much study has been done on the subject. 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. The application of Space Vector Modulation to novel three-phase topologies such as Resonant Three-Phase Converters, AC/DC Voltage Source Converters, AC/AC Matrix Converters, AC/DC or DC/AC Current Source Converters and so on has broadened the early usage of Space Vector Modulation at three-phase voltage-source inverters. [3]

To regulate pulse width, engineers developed a technique called "space vector modulation". It generates alternating current (AC) waveforms and is generally used to drive variable-speed three-phase AC motors from a supply of direct current (DC) through a bank of class-D amplifiers. Several different types of SVM exist, each with its own specific quality requirements and processing overhead. One active area of study is to taming the "total harmonic distortion (THD)" that comes from the frequent switching utilised by these methods.[4][5]

There are many different kinds of SVM, each with its unique requirements in terms of accuracy and processing power. One area of active study is on mitigating the increase in total harmonic distortion (THD) brought on by the more frequent algorithmic switches. The image on the right depicts a three-phase inverter, which takes a direct current (DC) input and turns it into three separate output legs that may be connected to a three-phase motor by a series of switches. To prevent a short in the DC supply, the switches must be programmed such that only one of the two switches in a given leg is on at any one moment. This need may be met, for example, by the complementary action of the switches within a leg. “If A+ is turned on, A is turned off, & vice versa. As a result, the inverter has eight possible switching vectors; V0 through V7, with six active switching vectors as well as two zero vectors.” A reference signal Vref is sampled with a frequency fs (Ts = 1/fs) to execute space vector modulation. The - transform can be used to create the reference signal from three distinct phase references. [6]

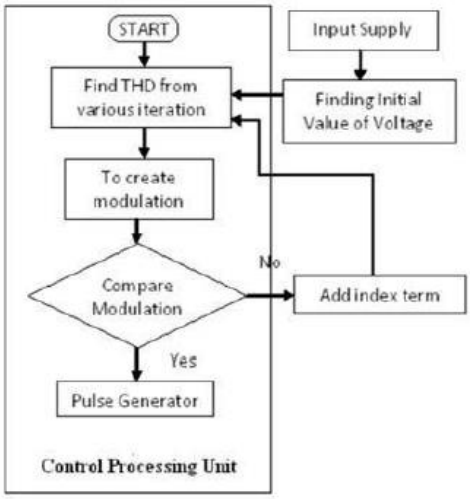

Figure 1: SVM Algorithm

B. FUZZY LOGIC CONTROLLER:

Fuzzy logic or fuzzy set theory was given by LotfiZadeh, a computer scientist at the University of California, Berkeley, in 1965, for representing and manipulating data that is not precise and rather fuzzy or vague. In the beginning he was criticized by the professional community, but progressively, Fuzzy logic (FL) gained importance in the professional society and in due course emerged as a new order of Artificial Intelligence. Since the FL found a good balance between importance and accuracy, a task that has traditionally been performed by hand, it has been a popular topic of study.

By providing an inference, the FL makes it possible for knowledge-based systems to make approximations to the reasoning powers of humans. Informational uncertainties, such as those associated with thinking and reasoning, may be captured mathematically according to the FL theory. Boolean logic, upon which classical set theory rests, states that a variable must either be a member of a set or not. However, in FL-based fuzzy set theory, the degree to which an item belongs to a set might vary from 0 (totally not belonging to set) to 1 (absolutely belong to set). This is why, unlike the 0/1 logic of Boolean logic, FL is often characterised as a logic with many values. Thus, FL-based methods do provide a useful conceptual framework for dealing with the encoding of common-sense information. [7][8]

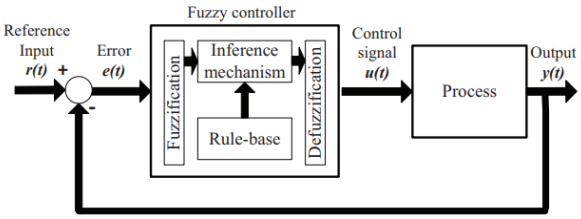

Figure 2: Scheme of a fuzzy logic controller

II. LITERATURE REVIEW:

(Bielecka&Wojciechowski, 2021) [1] In this study, we provide a SAPF with closed-loop control and an LCL coupling circuit for connecting to the grid. The test waveforms show that the system is very successful at reducing harmonics because of its fully predictive nature. In contrast, the stability of the control system is questionable. Therefore, the stability analysis of the proposed control system with an additional external supply current control loop using predictive control is the main emphasis of this study. The sampling rate and the coefficients of the proportional-integral (PI) controller were also taken into account, since they both have an effect on the system's stability, as did the precision with which the coupling circuit's parameters were estimated. The gathered data shows that there is a large stability window for the identification accuracy of the LCL circuit parameters. Given that the value of L1 inductance has the greatest influence on compensation quality, it follows that precise parameter determination yields the most effective compensation of supply current distortion.

(Ouchen&Benbouzid, 2021) [2] To regulate the power output of a SAPF, the current study suggests using direct power control with space vector modulation (DPC-SVM) (SAPF). The SVM has the potential to lower active and reactive ripples while maintaining a constant switching frequency, making it a desirable control for overcoming the drawbacks of conventional DPCs. This method is very dynamic and stable, even when subjected to external shocks. The suggested control DPC-SVM based on ST-SMC using MatLab/Simulink with a real-time interface based on a d SPACE 1104 board is analysed, both in simulation and in practise.

(Kishore et al., 2020) [3] The problems caused by nonlinear loads, as well as the remedies that have been used so far, are briefly covered in this work. A new shunt active filter reference current generation method is described that is both simple and effective. In this research, researchers provide the findings of a MATLAB model of a typical power supply system with a nonlinear load as well as a shunt active power filter, which show that the suggested scheme has a superior dynamic performance than the fuzzy logic controller for managing voltage source inverters.

(Kedar et al., 2020) [4] The reference frame theory has been applied to the Voltage Source Converter (VSC) of a Shunt Active Power Filter in this research to eliminate harmonics (SAPF). Because harmonics play such an important part in the occurrence of defects and disturbances in the system, the approach detailed in this paper outperforms traditional Voltage Source Converters due to its unique structure. Because traditional voltage-current controllers have their own drawbacks, the P-I controller is used in this manner to get more precise control over the system. The procedure is based on the Pulse Width Modulation technology, in which the SVM is utilized, which has some advantages over traditional PWM, and the P-I controller is used to achieve synchronisation. The results were acquired using a simulation model of a Shunt Active Power Filter.

(Abdelkhalek, 2018) [5] Through simulation and experimental validations, this study aims to reveal the performance of a SAPF with PI and Fuzzy controllers. By injecting a voltage component in series with the source voltage that is either higher than or lower than the source voltage, the ability to compensate for voltage dips and spikes, reduce harmonic voltage, and regulate the load's terminal voltage is shown. The active filter in this investigation was controlled using a simple control strategy that used a phase locked loop (PLL). It's solely relevant to the phase system. Prototype testing and simulated results from MATLAB/Simulink show that the suggested method works. The outcomes show the prototypes' potential.

(Kamble, 2017) [6] In this study, we evaluate the effectiveness of several methods for producing switching signals in three-phase SAPF under steady-state load conditions. Author performed an in-depth analysis of the aforementioned two switching signal generating methodologies in the MATLAB/SIMULINK environment, taking into account % THD, complexity, speed of response, switching frequency, and delay time. Following simulation, we can compare the results of the aforementioned two approaches using SAPF settings. According to IEEE Standard, the percent of THD supply current decreases. Over the SVPWM technique, HCC is straightforward to apply. Hysteresis controllers have a quick response time. The HCC approach uses a variable switching frequency, whereas the SVPWM technique uses a fixed switching frequency. The SVPWM approach requires a delay time.

(Mr. Shashibhushan R. Shahu, 2017) [7] The effectiveness of a SAPF is measured under constant load conditions. When supplying a nonlinear load from a single-phase ac/dc converter, the SAPF is used to cancel out harmonics. By injecting a current in the opposite direction, we may reduce the amount of distortion that is sent back to the voltage source by the nonlinear load. Supply current will be in sinusoidal phase with supply voltage as a consequence of the injected current. The differences between the above two approaches' findings depending on SAPF parameters are investigated. Over the SPWM approach, HCC is straightforward to apply. Both controllers have the same response time. A key difference between the HCC method and the SPWM methodology is that the former employs a varying switching frequency while the latter maintains a constant one.

(Anusha, 2017) [8] This study demonstrates the use of a fuzzy logic-driven shunt active power filter to mitigate harmonic distortion in three-phase, four-wire power distribution systems. Power systems may employ SAPF to enhance transient stability and expand transmission capacity, and it is a key controller in the Flexible Alternating Current Transmission System (FACTS). Fuzzy logic's ability to deal with uncertain and amorphous real-world data has made it applicable to a broad variety of contexts, especially when the underlying models or processes are too intricate to be investigated using more conventional methods. In this study, a fuzzy logic controller is also used to regulate the voltage across the DC capacitor. The results demonstrate that the proposed controller has a fast dynamic response and high precision. We used MATLAB and SIMULINK to double-check our findings.

(Sathvik et al., 2017) [9] Harmonic currents and reactive power caused by non-linear loads may be mitigated with the help of shunt active power filters and their accompanying controllers. In contrast to fuzzy logic controllers, which are easier to implement since they are based on language variables rather than mathematics, PI controllers provide a greater challenge due to the mathematical model they need. As a result, this research developed a control strategy and examined it using simulations.

(Thangaraj&Gopalasamy, 2016) [10] In order to keep up with the ever-increasing need for energy, renewable sources have been increasingly put to use. When renewable energy sources are included into the grid, power electronic converters are employed to transform the energy. These power electronic converters create issues with power quality such as harmonics, voltage management, and so on. Therefore, this study proposes a new control method for a grid-connected solar system to deal with power quality issues. A dynamic simulation utilising the MATLAB/Simulink Power system toolbox is used to implement the proposed technique, and the results are shown to back up the work's claims.

III. PROPOSED METHODOLOGY:

In electric power networks, harmonic contamination is a major and dangerous problem. And to eliminate this, a shunt active power filter with low current total harmonic distortion THD, reactive power compensation, as well as power factor correction are proposed by the researcher.This work proposes a fuzzy controlled shunt active power filter to decrease harmonics caused by non-linear loads connected to three-phase grids.

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

IV. CONCLUSION:

The primary objective of this paper is to provide a comprehensive overview of SAPF operation, empowering power engineers with the background and impetus they need to pursue further study of this topic. Literature study is used to examine and highlight the many distinct elements of SAPF, including its many varied topologies and control mechanisms, and the many problems that each present. The primary objective of this review is to provide a comprehensive introduction to the principles underlying SAPF and the control algorithms used to implement them, allowing readers to quickly grasp SAPF's fundamentals while also engaging in a subjective comparison and evaluation of those same algorithms Hybrid, intelligent, and optimised systems for efficient and dependable synchronisation, especially under unfavourable and dynamic grid circumstances, are recommended for further study..

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