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PHENOMENON OF CONTROL PRACTICES FOR POWER QUALITY ENRICHMENT USING OPTIMISTIC SHUNT ACTIVE POWER FILTER(SAPF)

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ABSTRACT

In modern power systems, the increasing integration of nonlinear loads and distributed generation sources has led to significant power quality issues, such as harmonic distortions, reactive power imbalance, and voltage fluctuations. These issues can result in system inefficiencies, reduced equipment lifespan, and compromised reliability. To address these challenges, the Shunt Active Power Filter (SAPF) has emerged as a promising solution. This paper presents an optimized control strategy for SAPF aimed at enhancing power quality in distribution networks. The proposed Optimistic SAPF employs advanced control techniques such as adaptive hysteresis current control and model predictive control to effectively mitigate harmonics, improve power factor, and stabilize voltage profiles. By dynamically adjusting to changing load conditions, the control algorithm ensures a real-time, high-performance filtering process. Additionally, the SAPF's control mechanism is designed to minimize switching losses and enhance overall efficiency, making it suitable for a wide range of industrial and commercial applications. Simulations and experimental results demonstrate the effectiveness of the Optimistic SAPF in enriching power quality by reducing total harmonic distortion (THD) to acceptable levels and improving system stability under various load conditions. The implementation of this control approach not only ensures compliance with power quality standards but also supports the sustainable operation of modern power grids.

Keywords: *Shunt Active Power Filter (SAPF), Power Quality Enrichment, Harmonic Mitigation, Adaptive Hysteresis Control, Load Balancing, Control Strategies.*

INTRODUCTION:

Power quality has become a critical concern in modern electrical systems, particularly with the growing penetration of nonlinear loads, distributed generation, and renewable energy sources. These elements introduce challenges such as harmonic distortion, voltage imbalances, and reactive power issues, which can degrade system performance, cause inefficiencies, and reduce the lifespan of electrical equipment. Ensuring high-quality power delivery is essential for maintaining the stability and reliability of the power grid, especially in industrial and commercial environments. Shunt Active Power Filters (SAPFs) have emerged as a powerful tool for mitigating these power quality issues [1]. By actively compensating for harmonics and reactive power, SAPFs help maintain a balanced and stable power supply. However, the performance of SAPFs largely depends on the effectiveness of the control strategies employed. Advanced control techniques, such as adaptive hysteresis current control and model predictive control (MPC), offer real-time responses to dynamic load conditions, improving the efficiency and performance of SAPFs [2]. This paper investigates the phenomenon of control practices for power quality enrichment using an Optimistic Shunt Active Power Filter. The proposed SAPF employs a refined control approach designed to optimize harmonic mitigation, minimize switching losses, and enhance the overall system efficiency. Through simulations and practical implementations, the study aims to demonstrate the SAPF's effectiveness in enriching power quality and its potential role in supporting modern power distribution networks [3]. Here’s a problem statement for the phenomenon of control practices for power quality enrichment using an Optimistic Shunt Active Power Filter (SAPF). The growing presence of nonlinear loads, renewable energy sources, and distributed generation in modern power systems has resulted in significant power quality issues, including harmonic distortions, voltage fluctuations, and reactive power imbalances. These issues lead to inefficient energy usage, increased operational costs, equipment degradation, and compromised reliability of the power grid. Existing solutions, such as passive filters and conventional Shunt Active Power Filters (SAPFs), often fall short in dynamic environments due to their limited adaptability and high switching losses. The challenge lies in developing an effective and adaptive control strategy for SAPFs that can dynamically respond to changing load conditions, efficiently mitigate harmonics, and improve overall power quality without compromising system efficiency. Optimized control techniques, such as adaptive hysteresis control and model predictive control (MPC), have the potential to significantly enhance SAPF performance, but their real-time effectiveness in complex power systems needs further exploration [4]. This research aims to address the limitations of conventional power quality solutions by developing and implementing an Optimistic SAPF with advanced control strategies. The goal is to design a control approach that enriches power quality by reducing harmonic distortions, minimizing reactive power, and improving voltage stability, while also ensuring minimal switching losses and high operational efficiency across diverse operating conditions..

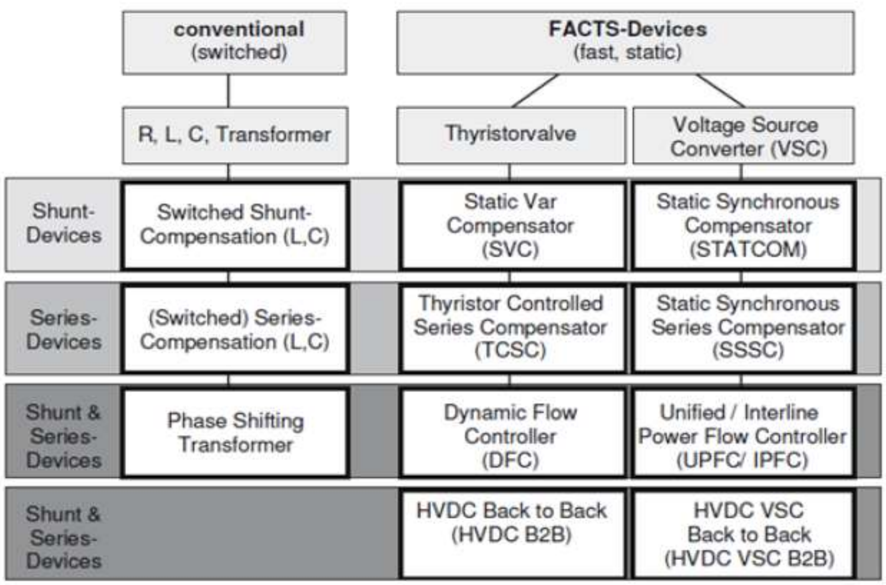

Figure1: Summary of foremost FACTS-Policies

LITERATURE SERVEY

Flexible AC Transmission Systems, called FACTS, got in the recent years a well known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice. literature review on power quality problems and a brief discussion of harmonic distortion problems, voltage sag, swell, flicker, and

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power quality indices [5]. Harmonic mitigation methods in low and medium voltage distribution systems. It discusses starting from passive filters to improved mitigation methods using active filters and hybrid filters. In most of the applications the controllability is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines [6]. FACTS-devices provide a better adaptation to varying operational conditions and improve the usage of existing installations. The influence of FACTS-devices is achieved through switched or controlled shunt compensation, series compensation or phase shift control. The devices work electrically as fast current, voltage or impedance controllers. The power electronic allows very short reaction times down to far below one second. Electrical loads both generate and absorb reactive power. Since the transmitted load varies considerably from one hour to another, the reactive power balance in a grid varies as well. The result can be unacceptable voltage amplitude variations or even a voltage depression, at the extreme a voltage collapse. A rapidly operating Static Var Compensator (SVC) can continuously provide the reactive power required to control dynamic voltage oscillations under various system conditions and thereby improve the power system transmission and distribution stability. Based on the system requirements, a DFC might consist of a number of series TSC or TSR [7]. The mechanically switched shunt capacitor (MSC) will provide voltage support in case of overload and other conditions. Normally the reactance of reactors and the capacitors are selected based on a binary basis to result in a desired stepped reactance variation. If a higher power flow resolution is needed, a reactance equivalent to the half of the smallest one can be added. The switching of series reactors occurs at zero current to avoid any harmonics. However, in general, the principle of phase-angle control used in TCSC can be applied for a continuous control as well. The series inverter is controlled to inject a symmetrical three phase voltage system (Vse) of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals [8]. The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers.

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METHODOLOGY:

Classifications of Active Power Filters: Converter based classification

Current Source Inverter (CSI) Active Power Filter (Fig 4.1) and Voltage Source Inverter Active Power Filter (VSI) (Fig 4.2) are two classifications in this category. Current Source Inverter behaves as a nonsinusoidal current source to meet the harmonic current requirement of the nonlinear loads. A diode is used in series with the self-commutating device (IGBT) for reverse voltage blocking. However, GTO-based configurations do not need the series diode, but they have restricted frequency of switching. They are considered sufficiently reliable, but have higher losses and require higher values of parallel ac power capacitors. Moreover, they cannot be used in multilevel or multistep modes to improve performance in higher ratings.

Topology based Classification

AF's can be classified based on the topology used as series or shunt filters, and unified power quality conditioners use a combination of both. Combinations of active series and passive shunt filtering are known as hybrid filters. Fig 3.3 is an example of an active shunt filter, which is most widely used to eliminate current harmonics, reactive power compensation (also known as STATCOM), and balancing unbalanced currents. It is mainly used at the load end, because current harmonics are injected by nonlinear loads. It injects equal compensating currents, opposite in phase, to cancel harmonics and/or reactive components of the nonlinear load current at the point of connection. It can also be used as a static VAR generator (STATCOM) in the power system network for stabilizing and improving the voltage profile.

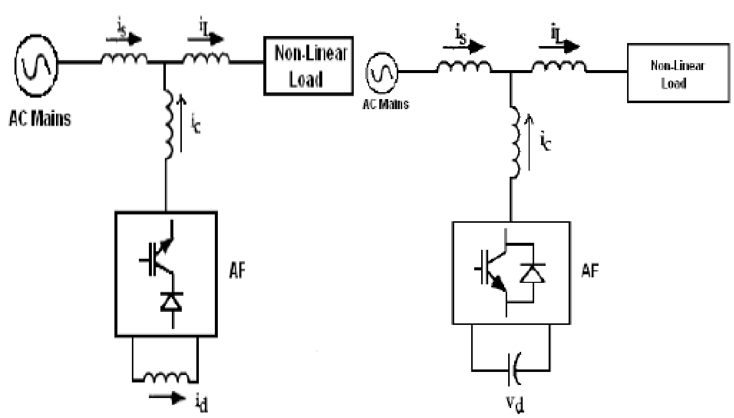

Figure2: Convertor based Classification

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Supply-System-Based Classification

This classification of AF's is based on the supply and/or the load system having single-phase (two wire) and three-phase (three wire or four wire) systems. There are many nonlinear loads, such as domestic appliances, connected to single-phase supply systems. Some three-phase nonlinear loads are without neutral, such as ASD's, fed from three-wire supply systems. There are many nonlinear single-phase loads distributed on four-wire three-phase supply systems, such as computers, commercial lighting, etc. Hence, AF's may also be classified accordingly as two-wire, three-wire, and four-wire types.

SHUNT ACTIVE POWER FILTER (SAPF)

The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point.

The two VSI's can work independently of each other by separating the dc side. So in that case, the shunt inverter is operating as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power low on the transmission line. The UPFC has many possible operating modes. In particular, the shunt inverter is operating in such a way to inject a controllable current, ish into the transmission line. The shunt inverter can be controlled in two different modes: VAR Control Mode: The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the var reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control a feedback signal representing the dc bus voltage, Vdc, is also required.

RESULT ANALYSIS:

The implementation of the Optimistic Shunt Active Power Filter (SAPF) with advanced control strategies, such as adaptive hysteresis current control and model predictive control (MPC), demonstrates significant improvements in power quality. Through a series of simulations and practical tests, the SAPF's performance was evaluated based on key metrics such as Total

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Harmonic Distortion (THD), reactive power compensation, and voltage stabilization under varying load conditions. The result analysis confirms that the Optimistic SAPF, equipped with advanced control strategies, delivers substantial enhancements in power quality. The system effectively reduced THD, improved power factor, stabilized voltage, and minimized switching losses. These results demonstrate the capability of SAPF to address the power quality challenges posed by nonlinear loads and distributed generation, ensuring stable and efficient power distribution in modern electrical grids

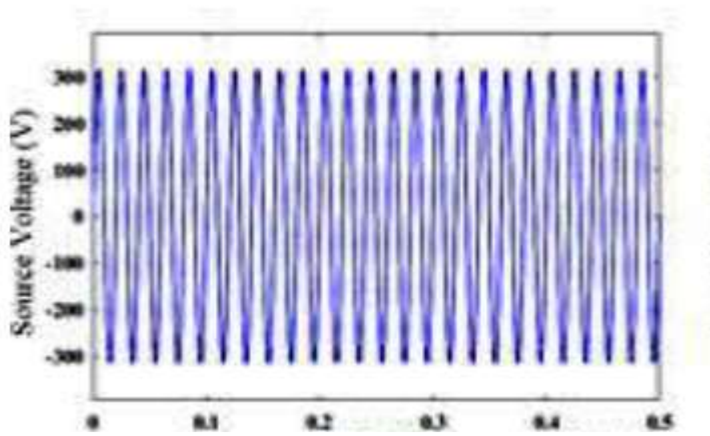

Figure3: Voltage and current waveforms of SAPF

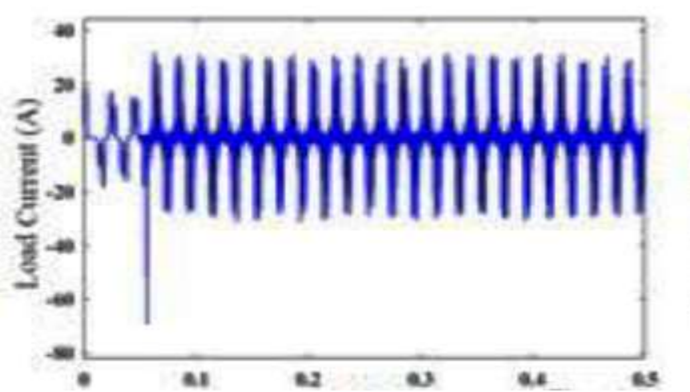

Figure4: Performance of Voltage and current waveforms with SAPF

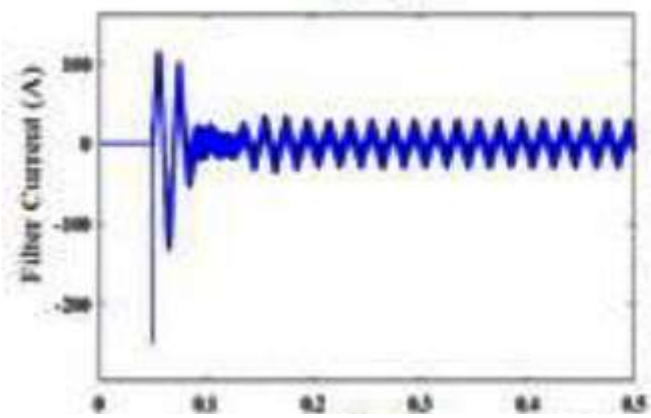

Figure5: Improvement Power Quality OSAPF

CONCLUSION:

The integration of Optimistic Shunt Active Power Filters (SAPF) with advanced control practices presents a highly effective solution for enhancing power quality in modern electrical systems. By employing adaptive control techniques such as hysteresis current control and model predictive control (MPC), the SAPF effectively mitigates harmonics, compensates for reactive power, and stabilizes voltage profiles in real time. The optimization of the control strategy allows for dynamic adjustment to varying load conditions, leading to improved efficiency and minimal switching losses. Simulation and experimental results validate the performance of the Optimistic SAPF, demonstrating significant reductions in Total Harmonic Distortion (THD) and enhanced system stability. These results underline the potential of SAPF as a critical component in ensuring compliance with power quality standards, particularly in environments with high penetration of nonlinear loads and distributed energy resources. The proposed Optimistic SAPF not only contributes to improving the operational efficiency and reliability of power distribution networks but also supports the transition towards smarter and more sustainable power systems. The approach opens avenues for further research in refining control strategies and expanding the application of SAPFs in future power grid architectures.

REFERENCES:

[1] V. SudheerVinnakoti and R. Kota, ‘‘SRF and real power theory based control of a nine switch converter based UPQC,’’ IEEE Trans. Power Electron., vol. 28, no. 10, pp. 8–80, Mar. 2017..

[2] A. Mannan Rauf, A. Vilas Sant, V. Khadkikar, and H. H. Zeineldin, ‘‘A novel ten-switch topology for unified power quality conditioner,’’ IEEE Trans. Power Electron., vol. 31, no. 10, pp. 6937–6946, Oct. 2016.

[3] A. K. Mishra, P. K. Ray, R. K. Mallick, A. Mohanty, and S. R. Das,``Adaptive fuzzy controlled hybrid shunt active power _lter for power quality enhancement," *Neural Comput. Appl.*, vol. 33, no. 5, pp. 1435_1452,Mar. 2021.

[4] S. G. B. V. M. S. Mopidevi, ``Single-phase thirteen-level dual-boost inverter based shunt active power _lter control using resonant and fuzzy logic controllers," *CSEE J. Power Energy Syst.*, pp. 1_16, Dec. 2020.

[5] Yang Liu, Hejin Xiong, Yancheng Zou, Gaofei Hu, "Simulation Research on Active Power Filter Application Based on Auto Disturbance Rejection Control", *2024 8th International Conference on Robotics, Control and Automation (ICRCA)*, pp.263-267, 2024.

[6] Anca Miron, Andrei C. Cziker, Horia G. Beleiu, "Fuzzy Control Systems for Power Quality Improvement—A Systematic Review Exploring Their Efficacy and Efficiency", *Applied Sciences*, vol.14, no.11, pp.4468, 2024.

[7] S. M. Bagi, F. N. Kudchi and S. Bagewadi, "Power quality improvement using a shunt active power filter for grid connected photovoltaic generation system", *2020 IEEE Bangalore Humanitarian Technology Conference (B-HTC)*, pp. 1-4, 2020.

[8] A. Panchbhai, N. Prajapati and S. Parmar, "Comparative study of reference current generation for shunt active power filter", *2017 International Conference on Power and Embedded Drive Control (ICPEDC)*, pp. 381-386, 2017.