International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 3 Issue 10, October 2022

A review on Three-Phase Transformer less integrated Shunt Active Power Filter with Reduced Switch Count for Harmonic Compensation

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Abstract: *It is obvious that power quality is an important characteristic of today's distribution power systems as loads become more sensitive on the other hand nonlinear loads are increasing in the electrical distribution system. From years ago, researchers have been working on various kinds of filters and devices to enhance the overall power quality of power system, but today the nature of distribution system has been changed and power electronic based DGs play an important role in distribution grids. In this paper, several literature reviews have been studied which enhances the power quality, Harmonic reduction, Reactive power compensation. Power quality problems have become the most important concern now a days.*

Keywords: *Harmonics, hybrid topology, nonlinear load, power quality (PQ), Transformer less inverter, Grid-connected system.*

1. Introduction

As part of today's grid, power electronic devices may have certain unfavorable consequences on grid parameters, power quality, and system dependability. These devices, which are widely employed in modern networks, have a direct impact on the distribution network's power quality. Inverter-based DGs, which use power electronic equipment as an interface to connect to the grid, are an example of these contaminants. [6] The crucial aspect is that the use of DG is becoming more widespread, both among individuals and among electric utilities. However, in standalone applications, the output current and voltage of DGs could be enhanced in the generation source by using some inverter switching methods. It is really important to note that multilevel inverters are among the most exciting inverters for using these switching methods, like harmonic elimination methods, due to various abilities. [7] Power quality issues are becoming increasingly essential as the number of DGs in today's grid grows, so paying attention to this topic is unavoidable. Several studies have been conducted on reducing the negative effects of power electronic-based DGs in microgrids that use DGs; nonetheless, this appears to be the first iterations of the multi-functional DGs concept, and much work has to be done in this regard. [8]

The microgrid allows us to address some system issues, making the grid more dependable and safer. Microgrids were originally introduced in the 1990s, and academics began to pay greater attention to them after that. It has unique qualities that will enhance power quality; one of these features is the inclusion of many DG units of varying natures to increase overall system reliability. Because most of the DG units in use power electronics-based converters, such energy sources could be used to improve power quality. [10] Even though it performs some of the same functions as a standard converter, each power electronics-based converter deployed in microgrids has the potential to increase power quality.

1.1 Harmonic due to non-linear load

One of the most serious issues with power quality is harmonics. Harmonics generate current and voltage waveform aberrations, which have negative consequences for electrical equipment. Nonlinear loads include the following: [14]

1. Electric arc furnace
2. Adjustable drive systems
3. Rectifiers
4. Switching mode power supplies

5. Computers, copy machines, and television sets
6. Static var compensators (SVCs)
7. HVDC transmission
8. Electric traction
9. Wind and solar power generation
10. Battery charging and fuel cells

1.2 Passive and Active Power Filters

Passive Power Filters: To decrease or remove current harmonics and adjust reactive power, passive power filters were designed using a mix of inductances as well as capacitances. Parallel passive filters and series passive filters are the two types of passive filters. These Filters are used in parallel with loads to create a Detour for harmonic currents by configuring the inductance and capacitance values so that if the filter seems to have a high impedance in fundamental frequencies as well as a very low impedance in required harmonic frequencies to absorb the harmonic currents.

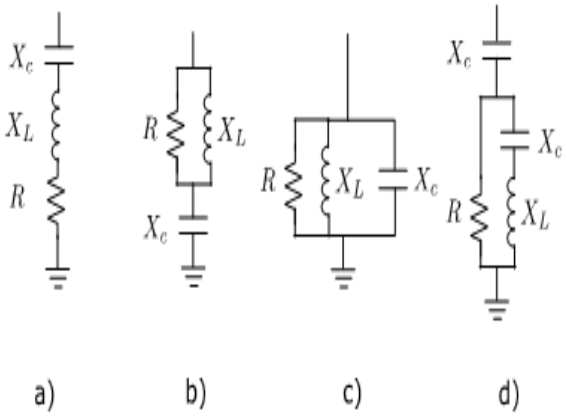

Figure 1: Passive Power Filter Designs

Active Power Filters (APF): Active power filters are a good option for tuned passive filters since their effectiveness is significantly reliant on the tuned factor, quality factor, and source equivalent impedance. Active power filters (APFs) were created to address the shortcomings of passive power filters. APFs can eliminate harmonics, enhance power factor, adjust for unbalances and flicker, as well as adjust voltage. With various topologies and control techniques, APFs have been deployed as PQI devices. There are some extensive comparisons between different APFs and their uses, however the most of the analyses are based on topology. Shunt active power filters as well as series active power filters are the two types of active power filters.

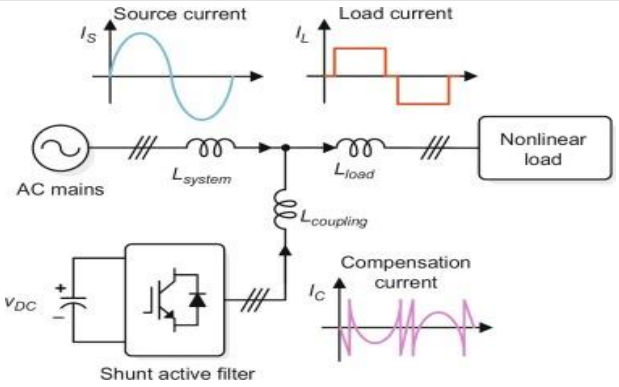

Figure 2: Active Power Filter

2. Literature Review

(Hariyaliyan, 2020) [1] the most effective solution for nonlinear loads, current harmonics, as well as power quality issues is a shunt active power filter. Because APF topologies for harmonic compensation rely on a large number of high-power rating components, they are inefficient. Topologies that combine low-power ratings and hybrid topologies APF with passive filters is being used to lower the voltage source inverter's power rating. A transformer with a large number of passive components is used in hybrid APF topologies for high-power rating systems. A novel four-switch two-leg VSI topology for a three-phase SAPF is described in this project in order to reduce overall costs and space. A two-arm bridge structure, 4 switches, coupling inductors, and sets of LC PFs are all part of the suggested topology.

(Manikanta et al., 2020) [2] When we talk about power transmission and distribution, the term "power quality" comes up frequently. We are shifting away from conventional energy sources and more towards alternative energy sources such as solar and wind energy. It decreases pollution and is safe for the environment. It can produce the stringent demand for power that has arisen as a result of population growth. In this study, researchers will incorporate solar energy into the grid to enhance the system's power quality. PV array, boost converter, inverter, PI controller, as well as Fuzzy Controller will all be used in this project. The Shunt Active Power Filter was created to filter harmonics and compensate for reactive power.

(Rameshkumar & Indragandhi, 2020) [3] In Single-Phase Shunt Active Power Filter, this manuscript provides a comprehensive overview of commonly utilized reference current extraction techniques (SAPF). The use of a single-phase shunt active filter in commercial as well as educational buildings has expanded significantly in recent years in order to enhance power performance and maintain customer satisfaction. The removal of harmonic current is

crucial to the performance of a shunt active power filter. Several reference current extraction strategies, such as the PI control algorithm, PQ Theory, DQ Theory, and others, are explored in order to duplicate the precise inverse image of harmonic currents. Furthermore, the key benefits and drawbacks of power filters are contrasted. Finally, the DC-Link capacitor voltage as well as capacitance rating, as well as the SAPF filter inductance, were thoroughly examined.

(Keerthi et al., 2020) [4] In recent years, the term power quality (PQ) has gotten a lot of attention from both the distribution and consumer sides. The growing use of power electronic devices in grid-tied applications, uninterruptible power supply (UPS), as well as motor drive applications, among other things, simplifies control technology and makes systems more durable and versatile. However, these gadgets damage the electrical system by injecting current harmonics into the line. It also consumes more reactive power, causing the system to become unbalanced. Researchers are always looking for new and more cost-effective ways to increase system PQ. Shunt active power filter (SAPF) has been one of the better options for improving power quality in grid-connected systems by balancing harmonic currents as well as other reactive power issues. The basic framework of SAPF is described briefly in this research, as well as the comprehensive control system features. The categorization, topologies, as well as comparisons of single-phase, three-phase three-wire (3P3W), as well as four-wire (3P4W) systems are all covered in this work.

(Khan, 2019) [5] Traditional electrical power networks have been gradually evolving into smart grids as well as emerging as next-generation power technology in recent years. The use of power electronics is a critical component of these changes. Recent advances in power electronics have accelerated the integration of renewable energy sources, energy storage, as well as modern loads into the hybrid microgrid linked with the smart grid. Following the references, disturbance rejection-based control techniques have been designed and implemented in this thesis to ensure superior steady state and dynamic performances. The grid synchronization method is used to operate power converters connected to the electrical grid, which necessitates quick and accurate calculation of grid voltage parameters (i.e., amplitude, phase, and frequency). The increasing power quality issues have an impact on the performance of synchronization systems.

(Suresh & Ramesh, 2019) [6] For improving current and voltage profiles, the SPV interfaced grid system with battery storage unit, bidirectional VSI interconnected shunt active filter, as well as an adaptive Proportional Integral (PI) controller is used. Using a diode rectifier or a non-linear load, the p-q theory is a commonly used technique for extracting the basic fundamental current harmonic components from a polluted or impacted power source. The PI-based instantaneous reactive power theory controls the bidirectional VSI-based shunt APF. To ensure DC-Link voltage, the proposed PI Controller interfaced shunt Active Power Filter is applied. The incremental conductance MPPT algorithm is connected to the SPV system. This SAPF control system must include features such as current harmonic mitigation and reactive power correction.

(Niranjana et al., 2018) [7] The non-linear properties and quick switching of power electronic gear cause serious problems in power systems. Because of sensitive technology, power quality issues are getting more serious. The proposed PQ theory is utilized to calculate the reference compensating currents that must be injected into the network at non-linear load linked points. Comparing the reference compensating currents produced from PQ theory with compensator currents provides a switching method for the compensator. To satisfy non-linear loads, compensating current must be injected to ensure reactive power as well as bring the source current waveform to a sinusoidal shape. Shunt active power filters have been used to reduce current harmonics and compensate for reactive power by emulating three phase four wire and three phase three wire systems. As a result, the power factor has already been enhanced by aligning the source voltage and current.

(Patil et al., 2018) [8] Every citizen's high level of living, as well as any country's progress, is primarily dependent on the availability of high-quality, abundant electric power. With the growth of science and technology, the demand for electric power has risen at an exponential rate in recent years. The operation of many consumer gadgets necessitates the use of high-quality power on a constant basis. As a result, these issues should be addressed in order to improve the consumer equipment's performance as well as the system's overall performance. Passive Filters (PF), Active Power Filters (APF), as well as hybrid filters can all be used to achieve harmonic compensation (HPF). Active Power Filters (APF) are frequently employed in applications where low current harmonics are desired and energy quality from the power grid needs to be improved. This study provides a thorough examination of active filter (AF) configurations, control strategies, component selection, and other relevant economic and technical factors, as well as their application selection. Its goal is to provide a broad overview of the current state of AF technology in terms of power quality problems.

(Biramwar, 2018) [9] In today's industries, the use of nonlinear loads has expanded significantly, injecting harmonic currents into the supply system. These harmonics wreak havoc on electricity quality. To decrease these harmonics, a shunt active power filter (SAPF) is a common and effective method. SAPF enhances power factor by overcoming voltage sag, eliminating harmonics, and reducing voltage sag. Total harmonic distortion (THD)

is reduced to an acceptable level using SAPF. The foundation of APF is reference current generation. This study presents reference current generation utilising the instantaneous reactive power (IRP) theory. Active power filters are frequently controlled using IRP theory (APFs). This technique's modeling is done in MATLAB/Simulink. (Luo et al., 2017) [10] This study introduces a new three-phase four-leg voltage source inverter (VSI) for megawatt-level system applications. The proposed four-leg inverter uses an integrated architecture that includes thyristors as well as insulated-gate bipolar transistors (IGBTs), with the goal of reducing the number of IGBTs. A neutral leg, featuring IGBTs, is creatively interwoven with the standard phase legs to handle the zero-sequence current. The modeling principles are also expanded and studied, with a focus on switching states as well as voltage vectors in six segments based on thyristor states. Furthermore, the suggested inverter's closed-loop current regulation is proven by simulation as well as experimentation using the carrier-based pulse width modulation (PWM) approach.

3. Conclusion

In this paper, it was observed that by reducing the harmonic, improve the power quality, reactive power compensation. A detailed discussion on power-system harmonics and standards are also discussed. Based on harmonic compensation, different types of filters like passive, active, and hybrid filters for PQ improvement are discussed. This review provides a brief study on the selection criteria of PQ based on different applications. Furthermore, detailed technical and economic considerations are approached, which are a very important perspective for researchers and engineers dealing with harmonics and PQ issues. Further, the scope of work in future developments with new trends to minimize the number of power semiconductor components, with reduced costs of the converter, is briefed in this literature.

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