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Power Filters to Improve Power Quality in Power System: A Survey

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Abstract— **Because of inflated level of harmonic pollution power signals, power quality acquisition has become indispensable, and thus, numerous power acquisition techniques were introduced. The power filters (PF) play important role for conditioning the voltage and current signals and also to maintain the current and voltage profile. Among the power signal conditioning methods, power filters seem to be the foremost viable device used for mitigating power quality problems. numerous ways of dominant active power filter (APF) area unit planned and enforced by researchers and engineers in aim of achieving close to excellent compensation. This survey presents a configuration type of active filters.**

Keywords—Active Power Filters, Power signal Conditioner, Harmonics And Reactive Power Compensation and Power Quality etc.

I. INTRODUCTION

The analysis on active power filters has been developing to provide a lot of solutions so as to determine a stable power system. many review articles concerning active power filters were dispensed in [1-15], however because of the rise in power quality issues that light-emitting diode to the looks of latest configurations and management techniques, a replacement review was necessary to hide all the recent and fashionable topics in a very simplified format. This paper starts with a quick discussion concerning harmonic distortion and also the principles of APF then it presents totally different classifications for APF, that embody circuit configuration, compensated system parameters, device sort, rating of the compensated system, reference signals estimation techniques and control ways, as well as recent configurations like unified power quality conditioner and multi-level converters additionally to the newest management techniques that ar used for eliminating higher and lower order harmonics within the totally different stages of the power system and additionally for attaining reactive power management and voltage stability employing a single filter or separate active filters [1,4, 5].

Harmonic waveforms square measure distinguished by the amplitude and harmonic variety. Harmonic distortion is often stipendiary using Passive Power Filters (PPF), Active Power Filters (APF),and hybrid power filters, that square measure a mix of each active and passive power filters. The harmonics compensator connected to the ability system should offer 2 blessings [10, 11]:

- Minimization of the full Harmonic Distortion (THD) part to 5% in line with IEEE 519 normal.
- Compensation of the reactive power to boost the power quality.

The conventional passive filter configurations that use tuned RLC filter banks won't to be put in on the grid to eliminate undesired harmonics, however thanks to the issues, related to them, active filters were given. the subsequent sections can demonstrate however active filters offer additional blessings and features examination to standard passive filters that created them preferred for harmonic compensation [12, 13].

Passive filtering is that the typical technique to eliminate harmonics from grid with the advantage of rising the facility issue, however since it will cause resonance and might be stricken by frequency variations of the facility distribution system active filters were used. APFs give several options over PPFs as a result of they're capable of eliminating current harmonics also as reactive power that provides reactive power compensation while not the drawbacks that face passive filtering [14]. The key principle of APF is to perform sort of a supply of reverse harmonics that generates harmonic parts with opposite impact to cancel the system harmonic parts [15]. A generalized diagram for APF is bestowed as fig. 1 in [1], which might be accustomed represent the most components of a simplified APF system.

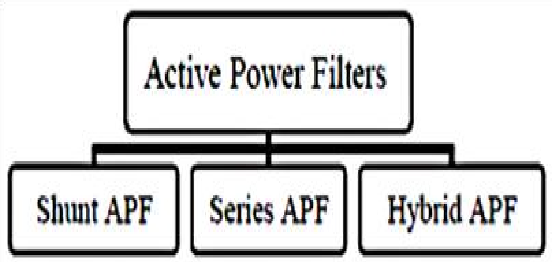

Fig. 1 Circuit Configurations Wise Active Power Filter [2]

Passive filters are traditionally used to mitigate harmonic distortion and have long been employed in the industrial and utility sectors. However, passive filtering has several drawbacks including the lack of adaptation during variations of the load and network impedance. Furthermore, passive filters may cause resonance with network and in some cases this latter, when excited, can cause large harmonics in the voltage and current of the filter capacitor and the network. Unlike passive filters, modern Active Power Filters (APFs) are power electronic-based devices which offer superior filtering performance and have faster transient response. They can compensate for current and voltage harmonics, reactive power and provide voltage control in the distribution network. APFs are basically classified into two types: Shunt, parallel and series APFs. Shunt active filters are connected in parallel and inject into the network a current that is equal in amplitude to the harmonic current to be suppressed but with opposite phase. Series active filters, on the other hand, are connected in series with the network voltage via a matching transformer and behave like a voltage generator which imposes a harmonic voltage such that, when added to network voltage, produce a sinusoidal-like voltage waveform at the connection point. SAPF can compensate for voltage disturbances acting on the load side.

A. Shunt active filter

This type of is taken into account to be the foremost noted configuration within the field of active filtering. The association of Shunt active filter to the grid is shown in Fig. 2 [2, 8], wherever PCC is that the purpose of common coupling, and also the used device configuration is a controlled voltage supply or controlled current supply, however active filter with voltage supply device is usually used [15]. The filter aims to eliminate this harmonic fed to the provision [5]. It may also participate in reactive-power compensation and within the balance of three-phase currents [4]. Shunt filters area unit adequate for usage during a broad vary of power ratings thanks to the likelihood of connecting variety of filters in parallel for prime current ratings.

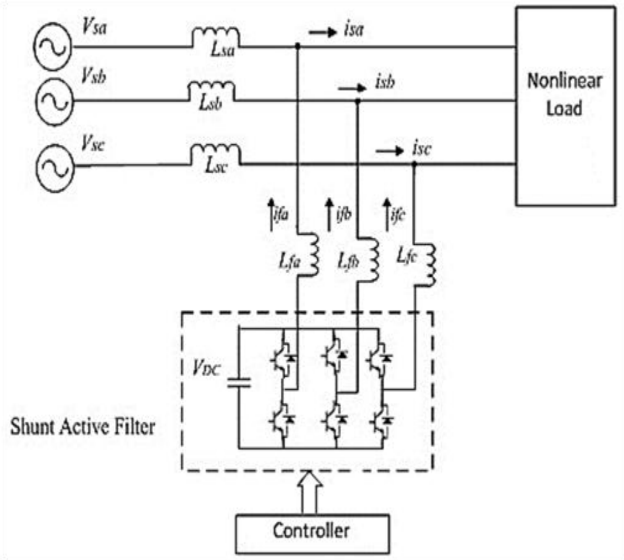

Fig. 2 Circuit diagram of Shunt active filter [2, 8].

B. Series active filter

Such filter circuit is put in series affiliation employing a current electrical device and its largely accustomed cut back the harmonics generated at the supply aspect [6]. Series active filter configuration generates a correct voltage wave shape to mitigate the voltage harmonics and maintain a curving voltage wave shape at the load. The line diagram shown in Fig. 3 shows the affiliation of the series active filter that is put in by the electrical utility to complete voltage harmonics and to beat resonance downside that happens within the line [10]. The used convertor for this method could be a voltage supply electrical converter with no current-control loops. Series active filters aren't wide utilized in industrial applications not like the shunt filters as a result of series configurations wear down substantial obstacles like high load currents, that makes their current rating to be quite high compared to shunt filters.

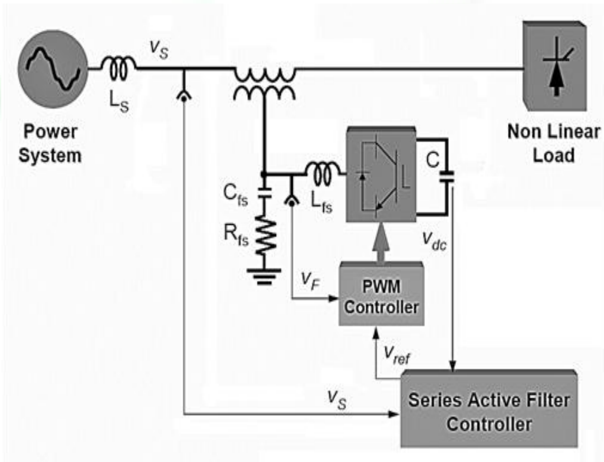

Fig.3 Circuit Diagram of Series Active Filter [6]

C. Hybrid APF Filter

Active power and passive filters (APF and PF) are the traditional ways of compensating for harmonics. However, both of the two ways have some disadvantages, namely resonance and tuning problems in passive filters (PF), and capacity, initial and running cost in active power filter (APF). Hybrid Active Power Filter (HAPF) has been proposed to overcome the disadvantages of APF and PF. It is a combined system of PF and APF. Abundant research has been done recently to combine APF and PF. Various topologies of HAPF have been proposed and studied to reduce the capacity of APF and to improve the compensation characteristics in recent twenty years.

II.LITERATURE SURVEY

Deng, Y., et. al (2019), Thisresearch work,presented a sequence-to-sequence model based on bidirectional Gated Recurrent Unit (Bi-GRU) intended for type recognition and time location of combined power quality disturbance. Furthermore, the effectiveness and feasibility for theoretical analysis and experiment realization of the proposed model are confirmed by synthetic signals and practical field signals, respectively.The presented sequence-to-sequence deep learning architecture based on bidirectional Gated Recurrent Unit (Bi-GRU) can correctly recognize the type of each element in the sequence and then the starting-ending times can be accurately located. This is great different from the existing sequence-to-sequence model employing encoder-decoder network, in which challenge may be faced to capture the intrinsic temporal information of PQD and difficulty may arise to locate starting-ending times of PQD**[01].**

Hossain, E., et. al (2018),In this research work, discusses the power quality issues for distributed generation systems based on renewable energy sources such as solar and wind energy. A thorough discussion about power quality issues, their sources, and parameters have been presented here. Discussion on power quality standards have been carried out afterwards. After that, power quality issues in renewable energy systems, techniques to monitor power quality, the devices used for that purpose, and application of CPDs for mitigating power quality problems have been described. Ways of improving power quality in renewable systems, and analysis of power quality in DC systems have followed all these; and the outcomes have been presented finally to summarize the findings of this work. From the outcomes of this research, transient has been found out to be the most severe power quality issue, followed by voltage spike and fluctuation. The power quality monitoring techniques have been found to be employed for monitoring harmonics mainly, while UPQC, STATCOM, and spinning reserve have been found out to be the most effective CPDs. It has been resolved that STATCOM can be a potential choice due to the advantages it offers**[02].**

Tareen, W. U., et. al (2017),Thisresearch work, provides the state-of-the art and strong perspectives on the transformerless, passive components of APF and grid-connected renewable energy systems. This review provides a broad perspective to researchers, manufacturers, and engineers who deal with harmonics and power quality issues. To enhance the power quality of the DER and DPGS, innovative and novel developments have been reported in the field on grid-connected inverters. The main research trends related to the reduced switch count inverters with APF topologies include the back-to-back inverter, AC-to-AC inverters, and common-leg inverter configurations. Therefore, the PFs, APF, HAPF, hybrid filters, UPQC, and STATCOM are considered as power quality improvement techniques. APFs are mature technologies that act as a powerful bridge between distributed grid systems and harmonics pollution. To date, a large number of well-developed and large-capacity advanced APF technologies are available in the market for consumers. The demand for APFs has been reviewed to reduce the power semiconductor components, auxiliary circuits, and coupling transformers in terms of the cost, volumetric size, weight, THD, power loss, and efficiency. Additionally, the present grid-connected APF PV inverters and wind energy conversion inverters are investigated, analyzed in detail, compared, and discussed. To sustain the power quality at an acceptable level in the long run, the utilities will encourage the installation of APF technology alongside the nonlinear loads. The new APF principles described in this article are SVG and STATCOM. The APF is an effective solution for power quality problems, such as harmonic mitigation, voltage regulation, load balance, power factor correction, and neutral current compensation, in grid-integrated distribution systems. Therefore, the dual-terminal inverters, shared legs between inverters and rectifiers, and substitution of the split capacitor configurations are potential techniques for advanced SAPF systems**[03]**.

Tabart, Q., et. Al (2017).In thisresearch work, the use of a 4-Leg 3L-NPC power converter topology to interface a RES with a HESS (formed by a VRB and a Li-Ion battery) in a microgrid context has been investigated. A new model of the structural limits is presented and implemented to exploit the entire capability of the 4-Leg 3L-NPC converter to insure a maximum power division between the two ESS. A non-linear 2-SMC scheme has been designed and tuned to control the zero sequence injection in the modulating signals in order to control the power flow of the HESS. Furthermore, the fourth leg of the converter allows the unbalanced load issue to be addressed, and thus enable active power filter capabilities. The investigation of the limits of the topology showed a power exchange capability amongthe HESS. Simulation and experimental results proved the capacity of the presented control strategy to manage a HESS in order to improve the power quality and stability as well as to control the renewable energy injected into a micro grid **[04].**

Mahela, O. P., et. al (2016).In this research work, discusses an extensive review on various power quality improvement techniques to enhance the quality of electrical power in the distribution network has been provided to the researchers, designers, manufacturers and engineers working on power quality. It also provides substantial knowledge to beginners in the field of power quality. A broad classification of PQ improvement techniques into five categories with further sub classification of various techniques is expected to provide an easy selection of appropriate technique for particular application. The selection criteria of PQ improvement devices for specific applications as well as technical and economic considerations are well summarized. According to the developed review, it can be concluded that passive filters, APF, Hybrid filters, UPQC and DSTATCOM are commonly used PQ improvement techniques. Passive filters are the simplest and most economical along with the demerits of large size and tuning issues. To overcome the limitations of passive filters QPF is used. APFs are more effective with nonlinear loads to maintain power quality. Hybrid filters provide optimal solution for PQ mitigation with reduced cost, simple design and control with high reliability for PQ improvement. The FACTS devices provide more effective and accurate alternative for PQ improvement. Coordination between different types of distributed generations would also help in PQ mitigation. UPQC which is basically an UPFC can effectively be used to mitigate PQ issues. However, it is an expensive solution. DSTATCOM is highly effective for improving PQ at distribution voltage level and has advantage of making stable voltage. Users can select the most appropriate technique with required features to suit a particular application**[05]**.

Singh, B., et. al (2015). This research work, presented a self tuning filter based IRPT control algorithm with an adaptive fuzzy logic controller has been used in VSC based D-STATCOM for power quality improvement in a distribution system. The use of self tuning filter has a satisfactory performance of a DSTATCOM which has been validated by both simulation and experimental results. Since it perfectly extracts the fundamental component of current under distorted voltages condition, it has been found as an effective solution to power quality problems. For DC bus control of VSC of DSTATCOM, an adaptive fuzzy logic controller has been used which has regulated the DC voltage to the desired level without much overshoot and undershoot under both distorted and unbalanced load currents conditions. The adaptive fuzzy logic controller has also demonstrated its effectiveness in regulating DC voltage under supply voltage fluctuation. The simulation and experimental results have demonstrated the major advantages of presented control algorithm**[06].**

III. Hybrid filter

The hybrid active filter uses a mixture of active filter and passive filter and its typically accustomed overcome technical problems with standard APFs [5]. Hybrid APFs have the deserves of each filter varieties, which offer additional economical operation with less price. today many hybrid APFs are being employed in electronic business, like shunt APF with shunt PPF, series APF parallel with PPF, Series APF connected nonparallel with shunt PPF and FACTS controllers, however the foremost distinguished connections are the primary types, that are shown in Fig. 4 show the configurations of the hybrid filter wherever active and passive filters are used along and also the task of eliminating harmonics is partitioned off between each of them.

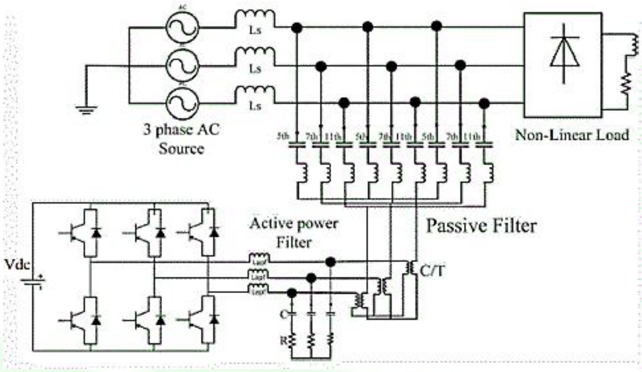

Fig.4. Circuit diagram of Hybrid filter [4]

Active power filters are mainly used for reactive power compensation, eliminating voltage and current harmonics and for maintaining the system balance.

A. Reactive Power And Harmonic Compensation

VAR compensation can be usually achieved using traditional techniques not by using complex APF configurations for VAR compensation only. Also, it is considered to be the most significant in the grid that needs to be compensated including both voltage and current harmonics.

B. Control Methods

The control unit plays the most important role in APF because the selection of the control technique can be crucial to the APF performance. The controller generates the required gating signals for the switches to compensate the harmonics based on the estimated reference signals. APF controllers implementation has been motivated by the developments of the microcontrollers, DSP's and FPGA which led to further progression Different control techniques algorithms have been used with APF, such as Space Vector PWM , carrier phase shifted SPWM, repetitive control one-cycle control , linear control technique , sliding mode control , Delta Modulation control , hysteresis control technique , ramp comparison current control dead-beat control, predictive control fuzzy control Artificial Neural Network , Genetic Algorithm and Particle Swarm optimization In addition to, reduced DC link voltage Negative sequence current control and other optimization techniques.

IV.CONCLUSION

The review discusses the principle of operation of APF and presents completely different classifications of active power filters supported many factors. variety of various APF topologies and management techniques are reviewed. Most of the recent reviews targeted on the active filters configurations and plenty of the recent reviews were dedicated to the management techniques. This reviewgive glimpse about points mentioned in recent review articles and multi-level converters that offer glorious results, however they have additional analysis to reduce their drawbacks.

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