Harmonics Mitigation Using Active Power Filter

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Abstract

This paper is proposed to reconsider the development of active power filter (APF) technologies that are routinely utilized to mitigate harmonics in utility power lines. This reconsider can furthermore be considered as a "tutorial-type paper" as it provides a holistic coverage of the APF technologies by omitting the tedious details, but without losing the major essence of the subject matter. It is wanted that by this approach, it would be likely to lure more power engineering readers to be involved in this important and growing area. The discussion starts with a short overview of harmonic distortion difficulties and their impacts on electric power and powered value. The operation of common APF topologies, namely the shunt, sequence and hybrid APFs are recounted in minutia. This is followed by a reconsider on different types of reference pointer estimation extraction methods. In specific, the application of the p-q and elongation p-q theorems to extract the quotation pointers are elaborated, as they are the most commonly discovered in practical APF systems eventually, an overview of the APF command schemes is provided. A short consideration on the APF-solar photovoltaic scheme is furthermore granted. At the end of the paper, important references are cited to aid readers who are interested to discover the subject in larger detail.

Keywords

Active power filter, Harmonics mitigation, Power electronics, Power quality, Voltage source inverter.

1. Introduction

The power value (PQ) problems in power utility distribution schemes are not new, but only recently their consequences have gained public perception. Improvement in semiconductor apparatus technology has fuelled a revolution in power electronics over the past decade, and there are suggestions that this tendency will extend [1].However the power electronics founded equipments which include adjustable-speed engine drives, electrical devices power provision, DC motor drives, battery chargers, electrical devices ballasts are to blame for the rise in PQ associated problems [2],[3]. These nonlinear burdens emerge to be major causes of harmonic distortion in a power circulation scheme. Harmonic currents produced by nonlinear burdens are injected back into power circulation schemes through the issue of common coupling (PCC). As the harmonic currents pass through the line impedance of the system, harmonic voltages emerge, initiating distortion at the PCC.

Harmonics have a number of undesirable effects on the distribution system. They drop into two rudimentary classes: short-term and long-term. Short-term consequences are usually the most noticeable and are related to unwanted voltage distortion. On the other hand, long-term effects often proceed undetected and are usually associated to advanced resistive deficiency or voltage stresses [4]. In addition, the harmonic currents made by nonlinear burdens can merges adversely with a wide range of power system gear, most especially capacitors, transformers, and engines, causing added losses, overheating, and overloading.

These harmonic currents can furthermore origin interferences with telecommunication lines and mistakes in metering apparatus [2]-[3]. Because of the adverse effects that harmonics have on PQ, benchmark has been developed to characterize a reasonable structure for harmonic command [5]. Its target is to ensure steady-state harmonic limits that are acceptable by both electric power and power utilities and their customers. Harmonic distortion in power distribution schemes can be stifled utilizing two advances namely, passive and active driving. The passive filtering is the simplest conventional solution to mitigate the harmonic distortion [6]-[8]. Although simple, the use passive components do not habitually reply correctly to the dynamics of the power circulation schemes [9]. Over the years, these passive filters have evolved to high level of sophistication. Some even tuned to bypass exact harmonic frequencies. Accepted passive filters comprise of

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inductance, capacitance, and opposition components configured and tuned to command harmonics. Fig 1 displays common kinds of passive filters and their configurations. The single-tuned "notch" filter is the most widespread and economical type of passive filter [8]. The notch filter is attached in shunt with the power distribution scheme and is series-tuned to present low impedance to a specific harmonic present. Therefore, harmonic currents are diverted from their usual flow route through the filter. Another well liked kind of passive filter is the high-pass filter (HPF) [7]. A HPF will permit a large percentage of all harmonics overhead its corner frequency to overtake through. HPF normally takes on one of the three types, as shown in fig 1.

The first-order, which is distinguished by large power losses at basic frequency, is rarely utilized. The second-order HPF is the simplest to apply while providing good filtering activity and reduced fundamental frequency deficiency [9]. The filtering presentation of the third-order HPF is better to that of the second-order HPF. However, it is discovered that the third-order HPF is not routinely used for low-voltage or medium-voltage applications since the economic, complexity, and reliability components do not justify them [8].

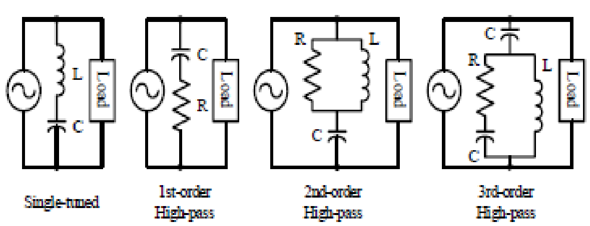


Figure 1: Common types of passive filters and their configurations

Whereas easy and smallest costly, the passive filter inherits several shortcomings. The filter constituents are very bulky because the harmonics that need to be stifled are generally of the low order [4], [9]. Furthermore the compensation characteristics of these filters are influenced by the source impedance. As such, the filter conceives is very strongly reliant on the power system in which it is connected to [8]. Passive filters are renowned to origin resonance, therefore affecting the stability of the power distribution systems [9]. Frequency variety of the power circulation system and tolerances in components values sway the filtering characteristics. The size of the constituents become impractical if the frequency variety is large [8], [9]. As the regulatory obligations become more stringent, the passive filters might not be adept to rendezvous future modifications of a specific benchmark. This may required a retrofit of new filters.

2. Active Power Filter

Remarkable advancement in power electronics had spurred interest in APF for harmonic distortion mitigation. The rudimentary principle of APF is to utilize power electronics technologies to produce exact currents constituents that annul the harmonic currents constituents caused by the nonlinear burden. Figure 2 displays the constituents of a usual APF scheme and their connections. The data regarding the harmonic currents and other scheme variables are passed to the reimbursement current/voltage quotation signal estimator. The reimbursement quotation signal from the estimator drives the general scheme controller. This in turn presents the command for the gating signal generator. The yield of the gating pointer generator controls the power circuit by an apt interface. Eventually, the power circuit in the generalized impede diagram can be connected in parallel, series or parallel/series configurations counting on the interfacing inductor/transformer used. APFs have a number of advantages over the passive filters. First of all, they can suppress not only the supply current harmonics, but also the reactive currents.

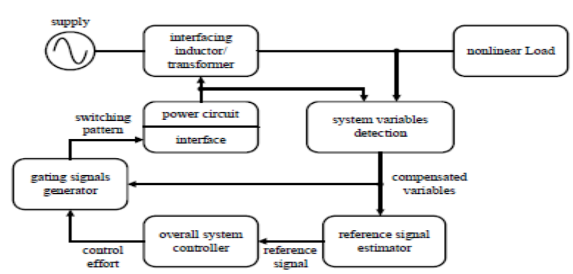


Figure 2: Generalized block diagram for APF

Furthermore, unlike passive filters, they do not origin harmful resonances with the power distribution systems. Consequently, the APFs performances are unaligned on the power circulation scheme properties [9]. On the other hand, APFs have some drawbacks. Active filtering is a somewhat new expertise, practically less than four decades old. There is still a need for farther study and development to make this technology well established. An unfavorable but inseparable feature of APF is the necessity of very quick swapping of high currents in the power circuit of the APF. This results in a high frequency disturbance that may origin an electromagnetic interference (EMI) in the power distribution schemes [34]. APF can be connected in several power circuit configurations as showed in the block diagram shown in Figure 3. In general, they are split up into three major classes, namely shunt APF, series APF and hybrid APF.

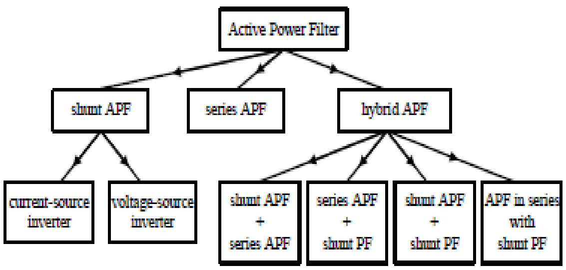


Figure 3: Subdivision of APF according to power circuit configurations

2.1 Shunt Active Power Filter

This is most important configuration and broadly used in hardworking filtering submissions [10]-[15], [36]. A shunt APF comprises of a controllable voltage or current source. The voltage source inverter (VSI) founded shunt APF is by far the most widespread kind utilized today, due to its well renowned topology and straight ahead setting up method. Fig 4 shows the standard configuration of a VSI founded shunt APF. It comprises of a DC-bus capacitor (Cf) , power electrical devices swaps and interfacing inductors (Lf). Shunt APF acts as a current source, reimbursing the harmonic currents due to nonlinear loads. The procedure of shunt APF is founded on injection of compensation present which is equals to the distortion current, therefore eradicating the initial distortion current. This is achieved by "shaping" the reimbursement present waveform (i_f), utilizing the VSI swaps. The shape of reimbursement present is got by measuring the load present (i_L) and subtracting it from a sinusoidal quotation. The aim of shunt APF is to obtain a sinusoidal source current (i_s) utilizing the relationship: $i_s = i_l - I_f$

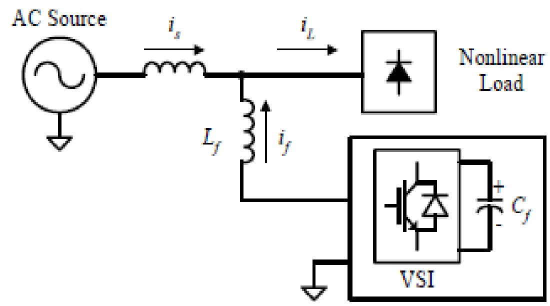


Figure 4: Principle configuration of a VSI based shunt APF

This only comprises the fundamental constituent of the nonlinear load present and therefore free from harmonics. Fig 5 shows the ideal source present when the shunt APF presents harmonic filtering of a diode rectifier. The injected shunt APF current completely cancels the current harmonics from the nonlinear burden, resulting in a harmonic free source current. From the nonlinear load current point of outlook, the shunt APF can be considered as a varying shunt impedance. The impedance is none, or at least small, for the harmonic frequencies and infinite in periods of the basic frequency. As a outcome, decrease in the voltage distortion happens because the harmonic currents flowing through the source impedance are decreased. Shunt APFs have the benefit of carrying only the compensation present plus a little allowance of active basic present supplied to reimburse for scheme deficiency.

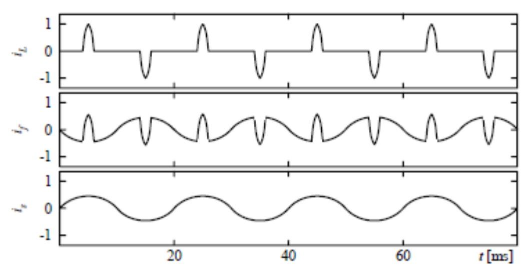


Figure 5: Shunt APF harmonic filtering operation principle

2.2 Series Active Power Filter

The sequence APF is shown in Fig 6. It is connected in series with the distribution line through a equivalent transformer. VSI is used as the controlled source; therefore the principle configuration of series APF is alike to shunt APF, except that the interfacing inductor of shunt APF is restored with the interfacing transformer.

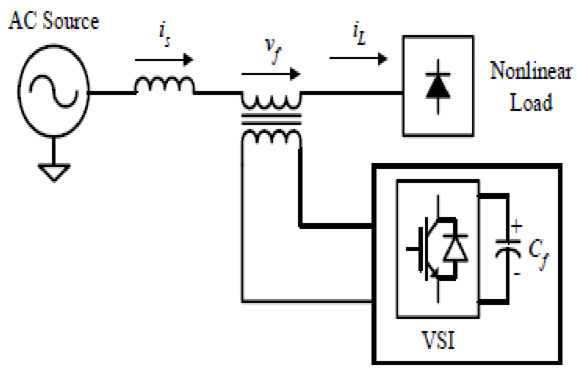


Figure 6: Principle configuration of a VSI based series APF

The operation standard of series APF is based on isolation of the harmonics in between the nonlinear burden and the source. This is got by the injection of harmonic voltages (vf) across the interfacing transformer. The injected harmonic voltages are added/subtracted, to/from the source voltage to maintain a untainted sinusoidal voltage waveform across the nonlinear burden. The sequence APF can be considered of as a harmonic isolator as shown in Figure 7. It is controlled in such a way that it presents none impedance for the fundamental constituent, but appears as a resistor with high impedance for harmonic frequencies components. That is, no current harmonics can flow from nonlinear load to source, and vice versa. Sequence APFs are less widespread than their competitor, i.e. the shunt APF. This is because they have to handle high burden currents. The producing high capability of burden currents will increase their current rating considerably contrasted with shunt APF, particularly in the lesser side of the interfacing transformer. This will increase the I^2R losses. Although, the major benefit of sequence APFs over shunt one is that they are ideal for voltage harmonics elimination. It presents the load with a pure sinusoidal waveform, which is significant for voltage perceptive apparatus (such as power scheme protection devices). With this characteristic, sequence APF is apt for improving the value of the distribution source voltage.

3. Simulation of active filter for nonlinear loads

The simulation of active power filter with non- linear load is shown as in the fig 7. In the simulation active filter are connected in parallel. In simulation of active filter the result of current and voltage are shown in the fig 8. And fig 9 as given below. With the help this arrangement, harmonics can be reduced up to a great extents. The wave forms show that harmonics gets reduced and their THD are also shown in Fig.10.

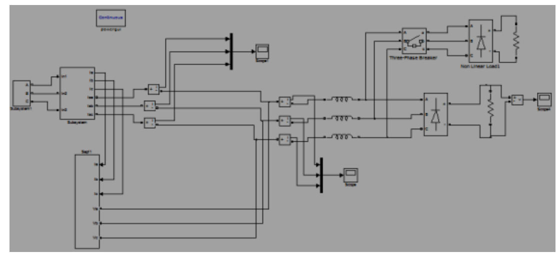


Figure 7: Circuit diagram of nonlinear load system with shunt active power filter

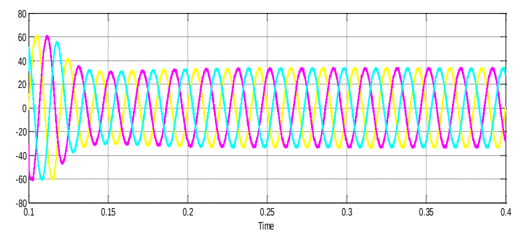


Figure 8: Simulation results waveforms of current of nonlinear loads

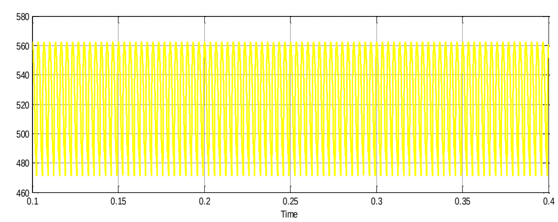
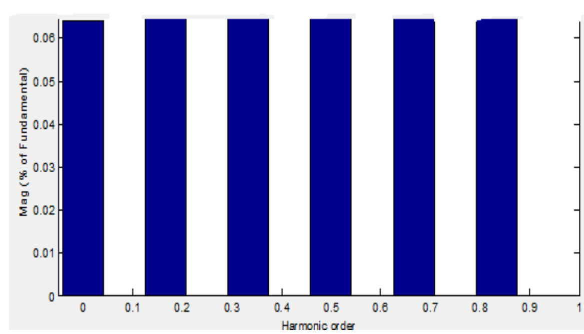


Figure 9: Simulation results waveforms of voltage of nonlinear loads



Fundamental(50Hz)= 31.99 , THD= 1.48

Figure 10: THD of nonlinear load system with shunt active power filter

4. Conclusion

This paper gives an overall outlook on the development of APF technologies. A short discussion on the harmonic distortion difficulties and their impacts on electric powered PQ are given. The conventional mitigation procedures utilizing passive filters are presented first, followed by the advanced mitigation procedures utilizing APFs. It also reviews different kinds of reference pointer estimation methods which is an integral part of the APF. An overview of the control schemes for APF is offered. Finally latest efforts in combining the PV system with the shunt APF are considered briefly.

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