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SHUNT ACTIVE POWER FILTER MODELING, CONTROL, AND ANALYSIS FOR IMPROVING POWER QUALITY

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Abstract
The goal of this paper is to develop and build a Shunt Active Power Filter (SAPF) to improve the power quality of modern power systems. Manypower electronics-based loads and controllers are used in today's power system. These power electronics-based loads and controllers inject non-linearity and harmonics into the system, in addition to numerous other benefits. The voltage and current waveforms get distorted as a result, and power quality suffers. Passive filters are commonly employed to address concerns linked to power quality issues. However, this approach can only provide fixed compensation and has a large size. Active power filters (APFs) are a good alternative for improving the power quality of modern power systems, since they may be utilised as current and voltage sources for balancing voltage harmonics, current harmonics, and providing reactive power support.The goal of this paper is to develop a voltage source based SAPF to address the issue of power quality. The control signals isgenerated using an instantaneous power theory control method. The oscillating components of real and reactive powers isused to generate the reference current in the instantaneous power theory. Furthermore, VSI provide real power to compensate for switching losses. The current controller's reference currentis obtained using a hysteresis current controller. Because the hysteresis current controller has a good dynamic response, it can track and compensate for continuously varying current harmonics.The MATLAB/Simulink platform to be used to implement the proposed system model and control method. In this study, two scenarios are compared: one with SAPF and one without SAPF.
Keywords: Shunt Active Power Filter(SAPF), Programmable Logic Controllers(PLC), Passive Filters (PF).

1. INTRODUCTION

It's worth noting that a significant quantity of power electronics equipment has been integrated into today's electrical power system. The large number of diverse power conversion units, power electronic devices, and nonlinear loads, such as adjustable speed drives, household instruments, transformer saturation, and so on, create increased harmonics on alternating current mains. The number of non-linear loads is increasing rapidly as technological knowledge and electronic equipment progress, resulting in the generation of characteristic and non-typical harmonics in the power system, which is damaging to the system. Over the last two decades, thyristors have grown in popularity, allowing for more control flexibility.The introduction of harmonics into the system is a drawback. Loads draw non-sinusoidal current from alternating current mains, which degrade the system's output. Lightning, short circuits, and sudden overloads were all common causes of failure in early technology, which was designed to withstand them without requiring additional expenditure. The equipment would be significantly more expensive if current power electronics (PE) prices were predicated on the same amount of resilience. Contaminants were introduced into power networks prior to the introduction of nonlinear loads such as transformers and saturation coils; however, the rate of perturbation has never approached the levels that exist now. Because of its nonlinear features and quick switching, PE is to blame for the majority of pollution issues.

The majority of pollution concerns are caused by PE's nonlinear characteristics, as well as its quick switching. PE currently processes around 10% to 20% of the world's energy; by 2020, that percentage is predicted to climb to 50% to 60%, owing primarily to the rapid expansion of PE capacity. Current research focuses on the rivalry between rising levels of polyethylene (PE) pollution and sensitization on one hand, and the development of innovative polyethylene-based corrective devices that have the ability to ameliorate polyethylene-related problems on the other. A surge in this type of nonlinearity has a number of undesirable consequences, including low system effectiveness and a low power factor. Other consumers are in convenienced, and adjacent communication.

1.2POWER QUALITY (PQ)

A power quality (PQ) problem, according to the definition, is any voltage, current, or frequency fluctuation that damages, upsets, fails, or causes end-use equipment to malfunction or stop working. Practically all Power Quality issues are tied to PE in a variety of residential and industrial settings. Televisions, computers, printers, copying machines, and equipment used in various industries such as adjustable speed drives (ASDs), CNC tools, programmable logic controllers (PLCs), rectifier and inverters are all examples of equipment that uses power electronic devices. One of the several indicators described below can be used to identify the PQ issue, depending on the nature of the problem.

a) Overheated elements and equipment
b) Frequent blackouts
c) Communications interference
d) Voltage to ground in unexpected
e) Locations
f) Sensitive-equipmentfrequent dropouts
g) Lamp flicker

The PE is the most important source of harmonics, notch current, inter-harmonics, and neutral current. Electronic ballasts for discharge lights, rectifiers, soft starters and ASDs, SMPS, and HVAC systems that use ASDs as heat exchangers are all generators of harmonics. Harmonics can affect capacitors, motors, cables, transformers, and interrupters, among other equipment (resonance). The majority of converters produce notches, which have a considerable impact on equipment that is operated electronically.

TABLE I
HARMONIC CURRENT LIMITS IN IEEE STANDARD 519-2014 (120 V - 69 KV)

Isc/IL	35 ≤ h ≤ 50	23 ≤ h < 35	17 ≤ h < 23	11 ≤ h < 17	< 11	TDD (%)
> 1000	0.3	0.6	1.5	2.0	4	20.0
100< 1000	0.5	1.0	2.5	3.5	7	15.0
50 < 100	0.7	1.5	4.0	4.5	10	12.0
20 < 50	1.0	2.0	5.0	5.5	12	8.0
< 20	1.4	2.5	6.0	7.0	15	5.0

Devices that use SMPS, such as personal computers, printers, photocopy machines, and any other generation device, generate neutral currents. Neutral currents have a substantial impact on the temperature of the neutral conductor as well as the transformer's capacity.

Based on the facts in Table 1.1, according to our analysis, Similar to the limitations stated in Table 1.2, the IEEE Standard 519-2014 proposes voltage distortion limits that are identical to those mentioned in Table 1.1

Table 1.2: Harmonic Voltage Limits according to IEEE Standard 519-2014

Bus Voltage at PCC	Total Voltage Distortion (%)	Individual Voltage Distortion (%)
> 161 kV	1.0	1.0
69 kV ≤161 kV	1.5	2.5
1 kV ≤69 kV	5.0	3.0
V ≤ 1.0 kV	8.0	5.0

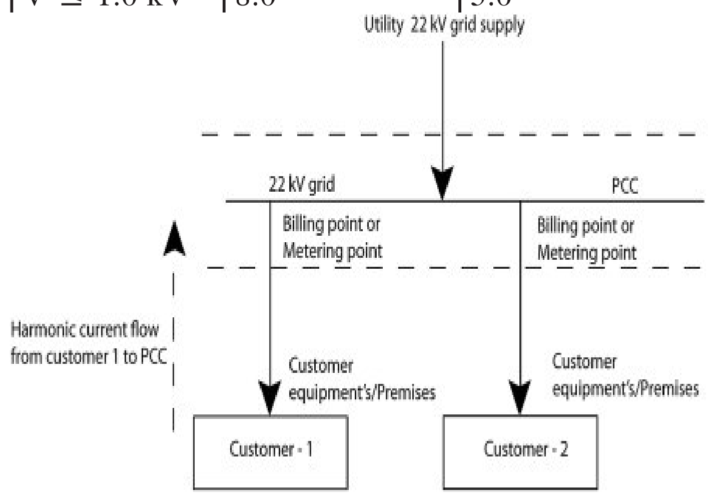

Fig. 1 Characterization of point of common coupling

1.3 HARMONICS AND THEIREFFECTS

Harmonic currents, if present in the utility feeder, cause a slew of problems as a result of their presence. Power factor correction capacitors, on the other hand, may lock them in place, overloading them or creating resonant over-voltages. They may distort the feeder voltage due to eddy current losses, causing problems with power supply, motors, telephone connections, and computers. Because of the voltage They may cause transformer faults due to distortion. Harmonic currents can be captured using series LC filters that resonate at the frequencies where the currents are created. There is, however, one more "gotcha" that must be revealed. A filter with a 7th harmonic series resonance will produce a parallel resonance with the utility when the supply inductance is added to the filter inductance; if a filter with a 7th harmonic series resonance is installed. It's probable that the parallel resonance will be on or around the 5th harmonic, resulting in the previously described resonant above currents. Parallel resonances at frequencies below the trap frequency will always result from the arrangement of series resonant traps. Best practises call for a large number of traps to be placed at the lowest harmonic frequency first, followed by trap placements at higher harmonic frequencies.

1.4 POWER FACTOR

The power factor of a machine is a measurement of how much energy it can produce. Power factor is the ratio of actual power to volt-amperes in an alternating current circuit. It's also known as the voltage-current phase angle's cosine. Sinusoidal voltages and currents have well-defined values that are free of ambiguity. Increase the power factor of the power distribution system by introducing capacitors, which will draw a leading current and supply the system with lagging VArs, respectively. Changing in and out capacitors as needed for power factor adjustment to provide VAr and voltage adjustment control is achievable.

2.SOLVING POWER QUALITY PROBLEMS

One of two approaches can be used to mitigate power quality difficulties. Load conditioning is the first way, and it is designed to make equipment less vulnerable to power disturbances, allowing it to operate even when the power grid has significant voltage distortion. Installing line conditioning equipment, which can either decrease or offset the consequences of power supply variations, is another alternative. For many years, passive filters have been the most extensively used means of regulating harmonic current flow in electrical distribution networks. They are frequently made with a specific purpose in mind. Their output, on the other hand, is limited to a few harmonics, and they have the potential to cause power system resonance.

2.1 RESONANT FILTERS

The resonant passive filter is made up of a series inductor linked to a capacitor whose value is proportionate to the harmonic range to be eliminated. A resonant passive filter has a low impedance for the harmonics in question but a high impedance for the fundamental frequency. As a result, each harmonic range to be eliminated requires its own filter. The equivalent circuit of the resonant filter in combination with the harmonic source and grid impedance is shown in Figure 2.(resonant filter with harmonic source and grid impedance).

3. DESIGN OF THREE PHASECONVERTER

Depending on the application, many converter topologiescan be used to build a shunt APF. Figure 3. depicts two three-phase, three-wire power convertersA voltage source converter (VSC) with pulse width modulation (PWM) and a capacitor as an energy storage device is shown in Figure 3(a). A current source converter (CSC) with a PWM output and an inductor serving as an energy storage element is shown in Figure 3 (b).

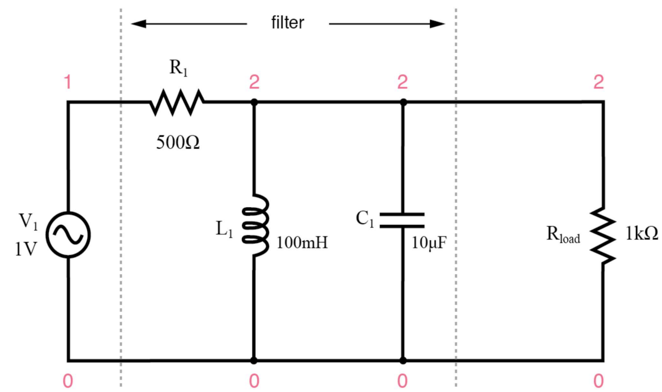

Fig. 2. Resonance Filter

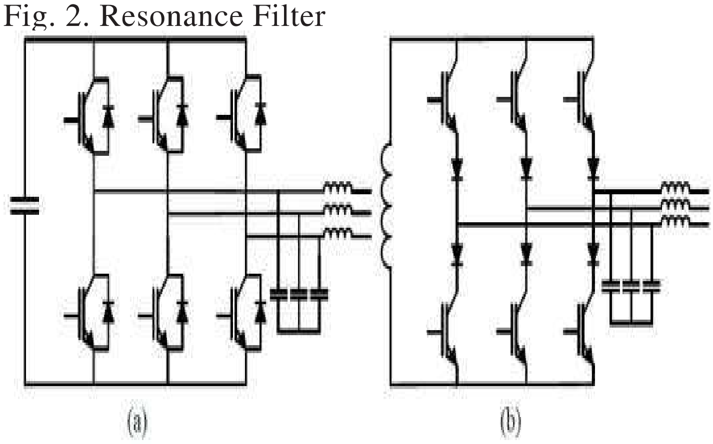

Fig. 3(a) VSC or Voltage source converter (b) CSC or Current source converter.

4.RESULTS AND DISCUSSIONWITHOUT SAPF

Being "connected at the load end" means that a connection is created between the non-load end and the load end. The harmonics generated by the non-linear load distort the load current waveform, and the load current waveform has a large concentration of heavy harmonics contents. This is correct, as illustrated in Fig. 4. A nonlinear load is connected to a nonlinear system, and the load's current is also a nonlinear current. The source current will be

4.1 WITH SAPF

Figures 5. and 6 provide an example of common fix band hysteresis current organises as well as hysteresis band current control methods, respectively. P0, P, and Q are displayed as instantaneous values in the same time interval in Fig. 4. It is critical to keep the switching frequency within defined limitations in order to effectivelyidentify the switching device and its switching losses in a real-world application. Even after taking all of these factors into account, the switching frequency of a hysteresis band current controller remains constant, regardless of the system's characteristics or the current controller's stated frequency range.nonlinear as well because there is no SAPF linked. The compensating current is 0 in the absence of a SAPFconnected to the system. This is correct, as illustrated in Fig. 4.

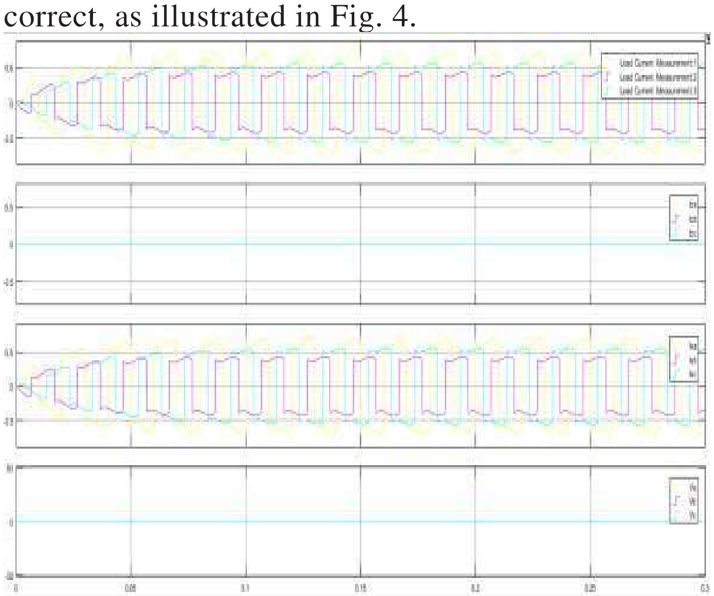

Fig. 4. Waveforms of source current, load current voltage and compensatory current, across the load

4.CONCLUSIONS

The effects of current harmonics on electrical systems, as well as their causes and effects, are investigated in this study. In addition, the investigation of numerous potential treatments for the harmonics problem is carried out.

Parallel active powers filters are an effective solution for the correction of harmonics produced by non-linear loads, according to literature study, and they are strongly recommended for use. The goal of this Paper is to look into a few different methods for controlling SAPF that have been employed in the past. Not only does the power circuit of an active power filter affect its performance, but so does the control technique used to regulate it.

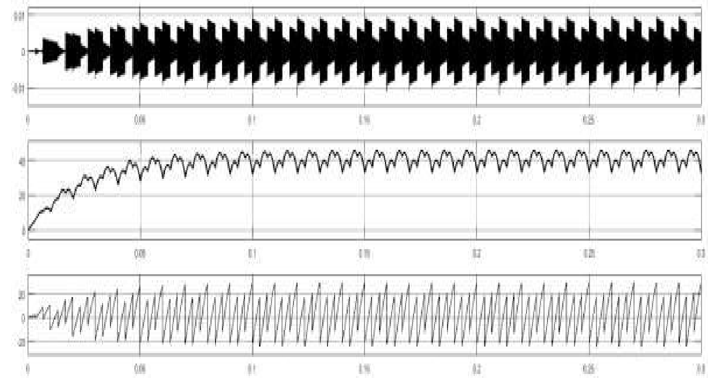

Fig. 5 Waveforms for P, P0 and Q

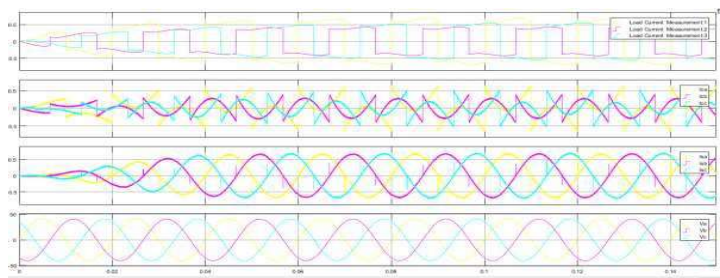

Fig. 6 Waveform for Load, source,compensating currents and load voltage

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