A Review on Three-Phase Parallel Hybrid Active Power Filter to Harmonic Elimination

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Abstract: *This paper includes analysis of passive filter and active power filter connected to a non-linear load connected grid system. The non-linear load induces harmonics into the system which is compensated partly by passive filter and further reduction of harmonics is done using active power filter. A proposed structure of a parallel hybrid power filter is introduced which is appropriate for group elimination of current harmonics as well as reactive power compensation in medium or low voltage power grids. According to the common structures of parallel hybrid filters, the proposed structures include a series resonance circuit with a small inductance in parallel with the active power filter.*

Keywords: *Passive filter; Active power filter; Sine PWM; SVPWM; harmonics; THD.*

1. Introduction

Energy conversion and usage experts are increasingly worried about power quality and service dependability as a result of the nation's booming economy. Some flaws will result in a failure of the electrical power system, and some voltage fluctuations will significantly impact the functioning of the system, especially in light of the growing sensitivity and accuracy of electronic equipment and automated controls. Voltage fluctuations are always brought on by harmonic distortion, surges and spikes, and short disturbances. Overheating of transformers and wiring, unnecessary breaker tripping, and a decrease in power factor are all caused by harmonic distortion, which is defined as voltage or current frequencies superimposed on typical sinusoidal voltage and current waveforms.
Current pulses, such as when an electrical switch is turned on or off, generate harmonics. A spectrum of harmonic frequencies, including the fundamental frequency and its multiples, is produced by these "nonlinear loads" because the current pulse does not fluctuate smoothly with voltage.
Distribution harmonics aren't always an issue, since even the most power-efficient contemporary electronics emit harmonic frequencies. However, the more power used by nonlinear loads, such as those found in modern electronics, the more harmonic distortion is introduced into the system.
The level of industrial activity in a nation may be roughly gauged by looking at the amount and quality of its power production. Harmonic current drawn by nonlinear loads distorts the voltage, resulting in poor power quality. In recent years, power electronic devices have become more commonplace as harmonic sources in a variety of power system applications. Other systems that inject current or voltage harmonic into power systems include arc furnaces, electronic ballasts, welding equipment, and high-voltage direct current (HVDC) systems. Large amounts of harmonic currents may be generated by electrical power equipment at their structures and action locations. Since harmonic currents are a kind of power quality degradation, the power grid would be compromised. Harmonics in power systems were amplified and were slated for restriction. Limits on harmonic indices are suggested by IEEE Standard C19. This specification is for a customer utility PCC and has nothing to do with actual equipment.

Filter Classification

Transients, noise, and voltage sag and swell are some of the problems that affect the electric power system and cause the generation of harmonics, which in turn degrade the power supplied to the end user. Harmonics, which are integral multiples of the fundamental frequency and do not contribute to the active power supply, may occur in voltage or current waveforms. As a result, the effect of the response at these frequencies on the behaviour of the system should be minimised.
This is achieved by installing the filter at the Point of Common Coupling (PCC), which is the point at which the load connects to the source. By eliminating the harmonics, this filter improves the system's efficiency. The many filters designed for this function are widely accessible.

Detailed explanations of each of them may be found below.

Filters in the literature may be broken down into three distinct categories. Hybrid filters combine the best features of active and passive filters. There is a particular subclass for every major category. Filter types and their respective categories are shown in Fig. 1

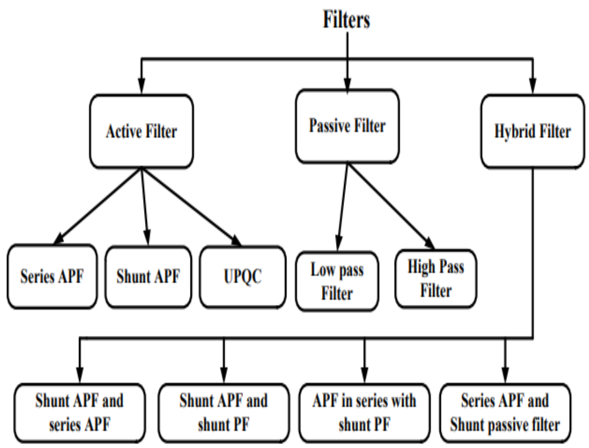

Figure **Error! No text of specified style in document.**. Classification of Filters

2. Literature Review

The suggested system's primary goal is to provide a low-priced universal PV battery charger that may be used for electric car applications. The suggested system includes a slope-compensated current controller for regulating the charging current at the highest power point of the PV module. The suggested system uses a buck converter as an interface converter to regulate charging current flow and determine the PV array's MPP's reference current Iref. The state of charge (SOC) of the battery is employed to create the battery management circuit, and the battery's properties are monitored using an LCD display. E-vehicles may benefit from this suggested system since it is a clever and efficient PV battery charger [1] .

This research presents an inverter-based analysis of the effects of harmonic content in 3-phase induction motor (IM) current generated by "sinusoidal pulse-width modulated (SPWM) and space vector pulse-width modulated (SVPWM) drives." The IM drive's topology and circuit are introduced, followed by its operational basics and the waveform it produces [2].

The load-control process, including the 3-phase IM model fed from the grid, is also covered in detail, as are the characteristics of its operation. This thesis makes use of the MATLAB/Simulink simulation software package to model the operation of a three-phase IM connected to a pulse-width-modulated (PWM) inverter [3].

With each passing day, the issue of poor electricity quality becomes more pressing. The primary elements affecting power quality are harmonic current and reactive power. Harmonic current and reactive powers are used by the induction motors from the mains supply [4].

Power Line Communications (PLC) have a significant challenge from impedance mismatch, which reduces signal power transfer and may disrupt transmissions. Power line modems and power line networks have an inherent impedance mismatch; however, this may be efficiently compensated for by using impedance matching methods tailored to a particular frequency or frequency range [6].

A single-phase inverter operating in the over-modulation domain is analyzed in detail, including a full spectrum analysis of the three levels of output voltage. Based on the analytical findings of a frequency spectrum assessment, the third harmonic component in the output voltage is almost nullified due to the opposite third harmonic component in the modulator unit. This component is formed by triangular "Sinusoidal Pulse-Width Modulation (SPWM) [7]

The Reduction of Transmission-System Harmonics is the subject of this paper. Since harmonic frequencies are a common source of power quality issues, this study focuses on methods for removing harmonic content from the system using a variety of Active and passive Filter configurations, each of which is managed by an Active Damper Controller. The non-linear load is the primary generator of harmonics since it uses discontinuous current and injects harmonics, both of which result in transmission losses [8].

3. Methodology

Fig.2 represents the structure of the recommended parallel hybrid active power filter system,

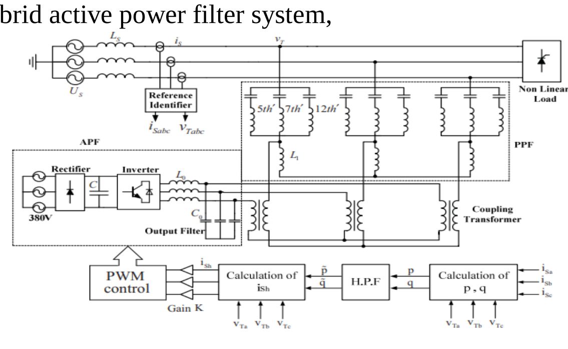

Figure 2. System of the HAPF

Active Power Filter Structure: The inverter is found in the active part of the circuit. Inverter three-phase voltage source. Advantages of a VSI DC bus with a high-quality dc capacitor. This kind of inverter has a low switching frequency, is portable, and can be upgraded to higher levels of performance with relative simplicity.

Passive Power Filter Structure: This innovative topology is built from a sequence of resonant circuits

(PPFs). In order to illustrate the primary benefit of the resonant filter, the discussion starts with the conjunction of three parallel RLC branches through inductor L1. The value of inductor L1 is maintained low and constant. "Resonant circuit has three branches' series with inductor L1 as combination of one of them by L1 resonance at 5th harmonic and other one by L1 resonance at 7th harmonic and the last one branch resonance with L1 at 12th harmonic." The 12th harmonic has a high quality factor (Q), hence the 11th and 13th harmonics are weakened as a result. With a modest and constant value for L1, the 5th, 7th, and 12th harmonics and the fundamental reactive current are diverted away from the active power filter (APF) and onto the inductor L1. Since the inductor L1 has a low fundamental impedance, the HAPF's active component is not responsible for transporting the fundamental voltage and current, which significantly reduces the APF's voltage-current capacity.

PWM Control: Pulse Width Modulation (PWM) is a digital technique that modulates the frequency and/or amplitude of the electrical current flowing through an electronic device. It takes a digital input and turns it into an analogue signal. A pulse-width modulated (PWM) signal is essentially a square wave that alternates between on and off states. The characteristics of a PWM signal are determined by its duty cycle and frequency.

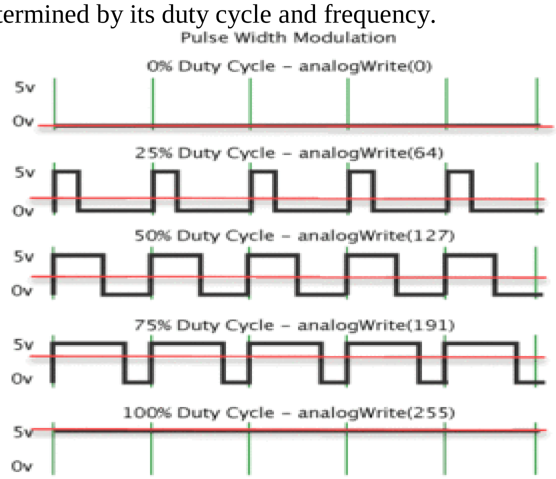

Figure 3. PWM Duty cycle

Controlling the power switches in the right order to minimise switching loss and maximise efficiency is the goal of Space Vector Modulation (SVM).

The output voltage and input current are modulated via a space vector pulse width modulator. The method's benefit lies in the fact that the switching vector used to regulate the input current and the output voltage may be selected arbitrarily. When the scales are tipped in one direction, this strategy may be advantageous. Vectors in space are used to represent the three phase variables. In order to ensure that each PWM cycle has the correct gate drive waveform, this module creates that waveform automatically.

Because of this, the inverter may merge many switching states into a single one (number of switching states depends on levels). For each of these states, the SVPWM calculates a different switching time. This method is compatible with all types of multilevel inverters and may be simply adapted for use with greater voltages (cascaded, capacitor clamped, diode clamped). The required voltage vector Vref may be calculated from the duty cycle time of each of the three input vectors that compose a triangle. [31] The SVPWM vector chart is shown in the figure:

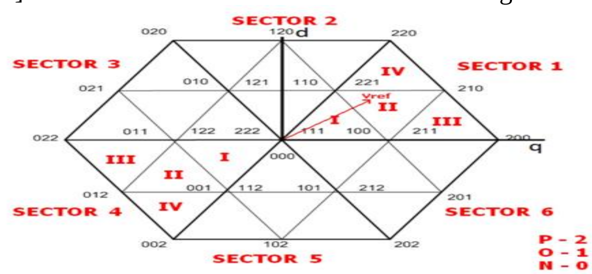

Figure 4. SVPWM Chart

4. Conclusion

A novel circuit topology for the three-phase parallel hybrid active power filter (HAPF) is proposed to suppress harmonic currents and compensate reactive power simultaneously in medium or low voltage power systems, which can greatly reduce the VA rating of the active power filter (APF). The power rating of the active filter is less than the recently introduced HAPF. The HAPF structure can effectively eliminate the harmonic currents of the power system and strongly compensate the reactive power.

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