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DSMPI Controller Based on a Three-Phase Parallel Hybrid Active Power Filter for 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. In other words, the passive filter design is a hybrid structure in which the majority of the main reactive current passes through additional inductance instead of passing through the active power filter, which reduces the current flowing through the switching equipment of the power converter. Also, due to the special design of the passive filter in this proposed structure, the active power filter does not need to withstand the harmonic voltage. Therefore, the result and advantage of these features is that the volt-ampere of the active power filter is significantly reduced. The conventional proportional gain is replaced with DSM-PI controller which further reduces the harmonics to lower value. The modeling is done in MATLAB computer simulation with comparative analysis done with respect to THD.*

Keywords: *Passive filter; Active power filter; Sine PWM; DSMPI; THD; MATLAB.*

1. Introduction

Energy conversion and usage experts are increasingly worried about power quality and service dependability due to the nation's booming economy. Some flaws will fail 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. Harmonic distortion, surges and spikes, and short disturbances always bring on voltage fluctuations. 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

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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 responses 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

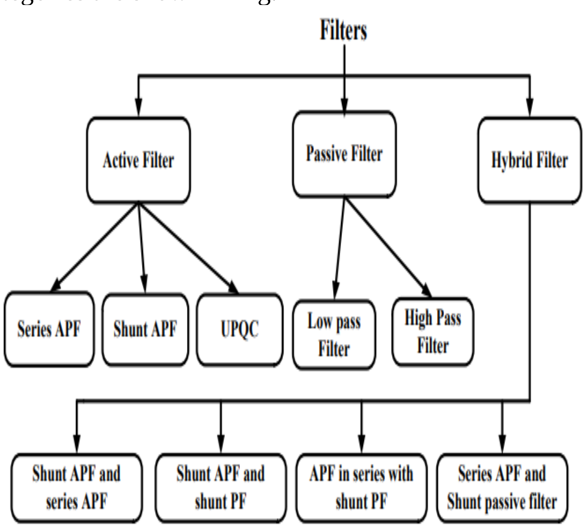

Figure 0. Classification of Filters

2. Methodology

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

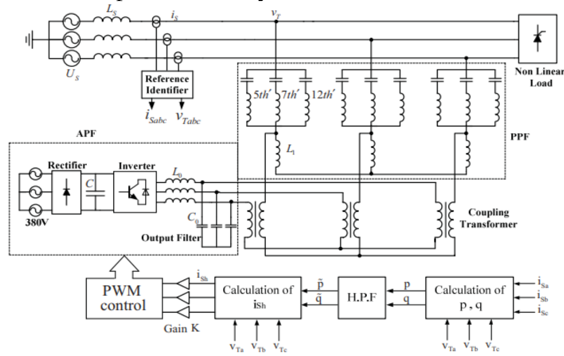

Figure 2 System of the HAPF

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.

DSM-PI Control

A Dual Sliding Mode PI (DSM-PI) controller combines the robustness of sliding mode control with the advantages of PI control, offering improved performance and robustness, particularly in nonlinear systems, by using two distinct control modes or switching between PI and sliding mode control based on error conditions. SMC is a robust control

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technique that forces the system's trajectory to a predefined "sliding surface" in the state space, regardless of disturbances or parameter variations. Integral actions to reduce steady-state errors and improve system performance. DSM-PI controllers employ two distinct control modes or switching between PI and sliding mode control based on error conditions.

Mode 1 (High Error): When the system error is large, the controller operates in a sliding mode to quickly drive the system towards the sliding surface, regardless of disturbances.

Mode 2 (Small Error): Once the system is close to the desired state, the controller switch to PI control to fine-tune the system and achieve accurate tracking and regulation.

DSM-PI controllers are suitable for controlling nonlinear processes, such as continuous stirred-tank reactors (CSTRs) and mixing tanks with variable dead times.

The conventional PI controller has the gains fixed at one particular value. Whereas in DSM-PI controller gain values are frequently changed according to the error generated. DSM-PI controller is used to obtain current signal from speed error input. It continuously monitors the proportional and integral gains respectively and as a result the response time is minimized.

A PI controller has proportional K_p and integral K_i gains fixed at a particular value, that remains constant for both higher value or lower value of error. While in DSM-PI controller the values of gains K_p and K_i are uneven with respect to the error generated. If the error in voltage or current is high, value of gains K_p and K_i are amplified and if it is low the gain values are reduced in order to reduce the settling time.

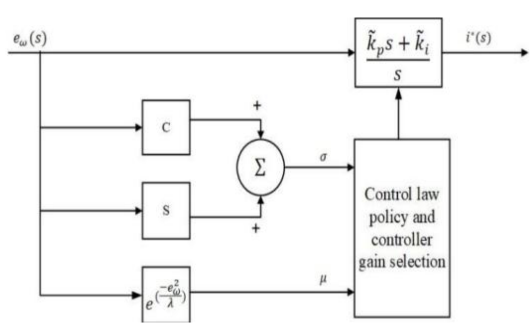

Fig.3 DSM-PI Control Scheme Block Diagram

The main advantage of this DSM-PI Control scheme is that the settling time of the speed-time response is decreased with reduction in disturbances and oscillations and this helps in faster control and stabilization of current of the battery hence improving the response time.

Advantages of DSM-PI Controllers:

Improved Robustness:

DSM-PI controllers inherit the robustness of SMC, making them less sensitive to disturbances and parameter variations.

Enhanced Performance:

The PI control mode allows for accurate tracking and regulation, especially around the set point.

Reduced Chattering:

The switching between modes can help mitigate the c attering problem often associated with traditional SMC, especially in nonlinear systems.

Better Transient Response:

The combination of SMC and PI control can lead to faster settling times and reduced overshoot compared to either controller alone.

3. Simulation Results and Discussion

The proposed parallel HAPF system is extensively simulated using MATLAB/SIMULINK. As for the specific condition that there is low-power factor and excessive harmonics for the 5th, 7th, 11th, and 13th in the 11-kV grid of a smeltery, simulation has been down using the topology structure, which is shown in Fig. 1. Three groups of passive power filter have been tuned in the 250, 350 and 600 Hz range and Simulation conditions are in the following: the line to line voltage is 11kV 50Hz.. The 5th , 7th , 11th , and 13th order harmonic currents modelled as the harmonic current sources. To illustrate filtering characteristics of the combined system As a result, the absence or presence of the active power filter produces distinct differences in filtering characteristics. The modeling of the proposed test system with passive and active power filter is shown below in fig 4

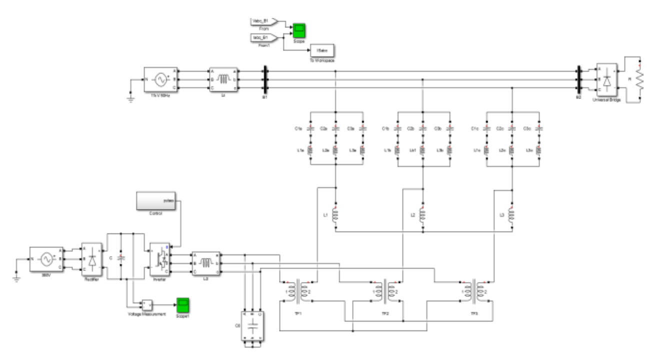

Figure 4 Simulink modeling of proposed test system with passive and active power filters

The controller takes feedback from source voltages and currents for generation of active and reactive power measurement. The P&Q is filtered using HPF (High pass

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filter) and the reference currents are generated using PQ and Vα Vβ. The equation is given below.

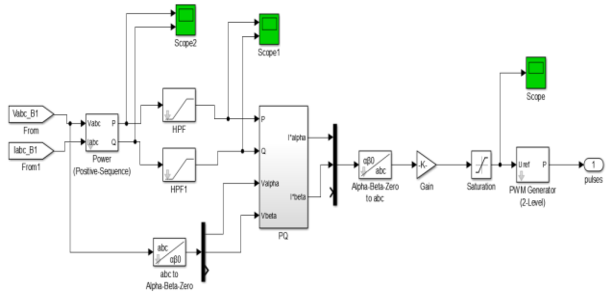


Figure 0 Control structure modeling of active power filter inverter control

The output reference currents are converted to reference Sin signals using a gain. The reference Sin waveforms are compared to high frequency triangular waveform for controlling the three-phase inverter.

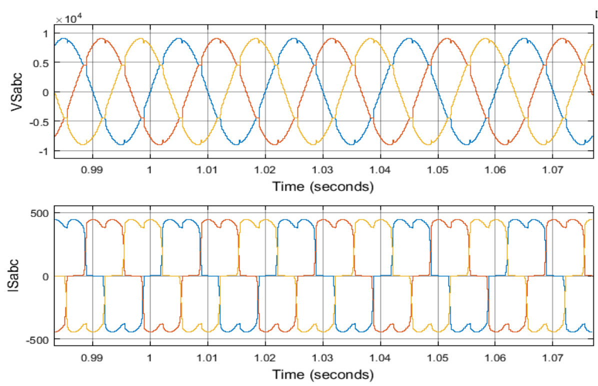
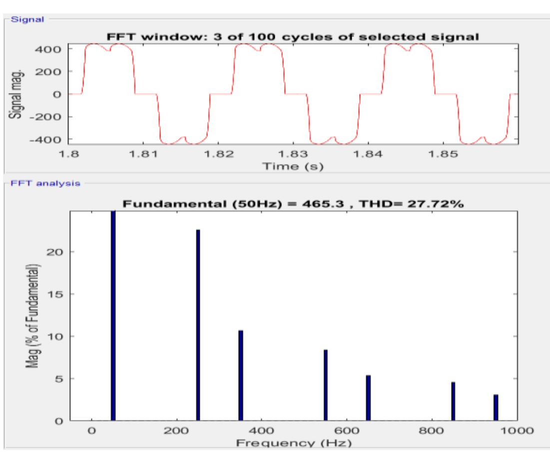


Figure 6 Three phase source voltages and currents before connecting filters



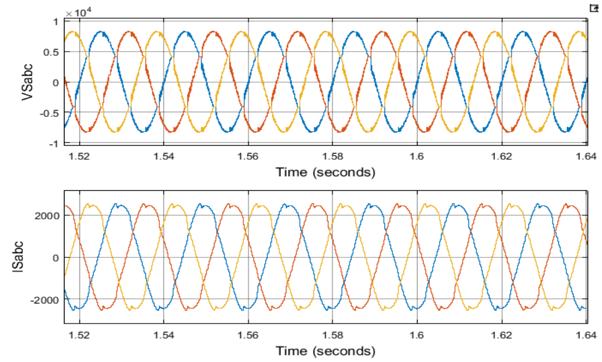


Figure 7 THD of the source current before connecting filters

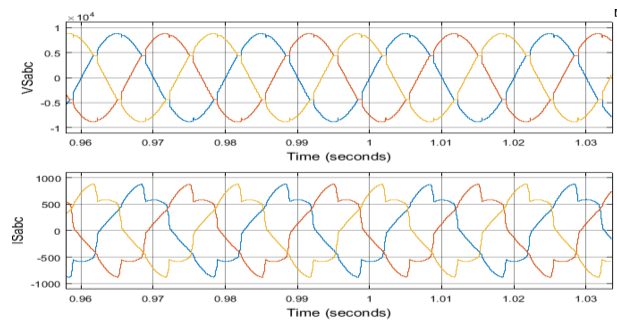


Figure 8 Three phase source voltages and currents after connecting passive filter

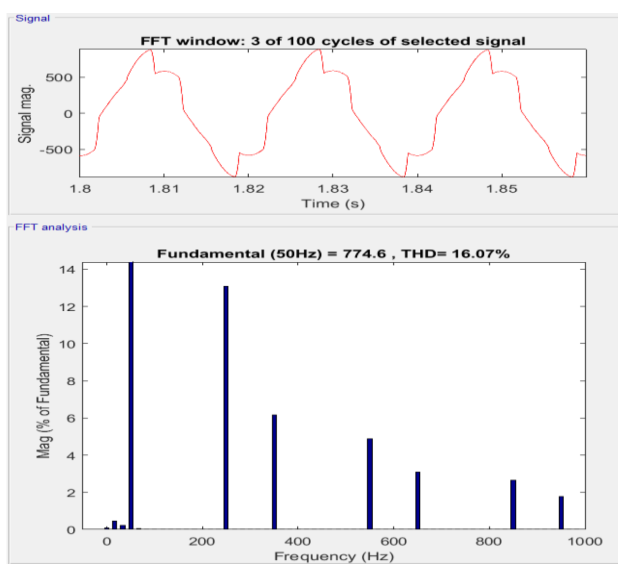


Figure 11 THD of the source current after connecting passive filter

Figure 12 Three phase source voltages and currents after connecting both passive and active filters with P controller

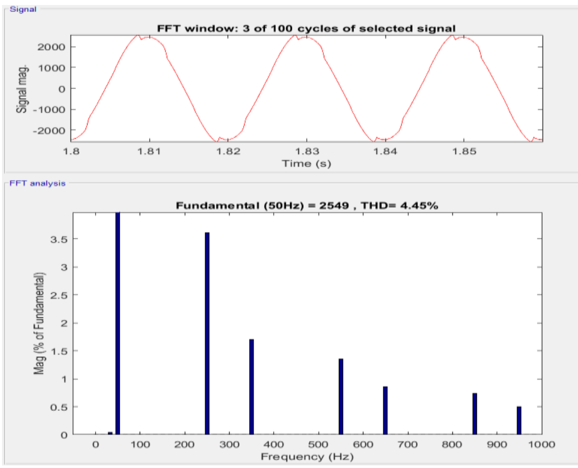


Figure 9 THD of the source current after connecting passive and active filters with P-Gain controller

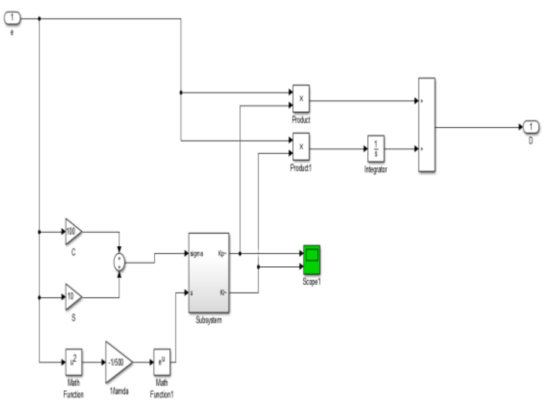


Figure 10 Dual Sliding Mode PI controller

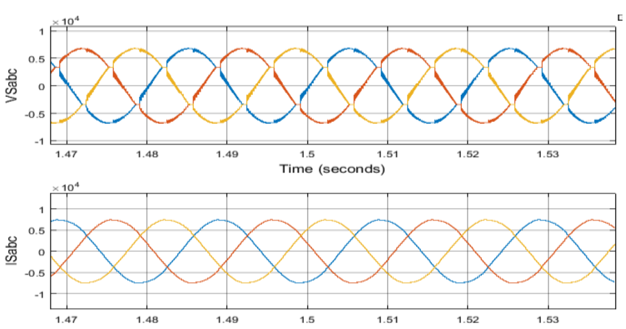


Figure 13 Three phase source voltages and currents after connecting both passive and active filters with DSM-PI controller

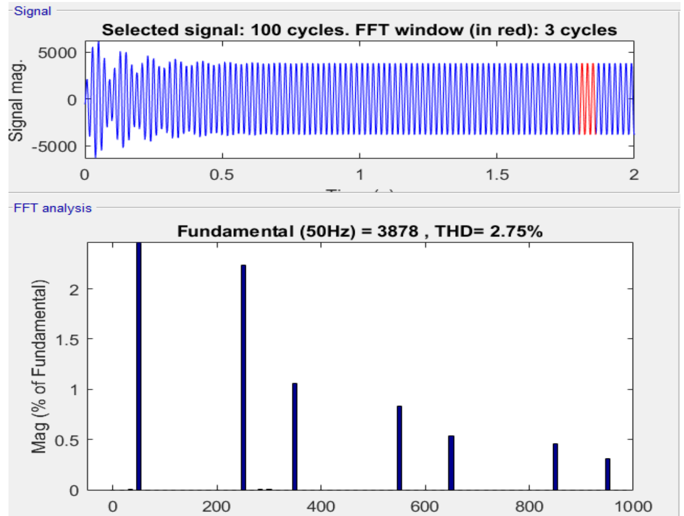


Figure 14 THD of the source current after connecting passive and active filters with DSM-PI controller

All the above THD values are calculated using FFT analysis tool available in MATLAB Simulink module.

4. Conclusion

A successful 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. Simulation results prove the effectiveness operation of the proposed parallel hybrid parallel active filter (HAPF) for harmonic currents suppression, reactive power compensation and simultaneously ability to suppress parallel and series resonance between system impedance and shunt passive filter. The harmonics before connecting the filter is noted to be 27.72% which later dropped to 16.07% with only passive filters. Further reduction of harmonics is done after connecting active power filter noted to be 4.45% which further reduced to 2.75% when proportional gain is replaced with DSM-PI controller.

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