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Design and Simulation of Harmonic Mitigation Technique by Shunt Active Filter

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ABSTRACT: This paper is all about the harmonic mitigation techniques by using a shunt active filter for the reduction of harmonics in a permissible limit. The major source of harmonics are nonlinear loads connected in the power system and several problems occurs like voltage sag swell, flicker and other power quality issues. Therefore to protect the system shunt active power filters are being used in the modelled power system and analyse the results. The performance of shunt active filter depends upon the control strategies and that plays an important role in harmonic reduction of the system. In this work hysteresis control and phase control is taken as the reference procedure for the harmonic reduction techniques. The whole model is being designed and simulated by using Matlab Simulink software to analyse the outputs.

KEYWORDS: SAPF shunt active power filter, Phase control, Harmonics reduction, nonlinear loads, and PCC point of common coupling.

I.INTRODUCTION

Harmonics can be a major issue of concern as it can cause excessive heating and torque reduction in motors and generators, voltage stress may be increased in capacitors as well as heating effect and can cause misleading in operation of electronics based instruments or relaying commands. The conclusion is the harmonics can reduce the life of the equipment's and overall system. So a system should be properly designed considering the harmful effects of harmonics in the system.

Therefore it is mandatory requirement that harmonics should be measured and limit harmonics in a proper limit. IEEE STD 519-1992. IEEE recommended practices and requirement for harmonics control in electric power systems. This theory provides a baseline for limiting harmonics.[1]

Voltage and Current Harmonics Limits

According to IEEE 519, harmonic voltage distortion on power systems 69 KV and below is limited to 5% total harmonic distortion THD with each individual harmonic is limited to 3%. The current harmonic limit depends upon the short circuit strength of the system they are being injected into. Essentially the more the system is able to handle the harmonics currents, the more the customer is allowed to inject.[1]

Table 1- IEEE STD 519-1992 Harmonic voltage limits

Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage distortion (%)	Total Voltage Distortion THD (%)
Below 69 KV	3.0	5.0
69 to 161 KV	1.5	2.5
161 KV and above	1.0	1.5

Note- High Voltage systems can have upto 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for the user



Table 2- IEEE STD 519-1992 Harmonic Current limits

Current Distortion Limits for general Distribution system

Maximum harmonic current distortion in percent of I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{sc}/I_L	<11	11<h<17	17<h<23	23<h<35	35<h	TDD
<20	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Even Harmonics are limited to 25% of the odd harmonics limits above

Current distortions that result in a dc offset, Ex – Half wave converters are not allowed

All power generation equipment is limited to these values of current distortions, regardless of actual I_{sc}/I_L

Where I_{sc} = maximum short circuit current at PCC
 I_L = Maximum demand load current
 TDD= Total Demand Distortion, harmonic current distortion in % of maximum demand load current.
 PCC= Point of Common Coupling

II.SHUNT ACTIVE FILTER AND CONTROL ALGORITHMS

Figure 1 shows the circuit configuration of the shunt active power filter of a voltage source inverter based shunt active power filter configuration. Generally SAPF is connected in the point of common coupling between voltage supply and nonlinear load or harmonic producing loads. The structure of SAPF is mainly consists of two main elements, a standard two level voltage source inverter and its control system. Meanwhile its controller has four main algorithms, harmonic extraction (known as reference current generation), DC link capacitor voltage regulation, current control (switching), and synchronizer algorithm.

1. Harmonic extraction algorithm- This algorithm operates by taking the load distorted current from the power system, followed by isolation of harmonic and fundamental current components and ends with the generation of reference current signal i_{ref} . The generated signal is used to govern the operation of SAPF in reducing the harmonic distortion.
2. DC Link capacitor voltage regulation algorithm- This algorithm take the instantaneous value of DC link capacitor voltage V_{dc} and compares with the desired reference value, the resulting error is used to calculate the suitable magnitude of DC link charging current i_{dc} , the i_{dc} needed to be drawn by SAPF to reduce the switching losses so a to maintain a constant DC link capacitor voltage.
3. Current Control Algorithm- This algorithm takes the output of the harmonic extraction and DC link capacitor voltage regulation algorithm to maintain switching pulses and a current loop that ensures the injection current i_{inj} is generated according to the reference current.
4. Synchronizer algorithm- This algorithm takes the source voltage signal V_s and generates a synchronisation angle or phase so that injection current I_{inj} which is injected by the SAPF into the power systems synchronized with the source voltage.

5. Voltage source inverter- This is a power converter designed to reproduce the reference current I_{ref} as injection current I_{inj} at suitable magnitude and it is equipped with DC link capacitor to compensate real power unbalance that occurs during dynamic operation of the SAPF to reduce the ripples of injection currents.
6. Harmonic producing loads- This is a nonlinear load which injects harmonic currents in the system through the point of common coupling PCC, SMPS, rectifiers, arc furnaces and rectifiers are the few examples of practical loads that generate major amount of harmonic currents and reactive power system.

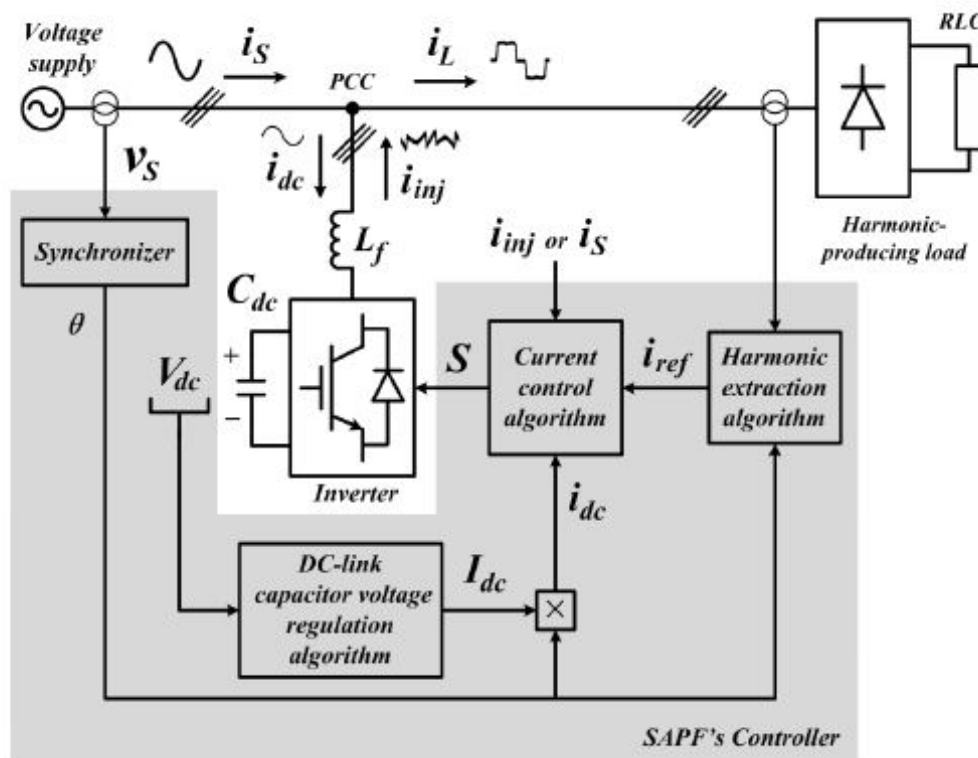


Fig. 1 Typical Shunt Active Power Filter with inverter based control configuration

III. ASSUMPTION AND MODEL DESCRIPTION

Harmonic extraction based on the synchronous reference frame is accomplished by a series of mathematical calculations of three phase load currents which is conducted in dq0 direct quadrature zero reference frame. Park transformation is applied to convert three phase load current from abc frames to dq0 frames. Here dq frames are determined by the reference phase which is delivered by a synchronizer. In dq frames fundamental component will appear as DC signal, and the harmonic component will appear as ripples. A low pass filter will be used for the separation of fundamental component and harmonic component. Finally the desired reference signal is generated by using extracted harmonic components.[11][12]

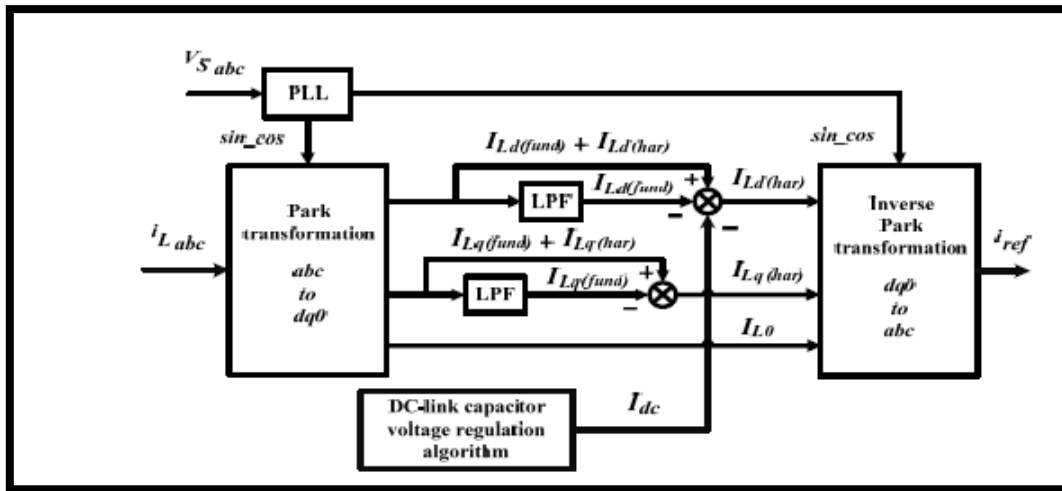


Fig. 2 Typical control structure of synchronous reference frame

IV. RESULT AND DISCUSSION

The complete active power filter system is composed mainly of three-phase source, a nonlinear load, a voltage source Converter, and a dq reference based control theory. All these components are modelled separately to simulate the system. The spectrum of different source current and voltages and load current and voltages are shown below.

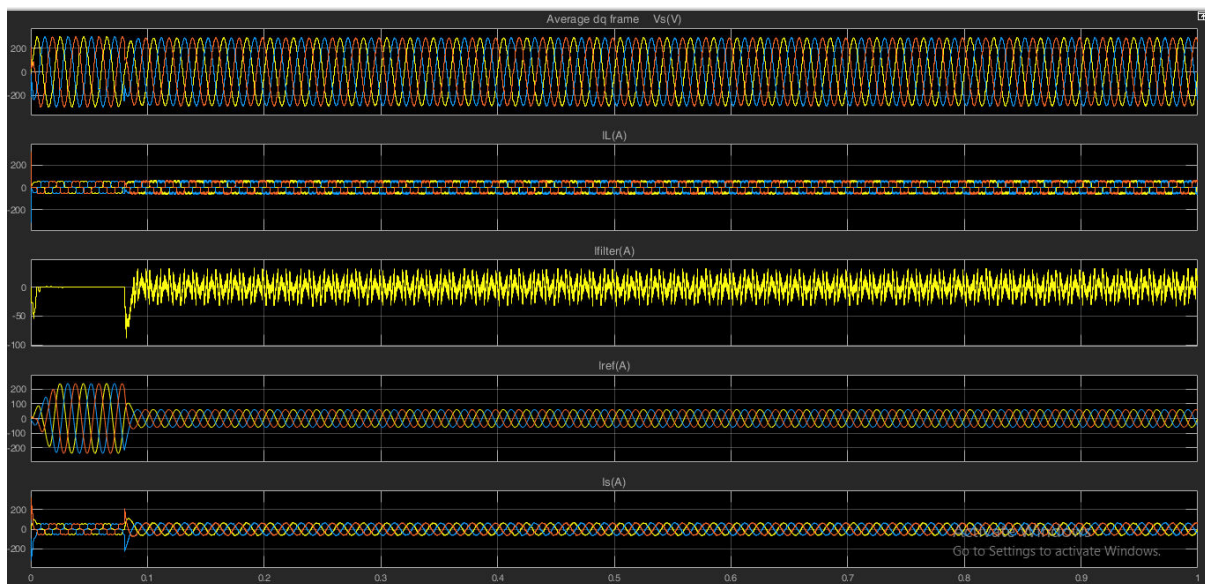


Fig. 3 Three phase source voltages and currents with SAPF

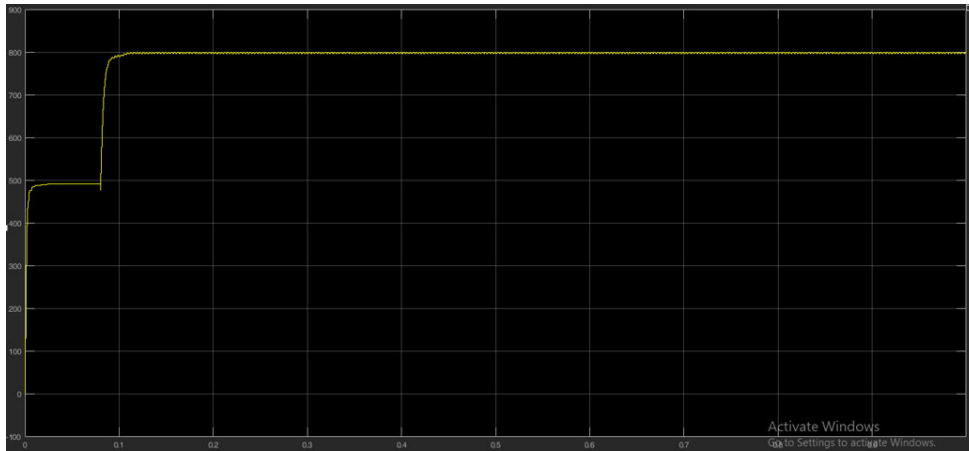


Fig. 4 DC link Capacitance voltage

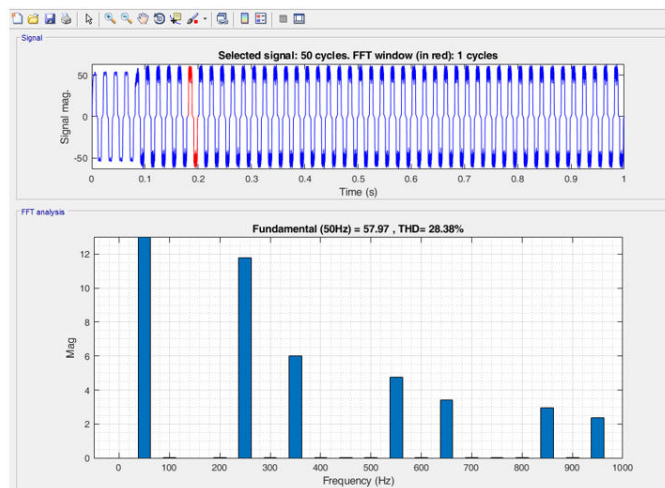


Fig. 5 THD of load current without filter 28%

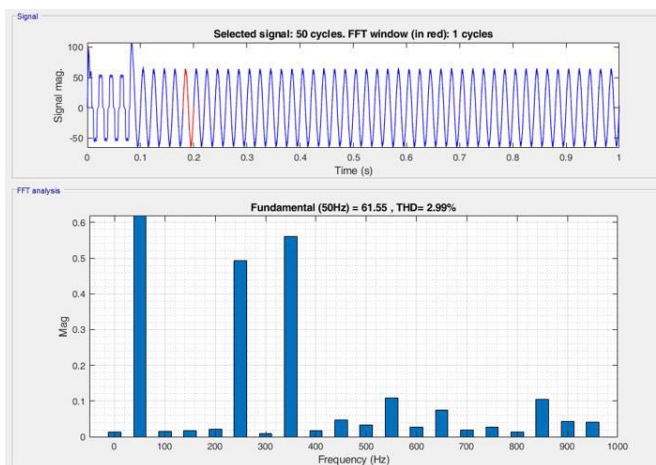


Fig. 6 THD of Load current after SAPF 3%

V.CONCLUSION

Shunt Active Power filter is the most effective solution for the current harmonics problem. This work is all about simulation of a model designed in Matlab Simulink software based on the dq reference theory based active power filter for the mitigation technique of harmonic reduction and power quality improvement. It is found that the shunt active power filter improves the quality of power by reduction of harmonics in load current which makes the output waveform sinusoidal. FFT analysis also been done for the analysis of harmonics in load current and after the implementation of filter we can see that the results are much better with a better smooth waveform.

VI.FUTURE WORKS

In the next phase we can work for some other control techniques as mentioned above and accordingly improve the output and comparison can be done. Some real time data can be find out and try to implement filters for the harmonics reduction. A real time analysis for power quality improvement is a scope of future analysis.

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