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ELIMINATION OF POWER SYSTEM HARMONICS USING SHUNT ACTIVE POWER FILTER WITH HYSTERESIS CURRENT CONTROL TECHNIQUE

D. Maruthu Pandian and D. Godwin Immanuel
Department of Electrical and Electronics Engineering, Sathyabama University, Chennai, India
E-Mail: maruthu.spark@gmail.com

ABSTRACT

This paper proposes a SAPF with hysteresis current control technique. Active power filter consist of VSI, gate pulse to VSI is given by pulse generation circuit. This pulse is generated by the hysteresis controller which consists of PI controller, pulse generation circuit and control technique circuit. VSI and Vref will drive the PI controller which in turn gives to control technique circuits and then to pulse generation circuit. The load voltage is not constant in the line when extra load is connected, which create unbalance in the system. By means of online tuning the above said drawbacks can be eliminated.

Keywords: active power filter, PI controller, reference current generator, pulse generation circuit.

1. INTRODUCTION

Nowadays Power Quality (PQ) related issues are of most concern. Major use of electronic equipment like information technology equipment, power electronics like adjustable speed drives (ASD), programmable logic controllers (PLC), energy-efficient lighting, led to a complete change of electric loads behaviour. Simultaneously these loads are the major causes and victims for the power quality problems. Due to non-linearity, majority of these loads cause disturbances in the voltage waveform. Along with technological advance, the organization of the worldwide economy has evolved towards globalization and the profit margins of many activities were reduced. The increased sensitivity of vast majority of processes (industrial, services and even residential) to PQ problems turns the availability of electric power with quality a crucial factor for competitiveness in many sector. The critical areas are the continuous process industry and the information technology services. During a disturbance in power quality, huge financial losses will arises, which leads to consequent loss of productivity and competitiveness. Although many efforts have been taken by the power utilities, few consumers require a level of PQ higher than the level provided by modern electric networks. To operate the system at good power quality many measures are taken.

Even the most advanced transmission and distribution systems are not able to provide electrical energy with the desired level of reliability for the proper functioning of the loads in modern society. Modern T and D (Transmission and distribution) systems are projected for 99.9 to 99.99% availability. This value is highly dependent on the redundancy level of the network, based on the geographical location which is different and also the voltage level (availability is higher in HV network). In few remote locations, availability of T and D systems may be as low as 99 percentages. Even with a 99.99 percentages level, there is an equivalent interruption time of 52 mins/year. Modern digital economy needs electrical energy with 99.99 percentages availability to function properly; this is the most demanding process. EPRI carried out a study in the US (during 1992 to 1997) to characterize the average duration of the disturbances. The study results during the 6-year period are presented below.

The vast majority of the disturbances registered (about 87%) lasted < 1s and only 12 have duration greater than 1 mins. Not all these disturbances cause equipment malfunctioning which is clear from the study, many types of sensitive equipment may get affected. The availability of electric power with high quality is crucial for the running of the modern society. If some sectors are satisfied with the quality of the power provided by utilities, some others are more demanding. To avoid the huge losses related to PQ problems, the most demanding consumers must take action to prevent the problems. Among the various measures, selection of less sensitive equipment can play an important role. When even the most robust equipment is affected, then other measures must be taken, such as installation of restoring technologies, distributed generation or an interface device to prevent PQ problems.

2. SHUNT ACTIVE FILTER

An active power filter is connected in shunt mode between the source and load. Current harmonics are reduced to a major extent by means of Shunt active filter. Whenever an excess load is introduced in the consumer side it will create the power quality problems to the other who are all connected in the line. To mitigate the above said issue it is highly recommended to uses Active power filter in the line.

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The shunt active power filter is nothing but the inverter circuit with dc link capacitor is connected at the output terminal. The 3 phase voltage source inverter is normally used which consists of totally 6 switches legs, each leg having 2 switches. The gate pulses required for this VSI is obtained by the pulse generation technique. The voltage across the dc link capacitor is to be maintained as constant in order to achieve better compensation.

The filter performance is limited due to the fixed value of hysteresis bandwidth. At sudden increasing load period the system fails to provide compensation, the value of hysteresis bandwidth exceeds its limit. To overcome this bandwidth variation we need to change its value by manually. But this is not possible in real time. The main drawback of this method is that it produces variable switching frequency so that the stability gets affected.

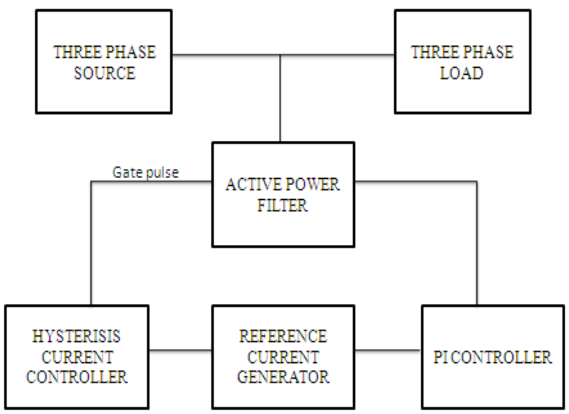

Figure-1. Block diagram of Shunt APF.

Shunt APF provides better compensation for current related problems. As per IEEE standard the value of %THD should be maintained within the limits, the conventional method gives %THD of 4.69 for diode rectifier load. But the value of hysteresis bandwidth is fixed, so that it is not able to provide better compensation during the sudden load increasing period.

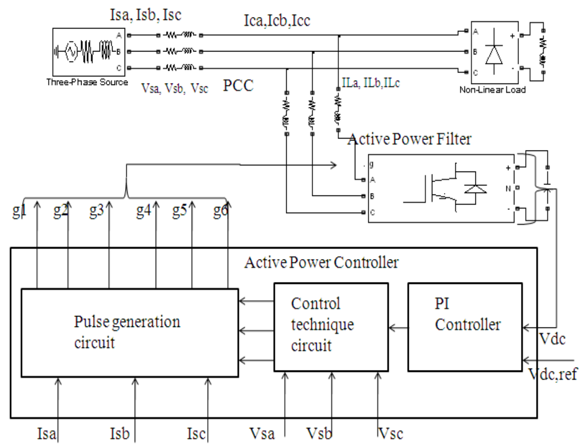

Figure-2. General block diagram of Shunt APF.

The shunt active power filter is nothing but the inverter circuit with dc link capacitor is connected at the output terminal. The 3phase voltage source inverter is normally used which consists of 3 legs. Each leg is having 2 switches of totally 6 controllable switches. The gate pulses required for this VSI is obtained by the pulse generation technique. The voltage across the dc link capacitor is to be maintained as constant in order to achieve better compensation.

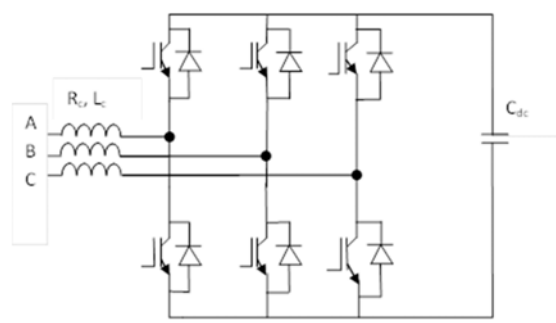

Figure-3. General voltage source inverter.

For a closed loop operation of VSI, PI controller is used. The actual voltage of dc link capacitor is compared with the reference voltage which is given to PI control block. The output of the PI controller is an error signal. This error signal is applied to the reference current generator circuit to produce the reference source current.

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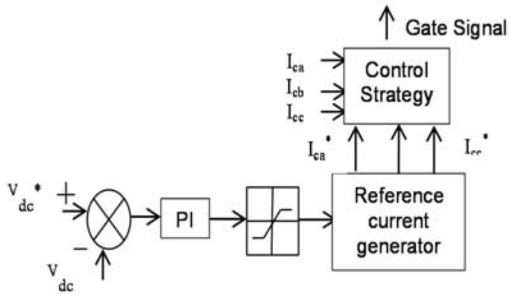

Figure-4. PI controller.

3. HYSTERESIS CURRENT CONTROLLER

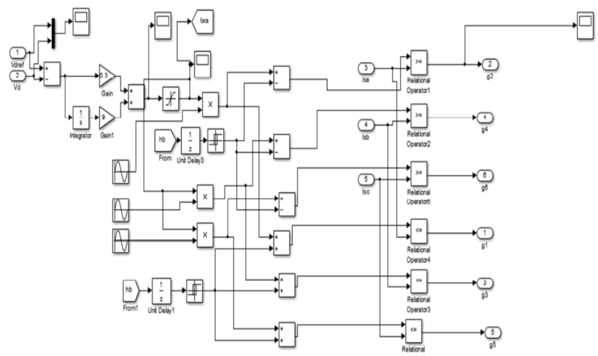

Figure-5. Hysteresis current control technique.

The actual source current is compared with the reference source current which is an error signal. The obtained error signal is given to the hysteresis block; it produces the gate pulses for VSI. The current controller decides the switching patterns of the devices in the APF. The switching logic is formulated as If isa < (isa* - hb) upper switch is OFF and lower switch is ON in leg "a" of the APF; If isa > (isa* - hb) upper switch is ON and lower switch is OFF in leg "a" of the APF.

4. UNIT VECTOR TEMPLATE GENERATION TECHNIQUE

The error signal obtained from the PI controller is multiplied with the unit sine wave vectors. The three phase unit sine vectors are 120 degree phase shift with each other. Then the multiplied signal is the reference source current and is given to current controller circuit to generate required gate pulses.

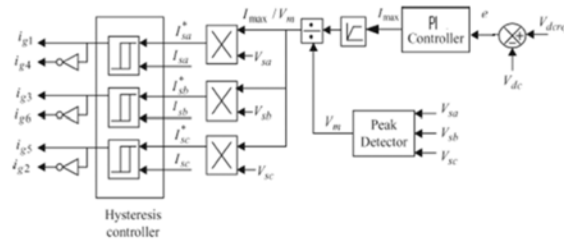

Figure-6. Unit vector template generation technique.

5. EXPERIMENTAL RESULTS

In the proposed model online tuning is implemented by which hysteresis bandwidth varies automatically based on the harmonics generation. Figures 7 and 8 shows the dc link capacitor voltage with and without online tuning. Transients arise in the system when additional load is added in the line. Due to which all the loads connected in the system gets affected, and reliability of the equipments are reduced due to the above said reason. To nullify the problem it is recommended to use the online tuning.

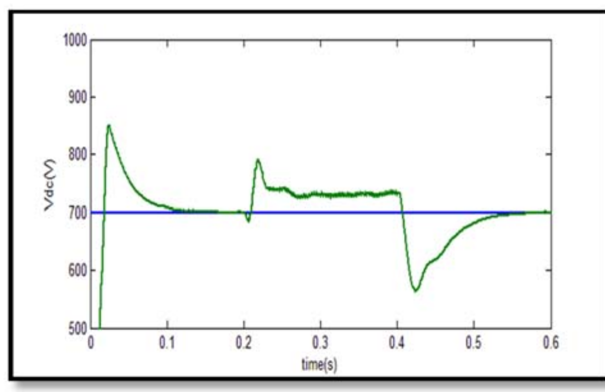

Figure-7. DC Link capacitor voltage without online tuning.

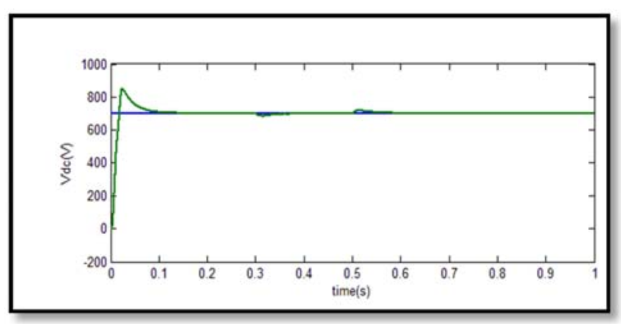

Figure-8. DC link capacitor voltage with online tuning.

Figures 9 and 10 represents % THD with and without online tuning.

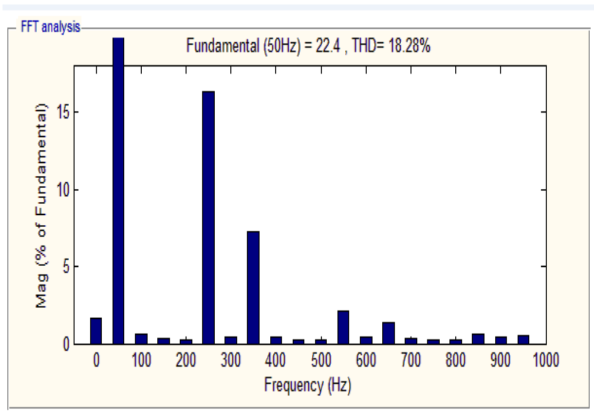

Figure-9. % THD without online tuning.

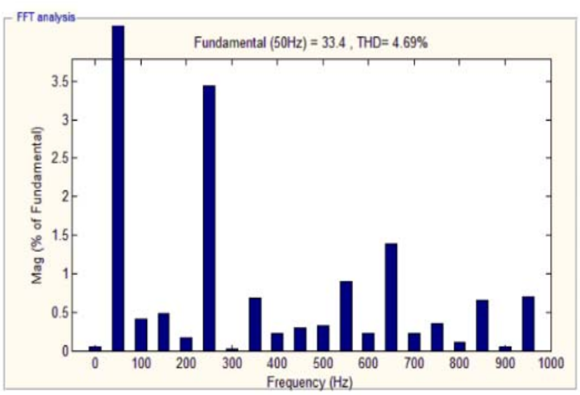

Figure-10. % THD with online tuning.

6. COMPARISION TABLE

Table-1. Numerical results for example.

Parameters	Existing	Proposed
% THD	18.28	4.69

7. CONCLUSIONS

In the proposed current control technique harmonic percentage level is reduced. In conventional method THD percentage is 4.69. In conventional method hysteresis bandwidth is fixed, so poor compensation in case of sudden increasing in load during a particular period? With online tuning %THD value is very low. Hence the entire load connected to the system get low stress and harmonic is reduced to a greater extent.

In this paper simulation is included with and without online tuning for R load.

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