Harmonic Mitigation and Reactive Power Compensation using Shunt Active Power Filter

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ABSTRACT

Traditionally when one imagine about power quality, images of classical waveforms comprising 3rd, 5th, 7th etc. harmonics come into picture. Reactive-power compensation, Harmonic compensation, harmonic isolation, harmonic damping, and harmonic termination, Negative sequence current/voltage compensation, Voltage regulation. The terminology active filters are often seen in different fields apart from power processing.

In this work both PI controller based and Hysteresis Band controller, three phases SAPF is used to compensate harmonics and the reactive power by a non linear load to better the quality and is implemented on three phase wire system. The simulation of the results done through MATLAB program, and number of simulation results of the method are observed under steady conditions.

Keywords— Shunt Active Power Filter (SAPFs), Hysteresis band current controller, DC link voltage controller, PI controller.

I. INTRODUCTION

A power quality problem is defined as any power problem that has relation with voltage, current and frequency deviation that results in failure of the system, damage to any equipment installed or mal operation. Almost all the power units operates with the loads that are inductive in nature, for example arc furnaces, welding machine, elevators, power transformers, pumps, etc. Mostly, every severe power quality issues are encountered because of these inductive loads. The most feared power quality setbacks that are experienced in contemporary times are Harmonics and Reduced Power Factor (Reactive Power). Now we address to the other important power quality issue i.e. Harmonics. With the increased usage of Semiconductor switching devices on a large scale in distribution networks, especially in household and commercial loads the Harmonics challenges have increased manifolds. These switching devices provide the ease to regulate and manage the electrical energy. These devices are both dependable and cost-effective. But these power electronic devices offer non linear characteristics while operating, which results in disturbance in the voltage and current waveforms at the point where the device is installed. Gradually, these devices have emerged as the prime source of power quality degradation, the main pollution sources of the current power systems. These non linear loads draw non-sinusoidal (distorted) current from the utility which contains harmonics. Harmonics are those frequency components that are integral multiple of the fundamental frequency (50Hz).

II. METHODOLOGY

Active Filters can be categorized on the basis of type of the converter namely, CSI(current source inverter) or VSI(voltage source inverter) bridge, and on the basis of topology which can be either shunt, series, or hybrid filters which is the combination of both shunt and series and third category of active filters is based on the number of phases such as single phase (two wired) and three phase (three or four wired) systems.

1. Active Filters based on their topologies:

On the basis of topologies active filters can be categorized as shunt filters, series filters and UPQC (unified power quality conditioners) which is the union of both shunt and series filters. Another type of filters that are based on topologies are Hybrid Filters which are actually the blend of passive shunt and active series filters. The active shunt filter which is commonly used for the removal of harmonics in current and compensating the reactive power and stabilizing unbalanced current.

2. Shunt active power filter

Shunt active power is used for reactive power compensation same as the topology of statcom (static
compensator. Shunt active power filter injects equal and opposite currents in the system for the compensation of harmonics present in the system. Here the shunt active power filter works as a current source. It injects the currents opposite in phase (phase shifted by 180 degrees) to the load generated harmonics.

III. CONTROL STRATEGIES

1. The adaptive hysteresis band current controller

The hysteresis band current control technique has proven to be most suitable for all the applications of current controlled voltage source inverters in active power filters. The hysteresis band current control is characterized by unconditioned stability, very fast response, and good accuracy. On the other hand, the basic hysteresis technique exhibits also several undesirable features; such as uneven switching frequency that causes acoustic noise and difficulty in designing input filters.

The conventional hysteresis band current control scheme used for the control of active power filter line current is shown in figure. The reference line current of the active power filter is referred to as $I_{ca}^*$ and actual line current of the active power filter is referred to as $I_{ca}$.

The hysteresis band current controller decides the switching pattern of active power filter. The switching logic is formulated as follows:

If $i_{ca} < (I_{ca}^* - HB)$ upper switch is OFF and lower switch is ON for leg “a” (SA=1).

If $i_{ca} > (I_{ca}^* + HB)$ upper switch is ON and lower switch is OFF for leg “a” (SA = 0).

The switching functions SB and SC for phases B and C are determined similarly, using corresponding reference and measured currents and hysteresis bandwidth (HB).

The switching frequency of the hysteresis band current control method described above depends on how fast the current changes from the upper limit of the hysteresis band to the lower limit of the hysteresis band, or vice versa. The rate of change of the actual active power filter line currents vary the switching frequency, therefore the switching frequency does not remain constant throughout the switching operation, but varies along with the current waveform. Furthermore, the line inductance value of the active power filter and the dc link capacitor voltage are the main parameters determining the rate of change of active power filter line currents. The switching frequency of the active power filter system also depends on the capacitor voltage and the line inductances of the active power filter configuration.

The band width of the hysteresis current controller determines the allowable current shaping error. By changing the bandwidth the user can control the average switching frequency of the active power filter and evaluate the performance for different values of hysteresis bandwidth. In principle, increasing the inverter operating frequency helps to get a better compensating current waveform. However, there are device limitations and increasing the switching frequency causes

2. Proportional Integral Controller

The PI controller algorithm involve two part parameters; the Proportional and the Integral. The Proportional value determine the reaction to the current error; the Integral determine the reaction based on the sum of recent errors. A comparison of the average and the reference values of the DC bus voltage for the shunt AF results in a voltage error, which is fed to a proportional integral (PI) controller and the output of the PI controller is multiplied by the mains voltage waveform $V_{sa}$, $V_{sb}$, $V_{sc}$ in order to obtain the supply reference currents $isa^*$, $isb^*$, $isc^*$. A PI controller used to control the DC-bus voltage is shown in Figure 6 whose transfer function can be represent as

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\text{Fig. Current and voltage waves with hysteresis band current control (for APF).}
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Where, $k_p$ is the proportional constant that determines the dynamic response of the DC-bus voltage control and $k_i$ is the integration constant that determines its settling time.

Figure: PI controller for DC-bus voltage control

It can be noted that if $k_p$ and $k_i$ are large, the DC-bus voltage regulation is dominant, and the steady state DC-bus voltage error is low. On the other hand, if $k_p$ and $k_i$ are small, the real power unbalance gives little effect to the transient performance. Therefore, the proper selection of $k_p$ and $k_i$ is essentially important to satisfy above mentioned two control performances. The computed three-phase supply reference currents are compared with the sensed supply currents and are given to a hysteresis current controller to generate the switching signals to the switches of the shunt AF which makes the supply currents.

IV. SIMULATION RESULT

A MATLAB model is developed for PI controller based shunt active power filter. The model constitutes the complete system having shunt active power filter with a three phase source and a combination load (linear and non-linear), with a PI controller and a hysteresis band controller. All of the systems are modeled separately and then added together to simulate the system. The figures shows the simulation results representing the functionality of our proposed filter which is shunt active power filter program.

Figure 1 and 2 shows the waveform for load active and reactive power separately. It is clear in the figure that the active power demand of load is 2kW and is not increased with the increase in load as after 0.4 seconds we have increased only the reactive power demand by increasing the reactive inductance in the load. On the other hand, Load reactive power demand is increased from 2 kVAR to 5kVAR after 0.4 seconds. We have increased the reactive power demand keeping the active power demand same to clearly show that the increase in reactive power after 0.4 seconds is taken care of by the shunt active power filter.

Figure 1 The active power demand of load. Which is 2kW

Figure 2 The reactive power demand of load and is increased from 2kVAR to 5kVAR.

Figure 3 and 4 shows the reactive power supplied by the source in the absence of filter and presence of filter respectively. In the absence of filter the source have to supply the increase in power demand by the load which is only the reactive power demand increase. It is clearly seen that there is an increase in the reactive power supplied by source in accordance with the increase in the reactive power demand. And when the filter is operated or say is connected to the system the increase in reactive power demand is now supplied by compensator and so the reactive power supplied by the source is not increased. That is now the increase in reactive power demand of the load is provided by the compensator and not the source.

Figure 3 The increase in reactive power supplied by the source.
It is very clear in the figure that source does not have to supply the reactive power demand of load.

Figure 4. Reactive power supplied by the source in the presence of shunt active power filter.

Figure 5. Compensating reactive power supplied by the shunt active power filter.

Figure 6 shows Harmonics produced in source current when filter was not connected to the system. In this case the THD of the system is 23.78%.

Figure 7 shows THD in source current after performing the FFT analysis , when the filter is connected to the system. In this case the harmonics in the system gets reduced and it is clear in the figure that the THD is reduced from 23.78% to 3.48% , which is less that 5% as per IEEE-519 standards.

V. CONCLUSION

Harmonics and Reactive power are severe problems amongst all the issues in power quality in todays world. This requirement of non-linear loads is a very serious issue. Active power Filter provides the proper solution to this problem. In our work a three phase shunt active power filter is modelled and simulated , and has proven to be effective for the compensation of reactive power and elimination of harmonics present in the system. Complete design parameters and control of shunt active power is presented in this work. Simulation has been done and simulation results show that how effective is the design and control presented in this work for harmonic power mitigation. The compensation process is easy to implement , instantaneous and simple , this can be concluded by simulation results. This method is simple because it only requires the sensing of line current , and the control method is also too simple , yet effective. The shunt active power filter modeled in this work is able to reduce the harmonics present in the system to be less than 5% as recommended by the IEEE-519 standard.

REFERENCES


[4] Panda, Anup Kumar, and Suresh Mikkili, “Types-1 and 2 fuzzy logic controllers-based shunt active filter Id – Iq control strategy with different fuzzy membership functions f or power quality improvement using RTDS hardware” IET Power Electronics, 2013.


[12] Heinz K. Tyll, SM, IEEE, and Dr. Frank Schettler “Historical overview on dynamic reactive power compensation solutions from the begin of AC power transmission towards present applications” Reference No : 978-1-4244-3811-2/09/$25.00 ©2009 IEEE.


