Power Quality improvement with Shunt Active Power filter using p-q control technique

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Abstract - Improvement of Power quality is major concern in the field of power supply. Various methods have been adapted towards the improvement of power quality. Trend of improving it by using active power filter has been increased in recent years because of its simplicity. In this paper we have used the p-q reference theory as controller to control the output of active power filter to delete the harmonics and to compensate the power factor, PI controller is used to maintain almost constant value under transient and steady state condition. The harmonics occurred due to non linear load which draw current in abrupt manner rather than smooth way leads to create distorted signal on source side on the line which affect the other customers on the same line. By using the vdc as the reference current has been calculated and this reference current is compared with the actual current of active power filter, output from the pq theory is compared with actual current and applied to the gate signal of 3-arm universal bridge used in active filter to delete the harmonics. Hence by using the active power filter IEEE 519 standard which say "IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems" has been meet. The proposed model has been simulated using MATLAB/SIMULINK and simulation results.

Key Words: (SAPF)-shunt active power filter, p-q instantaneous theory, voltage source converter (vsc) , matlab/simulink, non-linear load, harmonic elimination

1. INTRODUCTION

Decade ago most of the device used are linear and passive in nature have less number of non linear load leads to less impact on the quality of supplied power but In last few years the trend has been changed the electronics equipment has been taken Place a very important role in our day to day life whether it is our household mobile adapter, computer, inverter, refrigerator or commercial fax machine, Xerox machine, printer, PLC's, power electronic convertor device or other various non –linear devices, With addition to that various power electronic devices like convertors are used (in adjustable speed drives, switch mode power supplies, etc.) to increase the efficiencies and power factor of wind, solar, and other non-conventional sources to improve the efficiency and ability of system.[1][2] but excessive use of power electronics devices are the origin of harmonics disturbances. Harmonics are actually sinusoidal waveform of periodic waveform with the frequency that is integral multiple of fundamental frequency. When the current with the harmonics flow through transmission line, it increase the resistances of the conductors due to skin effect and cause an abnormal neutral-ground voltage difference. More the non linear load connected to the line higher is the harmonics present in the line which leads to the overheating of transformer, distortion of feeder voltage, excessive neutral current, and it may also leads to damage the circuit breakers, fuses and may leads to wrong measurement low power factor and poor quality of power supply to the customers using that line. Due to the following reason it is must to obligate. Earlier the technique used to compensate the harmonics present in the load current are L-C passive filters but as the problem of undesirable resonance produced in the passive filter and LC passive filter could only absorb harmonic waves of a specific frequency because of these fallbacks it is replaced by active filters . Active filters has the less weights and size ,no loading problem and cheaper due to absence of heavy and costly inductors and handling harmonics varies between the specific frequencies. and produce a non-linear voltage drop (Δv) in the line impedance, which distorts the load voltage (vL). and affect the system as discussed above[2]

Figure shown below represent the power system with non-linear load which leads to produce the current with harmonics and the change in the value of current By using the filters we can remove the harmonics, passive filter are generally not used because they will only filter out the frequency for which they are tuned and also resonance can occurred because of interaction take place between passive filter and load connected to line. Therefore the use of active filter is done to compensate the harmonics value unlike over the large frequency range and without any resonance problem.

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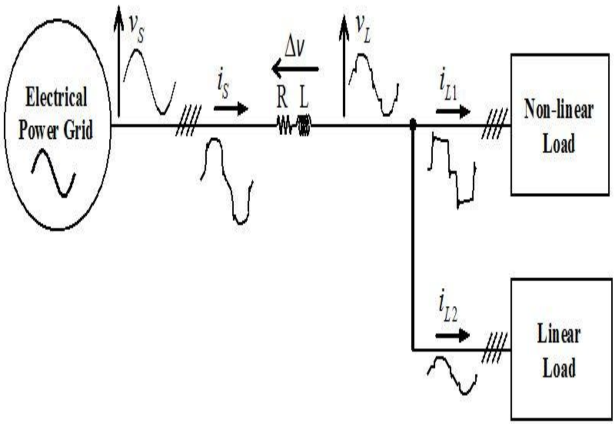

Fig1: power system with non-linear load

1.1 Active Filter

Active filter are the equipment which are used to improve both current harmonics and/or voltage harmonicas and compensate power factor, various researchers application shows that series active filter are used for compensate the voltage harmonics and shunt active power filter are used to improve the current harmonics. Figure shown below represent active shunt power filter it uses the voltage source inverter with capacitor at its dc side act as energy storages device. Filter is controlled in a way that it acts as the current source. Three phase Converters used are having six IGBT switches which are given pulses to store the energy in the capacitor and charge and discharge it when required. The supply voltage source gets the required active power and capacitor of shunt active power filter provides the reactive power for the load. The load is a 3-φ diode rectifier supplying a RL load, shown as (Fig. 2)[3]. After applying the shunt active power filter the harmonics which occurs onto the source side due to the non linear load has been removed which in return preserve other customers using same line. Also transformer overheating and misbehaving of measuring equipment has been stopped.

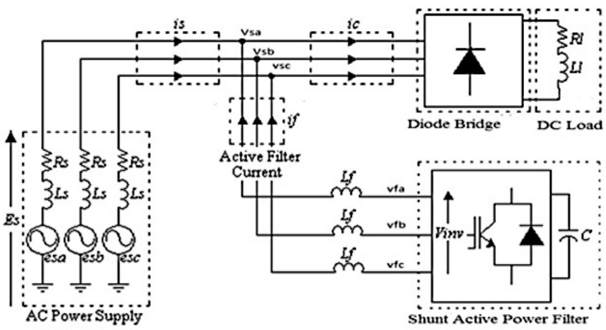

Fig2: 3-φ shunt active power filter

1.2. INSTANTENOUS REACTIVE POWER THEORY

There are various methods used to control the value of capacitor so that harmonics of current at source side can mitigate instantaneous reactive power theory is used because of its ease implementation the foremost step is to transform the source voltages into 2 component from three phase value i.e. from (Va, Vb, Vc) to (Vα , Vβ)and similarly the load current from (Ilabc) to (Iα ,Iβ) using direct conversion or By using Park transformation converting them in (d-q) component. The principle adjustment of this method is to extract the fundamental component and harmonic removed component using low pass filters (LPF). [4]

Source voltage is given by equation given below

$$V\alpha = \sqrt{\frac{2}{3}}\left[Va - \frac{1}{2}Vb - \frac{1}{2}Vc \right] \quad \text{..............(i)}$$

$$V\beta = \sqrt{\frac{2}{3}}\left[\frac{\sqrt{3}}{2}Vb - \frac{\sqrt{3}}{2}Vc \right] \quad \text{....................(ii)}$$

Similarly the load current equation is given by

$$I\alpha = \sqrt{\frac{2}{3}}\left[Ia - \frac{1}{2}Ib - \frac{1}{2}Ic \right] \quad \text{................(iii)}$$

$$I\beta = \sqrt{\frac{2}{3}}\left[\frac{\sqrt{3}}{2}Ib - \frac{\sqrt{3}}{2}Ic \right] \quad \text{........................(iv)}$$

3 phase stationary component value is being converted into d-q /*a-b* rotating coordinate the given figure shows the transformation of three phase stationary (a-b-c) component into rotating two phases. [7]

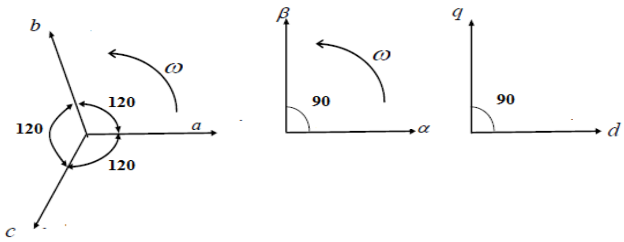

Fig 3: reference frame transformation

With the help of above values of current and voltage instantaneous real and reactive power is calculated by the following equation :

$$P = (V\alpha)(I\alpha) + (V\beta)(I\beta) \text{..................(v)}$$

$$q = (-V\beta)(I\alpha) + (V\alpha)(I\beta) \text{.................(vi)}$$

As shown in above equations real (P) and imaginary (q) power can be decomposed in Ac and Dc parts. Fundamental current and fundamental voltage is the result of Dc part and harmonics present are resulted due to the presence of Ac part.

$$p = \bar{p} + \tilde{p}$$
$$q = \bar{q} + \tilde{q}$$

After the calculation of P,q reference current has been calculated with the help of these equation as shown below

$$\begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}^{-1} \begin{bmatrix} -\tilde{p} \\ -q \end{bmatrix}$$

Which give equation of reference current *icα ,icβ* with the help of these value current has been transformed again into three coordinate Ica,Icb,Icc having equation given below

$$\text{Ica} = \sqrt{\tfrac{2}{3}}\ ica \text{.................................(vii)}$$

$$\text{Icb} = \sqrt{\tfrac{2}{3}}[\left(-\tfrac{1}{2}\right) ica + \tfrac{\sqrt{3}}{2}(icb)] \text{.............(viii)}$$

$$\text{Icc} = \sqrt{\tfrac{2}{3}}[\left(-\tfrac{1}{2}\right) ica - \tfrac{\sqrt{3}}{2}(icb)] \text{..............(ix)}$$

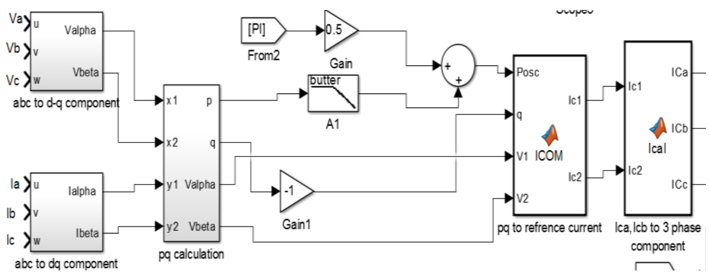

Fig4: Simulation controller block for p-q theory

As in above block by using the equation (i) (ii) and (iii)(iv)[6] we transform three phase voltage source and three phase load current into two component system respectively which is then allow to calculate the value of instantaneous real and imaginary power the output is compared with the error value which came from dc capacitor voltage which is compared with reference dc voltage through pi controller as shown below.[7]

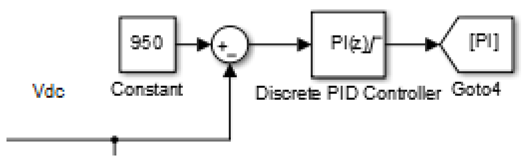

Fig5: Vdc compared with Vdc reference and passes through Pi controller

The voltage source inverter used in the active power filter makes the harmonic control possible. This inverter uses a d.c. capacitor as the supply and can switch at a high frequency to generate a signal which will cancel the harmonics from the nonlinear load .The capacitor present on DC side of universal bridge/convertor serves to maintain DC voltage in steady state and act as energy storage element while meet real power difference between load and source side at transient periods. In steady state condition the real power supplied by the source is equal to power demand at load plus small power required at active filter to compensate the losses. When load condition changes the power demand changes and hence balance of source and load side effects. This effect has to be compensating by the capacitor present at dc side of universal bridge/convertor. The power is charged or discharged by the capacitor according to its requirement, when real power supplied is equal to the load side power then the capacitor attains the value equal to reference value. Smaller capacitor voltage than reference value indicates that real power supplied from source side is not enough to meet the demand required at load side, and when the dc capacitor voltage attains higher value than the reference than it tries to decrease the value of source current. The dc capacitor voltage is compared reference value which than fed the error signal to pi controller whose output is compared with the instantaneous real power after that it is converted into *ica, icb* from the equation given above and then this reference current value is being transformed into three component system. Three phase reference current is compared with the actual filter current outcome error signal is send towards the 6 pulse gate signal which leads to operate the switches according to meet the need.[5]

2. MODELING AND SIMULATION RESULT

The mat lab model with shunt active filter is as shown below it leads to operate for 0.2 sec ,the source voltage, source current, load current, filter current, and dc side capacitor voltage is as shown in the waveforms. The waveform with linear load and non linear load are shown.

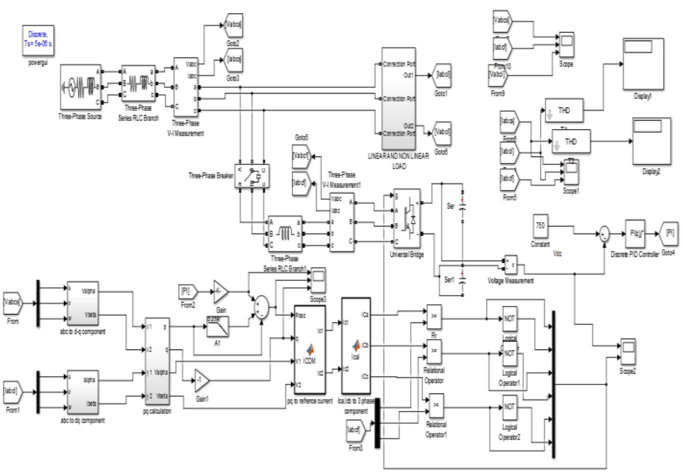

Fig6: Simulation model for non linear load with shunt active filter

Table 1: Parameter used

SOURCE VOLTAGE	415 V
SYSTEM FREQUENCY	50HZ
DC LINK REFERENCE VOLTAGE	950 V
DC SIDE CAPACITANCE	$2500x10^{-6}$
LOAD SIDE RESISTANCE	15ohm
LOAD SIDE INDUCTANCE	$10x10^{-3}$
AC SIDE RESISTANCE	0.01ohm
AC SIDE INDUCTANCE	1e-6

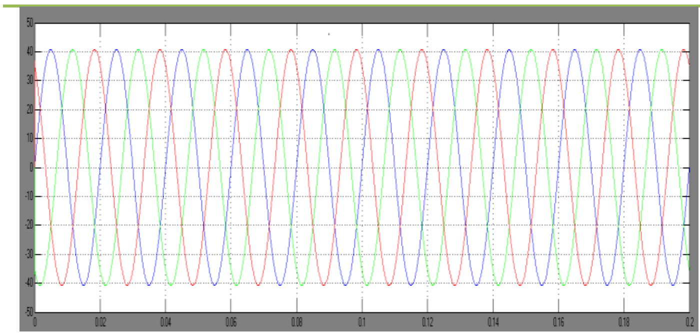

Fig7: Source current with linear load

The source current with linear current shown above indicate pure sinusoidal waveform i.e. There is no harmonics present in the line. But when the load side is equipped with equipments with power electronics devices it leads to produce the harmonics pollution in the source current as shown below

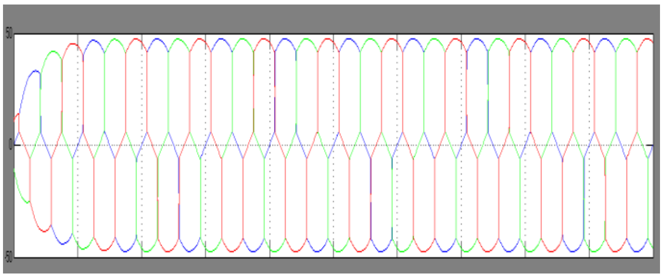

Fig8: load current with non linear load

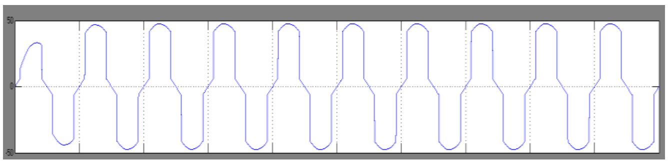

Fig9:single phase load current

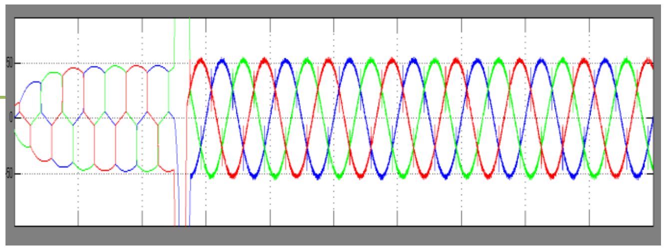

Fig10: Source current with shunt active filter

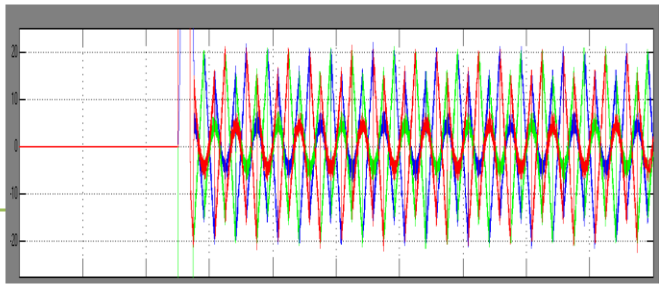

Fig11: Waveform show 3-phase active filter current

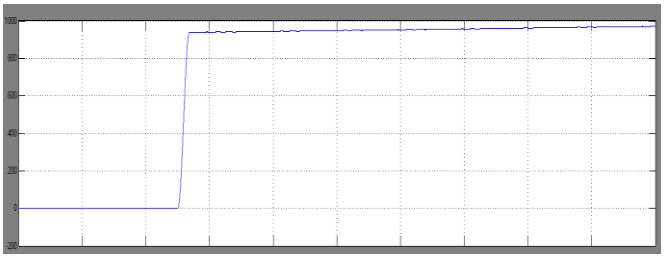

Fig12: Dc side capacitor voltage

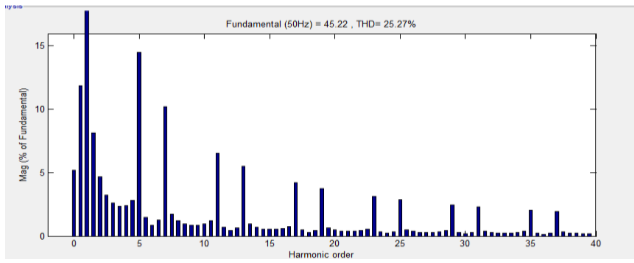

Fig13: FFT Analysis show harmonic

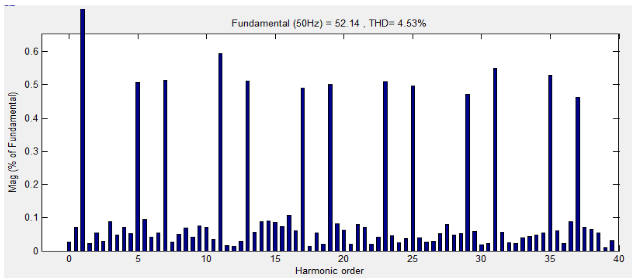

FIG14: FFT Analysis with shunt active filter

CONCLUSIONS:

Increase of the use of power electronics device as the load leads to create the need of research in the field to mitigate the harmonics pollution. In order to protect the various equipment connected to the line flow with harmonics. It does not only effect the transformer or generator like equipment but also the quality of power at household consumers effected by it and suffer the poor quality, hence in the world of privatization of electrical utility it is necessary for various company to overcome the situation of harmonic ,so the customer can get the good quality of power. In this paper we are using the shunt active power filter to compensate the harmonics with the help of p-q control scheme. The harmonics has been decreased from 23 percent to 4 percent which are under the IEEE standardization.

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