

# Control Strategy for Active Filter on Non Ideal Voltages

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## ABSTRACT

This paper described load characteristics shifting problems that happen in a large quantities, which is from linier load to non linier load caused some related problems with harmonics introduction. These problems are caused device incompatibility, increased losses and system deficiency, aberration measurement system and power system analysis, reliability decreasing and policy/responsibility problems. In general, this research reviews harmonics generator, the problems that exist and the solution for that problems, technically and policy. The Instantaneous Power System theory (pq theory) implementation method is proposed to extract harmonics signal on the power system. Active Filter used to eliminate harmonics current on customer side. This paper also evaluated the method to compute current compensation for all active filters which compensate three phase system with unbalance load. The model design was simulated in the Matlab Simulink. Simulation result is the source current could be back to smooth sinusoidal position with neutral current value closed to zero.

Keywords : Active Filter, Harmonics Compensation, Unbalance Load

## I. INTRODUCTION

The tendency of using electronic loads in a large amount had cause so much unpredictable problems. Different with electricity loads which pull sinusoidal current, this loads pull current with non sinusoidal shape, even it supplied from sinusoidal voltage source. The load which has this characteristic called as non linier load. Current with non sinusoidal shape introduce high voltage current component with injected into the nets, usually called harmonics current (because this phenomenon often called as harmonics pollutions). This harmonics current was caused a lot of negative implications, for customer and power provider as well. Disadvantage from harmonics include technical aspects, costs and reliability. In general, harmonics which follow the nets caused by many electronic devices used which has high frequency wave generator (oscillator) or pattern switching. As an example, copy machine, electronics typewriter, lamp using ballast, personal computer, computer system, computer terminal, recorder, television, video player, audio visual equipment, SCR thruster motor, SCR incentive Elevator, UPS, test equipment tools in the laboratory, detection equipment at the hospital and so on. Beside that, a lot problems related to harmonics which exist in a building. As an example, overheating and neutral conductor failure, over heating and panel board channel failure, nets channel distortion, common higher mode voltage, tripping failure in circuit breaker, over heat and premature failure on distribution transformation, and so on. In active filter contains computation controller technique for harmonics effect which will be removed. Usually this active filter created with three phase inverter which used to current injection,  $I_c$  on nets network can be seen on figure 1.

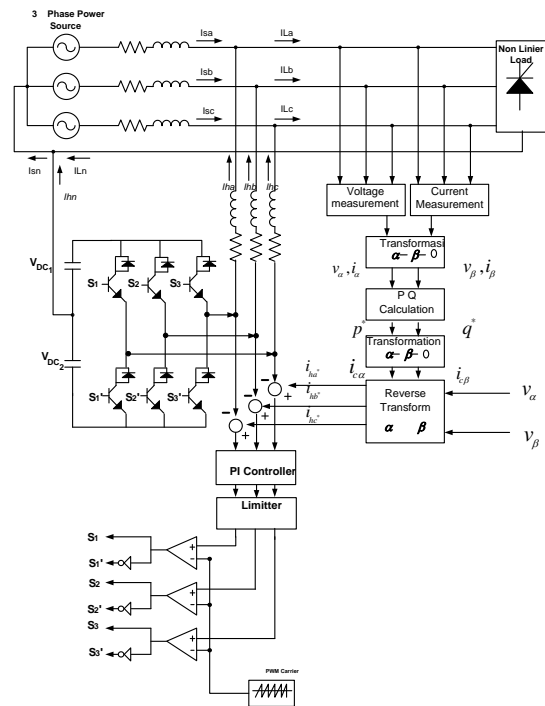


Figure 1. A Set of Shunt Active Filter

## 2. CONTROLLING METHOD ON ACTIVE FILTER

### A. FBD (Frize- Buchholz-Depenbrock) Method

This method proposed by Depenbrock which divide or decompose load current inside power component and power loss component. The purpose is to compensate all the components which didn't produced by power system, but give power factor less than 1. This method said that average power ratio which

consumed by load and RMS voltage value, that statement can be seen below [1] [2] [3] [5] [6] :

$$G = \frac{\bar{P}_3}{V_\Sigma^2} \quad (1)$$

which  $V_\Sigma^2$  is RMS voltage

$$V_\Sigma^2 = \sqrt{V_a^2 + V_b^2 + V_c^2} \quad (2)$$

and  $V_a, V_b, V_c$  is RMS voltage value on a,b and c phase.  $\bar{P}_3$  is three phase instant average power value which counted from active power. Reference current value can be compute with :

$$i_{ca}(t) = G.v_a(t) - i_a(t) \quad (3)$$

$$i_{cb}(t) = G.v_b(t) - i_b(t) \quad (4)$$

$$i_{cc}(t) = G.v_c(t) - i_c(t) \quad (5)$$

### B. Synchronous Reference Method

This method use Park Component. Three Phase System Park Injection Current Component can be found through implementing Clark Transform which produce  $i_a, i_b, i_c$  current represented into two coordinate  $i_\alpha$  and  $i_\beta$  and with system reference rotation angle  $\theta$  included to  $i_d$  and  $i_q$ . Then with zero component availability, current value on coordinate  $0-d-q$  can be obtained from :

$$\begin{bmatrix} i_0 \\ i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ -\sin\theta & -\sin\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (6)$$

Instant Power can be obtained from :

$$p(t) = v_0.i_0 + v_d.i_d + v_q.i_q \quad (7)$$

To minimize reactive power which loss must compensate reactive power in the amount of :

$$\vec{q}(t) = \begin{bmatrix} v_q.i_0 - v_0.i_q \\ v_0.i_d - v_d.i_0 \\ v_d.i_q - v_q.i_d \end{bmatrix} \quad (8)$$

To make reactive power becoming zero, this formulation can be use :

$$\begin{aligned} \vec{q}(t) = \vec{0} &\Rightarrow v_q.i_0 - v_0.i_q = 0 \\ v_0.i_d - v_d.i_0 &= 0 \\ v_d.i_q - v_q.i_d &= 0 \end{aligned} \quad (9)$$

### C. p – q Theory Method

This theory also known as "instantaneous power theory" which written by Akagi in 1983 to active filter control. P – q theory contains voltage algebra transformation and three phase system current from  $a-b-c$  coordinate to  $\alpha-\beta-0$  coordinate which followed by instant power theory component calculation as followed [1] [2] [3] [4] [5] :

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad (10)$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (11)$$

$p_0 = v_0.i_0$  is instant power zero sequence

$$P = v_\alpha.i_\alpha + v_\beta.i_\beta \text{ is real power} \quad (12)$$

$q = v_\alpha.i_\beta - v_\beta.i_\alpha$  is imaginary power (Reactive power) (13)

the relation between voltage value and p – q component current on  $\alpha-\beta$  coordinate is :

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (14)$$

This values illustrated on figure 2 :

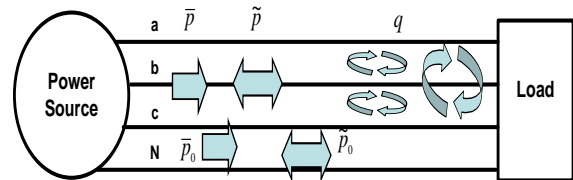


Figure 2 p- q theory current component

$\bar{p}_0$  = Average value from 0 sequence instantaneous power, that is related with energy per unit time which transferred from power supply to load through voltage component and 0 sequence current.

$\tilde{p}_0 =$  Turn around value from 0 sequence instantaneous power, energy per unit time which transform between power supply with load through 0 sequence component.

$\bar{p} =$  Instantaneous power average value, energy per unit time which transferred from power supply to load through wire or  $a - b - c$  coordinate

$\tilde{p} =$  Turn around value from instantaneous power, the energy per unit time which transform between power supply and load through wire or  $a - b - c$  coordinate.

$q =$  imaginary instantaneous power value, the power that transform between phase and load.

As has been described previously,  $\bar{p}$  is p - q power component which always expected. This quantity can be compensate using parallel active filter as seen on figure 3.  $\bar{p}_0$  can be compensate without consume much power supply on parallel active filter. This quantity transferred from power supply to load through active filter. It means the previous energy transferred from source to load through voltage and 0 sequence current, now transferred through balance channel on phase wired source.

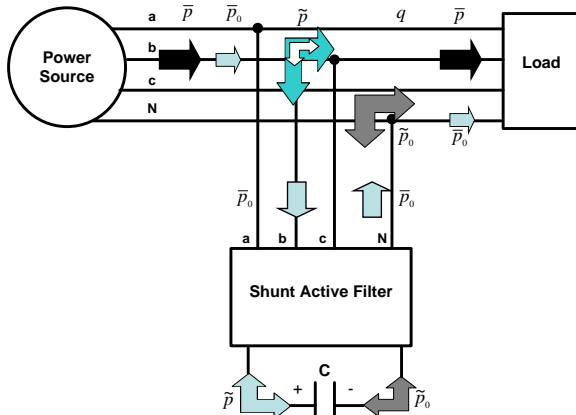


Figure 3. Power Component Compensation  $\tilde{p}, q, \tilde{p}_0$  dan  $\bar{p}_0$

Capacitors on figure 3 only need to compensate  $\tilde{p}$  and  $\tilde{p}_0$ , as long as this value must stored on that component for some time and then delivered to load. For calculation reference compensation current into  $\alpha - \beta$  coordinate, reverse equation and compensation current using equation :

$$\begin{bmatrix} i_{ca^*} \\ i_{cb^*} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} - \bar{p}_0 \\ q \end{bmatrix} \quad (15)$$

As long the zero sequence compensated, reference current on coordinate 0 is  $i_{0^*} = i_0$ , and to obtain coordinate  $abc$  reference compensation current, reversed transformation is given in :

$$\begin{bmatrix} i_{ca^*} \\ i_{cb^*} \\ i_{cc^*} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1 & 0 \\ 1/\sqrt{2} & -1/2 & \sqrt{3}/2 \\ 1/\sqrt{2} & -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{c0^*} \\ i_{ca^*} \\ i_{cb^*} \end{bmatrix} \quad (16)$$

$$\text{And } i_{cn^*} = -(i_{ca^*} + i_{cb^*} + i_{cc^*}) \quad (17)$$

**3. p q THEORY CALCULATION ALGORITHM**  
Control strategy to obtain compensation reference current  $i_{hx}^*$  that displayed on figure 4 from p q component calculation algorithm at below :

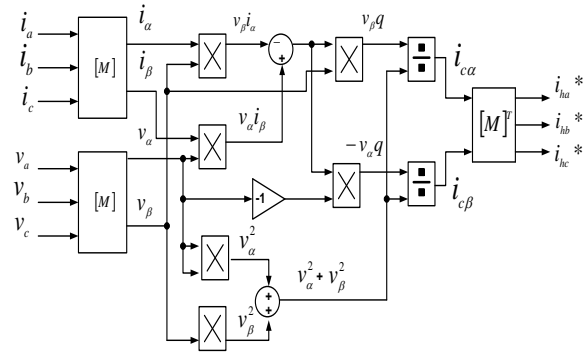


Figure 4. p q Theory calculation Algorithm

Where,  $[M]$  is a orthogonal transformation matrix

$$[M] = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \quad (18)$$

#### 4. SIMULATION RESULTS

This research to be done with Matlab Simulink Version 7.1. Tools, which used to build p q theory algorithm simulation to extract harmonic power system , while the simulation block diagram shown in figure 5 below:

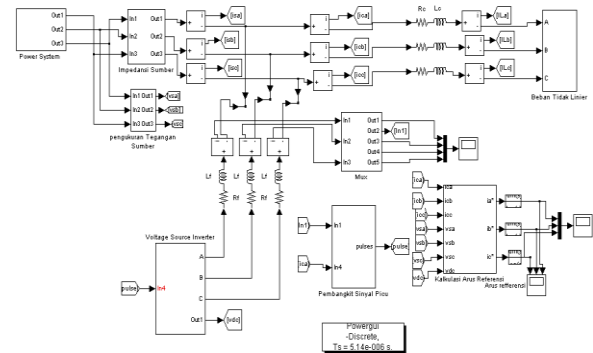


Figure 5. Model Active Power Filter

This load consists of a 30 mH inductor with 010  $\Omega$  resistance and 3 phase thyristor controlled converter . Figures 6 to 11 show waveforms obtained from simulation results performed with this type of load. Fig. 6 presents the system voltage ( $v_s$ ) and figure 7 the source current ( $i_s$ ) before the shunt active filter starts its operation. The source current distortion occurs because those non linier load impendant values are changing discretely so current number which be attracted by the current will follow non linier current impendant changes which cause source current form is becoming not sinusoidal. Fig. 11 illustrates the same waveforms after the connection of the active filter to the electric system. Fig. 10 presents the reference current of the active filter Fig. 6 and 11 presents the system voltage ( $v_s$ ) and the source current ( $i_s$ ) when the shunt active filter is connected to the power system (transient operation). As shown on the figure 8 and 9 that the reference current,  $i_{hx}^*$  is 180 degrees different with load current  $I_L$ , this indicate that original harmonics current has the same wave format with reference current but has oposites phase. If both of the waves are summed then it will generate sinusoidal wave form. Thus this source current will still becoming sinusoida even oad current is always changing. This is the expected source current wave format. Current is on the neutral wire, the result seems to have a very small values, which is close to zero  $2.10^{-14}$  A From these simulation results it is possible to concluded that, for this type of load the shunt active filter corrects successfully the power factor, and ought to that, the current source value decreases considerably.

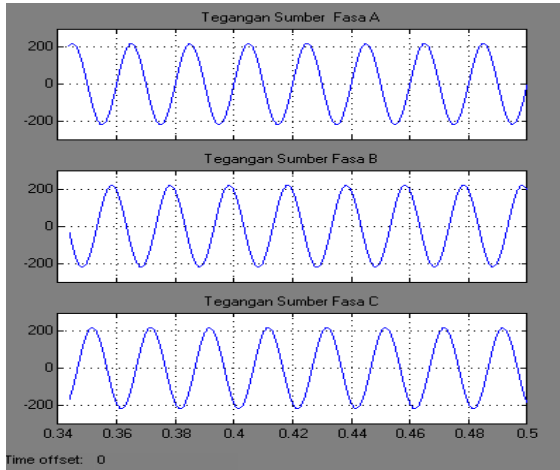


Figure 6. Source Voltages a b c Phase

Each phase input voltage has pure sinusoidal shape with 220 V amplitude  $120^\circ$  phase different.

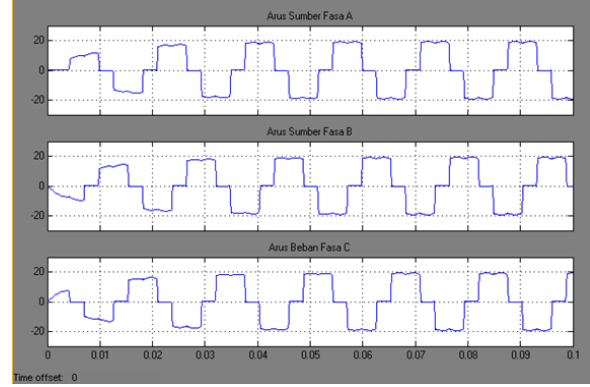


Figure 7 Distortion Current Source a b c phase

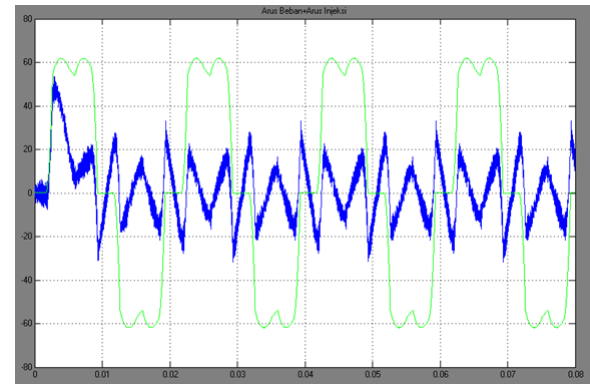


Figure 8. The Current Load and Current Reference of each phase

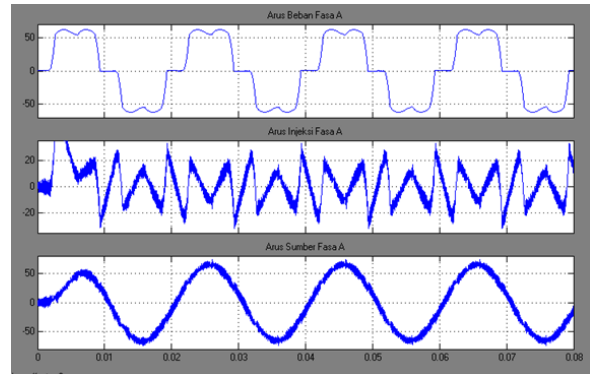


Figure 9. The Currents of Load, Compensation, and Source

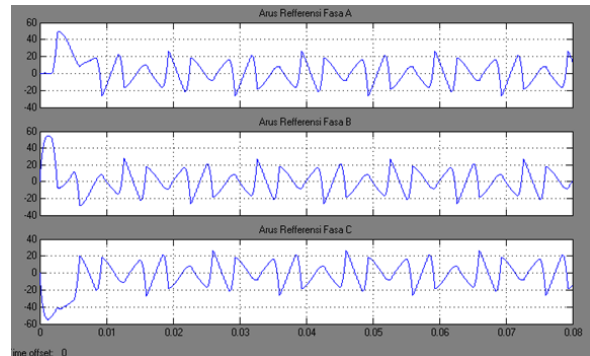


Figure 10. The Current References of each phase

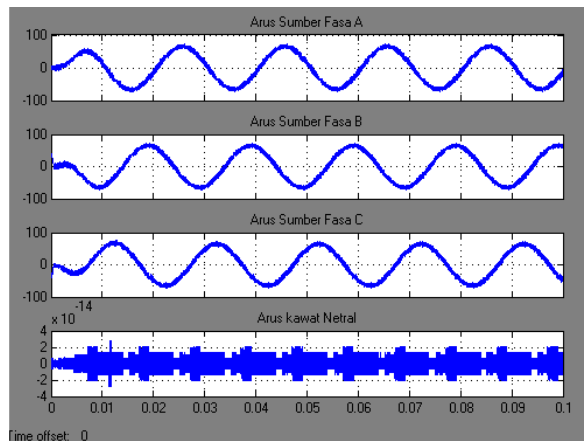


Figure 11. The Currents Source a b c phase and Neutral current wire Form

## 5. CONCLUSION

This paper presented simulation results obtained with a three phase shunt active power filter with a control system based on the p-q theory, and operating with Periodic Sampling switching technique, which is a very simple technique. The shunt active filter control system is based on a simple concept that enables the use of the traditional p-q Theory, originally developed to three-phase power systems. Three different types of loads were used to test the single phase active filter: a linear RL load, a rectifier with RL load, and a rectifier with RC load. The simulation results proved that the shunt active filter was capable of compensating harmonics currents and correcting power factor for the different types of loads used in the simulations. However it was observed that the performance of the active filter was not totally satisfactory for the case of Load C (full bridge rectifier with a parallel RC load), since the compensated source current presented still some distortion. The current source, will be smoothing sinusoidal after injected by shunt active filter which proposed., with neutral current value closed to zero.

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