IMPROVED THE ADAPTATION FOR THREE PHASE ACTIVE FILTER UNDER NON-IDEAL-LOAD USING SAMPLE CURRENT CONTROL

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ARTICLE DETAILS

ABSTRACT

In this paper, a comparison between sample current control and direct current control to show the efficiency of the two current control method of Active Power Filter. The main function of the scheme was a duty by the two-level three phases inverter. According to the classic approach, transistors are converted depending on the sign of the current error, in turn, sampled at equal intervals. Both methods follow the synchronous toggle principle. In the first method, the current vector at the end of the interval is predicted for two possible cases when the operating voltage vector towards the current fault or zero voltage vector is applied. An error generates a smaller current error at the end of the selected sampling period, thus reducing the switching frequency. In the second method, the most appropriate operating voltage vector will succeed in zero vectors over the same period. A simple algorithm is used to calculate the duty cycle to achieve the smallest possible error. Both methods are simulated with three different load modes: no load, RL load, and nonlinear load. At the end of the article, the behavior of the second method, SCC, is worth more. The simulation results demonstrate the viability and effectiveness of the two technique of current control in reducing the ripple, losses, and Total Harmonic Distortion of supply current.

KEYWORDS

Active power filter, sample current control - SCC, direct current control - DCC, power quality, total harmonic distortion - THD.

1. INTRODUCTION

The use of nonlinear loads such as variable speed drivers, electric arc welders, and switching power suppliers causes large amounts of harmonic currents to inject into distribution systems. These harmonic currents are responsible for voltage distortion, increasing power losses and heat on networks and transformers, and causing operational failure of electronic equipment. Using the traditional passive filters such as inductance (L), inductance-capacitance (LC) and inductance capacitance inductance (LLC) to eliminate line current harmonics and to improve the load power factor presents many disadvantages such as aging and tuning problems, series and parallel resonance, and the requirement to implement one filter per frequency harmonic that needs to be eliminated [1-5]. To overcome these problems, active power filter (APFs) has been proposed to study in the power-quality [6,7]. The author and his group have continued seeking the newer control methodology for the Active Filter (AF).

In recent years, APFs based on current-controlled PWM converters have been widely investigated and considered as a viable solution. Most of them are based on sensing harmonics and reactive volt-ampere requirements of non-linear load, and require complex control system [8-10]. Chen, Ming-hung have proposed a scheme in which the required compensating current is determined using a simple synthetic sinusoid generation technique by sensing the load current [1]. This scheme is further modified by sensing line current only, which is simple and easy to implement [1].

As it was mentioned in many study, the control method’s results point out the advantage and disadvantage for these applications [10-12]. This paper, with SCC (sample current control) method and DCC (direct current control) in three phases two-level inverter modulation making the difference in results, and the technique that makes improvements was showed in Matlab Simulink’s oscilloscope.

2. ACTIVE FILTER’S MODEL WITH TYPES OF LOAD

A model of three-phase Active Filter with kinds of current control in detail was shown in Table 1 and Figure 1. As it was viewed, there are three parts connecting. The first called “three-phase emf,” the second was named “Active Filter” and the third was known as “Loads.”

Figure 1: Active Filter with types of Load’s model

The first stands for three-phase – Grid, in that the voltages were established based on the vector on the alpha/beta frame. The second is the Active Power Filter contained the main controller inside. The last is the complex load including three kinds of load’s functions: no load, Symmetric RL Load, and Non – ideal load. Table 1 description signs and signals for scheme that declared as Figure 1.
The three-phase system can be generally declared by the following equations, (1) for voltage and (2) for current [1].

\[ V_i(t) = \sum_{n=1}^{\infty} \sqrt{2} V_{in} \sin(\omega t + \phi_{in}) k = (a,b,c) \]  

\[ I_i(t) = \sum_{n=1}^{\infty} \sqrt{2} I_{in} \sin(\omega t + \phi_{in}) k = (a,b,c) \]

With \( k \) being the harmonic order.

The two equations above can be modified by making alpha degree for the main view, including fundamental harmonic \((n=1)\) and order \( n \) harmonic [1].

\[ V_k = \sum_{n=1}^{\infty} V_{in} \angle \phi_{in} = \sum_{n=1}^{\infty} V_{in} \angle \phi_{in} k = (a,b,c) \]  

\[ I_k = \sum_{n=1}^{\infty} I_{in} \angle \phi_{in} = \sum_{n=1}^{\infty} I_{in} \angle \phi_{in} k = (a,b,c) \]

With matrix showing for balanced parts in each order harmonic of three phases \( a, b, c \), the results are told currents in forward, revert and zero order [2].

\[
\begin{bmatrix}
    i_a \\
    i_b \\
    i_c \\
\end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix}
    1 & -1 & -1 \\
    -\frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} \\
    -\frac{3}{2} & -\frac{3}{2} & -\frac{3}{2} \\
\end{bmatrix} \begin{bmatrix}
    i_1 \\
    i_2 \\
    i_3 \\
\end{bmatrix}
\]  

The revert matrix is given below (6)

\[
\begin{bmatrix}
    i_a \\
    i_b \\
    i_c \\
\end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix}
    1 & 0 & 0 \\
    \frac{1}{2} & \frac{1}{2} & 0 \\
    \frac{3}{2} & \frac{3}{2} & \frac{3}{2} \\
\end{bmatrix} \begin{bmatrix}
    i_1 \\
    i_2 \\
    i_3 \\
\end{bmatrix}
\]

Expanding the matrix above and get the details in (7)

\[
\begin{cases}
e = v_a + jv_b \\
i = i_a + ji_b
\end{cases}
\]

The same respectively, three-phase currents can be taken below (8)

\[
\begin{align*}
v_a(t) &= \sqrt{2} V \cos(\omega t + \phi) \\
v_b(t) &= \sqrt{2} V \cos(\omega t + \phi) - \frac{2\pi}{3} \\
v_c(t) &= \sqrt{2} V \cos(\omega t + \phi) + \frac{2\pi}{3} \\
i_a(t) &= \sqrt{2} I \cos(\omega t + \phi) \\
i_b(t) &= \sqrt{2} I \cos(\omega t + \phi) - \frac{2\pi}{3} \\
i_c(t) &= \sqrt{2} I \cos(\omega t + \phi) + \frac{2\pi}{3}
\end{align*}
\]  

With Direct current Control, the source three-phase will be without the 3 phase 2 level modulation, as showing in Figure 2.

![Figure 2: Model of the two of the current control](image)

So, with the switch in the red circle, we can choose the current control mode for the APF.

2.2 Model of Sample current Control - SCC

Model of this control mode is including the 3 phase 2 level modulation, as showing near as the green circle, Figure 2. And when the switch is pulled up, the APF working with the SCC mode. Figure 3 shows the algorithm of the 3 phase 2 level modulation in the SCC method, in that, was built from these equations below. The signals \( i_a, i_b, i_c \) were defined as the load currents, \( v_a, v_b, v_c \) for voltage – load – signals. Then the formatted converting to \( \alpha\beta \) reference will be as shown in (9) and (10):

\[
\begin{bmatrix}
v_a \\
v_b
\end{bmatrix} = \frac{\sqrt{2}}{3} \begin{bmatrix}
\sqrt{2} & 1 & \sqrt{2} \\
-\frac{1}{2} & -\frac{1}{2} & \frac{1}{2}
\end{bmatrix} \begin{bmatrix}
 i_a \\
i_b \\
i_c
\end{bmatrix}
\]

The currents in \( \alpha\beta \) ingredients:

\[
\begin{bmatrix}
i_a \\
i_b \\
i_c
\end{bmatrix} = \frac{\sqrt{2}}{3} \begin{bmatrix}
\sqrt{2} & 1 & \sqrt{2} \\
-\frac{1}{2} & -\frac{1}{2} & \frac{1}{2}
\end{bmatrix} \begin{bmatrix}
v_a \\
v_b
\end{bmatrix}
\]

![Figure 3: The algorithm of the 3 phase 2 level modulation in the SCC method](image)

2.3 Model of Active Power Filters

A general control model based on \( d-q \) theory as Figure 5 [1]. Then figure 6 is the main top of the Active Filter Control.
3. SIMULINK RESULTS

3.1 No Load

Choosing no-load switch at no load position and the screenshots of load current in (α, β) and load current in (d/q) will be shown as figure 6. In figure 7, the load current equals zero, filter current has the amplitude of noise, and certainly noise for the line current. dc link voltage has been kept in 250v position.

3.2 RL_Load Simulating

No load switch at load position "[2]", load switch 1 and load switch 2 at RL_load position "[1]", in figure 1. Figure 9 shows the signals of phase c.

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In Figure 12, load signal, filter signal, grid current signal, and DC capacitor voltage signal are shown. With DCC mode, THD = 22.94% at fundamental signal.

### 3.5 SCC mode Simulink results

![Figure 12: Monitor for SCC results](image12.png)

The effect of load on the three-phase power system using an active filter will be declared in Simulink results. The loads will leaded the formed source changing. With the load’s characteristics made these signals influenced. The paper is not to say about how to eliminate the harmonic caused by the non-linear load to improve the source quality but the effecting of the kinds of the load in the three-phase power system that using an active filter.

### 3.6 SCC mode Simulink results

In Figure 13, FFT in SCC mode result

The effect of load on the three-phase power system using an active filter will be declared in Simulink results. The loads will leaded the formed source changing. With the load’s characteristics made these signals influenced. The paper is not to say about how to eliminate the harmonic caused by the non-linear load to improve the source quality but the differences between the two-control method effecting in the three-phase power system that using Active Filter [13]. The Simulink result makes clear that with SCC the APF do better than DCC, in the detail of $\text{THD}_{\text{SCC}} = 14.74\%$ vs. $\text{THD}_{\text{DCC}} = 25.95\%$. This result validity of the SCC method for making progress in filtering harmonic results.

### 4. CONCLUSIONS

In this paper, two different approaches of controlling the current for the Active Power Filter are presented. In both cases, the choice of the next vector space voltage is based on the current prediction. Although SCC demonstrates good performance, both methods have inherent disadvantages, because, for optimal performance, load parameters (or at least) must be known. When feeding the current into the active load of the active machine with the reverse emf, such as an electric machine, this voltage must be subtracted by the vector from the applied voltage. However, in systems that know back to emf, it can be improved on going down the THD index.

The show in figure 8 to speak to the efficiency of the control method and the adaptive of APF with other kinds of the current control scheme. Harmonics were eliminated from the line currents better when using the SCC method. The simulation results worth the students and researchers in studying power quality have more ideas about designing the controller of Active Filter.
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