Analysis of Reference Current Generation for Shunt Active Power Filter Using SRF Algorithm to Compensate Harmonic Current

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Abstract – Number of power electronic devices used in the power system to control the equipment. These power electronic devices are responsible to produce Harmonics in the system. These harmonics may pollute the entire power system. So it is necessary to develop the system for solving these harmonic problems. At the beginning LC filter, Passive filter and Active filter has been developed. But due to the drawback of passive filter and LC filter they are less in use. So importance is being given to the Active Power Filters to solve these problems of harmonics. Amongst them shunt active power filter is used to eliminate voltage and load current harmonics and for reactive power compensation. The shunt active power filters have been developed with a controlled strategy like p-q theory, PI controller, Sliding mode control. In this paper reference current is determined for compensation of harmonics source current with the help of Synchronous Reference Frame Algorithm Method. Park transformation is used to determine the reference current. Hysteresis band current control (HBCC) technique is used for the generation of firing pulses to the inverter. This system is simulated using MATLAB and results are obtained.

Key words: Shunt Active Power Filter, harmonics, Synchronous Reference Frame Algorithm, Hysteresis current control, Reference current.

I. INTRODUCTION

The wide use of power electronics based controller technology for non linear loads, industrial machines and automation devices in industries, in commercial and households appliances, have led to a significant increase in disturbances, which affect power quality in power systems. Therefore, it is necessary to develop and implement solutions to improve power quality in electrical power systems [1-2]. Conventionally passive L-C filters were employed to reduce harmonics and capacitors were used to improve the power factor of the loads. But passive filters have the demerits of fixed compensation, large size and resonance. The increased severity of harmonic pollution in power distribution network has attracted the attention to develop dynamic and adjustable solutions to the power quality problems giving rise to active filter [3]. Now days, shunt active power filters have appeared as an effective method to solve the problem of harmonics, with reactive power compensation. Active power filters are connected to 3 phase AC transmission lines in order to eliminate voltage distortion and harmonic components. Shunt active power filter are used to eliminate the current harmonic components working as a source with only the harmonic components and power factor correction, so that only the fundamental component is supplied in the 3 phase AC lines [4-7].

The Shunt Active Power Filter is connected in parallel with the line through a coupling inductor. Its main power circuit consists of a three phase three-leg current controlled voltage source inverter with a DC link capacitor. An active power filter operates by generating a compensating current with 180 degree phase opposition and injects it back to the line so as to cancel out the current harmonics introduced by the nonlinear load. This will thus suppress the harmonic content present in the line and make the current waveform sinusoidal. So the process comprises of detecting the harmonic component present in the line current, generating the reference current, producing the switching pulses for the power circuit, generating a compensating current and injecting it back to the line. [12]
II. SYSTEM DESIGN

A. Synchronous Reference Frame Algorithm

Various control strategies have been developed for the determination of reference currents in shunt active power filters namely Instantaneous Reactive Power Theory (p-q theory), sliding mode control strategy, Unity Power Factor method, One Cycle Control, Fast Fourier Technique etc. Here, SRF theory is used to evaluate the three-phase reference currents \(i_{ca}^*, i_{cb}^*, i_{cc}^*\) by the active power used filters by targeting the source \((i_a, i_b, i_c)\) current. Fig. 2 shows the block diagram which explains the three-phase SRF-theory, used for harmonic component extraction. Here in SRF theory Park transformation is used. In this method, the source currents \((i_a, i_b, i_c)\) are first detected and transformed into two-phase stationary frame \((a\beta, 0)\) from the three-phase stationary frame \((a-b-c)\), as per equation (1).

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

Fig.1 3-phase shunt active power filter with SRF controller

Here two direct and inverse Park transformation is used which allows the evaluation of specific harmonic component of the input signals and a low pass filtering stage LPF. Now, the two phase current quantities \(i_a\) and \(i_b\) of stationary \(a\beta\)-axes are transformed into two-phase synchronous (or rotating) frame \((d-q\)-axes\) using equation (2), where \(\cos\theta\) and \(\sin\theta\) represents the synchronous unit vectors which can be generated using phase-locked loop system (PLL).

\[
\begin{bmatrix}
    i_d \\
    i_q
\end{bmatrix} = \begin{bmatrix}
    \cos \theta & \sin \theta \\
    -\sin \theta & \cos \theta
\end{bmatrix} \begin{bmatrix}
    i_a \\
    i_b
\end{bmatrix}
\]

The \(d-q\) currents thus obtained comprises of AC and DC parts. The fundamental component of current is represented by the fixed DC part and the AC part represents the harmonic component. This harmonic component can be easily extracted using a high pass filter (HPF), as implemented in Fig 2. The \(d\)-axis current is a combination of active fundamental current \((id\ dc)\) and the load harmonic current \((ih)\). The fundamental component of current rotates in synchronism with the rotating frame and thus can be considered as dc. By filtering \(id\), the current is obtained, which represents the fundamental component of the load current in the synchronous frame. Thus, the AC component \(id_c\) can be obtained by subtracting \(id\ dc\) part from the total \(d\)-axis current \((id)\), which leaves behind the harmonic component present in the load current. In the rotating frame the \(q\)-axis current \((iq)\) represents the sum of the fundamental reactive load currents and part of the load harmonic currents. So the \(q\)-axis current can be totally used to calculate the reference compensation currents.

Now inverse transformation is performed to transform the currents from two phase synchronous frame \(d\-q\) into two-phase stationary frame \(a\-\beta\) as per equation (3).

\[
\begin{bmatrix}
    i_d \\
    i_q
\end{bmatrix} = \begin{bmatrix}
    \cos \theta & -\sin \theta \\
    \sin \theta & \cos \theta
\end{bmatrix} \begin{bmatrix}
    i_{db} \\
    i_{qb}
\end{bmatrix}
\]

Finally the current from two phase stationary frame \(a\beta\) is transformed back into three-phase stationary frame abc as per equation (4) and the compensation reference currents \(ica^*, icb^*\) and \(icc^*\) are obtained.
\[
\begin{bmatrix}
i_{\text{abc}}^* \\
i_{\text{cb}}^* \\
i_{\text{cc}}^*
\end{bmatrix}
= [T_{\text{abc}}]
\begin{bmatrix}
i_a \\
i_b \\
i_c
\end{bmatrix}
\] (4)

Where,
\[
[T_{\text{abc}}] = \begin{bmatrix}
\frac{1}{\sqrt{3}} & 0 & \frac{1}{\sqrt{2}} \\
\frac{-1}{\sqrt{3}} & \frac{\sqrt{2}}{2} & \frac{1}{2} \\
\frac{-1}{\sqrt{3}} & \frac{-\sqrt{2}}{2} & \frac{1}{2}
\end{bmatrix}
\] (5)

B. Hysterisis Band Current Control

The hysterisis band current control (HBCC) technique is used for pulse generation in current controlled VSIs. The control method offers good stability, gives a very fast response, provides good accuracy and has got a simple operation. The HBCC technique employed in an active power filter for the control of line current is shown in Fig.3. It consists of a hysterisis band surrounding the generated error current. The current error is obtained by subtracting the actual filter current from the reference current. The reference current used here is obtained by the SRF method as discussed earlier which is represented as \(I_{\text{abc}}^*\). The actual filter current is represented as \(I_{\text{abc}}\). The error signal is then fed to the relay with the desired hysterisis band to obtain the switching pulses for the inverter.

![Fig No.3 Hysterisis Band Current Controller](image)

The operation of APF depends on the sequence of pulse generated by the controller. Figure 4 shows the simulation diagram of the hysterisis current controller. A band is set above and below the generated error signal. Whenever this signal crosses the upper band, the output voltage changes so as to decrease the input current and whenever the signal crosses the lower band, the output voltage changes to increase the input current. Accordingly switching signals are generated.

![Fig No.4 Simulation diagram of hysterisis current control](image)

II. SIMULATION RESULTS AND DISCUSSION

In this paper simulation of SRF algorithm using park transformation has been done which is shown in fig 5. From this the reference signal \(I_{\text{abc}}^*\) is produced from SRF algorithm which is shown in fig 6. Then this reference current is compared with actual current signal from which error signal is developed shown in fig 7. which is fed to the hysterisis band control harmonic current. This developed the pulse signal for VSI shown in fig 8.
III. CONCLUSIONS

This paper describes compensation process for the line current harmonics generated due to nonlinear loads in the system. Using Synchronous Reference Frame Algorithm three phase reference current is generated, this is compared with the actual filter current and resultant signal is given to the HBCC, it provides control signal to three phase voltage source inverter. HBCC technique used for the switching pulse generation is found more effective and gives fast response.

IV. REFERENCES


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