Study on Phase-Segregated Active Power Filter using PLECS

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ABSTRACT

This paper presents an algorithm for a phase-segregated active power filter for three-phase electric system. Due to the symmetrical characteristic of three-phase system and the specialty of distribution system, the proposed algorithm focuses on the extraction of harmonic component of load current in each phase and simulations have been done by PLECS software to verify the validity of the proposed algorithm while loads are nonlinear.

1. Introduction

The growing use of nonlinear loads, such as computer equipments, electronic ballasts, speed motor drivers, switching mode power supplies etc., are producing a big increase in the harmonic distortion. Shunt active filters arise as effective devices to compensate reactive power, harmonic distortion and unbalance currents.

This paper presents the application of controllers of APF for three-phase distribution systems to compensate the distorted system current because of the nonlinear load[1]. The system considered in this paper shown in Fig. 1 shows the basic topology of APF. In Section 2, the structure of the controller is discussed. At the end, the simulation which used the proposed algorithm was made using PLECS.

2. The Proposed Phase-Segregated Algorithm

2.1 Zero sequence current elimination

In the three-phase system shown in Fig.1, zero sequence current is included in the three phase currents, it can be obtained by

\[ i_0 = i_a + i_b + i_c \]  
(1)

Then zero sequence current \( i_0 \) can be eliminated as,

\[
\begin{align*}
    i'_a &= i_a - i_0 \\
    i'_b &= i_b - i_0 \\
    i'_c &= i_c - i_0
\end{align*}
\]

After the elimination of \( i_0 \), \( i'_a + i'_b + i'_c = 0 \), they can be used to calculate the reference current.

2.2 Harmonic current extraction algorithm

If the three phase system is a symmetrical, we can take a single phase as example to explain the harmonic current extraction algorithm.

As shown in Fig.2, \( i_s \) is the source current, \( i_L \) is the load current, \( i_c \) is the compensate current from active power filter.

Fig.3 shows the control block of active power filter. In order to filter the harmonic current effectively, we transferred the AC current to DC current, so a virtual AC current \( i_L' \) was created, which has a 90 degree phase-shift after \( i_L \), to transform vector from stationary to rotating reference frame.

PI controller was implemented for the DC voltage regulator so that the voltage of capacitor could operate stably. And the harmonic current \( i_h \) can be obtained as the difference of \( i_L \) and \( i_{ref} \). By using the above algorithm, the harmonic component of the system current can be extracted successfully [2], and this algorithm can be extended from a single phase system to three phase system with the same principle.
3. Simulation

Both single phase and three-phase APF were made using PLECS software. Fig.4 shows the three-phase simulation circuit, the system consists of three-phase source, non-linear load, and APF circuit, which includes three full-bridge converters. The system simulation parameters are given in Table 1.

![Fig.4 Active Power Filter Simulation Circuit](image)

<table>
<thead>
<tr>
<th>Power System Element</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent Source</td>
<td>Voltage source(Vs) 380V(L-L)</td>
</tr>
<tr>
<td></td>
<td>Frequency 60Hz</td>
</tr>
<tr>
<td></td>
<td>Source resistance 1 ohm</td>
</tr>
<tr>
<td>Non-linear Load</td>
<td>Load inductance 190 mH</td>
</tr>
<tr>
<td></td>
<td>Load resistance 10 ohm</td>
</tr>
<tr>
<td>Active power filter(APF)</td>
<td>APF inductance 2 mH</td>
</tr>
<tr>
<td></td>
<td>APF capacitance 1500 uF</td>
</tr>
</tbody>
</table>

![Table 1 Simulation Parameters](image)

Fig.5 shows the load current \(i_L\) and reference source current \(i_{S\_ref}\), the harmonics current can be obtained as the difference of them. Fig.6 shows the harmonic current \(i_h\) and compensating current \(i_c\) started operating at 0.09s which was generated by active power filter.

In Fig.7, the source current in two different situations are shown while load inductance are 190mH and 10mH, resistance is 10ohm. The APF circuit starts to operate at 0.09s. Before APF operating, the source current has high frequency components because of the non-linear loads.

![Fig.5 Load current and reference source current](image)

![Fig.6 Harmonic current & compensate current](image)

![Fig.7 Source current waveforms](image)

After 0.09s, the APF using the proposed algorithm can filter the harmonic current effectively by generating the same current \(i_c\), and three-phase source currents follow very similar to sinusoid after APF compensation.

While the loads of three phases are symmetrical, load inductance is 190mH and resistance is 10ohm, the fundamental component magnitude is 17.27A as shown in Fig.8 (a), and the harmonic current ratio can account for 29.9%. And after the APF compensation, the fundamental component magnitude increases to 18.22A and the harmonic component decreases to 2.28% of the total current, seen from Fig.8 (b).

![Fig.8 Frequency analysis of Source current](image)

4. Conclusion

In this paper, an algorithm for a phase-segregated active power filter for three-phase electric system was proposed. Due to the symmetrical characteristic of three-phase system and the specialty of distribution system, the proposed algorithm focuses on the extraction of harmonic component of load current in each phase. The PLECS simulation results proved the validity of the proposed algorithm in power system while loads are nonlinear, the THD value can be decreased effectively.

References
