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

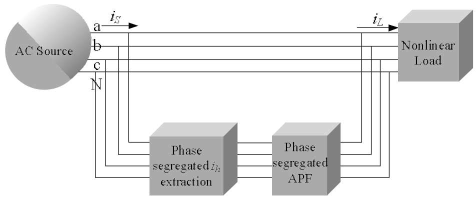


Fig.1 The proposed Phase-segregated algorithm

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

$$i_0 = i_a + i_b + i_c \tag{1}$$

Then zero sequence current i_0 can be eliminated as,

$$\begin{cases} i_a' = i_a - i_0 \\ i_b' = i_b - i_0 \\ i_c' = i_c - i_0 \end{cases} \tag{2}$$

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.

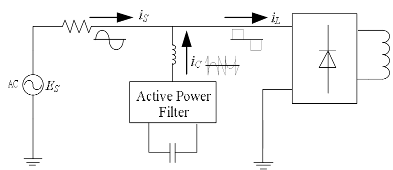


Fig.2. Single phase diagram of a power system with APF

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.

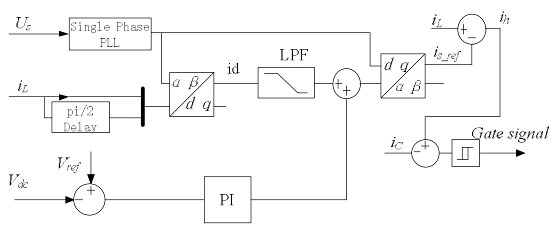


Fig.3 Active Power filter control block

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_{s_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.

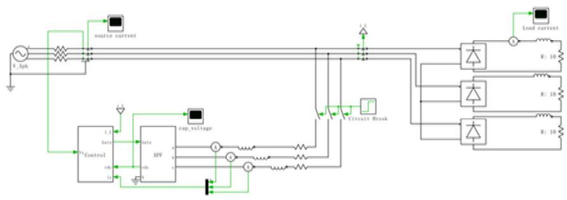


Fig. 4 Active Power Filter Simulation Circuit

Table 1 Simulation Parameters

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

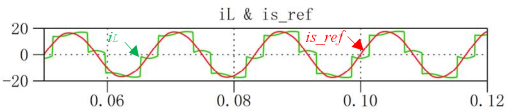


Fig.5 Load current and reference source current

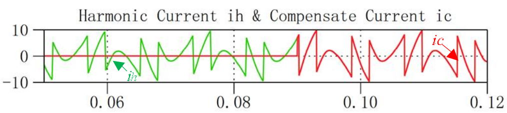
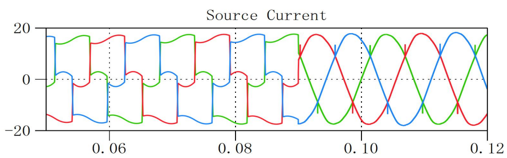


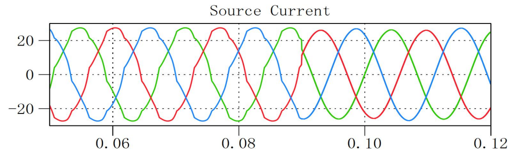
Fig.6 Harmonic current & compensate current

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.



a. L : 190 mH R: 10 ohm

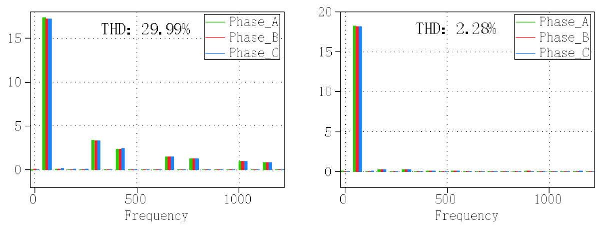


b. L: 10 mH R: 10 ohm

Fig.7 Source current waveforms

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).



a. Before APF compensation b. After APF compensation

Fig.8 Frequency analysis of Source current

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

[1] Rukonuzzaman, M.; Nakaoka, M., "Single-phase shunt active power filter with harmonic detection," Electric Power Applications, IEE Proceedings - , vol.149, no.5, pp.343,350, Sep 2002

[2] Montero, M.I.M.; Cadaval, E.R.; Gonzalez, F.B., “Comparison of Control Strategies for Shunt Active Power Filters in Three-Phase Four-Wire systems,” Power Electronics, IEEE Transactions on, vol.22, no.1, pp.220,236, Jan. 2007