DECENTRALISED POWER ACTIVE FILTERS

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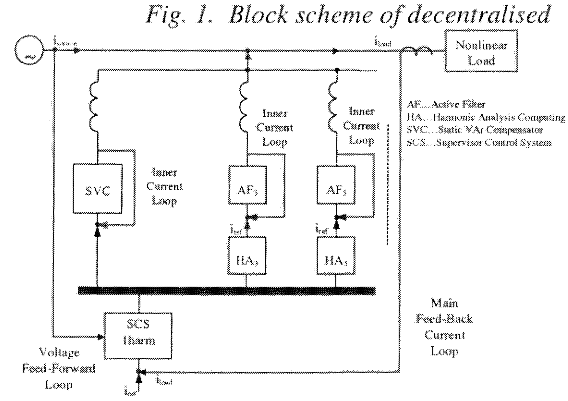
Summary This paper deals with a decentralised power active filter control based on the separated computation of reference currents for each active filter operating under determined harmonic frequency. The basic principle of such controlled active filter is explained. It is shown how the nth harmonic component of the reference current can be calculated. Simulation results are shown on the end of the paper.

1. INTRODUCTION

Power systems have been using power converters. Power semiconductor converters work in switching mode and therefore they are sources of higher harmonic components of the current and voltage in distribution systems. These ones cause the electromagnetic interference of the low voltage systems. Passive filters are not very sufficient in this case because the switching frequency of a converter usually vary.

Active filters consists of power electronics and a source of energy (active part of the filter) and hence they are able to keep up with any changes in switching frequency of a converter. They can not limit sources of higher harmonics. They are only able to filter higher harmonics components of voltage and current near the place of their generation and can ensure, that higher harmonic components of current and voltage will not be transmitted through the distribution systems. Only harmonic component caused by switching frequency of active filter occurs. The switching frequency is kept constant and for this reason this higher harmonic component can be filtered by a passive filter.Active filters represent big benefit by means of energy saving. Active filters, which have been used recently, compensate only power factor and lower harmonic components of load current because of the underage computational capacity of the microcomputer and because of the power electronic losses limitation. Active filter controlled based on separated computation of reference currents for each active filter, operating under determined harmonic frequency, is able to compensate higher number of harmonic components of load current. This is the main advantage of such controlled active filter, because each harmonic component of load current is compensated by their own active filter. So, the whole power of active filter is spread out into some active filters of smaller power. The best solution of control of a such system is that each partial active filter is tuned for certain expressed harmonic component [1], [3], see Fig. 1. This solution brings two main advantages: better reliability, because the failure of one converter will not significantly affect the functionality of whole active filter, and smaller switching losses due to reduced PWM modulation of partial converters. It is also very important the dynamic properties of such a system, which are strongly dependent on control strategy.

Fig. 1. Block scheme of decentralised



power active filter system.

2. CLASSIFICATION OF ACTIVE FILTERS

Active filters can be in common divided into two groups: series active filters and parallel active filters. There is a principal block diagram of the parallel active filter on Fig. 2 that is very frequently used in practical applications. Parallel active filter is directly connected to the line conductors. It senses load current and consequently compensates its higher harmonic components to ensure a harmonic current consumption from the net. Parallel active filter is dedicated to compensate the consumption of fully controlled converters with an inductive load, of cycloconverters and for reactive power compensation.

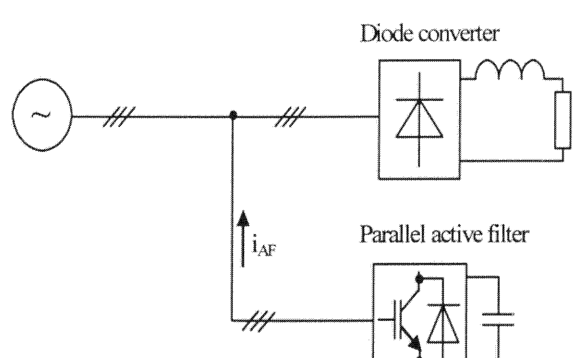


Fig. 2. Block scheme of parallel active filter.

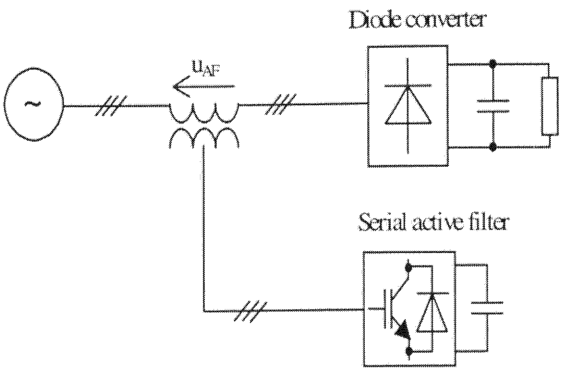


Fig. 3. Block scheme of serial active filter.

Fig. 3 shows the block diagram of series active filter. Series active filter is connected through a transformer to the net and it senses the voltage. This one is dedicated to compensate the consumption of the uncontrolled converters with capacitive load of higher volume, possibly for voltage regulation.

It should be noted that there is one more group of active filters. They are known as hybrid filters and they are given as combination of active and passive filters. The reasons for this kind of filter utilisation are: efficiency increasing and capital costs decreasing. The advantages and disadvantages of hybrid filters depend on the specific application.

3. PRINCIPLE OF OPERATION

Unlikely [1], [3], of the solution proposed in paper supposes distributed two level control with parallel computation algorithms. The tasks of level 1 control circuit are: 1st harmonic determination for power factor compensation, main (master) control loop control, and also supervisor control of partial active filters for failure states. The task of level 2 control circuit are similar: each partial control circuit of level 2 calculates the corresponding harmonic component (3rd -, 5th -, 7th – ones) and provides local slave current loop control, see Fig. 4.

The operation of both level 1 and level 2 control circuits is the parallel one. Besides this the Fourier harmonic analysis is executing in stationary α,β-reference frame in state-space with 4-side symmetry (in case of single-phase system) or 6-side symmetry (in case of three-phase system), respectively [2], [6], [7].

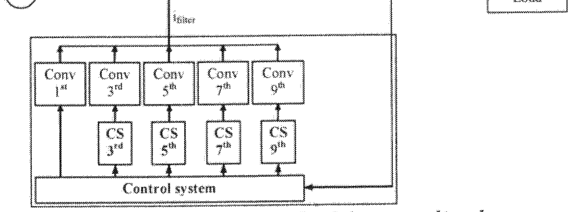


Fig. 4. Distributed control of decentralised power active filter system.

4. ORTHOGONAL TRANSFORM FOR SINGLE-PHASE SYSTEM

Completing harmonic function by its orthogonal component the complex exponential function can be obtained as [8]:

$$\cos(\omega t) \rightarrow \exp(j.\omega t) = \cos(\omega t) + j.\sin(\omega t) \quad (1)$$

This approach can be also used for non-harmonic functions:

$$\Sigma\cos(\omega t+\varphi) \rightarrow \Sigma\exp(j.\omega t+\varphi), \text{ etc.} \quad (2)$$

Based on four-side symmetry of the trajectory in the complex plane the orthogonal co-ordinates of the quantities can be generally defined:

$$X(j\omega t) = K[x(t) + x(t).\exp(j\pi/2)] \quad (3)$$

thus (for K = 1)

$$u_\alpha = u(t) \text{, respectively } u_\beta = u(t - T/4) \quad (4)$$

similarly

$$i_\alpha = i(t) \text{ and } i_\beta = i(t - T/4) \quad (5)$$

and similarly for any quantities. Note, that added second phase is just fictitious, imaginary one.

5. REFERENCE CURRENT DETERMINATION USING FOURIER ANALYSIS FOR nth HARMONIC

Complex Fourier coefficient for the nth harmonic can be now defined within one fourth of period:

$$C_n = \frac{4}{T}\int_0^{\frac{T}{4}} x(t).e^{-jn\omega t}\,dt \quad (6)$$

The magnitude and phase shift of the nth harmonic component of any quantity $x(t)$ is then:

$$C_n = \sqrt{(C_{n\alpha}^2 + C_{n\beta}^2}\ ,\ \varphi_n = \arctan\frac{C_{n\beta}}{C_{n\alpha}} \quad (7a,b)$$

where the nth harmonic components are:

$$C_{n\alpha} = \frac{4}{T}\int_0^T (x_\alpha(t).\cos(n\omega t) + x_\beta(t).\sin(n\omega t)).dt \quad (8)$$

$$C_{n\alpha} = \frac{4}{T}\int_0^T (x_\beta(t).\cos(n\omega t) - x_\beta(t).\sin(n\omega t)).dt \quad (9)$$

The reference current can be computed as:

$$i_{ref.n} = C_n.\cos\varphi_n.\cos n\omega t \quad (10)$$

6. EXPERIMENTAL RESULTS

The current transients are not important so much due to high current over capability of silicon switches of active filters. But current transients invoke certainly the voltage transient phenomena. The magnitudes of those (are dependent on parasitic inductance of power supply system, leakage inductance of transformers, etc.) are to be very dangerous for static devices. Optimisation (minimum over voltage) of the transients and improved dynamic properties of system can be provided by using of moving average method with computation of reference values in each calculating step[4], [5], [7].

Using of MatLab Power Block Set programming developing environment the simulation experiments (in Fig. 5) has been done. The floating point ADSP 2106x or TMS 320C31 respectively are supposed for real-time operation of decentralised power active filter system. Fig. 5 shows current waveforms of non-linear load, source and active filter under distributed control using parallel computation algorithm and under classical control for a case of the step change of the load current. It can be seen that in the case of parallel control a new steady state appears after 1/4th period whereas in the case of classical control a new steady state appears after one period. This dynamic properties improving approves in voltage transient phenomena.

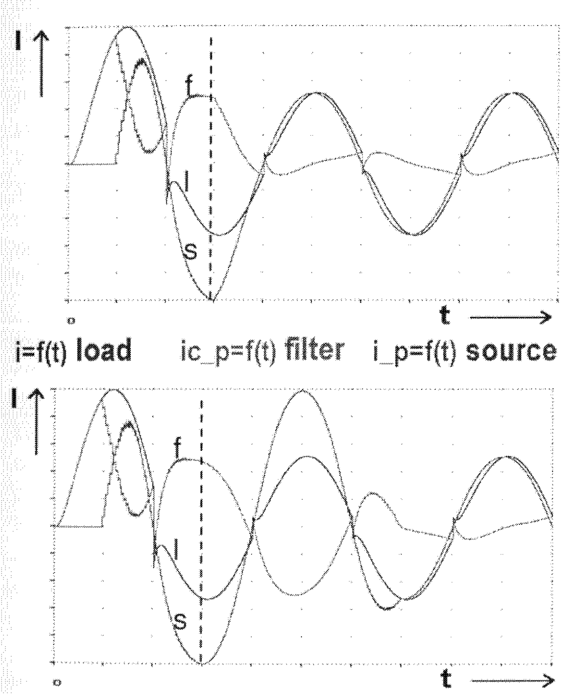


Fig. 5. Current transients a) under distributed control using parallel computation algorithms b) and under classical control.

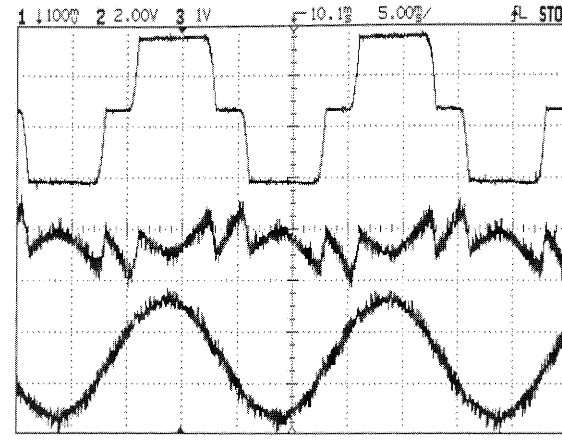


Fig. 6. Experimental results under distributed control using parallel computation algorithms with RL load.

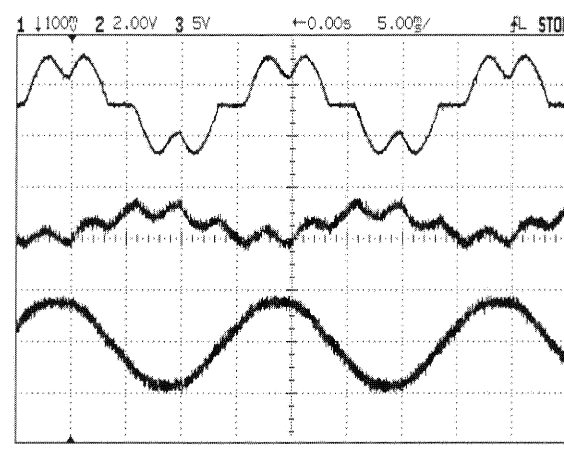


Fig. 7. Experimental results under distributed control using parallel computation algorithms with RC load.

Experimental verification of the simulation results for the modular active power filter are shown in Fig. 6 and Fig. 7. Computations of the reactive and reference currents and the necessary control algorithms would be carried out using of the Texas instruments, TMS320C31 floating point DSP.

7. CONCLUSION

The paper presents basic principles of decentralised active filter. The whole power of active filter is spread out into some active filters of smaller power. Each partial active filter is tuned for certain expressed harmonic component. Main advantages of such controlled active filter are presented in the beginning of this paper. Simulation of such controlled system was performed and obtained results verify these advantages.

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