Application of One-Cycle Control Based on Active Power Filter

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***Abstract*—For the great deal of harmonics and reactive power produced by these non-linear devices, active power filter can effectively compensate.To all alone realize the harmonic component and reactive power compensation,or to compensate both at the same time,the ip-iq detection method is applied in active power filter,according to the ip-iq detection method,the harmonic component and reactive power component are detected from load current, thus provide different target reference signal of compensation.Through theoretical derivat-ion and simulation,this method can separately compensate reactive component and harmonic current,or at the same time compensate harmonic and reactive component.The coalition of one-cycle control and the ip-iq detection method realizes many kinds of goal in compensation, has good stability control,makes the circuit structure simplify,has good compensation effect,and provides the application of the three phases active power filter a new way.**

Keywords-One-cycle control；ip-iq detection method；active power filter

I. INTRODUCTION

Active power filter is a kind of power electronic device,the effect is dynamic harmonic suppression and reactive power compensation.Its compensation characteristics has the advantages of fast response,high controllability and strong adaptability, so people pay close attention to it. The traditional one-cycle control is a kind of nonlinear control method. The basic idea is that in each cycle , forced switching variable mean value is equal or relative to control reference value, so that steady and transient error in a period is automatically eliminated, prior period error can't be brought to the next cycle[1] .But this kind of control method demand that power grid voltage is balanced without distortion, asks to take the DC side voltage for reference and can only compensate the harmonic and reactive compon-ents.In practical industrial applications,active power filter is mainly used for compensating harmonic.Meanwhile, harmonics and reactive component compensation is relatively small.Only compensating the reactive component is less[2][3].

Based on the three-phase three-wire shunt active power filter as the research object,we analyse its basic principle, introduce the basic structure of active filter control system[4][5].One-cycle control technique is adopted in this paper, which takes load current fundamental component or the active component of the fundamental wave as reference signal, combines a method of ip-iq current detection.It can achieve single harmonic compens-ation or compensation of both harmonic and reactive components. Through simulation and experiment, then the validity and feasibility of this method can be proved.

II. APF MAIN CIRCUIT AND CONTROL REFERENCE VALUE SELECTION

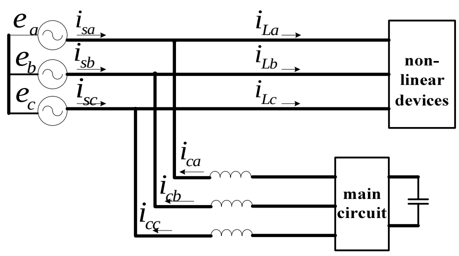


Figure 1. Main circuit of three-phase three-wire shunt APF

Three-phase three-wire shunt active power filter main circuit is as shown in Figure 1.e_a、e_b、e_c respectively represents a、b、c phase supply voltage.i_{sa}、i_{sb}、i_{sc} represents supply current separately.i_{La}、i_{Lb}、i_{Lc} represents the load current separately.i_{ca}、i_{cb}、i_{cc} represents compensating current separately.Speaking simply,its working principle is detecting the harmonic and reactive components by a current detecting circuit,and then through the active power filter,so harmonic and reactive power which is in accordance with grid needs can be generated,thereby the grids only contain the fundamental component[5].

In order to achieve a separate or simultaneous compensation of harmonic and reactive comp-onents,the key is the different selection of reference value,meanwhile the selection of reference value is decided by harmonics and reactive component in the process of current detecting[6].Based on the theory of instantaneous reactive power, current detection method is commonly used in detection of the power network harmonic and reactive components.Figure 2 is measurement schematic of reference value. In the Figure 2, PLL stands for phase-locked loop, with sine and cosine wave generating circuit's help,it can produce sine signal and cosine signal

($\sin\omega t$ and $\cos\omega t$) whose desired phase are same with the phase of A-phase voltage, then we can offer signals to ip-iq transformation.

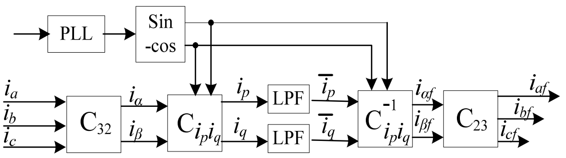


Figure 2. Measurement schematic of reference value

Its basic working principle is as follows : according to the instantaneous reactive power theory[5],we make i_a、i_b、$i_c$currents for 3/2 transformation and p-q transformation to obtain instantaneous active current named i_p and instantane-ous reactive current named i_q and then pass through a low-pass filter LPF, we can get instantaneous active current i_p and instantaneous reactive current i_q DC component.

In the next, through the coordinate inverse transform system i_a、i_b、i_c current fundamental component can be got.This fundamental component at the same time is the reference value of the harmonic and reactive compensating components. When disconnecting the calculating i_q chann-el,fundamental component obtained is reference value when only compensating harmonic.

i_p and i_q formulas are as follows:

$$\begin{bmatrix} i_p \\ i_q \end{bmatrix} = C_{i_pi_q}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = C_{i_pi_q}C_{32}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (1)$$

Fundamental components i_{af}、i_{bf}、i_{cf} calculation formulas are as follows:

$$\begin{bmatrix} i_{af} \\ i_{bf} \\ i_{cf} \end{bmatrix} = C_{23}C^{-1}_{i_pi_q}\begin{bmatrix} \overline{i_p} \\ \overline{i_q} \end{bmatrix} \quad (2)$$

In addition, i_p-i_q current detection method in the situation of electric network voltage waveform distortion or asymmetric,could also be able to detect the harmonic current component accurately.

III. DERIVATION OF ONE-CYCLE CONTROL MODEL

Because of the load current and active power filter compensation current which is generated by active power filter, the system power supply current's available formula is as follows:

$$\begin{cases} i_{sa} = i_{La} + i_{ca} \\ i_{sb} = i_{Lb} + i_{cb} \\ i_{sc} = i_{Lc} + i_{cc} \end{cases} \quad (3)$$

The sum of fundamental component and harmonic component can be regarded as load current,its formula is as follows:

$$\begin{cases} i_{La} = i_{fa} + i_{ha} \\ i_{Lb} = i_{fb} + i_{hb} \\ i_{Lc} = i_{fc} + i_{hc} \end{cases} \quad (4)$$

Combine formula (3) and formula (4)，then we can got:

$$\begin{cases} i_{sa} = i_{fa} + i_{ha} + i_{ca} \\ i_{sb} = i_{fb} + i_{hb} + i_{cb} \\ i_{sc} = i_{fc} + i_{hc} + i_{cc} \end{cases} \quad (5)$$

Compensating the harmonic component of source current, so that the power only concludes the fundamental component.That's the main function of active power filter.Regarded one-cycle control reference value as the fundamental wave component of the tracking load current, then we can get the formula as follows:

$$\begin{cases} i_{fa} - i_{sa} = 0 \\ i_{fb} - i_{sb} = 0 \\ i_{fc} - i_{sc} = 0 \end{cases} \quad (6)$$

The difference above can not be directly used, they need to enlarge K times then can be used as the control reference value, for example:

$$\begin{cases} U_{refa} = k\left(i_{fa} - i_{sa}\right) \\ U_{refb} = k\left(i_{fb} - i_{sb}\right) \\ U_{refc} = k\left(i_{fc} - i_{sc}\right) \end{cases} \quad (7)$$

So we can get the control equation:

$$\begin{cases} \frac{1}{T}\int_0^{d_aT} i_{sa}dt = U_{refa} = k\left(i_{fa} - i_{sa}\right) \\ \frac{1}{T}\int_0^{d_bT} i_{sb}dt = U_{refb} = k\left(i_{fb} - i_{sb}\right) \\ \frac{1}{T}\int_0^{d_cT} i_{sc}dt = U_{refc} = k\left(i_{fc} - i_{sc}\right) \end{cases} \quad (8)$$

Where T is switching cycle,simultaneously is the time constant for integrator;d stands for duty ratio.

When the power current value closes to the reference value,we also realize the control target.

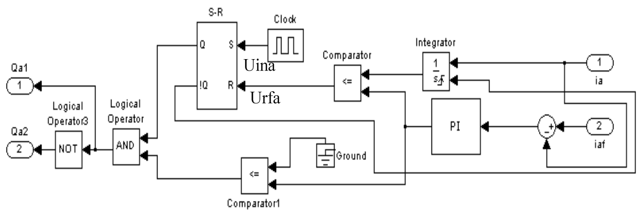


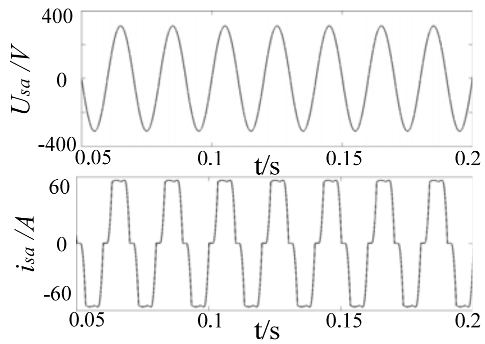
Figure 3. one-cycle control structure diagram

Figure 3 is one-cycle control structure diagram composed by control equation. Take A-phase as an example, the working principle is: when A-phase system current i_{sa} is smaller than the reference current i_{fa}, PI regulator's output U_{rfa} is positive, the signal Q_{a1} is "1", otherwise the signal Q_{a2} is "0".When A-phase current is greater than the reference current i_{fa}, PI regulator's output is negative, signal Q_{a1} is decided by trigger's output signal. At the beginning of each clock cycle, that also is the time when clock pulse arrives, integrator could start to integrate system current i_{sa} until integral value U_{ina} is equal to U_{rfa}, then the output of the comparator flips. Next step a reset signal which is generated by a RS trigger will make the integrator reset. Wait until the next periodic pulse signal arrives, it will repeat one-cycle action mentioned above.

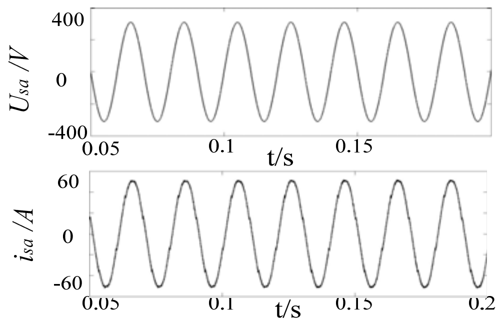
IV. RESEARCH OF SYSTEM SIMULATION

The APF system simulation model is built under the platform of Matlab/Simulink,the simulation parameters are expressed as follows:three-phase three-wire system line voltage is 380V,power frequency is 50Hz,AC reactor equivalent resistance of active power filter is 0.5Ω,the equivalent inductance is 7mH,DC side voltage is 900V,switching frequency in the control system is 10KHz.Taking three-phase uncontrolled rectifier bridge with Resistance-Inductance Load as the harmonic sources, inside, load resistance is 12 Ω, inductance is 48 mH. Following we will analysis and make research on A-phase simulation waveform.

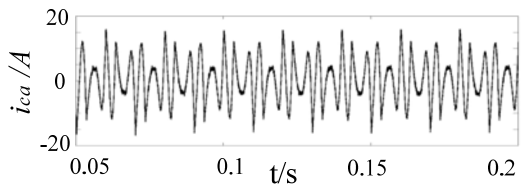
A. The simulation results of only compensating for the harmonic component



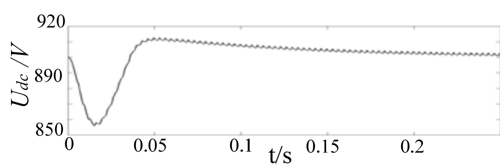
(a)A-phase system voltage and current waveform before the compensation



(b)A-phase system voltage and current waveform after the compensation



(c)A-phase compensating current waveform



(d) DC side voltage waveform

Figure 4. compensating only for the harmonic component simulation result

Figure 4 shows the simulation results of only compensating for the harmonic component, Figure (a) shows the voltage and current waveforms of the pre-compensation system, it can be concluded that before the compensation system voltage is not in distortion. However, the current emerges into distortion seriously due to the impact of the harmonic source. The whole distortion rate of the system current reaches 21.30%. As shown in Figure (b) after active filtering the whole distortion rate of the system current dropped to 2.65%.There is no significant changes in system voltage. Figure (c) shows a compensating current waveform, it can be seen that the basic DC voltage almost stay at 900V.From the several groups of waveform above, it can be seen that the system current have been greatly improved because active filter in single cycle control has filtered a large quantity of current harmonics.

B. The simulation results of both harmonic and reactive component compensation

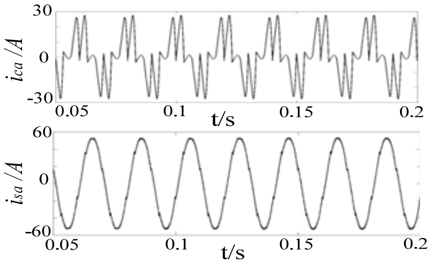


Figure 5. The simulation results of compensation harmonic and reactive component simultaneously

Start the simulation when the simulation conditions and separate harmonic are at the same condition.The Figure 6 shows compensation of both harmonic and reactive component of current waveform, even concludes the compensation of current waveform, the current distortion rate dropped to 3.24% after compensation,current waveform becomes sine wave approximately, and the distortion rate decreases.

V. CONCLUSION

Combine one-cycle control and the the ip-iq current detection based on instantaneous reactive power theory,and put this method into the active power filter applications, there is advantages not only one cycle control's robust is strong,but also compensation effect is superior,and it can compensate harmonics and reactive component flexib-ly.According to the control equation of theoretical derivation,we build MATLAB simulation model.Analysis emulational results,it can be seen the correctness of the theoretical analysis and derivation, then we have achieved the purpose of a flexible compensation,and the compens-ation effect favorable, meanwhile it has certain practical value.

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