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Research on Harmonic Detection Method based on Adaptive Algorithm

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Abstract

Harmonic current detection has become one of the key factors of influencing the function of active power filter. Due to the impact of the low pass filter,the classical ip-iq algorithm has the disadvantage of slow detection speed and low accuracy .In order to improve the accuracy and tracking speed of harmonic current detection ,the paper proposes a variable step-size LMS/LMF adaptive filter algorithm.The adaptive filter can not only change the step size according to the change of original signal, but also change the proportion of the Least Mean Square(LMS) algorithm and the Least Four-order Moment (LMF) algorithm,which makes the advantages of high detection accuracy of LMF and high detection speed of LMS fully played. The simulation and experiment show the validity and feasibility of the method.

Keywords

Harmonic Detection, Adaptive Filter, Variable Step LMS/LMF Algorithm, Ip-iq Algorithm.

1. Introduction

With the rapidly development of the power system, the use of many power electronic devices has brought vast harmonics into the power system, which has seriously affected the power quality. There are two ways to solve the harmonic problems caused by power electronic devices :one is to improve the structure of the power electronic equipment to minimize the harmonics; the other is to increase the harmonic suppression equipment by using active filter, thus compensating the generated harmonic.

The accuracy and speed of harmonic detection are fully important research indexes of active filter. Due to the influence of the low pass filter, the traditional $i_p - i_q$ harmonic detection algorithm has the problems of slow response and poor detection accuracy. The literature [1] and[2]uses an LMS algorithm with variable step, which is used to replace the influence of low pass filter. When the speed of change is fast, it adopts a longer step, otherwise the step is taken longer. But its dynamic response is still slow. The literature [3] and [4]propose a LMS(Least Mean Square) algorithm, which takes step to a constant value and use the minimum mean square error (mse) as a basis for the adjustment of the whole. However, its speed of dynamic response and precision is hard to arrive. In order to deal with these problems, this paper proposes a variable step size LMS/LMF adaptive filter algorithm and derives its formulas.

This paper includes three parts. Firstly, it makes a detailed state for the traditional harmonic detection algorithm, which involves the control principle and formulas derivation; Next, a improved harmonic detection algorithm based on LMS algorithm is proposed; Finally, the paper compares and analyzes the traditional and improved harmonic detection in tracking speed and detection accuracy through the MATLAB Simulation .Simulation verification proves that the proposed algorithm is reliable and the speed of harmonic current detection has improved greatly.

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2. Traditional harmonic detection algorithm

Three-phase instantaneous reactive power theory is a scientist by Japan in the 1990 s, thus, the harmonic detection algorithm proposed greatly contributed to the popularization and development of the active filter. The principle is shown in the figure below.

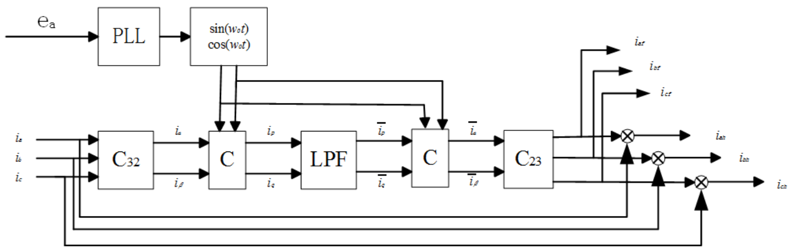

Fig. 1The harmonic detection algorithm based on instantaneous reactive power theory

Three phase current $\mathrm{i_a}, \mathrm{i_b}\ \mathrm{i_c}$ after C_{32} transform, transform into vector coordinates $\mathrm{i}_\alpha\ \mathrm{i}_\beta$.

$$C_{32} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \tag{1}$$

After the transformation of C, it can obtain the three phase instantaneous reactive current $\mathrm{i_q}$ and three-phase instantaneous active current $\mathrm{i_p}$

$$C = \begin{bmatrix} \sin\omega t & -\cos\omega t \\ -\cos\omega t & -\sin\omega t \end{bmatrix} \tag{2}$$

The three phase instantaneous reactive current $\mathrm{i_q}$ and active current $\mathrm{i_p}$ include dc and ac components. when Low-pass filter filters to the ac component, you can get direct current component of the three-phase instantaneous reactive current $\mathrm{i_q}$ and active current $\mathrm{i_p}$, through C, C_{23} transform, finally can get the fundamental component $\mathrm{i_{af}}, \mathrm{i_{bf}}, \mathrm{i_{cf}}$ of three phase current $\mathrm{i_a}, \mathrm{i_b}, \mathrm{i_c}$.

$$\begin{bmatrix} i_{af} \\ i_{bf} \\ i_{cf} \end{bmatrix} = \sqrt{\frac{2}{3}} C_{23} \begin{bmatrix} \sin\omega t & -\cos\omega t \\ -\cos\omega t & -\sin\omega t \end{bmatrix} \begin{bmatrix} \bar{i}_p \\ \bar{i}_q \end{bmatrix}$$

$$\frac{2}{3}\begin{bmatrix} \sin\omega t & \cos\omega t \\ \sin(\omega t - 2\pi/3) & \cos\omega t \\ \sin(\omega t + 2\pi/3) & \cos(\omega t + 2\pi/3) \end{bmatrix} \begin{bmatrix} \bar{i}_p \\ \bar{i}_q \end{bmatrix}$$

The above is the harmonic detection principle of ip - iq algorithm based on instantaneous reactive theory. Traditional ip - iq harmonic detection algorithm is affected by low-pass filter, leading that the harmonic detection is relatively slow, while the changes of c load can't accuracely track the change

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of the load current, that causes the harmonic detection inaccurateand has a big influence on the accuracy and speed of the active power filter.

3. Improved harmonic detection algorithm

The principle of adaptive filter is shown in figure 2. Figure I (n) is the input current component, e(n) is the error signal, x(n) is the reference input signal, wk(n) is the weight value coefficient, y(n) is the output signal, and the weight factor's adjustment adopts the fixed-step LMS algorithm.

Based on the above traditional LMS algorithm, the LMS/LMF algorithm is used to adjust the weight coefficient of the adaptive filter to improve the accuracy and speed of the adaptive filter.

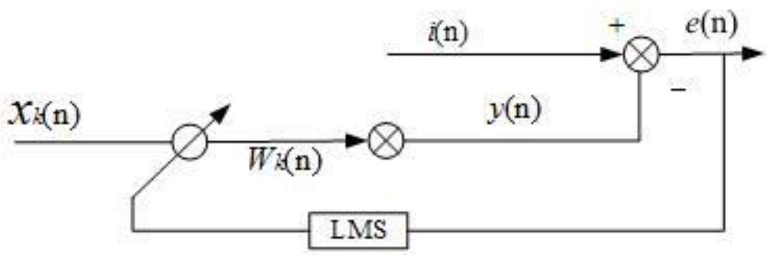

Fig.2 The adaptive filter algorithm based on LMS algorithm basic diagram

The basic principles of the algorithm are: When the original signal of the adaptive filter is changed, the whole system mainly adopts LMF algorithm, and adopts the coefficient of long length to adjust weight, which causes a good dynamic response speed. When the input signal of the whole system tends to be stable, LMS algorithm and the weight coefficient of the smaller step factor are adopted in the whole system, which has better detection accuracy. So we can suppose the algorithm adjustment function

$$L_n = (1 - r_n)E(e_n{}^2) + r_n E(e_n{}^4) \tag{3}$$

It can be seen that when rn is equal to 1, the whole system use the LMF algorithm. When rn is equal to 0, the whole system adopts LMS algorithm. Gradient update weight coefficient wk (n), then:

$$w_k(n+1) = w_k(n) - u(n)\frac{\partial J_n}{\partial w_n} \tag{4}$$

The formula of the right value renewal is:

$$w_k(n+1) = w_k(n) + 2u(n)\left[(1 - r_n) + 2r_n e_n{}^2\right]e_n x_k(n) \tag{5}$$

The adjustment of step factor is adopted by hyperbolic tangent function:

$$u(n+1) = \beta(n)[1 - \frac{m+1}{m + \exp(\alpha[p(n)^2])}] \tag{6}$$

$$p(n) = rp(n-1) + (1-r)e(n)e(n-1) \tag{7}$$

$$\beta(n+1) = \xi\beta(n) + \eta p^2(n) \tag{8}$$

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At the bottom of the hyperbolic tangent function waveform changes quickly, which makes the error signal close to zero in the larger changes, the introduction of coefficient m can improve the bottom of function waveform, and make the error signal in close to zero changing more smoothly.

The adjustment factor rn was updated by means of normalization method and memory factor.

$$r_n = a_1 p_n^{\ 2} + a_2 r_{n+1} \tag{9}$$

$$p_{n+1} = \beta p_n + k(1-\beta)\frac{e(n)e(n-1)}{\left|i(n)i(n-1)\right|} \tag{10}$$

The a1, a2, β and k in the upper formula are all memory factors, indicating degree of influence to the past errors and the current to achieve the adjustment of LMS and LMF share. The above formula (3) to formula (10) constitutes a new LMS/LMF algorithm. For the stability of the algorithm, the values of u(n) and r(n) need to be restricted.

$$u(n) = \begin{cases} u_{\max} & u > u_{\max} \\ u_{\min} & u < u_{\min} \\ u & \text{else} \end{cases} \tag{11}$$

$$r_n = \begin{cases} r_{n\max} & r_n > r_{n\max} \\ r_{n\min} & r_n < r_{n\min} \\ r_n & \text{else} \end{cases} \tag{12}$$

4. Simulation verification

In order to verify the function of the above algorithm, the simulation model is established to verify the function. we need to build the model in the simulink module of MATLAB, which uses the three-phase bridge uncontrollable rectifier circuit as the load. When the load is mutated, Figure 3 is the traditional IP - IQ algorithm used to detect the harmonic detection results, its speed of harmonic detection is slower, and about 1.5 periods can keep up with the change of system load quickly.

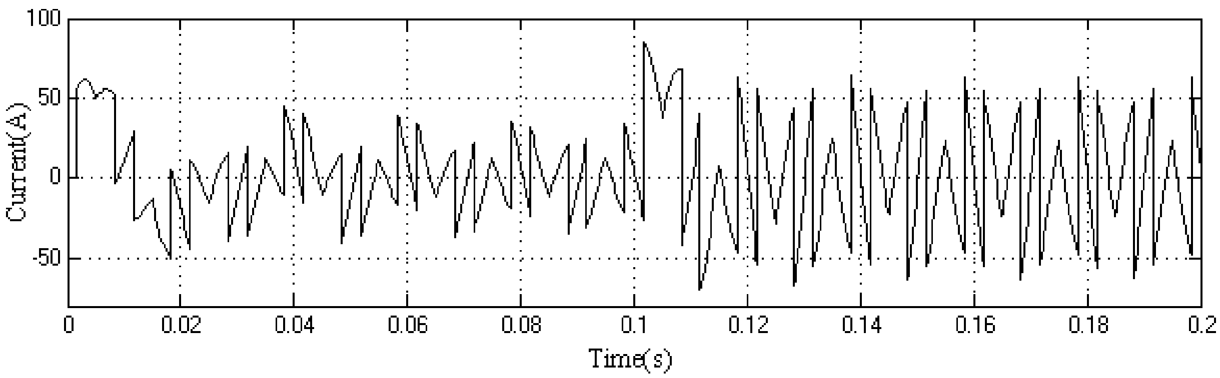

Fig 3. The simulation mutated load harmonic current result of the harmonic current detection method based on the ip-iq algorithm

When the load is not mutation, figure 4 is based on the traditional algorithm of harmonic current detection of ip-iq results, due to the influence of the low-pass filter, its speed of detection is slow, Only thorough 1.5 cycles can it be stable.

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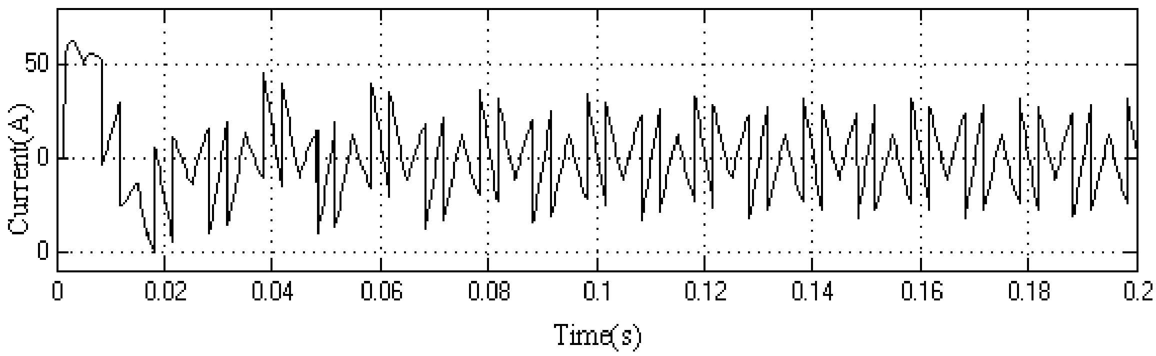

Fig 4. The simulation constant load harmonic current result of the harmonic current detection method based on the ip-iq algorithm

Fig. 5 is the harmonic detection effect of the modified ip-iq algorithm. The harmonic detection speed is obviously improved, and the tracking speed of the load is improved obviously when the load changes.

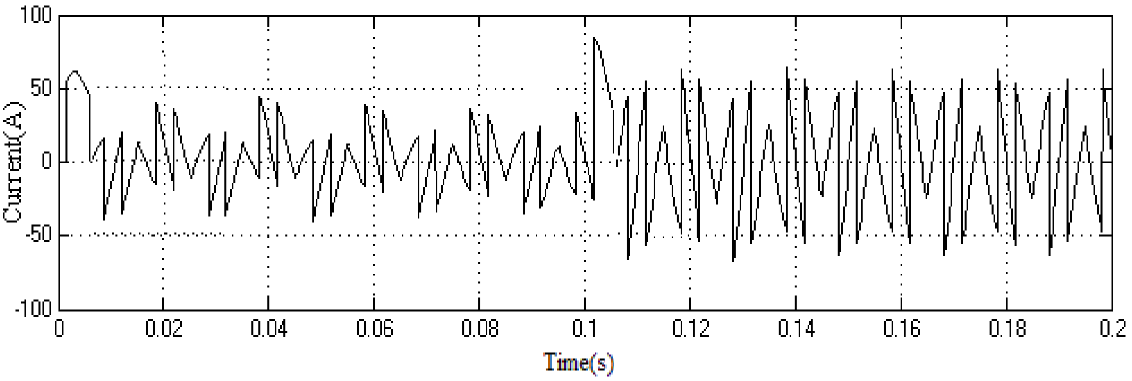

Fig 5. The simulation mutated load harmonic current result of the harmonic current detection method based on the improved ip-iq algorithm

Fig 6 is for the results of harmonic current detection based on the modified ip-iq algorithm and it uses adaptive filter based on variable step size LMS/LMF algorithm, the detection speed has an obvious improve, and needs only 0.5 cycles to keep up stable.

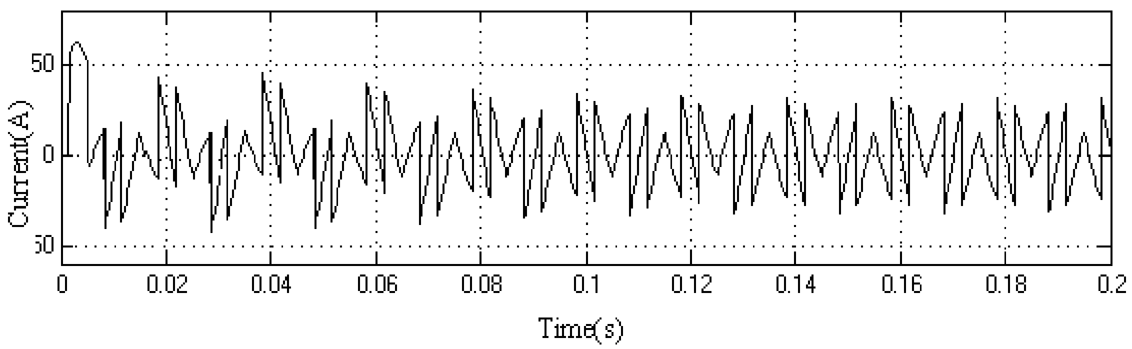

Fig 6. The simulation constant load harmonic current result of the harmonic current detection method based on the improved ip-iq algorithm

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5. Conclusion

Due to the influence of low- pass filter, the traditional IP - IQ harmonic detection speed and detection accuracy are poor. In this paper, an improved harmonic detection algorithm is proposed, which adopts a adaptive filter based on the variable step LMS/LMF algorithm, and replaces the traditional low-pass filter to filter the ac component. On the basis of it, we carry out the simulation verification, the simulation results show that the proposed algorithm is reliable and effective, which can effectively solve the problem of response speed and precision of traditional IP - IQ the algorithm and have certain engineering application value.

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