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Comparison and Analysis on Two Improved Detecting Methods for Harmonics without PLL in Single-phase Circuit

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Key words: phase-locked loop(PLL); low-pass filter(LPF); feedback; average theory; harmonics; detecting; single-phase circuit;

Abstract. In order to reduce the error of the phase-lock-loop(PLL) and compensate the delay of the low pass filter on harmonics detection, In the paper, a detecting-method without PLL in single-phase circuit is researched. In this method, the PLL and LPF are omitted, the feedback and average theory are used, so that the problem of detecting accuracy induced by PLL and real-time induced by LPF is solved. It is testified through comparison, analysis and simulation, that both methods can reduce the latency, improve dynamic response speed, the feedback method can reduce the delay in a dynamic, continuous process, while the average theoretical method can reduce the delay quantitatively.

Introduction

It is a tendency to restrain harmonics by active power filter. The real-time detecting for harmonics is one of the key technologies

But in current methods, PLL and LPF are used. When the frequency of electric voltage shifts, PLL may cause incorrectly detecting. Meantime, LPF brings some time delay.

A detecting method for harmonics without PLL in single-phase circuit is provided in this article. In this method, PLL is deleted, so, when the voltage of electric network changes and the frequency shifts, harmonics still can be detected accurately; the average theory is introduced to increase the speed of dynamic response and real-time detection, which cut down the delay-time to T/2; current feedback is introduced to increase the speed of dynamic response and compensate the delay-time of LPF. It is testified through comparison and analysis, both methods can detect harmonics timely and accurately with simple calculation.

Principle of the detecting method for harmonics without PLL in single-phase circuit

Suppose u_s and i_s change and fundamental frequency shifts, extended by Fourier's series:

$$u_s = U_1 \sin(\omega' t + \phi_1) + \sum_{n=2}^{\infty} U_n \sin(n\omega t + \phi_n) = u_1 + u_h \tag{1}$$

$$\begin{aligned} i_s &= I_1 \sin(\omega' t + \varphi_1) + \sum_{n=2}^{\infty} I_n \sin(n\omega t + \varphi_n) \\ &= I_1 \cos(\phi_1 - \varphi_1)\sin(\omega' t + \phi_1) + I_1 \sin(\phi_1 - \varphi_1)\cos(\omega' t + \phi_1) + \sum_{n=2}^{\infty} I_n \sin(n\omega t + \varphi_n) \\ &= i_{1p} + i_{1q} + i_h = i_1 + i_h \end{aligned} \tag{2}$$

In formula (1), both sides of voltage u_s multiply $\sin(\omega t+\theta)$

$$\begin{aligned} u_s\sin(\omega t+\theta) &= \frac{U_1}{2}\cos[(\omega^{'}-\omega)t+\phi_1-\theta]-\frac{U_1}{2}\cos[(\omega^{'}+\omega)t+\phi_1+\theta] \\ &+\sum_{n=2}^{\infty}\frac{U_n}{2}\{\cos[(n-1)\omega t+\phi_n-\theta)]-\cos[(n+1)\omega t+\phi_n+\theta]\} \end{aligned} \tag{3}$$

Because the deference of $\omega^{'}$ and ω is tiny, and LPF in practical is generally needed to set a lower frequency, the currents above cutoff frequency are all filtered out. So, after filtering and enlarging, we can get $U_1\cos[(\omega^{'}-\omega)t+\phi_1-\theta]$, then,

$$U_1\cos[(\omega^{'}-\omega)t+\phi_1-\theta]\sin(\omega t+\theta)=\frac{U_1}{2}\sin(\omega^{'}t+\phi_1)+\frac{U_1}{2}\sin[(2\omega-\omega^{'})t-\phi_1+2\theta] \tag{4}$$

Similarly, after both sides of u_s multiply $\cos(\omega t+\theta)$ and filtering, we can get $U_1\sin[(\omega^{'}-\omega)t+\phi_1-\theta]$, when it multiply $\cos(\omega t+\theta)$, then,

$$U_1\cos[(\omega^{'}-\omega)t+\phi_1-\theta]\cos(\omega t+\theta)=\frac{U_1}{2}\sin(\omega^{'}t+\phi_1)-\frac{U_1}{2}\sin[(2\omega-\omega^{'})t-\phi_1+2\theta] \tag{5}$$

Formula (4) plus (5), we can get

$$u_1=U_1\sin(\omega^{'}t+\phi_1) \tag{6}$$

As the same, we get

$$i_1=I_1\sin(\omega^{'}t+\varphi_1) \tag{7}$$

Also because

$$\cos(\phi_1-\varphi_1)=\cos[(\omega^{'}-\omega)t+\phi_1-\theta]\cos[(\omega^{'}-\omega)t+\varphi_1-\theta]+\sin[(\omega^{'}-\omega)t+\phi_1-\theta]\sin[(\omega^{'}-\omega)t+\varphi_1-\theta]$$

Integrating formula (2), (6), (7), we get

$$i_{1p}=\frac{U_1I_1\cos(\phi_1-\varphi_1)}{U_1^2}u_1=I_1\cos(\phi_1-\varphi_1)\sin(\omega^{'}t+\phi_1) \tag{8}$$

$$i_{1q}=-\frac{U_1I_1\sin(\phi_1-\varphi_1)}{U_1^2}u_1=-I_1\sin(\phi_1-\varphi_1)\sin(\omega^{'}t+\phi_1) \tag{9}$$

$$i_h=i_s-i_1 \tag{10}$$

In the formulas, U_1^2 is calculated by $U_1\cos[(\omega^{'}-\omega)t+\phi_1-\theta]$, $U_1\sin[(\omega^{'}-\omega)t+\phi_1-\theta]$.

From formulas (8), (9), (10), we can find θ of $\sin(\omega t+\theta)$, $\cos(\omega t+\theta)$ have no impact on the detection, that is, θ can be any value. And also fundamental frequency of the detected signals is generally fundamental frequency of electric network, so, ω can be set directly. Thus, the signals $\sin(\omega t+\theta)$, $\cos(\omega t+\theta)$ can be gotten by signal generator.

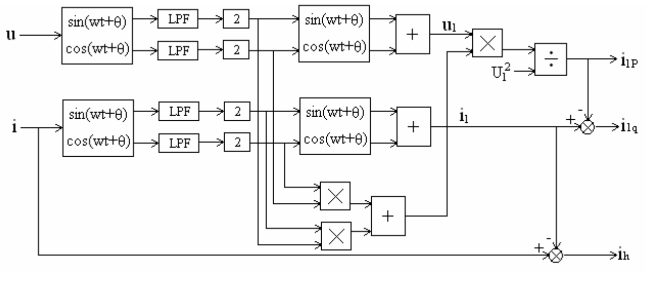


Fig.1 Principle structure of detecting method

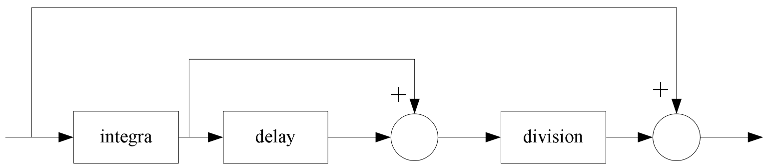


Fig.2 Average theory principle structure

Improving of the detecting methods

Improving on average theory

On formula (3), as the difference between $\omega^{'}$ and ω is tiny, then

$$\frac{2}{T}\int_{t-T/2}^{t}\cos[(\omega'-\omega)t+\phi_1-\theta]dt \approx \cos[(\omega'-\omega)t+\phi_1-\theta]$$

$$\frac{2}{T}\int_{t-T/2}^{t}\cos[(\omega'+\omega)t+\phi_1-\theta]dt \approx 0$$

$$\frac{2}{T}\int_{t-T/2}^{t}\cos[(n-1)\omega t+\phi_1-\theta]dt = 0$$

$$\frac{2}{T}\int_{t-T/2}^{t}\cos[(n+1)\omega t+\phi_1-\theta]dt = 0$$

This shows, $U_1\cos[(\omega^{'}-\omega)t+\phi_1-\theta]$ can be get when formula(3)is integral after averaging. So the filter is omission and the integral delay is cut down to T/2.

Improving on feedback theory

In figure3, fundamental current feedback is introduced. When fundamental current becomes larger, because of the low-pass filter, the detecting fundamental current are smaller than the real value. Thus harmonics include the same phase components of the fundamental current, feedbacks to the input to make the detected fundamental current larger, which compensates the detecting error in the procedure and increases the speed of dynamic response.

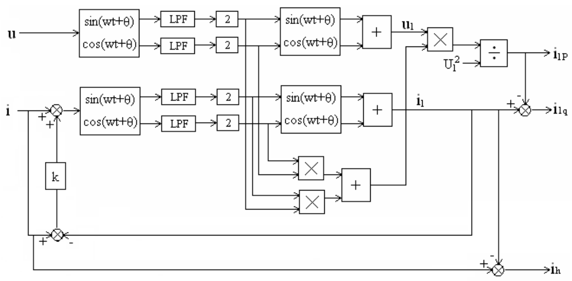


Fig.3 Principle structure of detecting method based on feedback theory

Comparison between the two improved methods

By introducing feedback and average theory, two improved methods are able to cut down the delay-time, improve the speed of dynamic response. Feedback method cuts down the delay-time in a dynamic constant adjusting and compensating procedure; while average method can cut down the delay-time to T/2 quantitatively.

Simulation and analysis

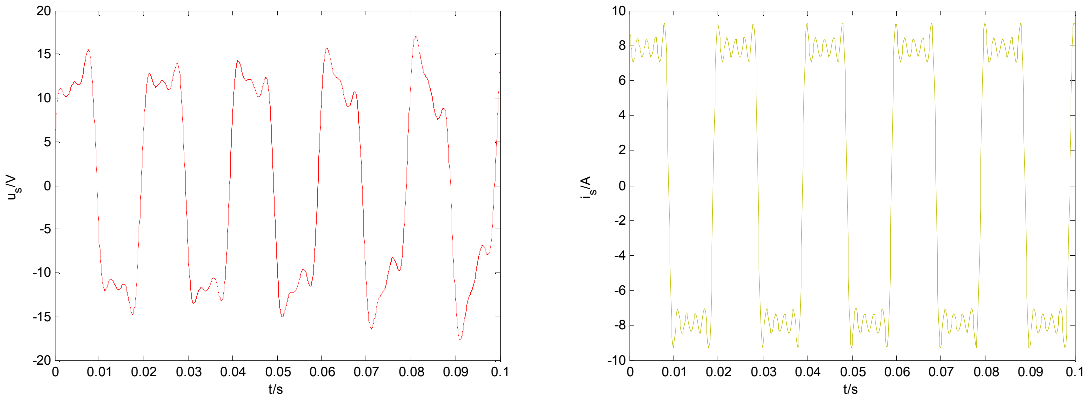
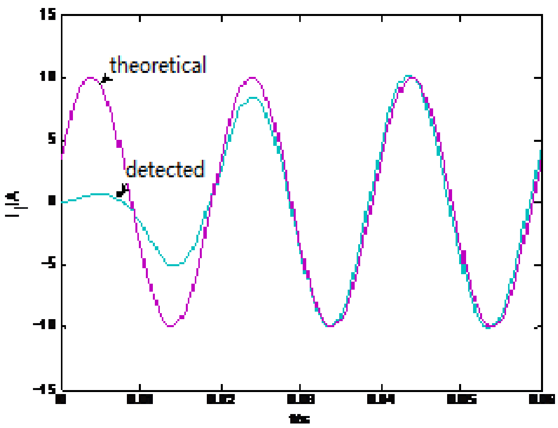


Fig.4 Electric network voltage, current

Suppose u_s is distortion and the fundamental frequency is deviation,and i_s include 3,5,7,9,11 harmonic, these are showed on figure 4.

Simulation and comparison between methods with or without PLL

From figure 5 and 6, the accuracy of method without PLL is better.



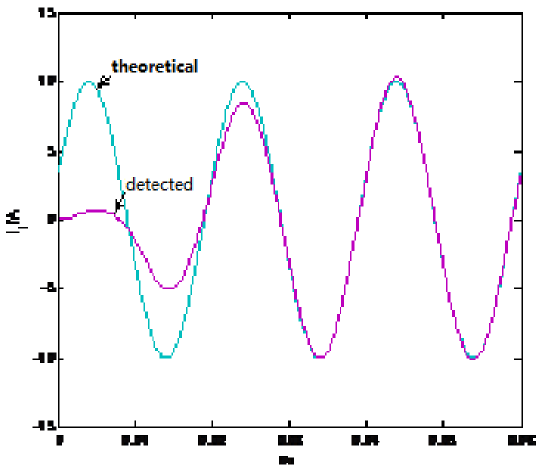


Fig.5 Detected fundamental current with PLL Fig.6 Detected fundamental current without PLL

Simulation and comparison of the two improved methods

The figure7 shows the time of dynamic response of the detecting method before improving is about a cycle.

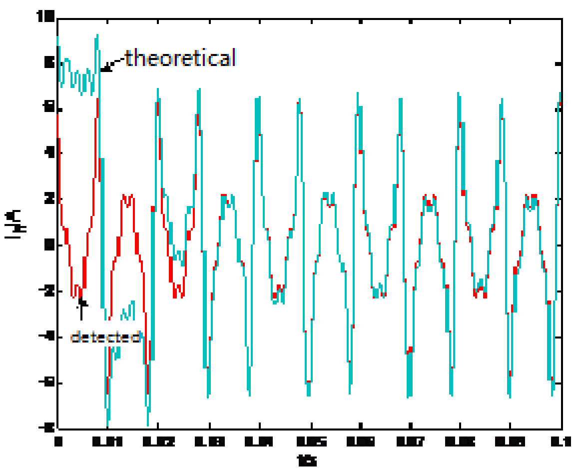


Fig.7 Detected harmonics before improving

The figure8 shows the time of dynamic response is about half of a circle after introducing average theory. The figure9 shows the time of dynamic response is about half of a circle after introducing the feedback theory.

Conclusion

A detecting method for harmonics without PLL is offered and improved in this paper. The method gets rid of the low-pass filter and introduces the fundamental current feedback and average theories, which solves the influence of PLL to detected accuracy, increases the speed of dynamic response, and compensates the delay-time of the low-pass filter. Illustrated by the theoretic and simulating analysis and comparison, the average method is able to cut down the delay-time quantitatively, while feedback method cuts down the delay-time in a dynamic constant adjusting procedure.

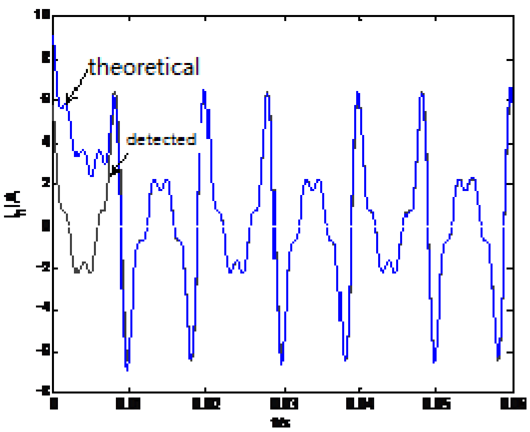


Fig.8 Detected harmonics after introducing average theory

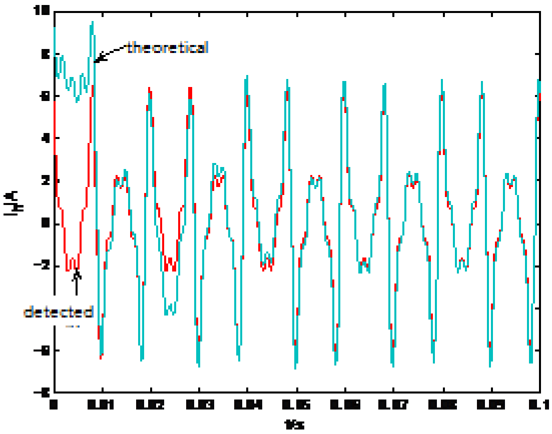


Fig.9 Detected harmonics after introducing feedback method

Reference

[1] Zhang Jue-sheng, Zheng Ji-yu, Wang Xin-ping. Lock technology. Xidian university press, 1994:1-18.

[2] Ren Yong-feng, Li Han-shan, He Gang, Ren Hai-long. The Analysis of Two Real-Time Detecting Approach of Instantaneous Harmonics and Reactive Currents In Single-phase Circuit [J]. Proceedings of the CSU-EPSA, 2003,15(1):95-98.

[3] Sun Shu-guang, Wang Jing-qin, Shi Shun-quan. The Study of Real Time Detection for Harmonics and Reactive Currents In Single-phase Circuit[J]. Electrical Measurement and Instrumentation. 2008, 1(45): 4-7.