단상 계통연계 운전을 위한 다양한 PLL 기법의 성능 평가

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Performance Evaluation of Various PLL Techniques for Single Phase Grids

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Abstract

In order to evaluate the response of the grid-connected systems, Phase lock technology is widely used in power electronic devices to obtain the phase angle, amplitude, and frequency of the grid voltage because phase locked loop (PLL) algorithms are very important for grid synchronization and monitoring in the grid connected power electronic devices. This paper presents a performance evaluation in tracking grid angular frequency through single phase synchronization techniques which are an enhanced PLL (EPLL), second-order generalized integrator-PLL (SOGI-PLL), and second-order generalized integrator-frequency locked loop (SOGI-FLL). These techniques are properly analyzed through several steps to get the best technique which can track the frequency accurately and smoothly.

I. Introduction

In grid-connected converters, the phase, amplitude, and frequency of the utility voltage are vital information for monitoring the performance of a grid-connected system. It is a well known fact that the power can be effectively transferred between two sources only if their frequencies are matched. Typically, a phase locked loop (PLL) [1] is employed for the purpose of tracking grid frequency. The PLL structure is a feedback control system that automatically adjusts the phase of a locally generated signal to match the phase of an input signal.
The basic PLL is comprised of the phase detector (PD), loop filter (LF), and voltage-controlled oscillator (VCO), as shown in Fig. 1. In this paper, we investigate the performance evaluation of various PLL techniques to estimate the grid frequency.

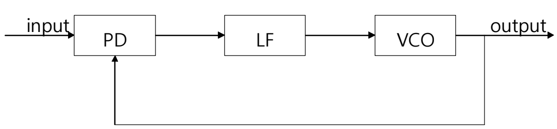

Fig. 1. Basic structure of PLL

2. Enhanced PLL

The block diagram of the EPLL is shown in Fig. 2. This PLL is based on the theory of self-adaptive filtering. Unlike the PD unit of the common PLL which has only one multiplier, the PD unit of the EPLL [4] is composed of three multipliers, an integrator, a $90°$ phase shifting unit, and a comparing unit.

The EPLL can rebuild the frequency, amplitude, and phase of the input signal, and thus, remove the interfering components from the ideal sinusoidal component of the testing signal, which realizes the function of the self-adaptive filtering. The PI gains are used to control the convergence rate of the amplitude where k_P and k_I adjust the dynamic property of the loop. Also, the response speed and filtering performance need to be compromised when the parameters are tuned. Thus, the signal errors are completely cancelled out by self-adaptive filtering, and the input signal angular frequency and phase angle are detected properly.

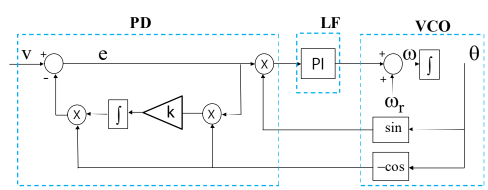

Fig. 2. Block diagram of the single-Phase Enhanced-PLL

3. Second-Order Generalized Integrator-PLL

A SOGI is an orthogonal signal generation system, which is shown in Fig. 3. In this figure, v' is in phase with the input signal v, qv' is $90°$ phase shift with signal v. Tuning the gain K can change the filtering performance of SOGI [3], [4]. When K is small, the filtering performance is good, but the response speed is slow accordingly.

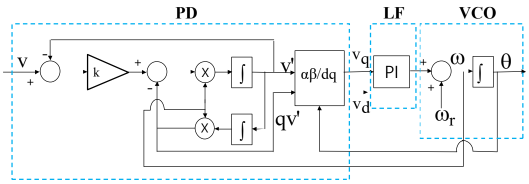

Fig. 3. Block diagram of the single-Phase SOGI-PLL

4. Second-Order Generalized Integrator-FLL

The block diagram of the SOGI-FLL is shown in Fig. 4. A SOGI-FLL can quickly lock the input signal frequency, which acts as a variable center frequency band pass filter.

It can produce two-phase orthogonal signals and an adaptive filter is used to reduce the complexity and to increase the filtering of the output signals. The remaining part is similar as the ordinary PLL. The regulator's output as a phase error signal is directly added to the integration of angular frequency of FLL [2] output, which improves the dynamic performance.

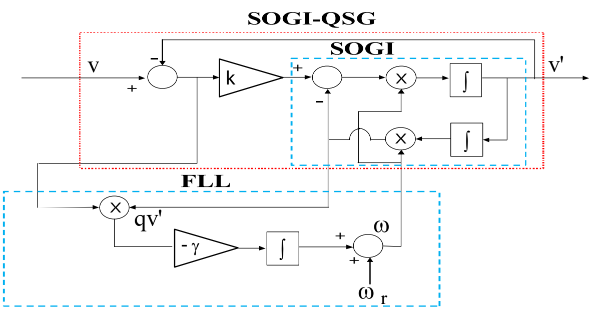

Fig. 4. Block diagram of the single-Phase SOGI-FLL

5. Evaluation of PLL Algorithms

Performance of different PLL techniques has been tested using PSIM simulation platform. Fig. 5, Fig. 6, and Fig. 7 show the grid frequency tracking capability of three methods where is the reference value and is the measured value. It can be seen that SOGI-FLL presents a good tracking capability as compared with the EPLL scheme having a constant ripple. Also, it is observed that SOGI-PLL has some deviation from the reference. Therefore, the frequency tracking performance of SOGI-FLL is favorable among three schemes.

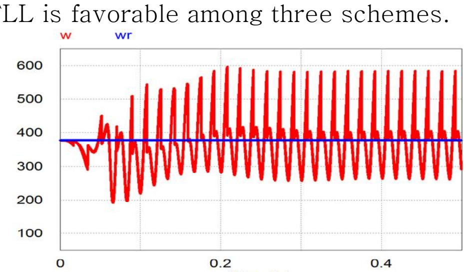

Fig. 5. EPLL Angular Frequency Tracking

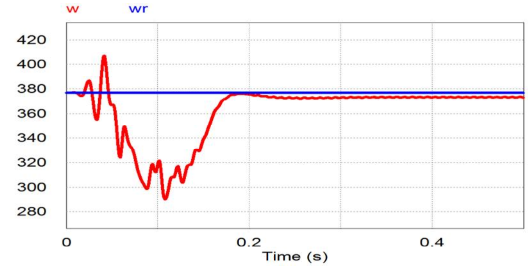

Fig. 6. SOGI-PLL Angular Frequency Tracking

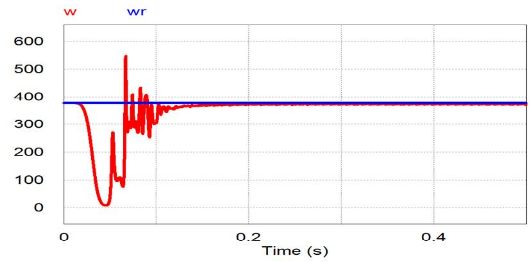

Fig. 7. SOGI-FLL Angular Frequency Tracking

6. Conclusion

This paper reviews several single-phase PLL algorithms first and then the performances of the PLL algorithms are compared. The comparisons in this paper show that the PLL based on SOGI-FLL can recover the distorted signal caused by harmonic and have good dynamic performance. This indicates that the PLL based SOGI-FLL has good filtering performance. So the PLL based on SOGI-FLL is a good synchronization scheme for single phase grid.

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