

Phase-Fast Estimation Algorithm Using PLL and Feed-Forward

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Abstract

Background/Objectives: In order to compensate the fluctuation of the generator frequency when the load of the generator suddenly changed, the control system by the mechanical time constant is operated through the governor control.

Methods/Statistical analysis: In this paper, we propose an algorithm to detect the active power of the generator momentarily and to perform feedforward control using it to reduce frequency fluctuation when the load suddenly changed. A high-speed PLL algorithm for grid linkage by phase estimation is also proposed in the case of phase topology

Findings: In order to compensate the instability of the phase information obtained from the two-phase stationary coordinate system, the proposed high-speed PLL algorithm implements an algorithm for estimating the phase angle robust to the disturbance as a result of using the phase information on the stationary coordinate system using the low.

Improvements/Applications: As a result of the use of the proposed algorithm through the PSIM simulation, a highly interlaced phase angle test was implemented and applied to the coupled inverter.

Keywords: PLL (phase-locked-loop), feed-forward, 3phase Inverter, DQ Transformation, Current Control

1. Introduction

Detecting the phase of the grid voltage perfectly in the power converter operating in conjunction with the power grid is the most important factor in improving the precision of the control. This is because the reference current or the reference voltage generated by the phase detection requires the system voltage and the incentives for performing the resistance control, etc. Power converter connected to the power meter pass requires precise phase detection of the system voltage and its strong, fast control characteristics even under the distorted voltage waveform conditions and under the various unsatisfactory conditions.[1] Otherwise, the reference current or voltage of the power converter will give rise to errors in the voltage phase of the system, thereby adversely affecting the overall control characteristics of the power shift system. For this reason, many studies have been performed on power converter control under distorted power voltages, and under these conditions many studies have been performed to ensure accurate phase detection.[2]

In order to detect the phase of the system voltage from a stable single-phase power supply, zero-crossing phase-locked loop (PLL) for detecting the zero point of the power supply voltage and a three- There is a way. However, the harmonic effects of the distorted power supply can not be avoided with these two methods.[3] The stable phase detection method in the distorted three-phase power condition can be realized by adjusting the PI coefficient on the synchronous coordinate system, adding a low-pass filter (LPF) on the synchronous coordinate system, We have designed an algorithm that implements the algorithm. The proposed method was simulated by Psim.[4,5]

2. Conventional PLL Algorithm and Proposed PLL Algorithm

Accurate information on the fundamental wave component of the grid voltage is essential to perform a reliable phase-locked loop (PLL) for generator parallel operation. The general PLL structure takes the form that the PI controller outputs the phase so that the d-axis voltage component can be zero. In this case, when there is a ripple component in the d-axis voltage component, there is a problem in the gain setting of the controller, which makes it difficult to follow the phase angle within a limited error range. In this paper, we propose a PLL algorithm applying feed-forward to the existing system phase tracking method.[6]

2.1. Conventional PLL Algorithm

When the real angle phase at the system side is the input angle shown in Fig. 1, the system voltage on the two-phase stationary coordinate system is expressed as Equation (1).

$$\begin{bmatrix} V_{\alpha} \\ V_{\beta} \end{bmatrix} = V \begin{bmatrix} \sin(\varphi_{in}) \\ -\cos(\varphi_{in}) \end{bmatrix} \quad (1)$$

In order to convert the expression (1), which is a voltage on the two phase trip coordinate system, to the two phase rotation system, the actual phase angle information on the system side is required, and if this estimate is given in the two phase rotation coordinate system.

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} \cos(\varphi_{out}) & \sin(\varphi_{out}) \\ -\sin(\varphi_{out}) & \cos(\varphi_{out}) \end{bmatrix} \begin{bmatrix} V_{\alpha} \\ V_{\beta} \end{bmatrix} \quad (2)$$

From the equations (1) and (2), the voltage on the rotating coordinate system by the power supply voltage is given by Equation (3). If the actual phase angle and the estimated phase angle are coincident, Eq. (3) becomes 0 and $-V$, and if the phase estimation error occurs, the voltage error on the rotating coordinate system is given by Eq. V_{de} becomes a base function, and if this variable is assumed to be 0, the phase difference error becomes zero.

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = V \begin{bmatrix} \sin(\varphi_{in}) \cos(\varphi_{out}) - \cos(\varphi_{in}) \sin(\varphi_{out}) \\ -\sin(\varphi_{in}) \sin(\varphi_{out}) - \cos(\varphi_{in}) \cos(\varphi_{out}) \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} V_{de} \\ V_{qe} \end{bmatrix} = V \begin{bmatrix} \sin(\varphi_e) \\ -\cos(\varphi_e) \end{bmatrix} \quad (4)$$

2.2. The Proposed PLL Algorithm

Figure 3 shows the suggested PLL algorithm. The system voltage on the two-phase stationary coordinate system has the phase information and the size information of the system. The phase angle is calculated using the atan function, and if the harmonics exist in the system, There is a drawback that it is very sensitive to external noise. [7]

In this study, phase value is calculated after passing the low - frequency filter on the grid voltage on the two - phase stationary coordinate system, and the phase angle delay compensation by the low - frequency filter is used for the d - axis voltage on the rotating coordinate system A new algorithm is proposed.

To compensate for the disadvantages of the atan function in the vicinity of the denominator Zero, we compensate for the extreme sensitivity to external noise by compensating the atan function with the denominator of the larger of the two variables.

3. Results and Discussion

Figure 4 shows the simulation circuit of this paper in PSIM. Figures 5 and 6 show the 3-phase voltage, the rotational phase voltage, the real angle phase, the estimated angle phase, and compensator output the 5th harmonic content of 5% is included in the power connection. As can be seen from the waveforms, the proposed method for Phase Switching is superior to the conventional method in the phase angle estimation time constant of 1/5.

The proposed three-phase PLL system is robust and has high-speed performance with high response even under the conditions of voltage disturbance, instantaneous voltage drop and harmonic inclusion, so that it will have excellent performance when controlling the power converter connected to the power system in the future do.

4. Conclusion

In this paper, to compensate the instability of the phase information obtained from the two-phase stationary coordinate system, the phase information on the stationary coordinate system using the low-pass filter is feed-forward as a control method for minimizing the frequency fluctuation during load fluctuation. We implemented the estimation algorithm and verified its validity through the simulation of Powersim.

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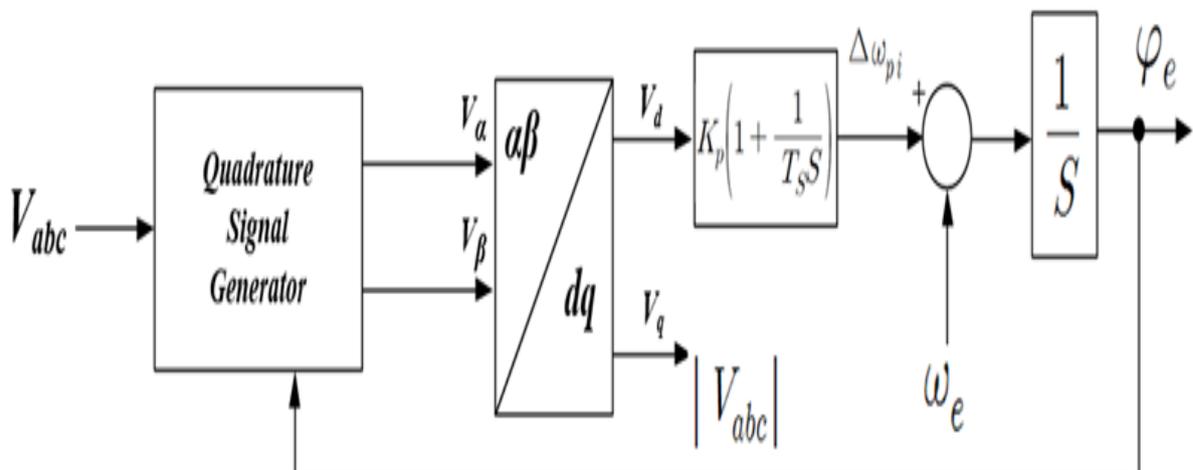


Figure 1: PLL block diagram based on d-axis voltage

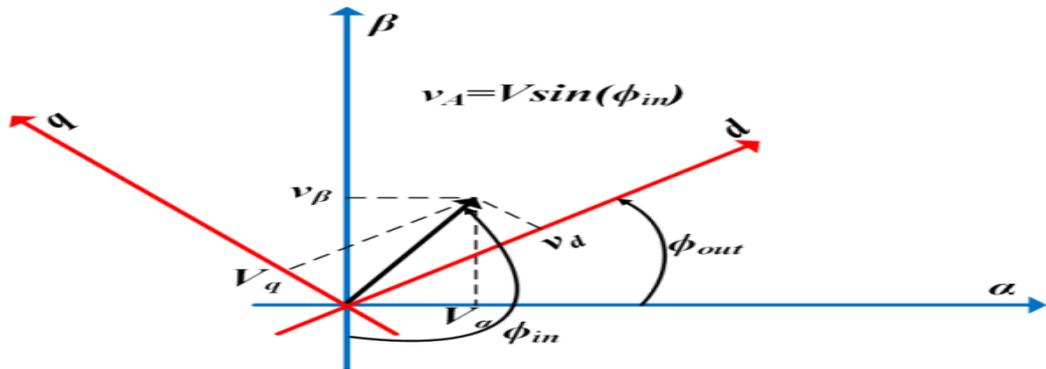


Figure 2: The PLL phaser picture by the d-axis voltage

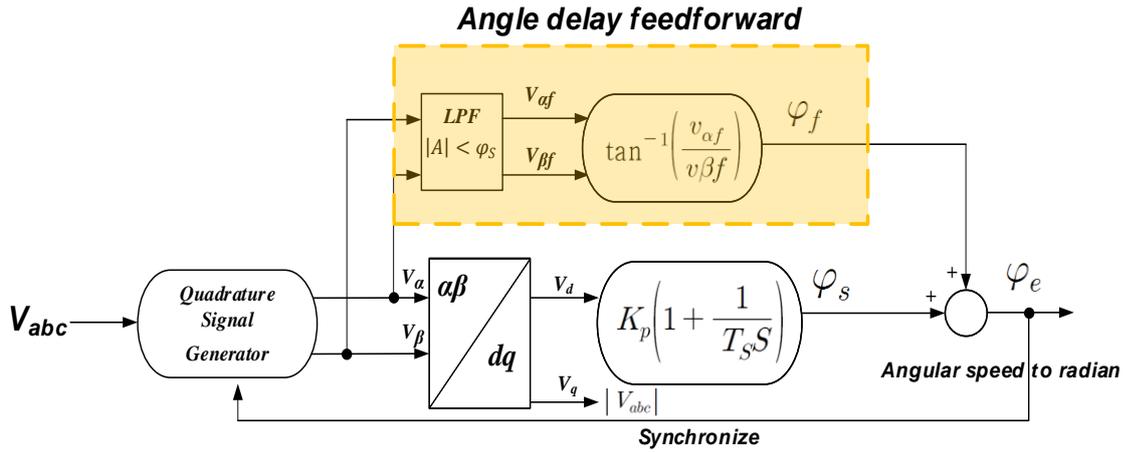


Figure 3: The suggested PLL algorithm

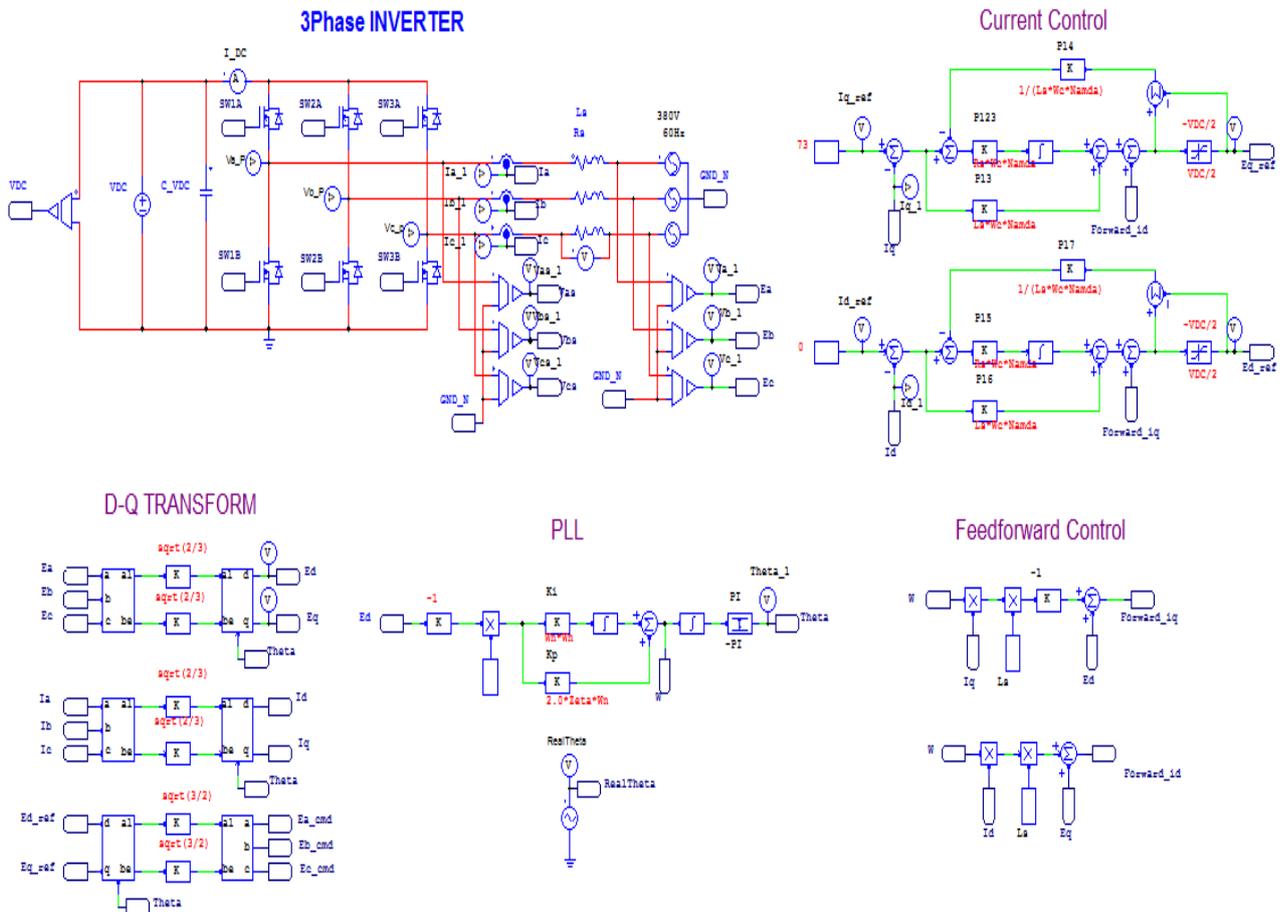


Figure 4: Circuit diagram of 3-phase inverter in PSIM

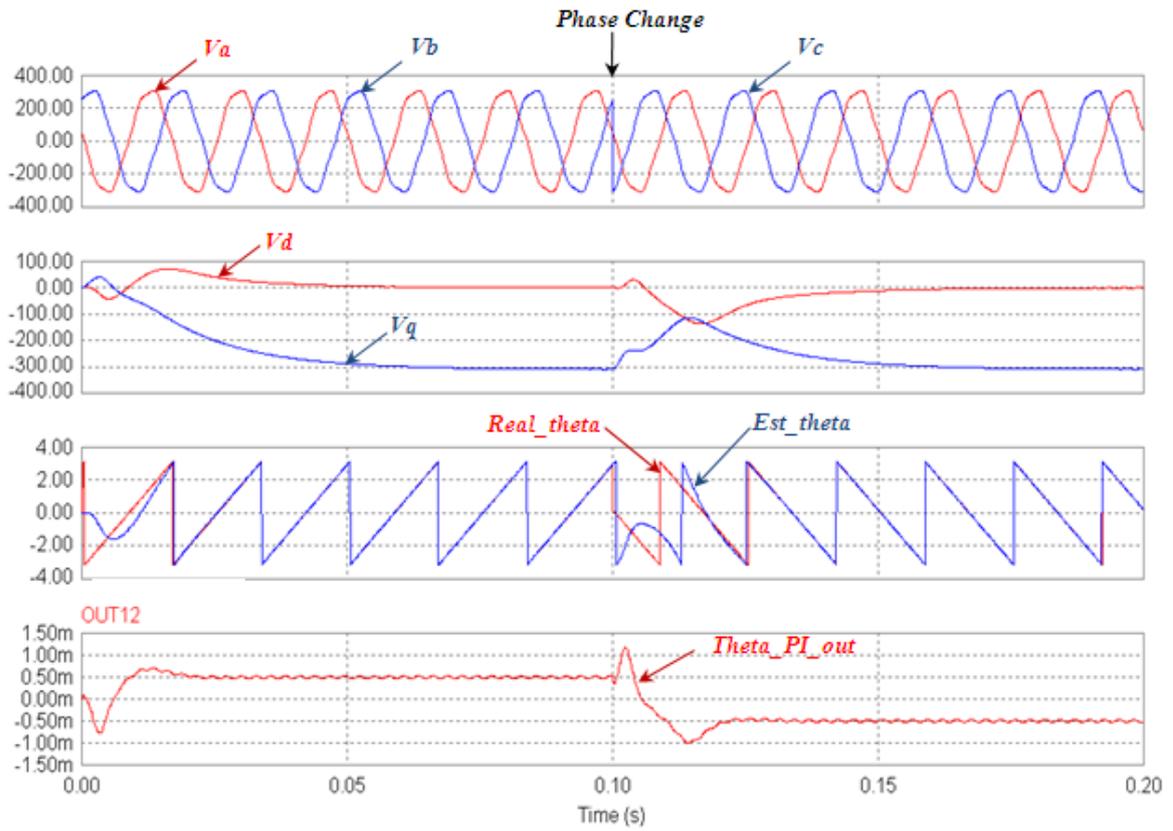


Figure 5: The conventional PLL characteristics during phase change-over

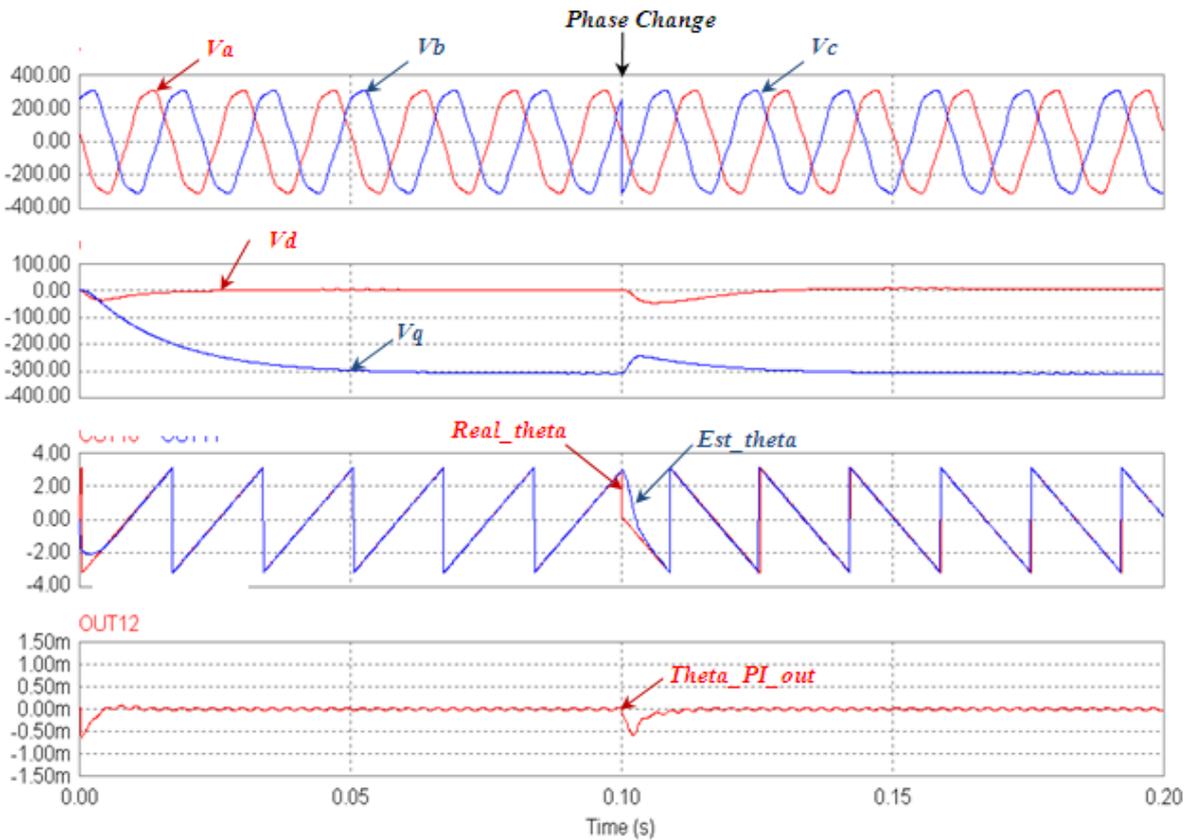


Figure 6: The proposed PLL characteristics during phase change-over