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Application of Particle Swarm Optimization to Three Phase Phase-Locked Loop

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Abstract: Phase-Locked Loop (PLL) is one of the most widely used synchronization methods available. The fast response is very important in synchronization. Unfortunately PLLs are still need to be improved in achieving fast response. In this paper an attempt is made to achieve fast response by applying one of the soft computing technique Particle swarm optimization (PSO) to alpha beta PLL (αβPLL). The effectiveness is verified in Simulink environment.
Keywords: Phase-Locked Loop (PLL), Synchronization, Particle swarm optimization (PSO), alpha beta PLL (αβPLL) and Simulink

I. INTRODUCTION

Phase-Locked loops (PLLs) are now widely used for the synchronization of power converters to the grid [1]-[3]. They are also highly popular for the control, monitoring and protection purposes in areas of power electronics and power systems [4]-[7]. According to [16] an ideal synchronization approach must competently track the phase angle of the utility grid, efficiently detect the frequency variations , immediately respond to utility grid changes. So an immediate and fast response is one of the main objective of the synchronization. But PLLs are suffering with sluggish response which not only requires development but also better tuning of controllers are necessary.

In this paper a normal αβPLL is considered and Particle swarm optimization (PSO) [8]-[9] is used for tuning the PI controller in the αβPLL. The corresponding responses are presented in simulation and results section below.

Remaining sections are as in section II the structure of PLLs are introduced, section III describes the Optimization algorithm, section IV simulation results and section V conclusion.

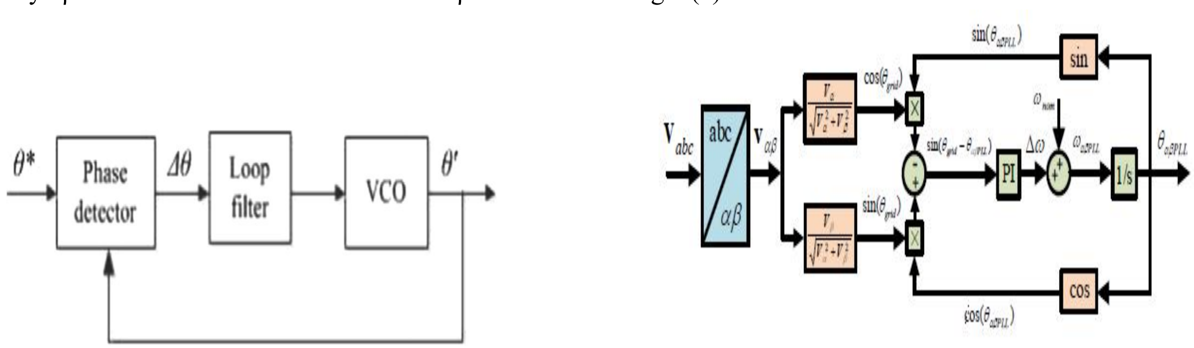
II. ALPHA BETA PHASE-LOCKED LOOP

A. Basic PLL

The basic PLL consists of three main blocks as shown in Fig. 1(a) [10]. They are phase detector (PD), loop filter (LF) and voltage controlled oscillator (VCO). A PLL is a device which causes one signal to track another one. It keeps an output signal synchronizing with a reference input signal in frequency as well as in phase. Which controls the phase of its output signal in such a way that the phase error between output phase and reference phase reduces to a minimum. [11].

B. αβPLL

The αβPLL [12] achieves synchronization in the stationary αβ-reference frame that translates the natural abc reference frame into the stationary αβ-reference frame. The structure of αβPLL shown in Fig. 1(b).



(a) (b)

Fig. 1. (a) Basic structure of PLL. (b) Structure of αβPLL.

III.PARTICLE SWARM OPTIMIZATION

Optimization can be used to find an optimum solution. The PSO [8]-[9] can be understood through an analogy of a swarm of birds in a field . Their goal is to find the location with the highest density of food without any prior knowledge of the field. The birds move in random locations with random velocities looking for foods. Each bird can remember the locations that it found to contain more food and somehow also knows the locations where the other birds have found an absolute highest concentration of food. The flow chart is show in Fig. 2.

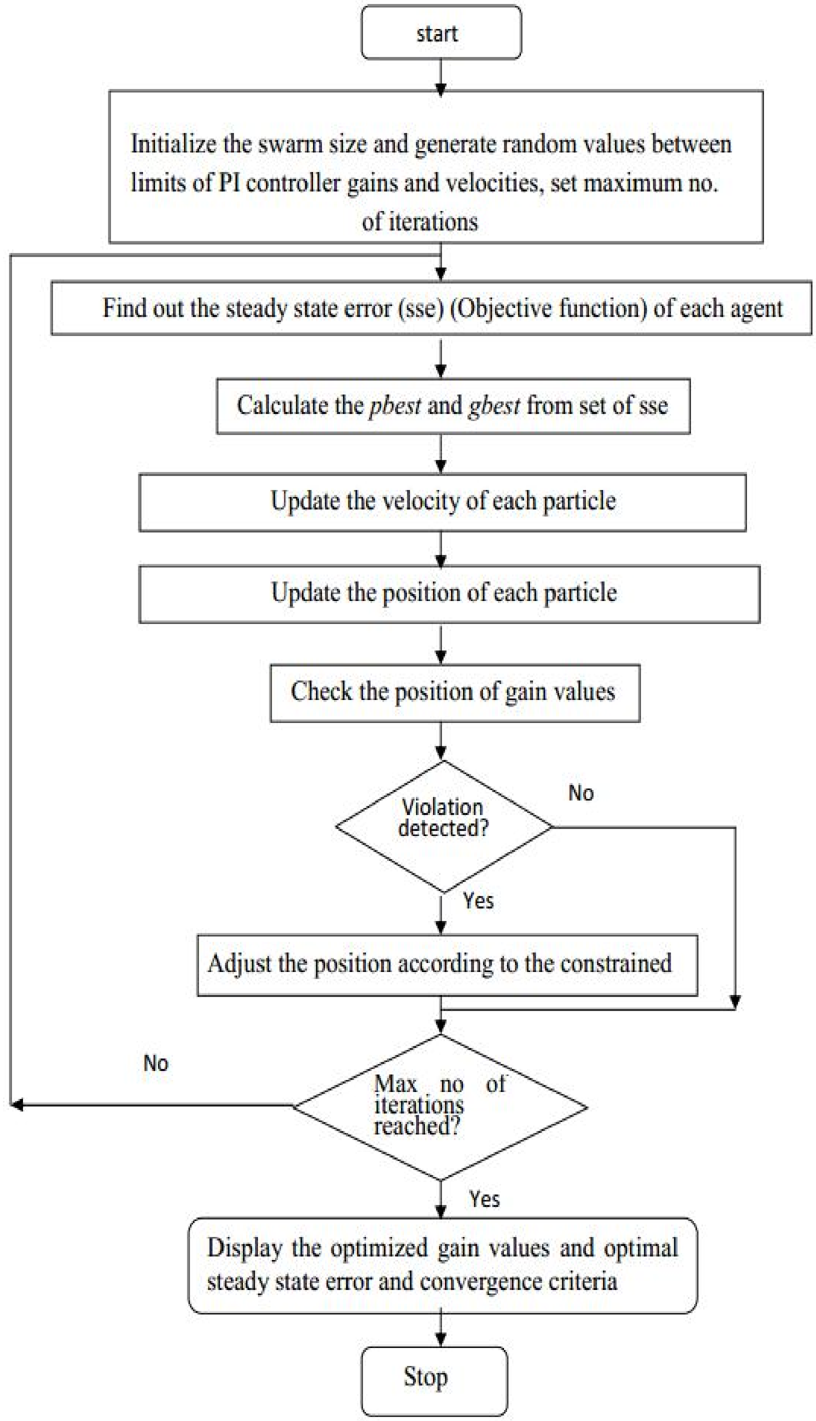


Fig. 2. Flow chart to implement PSO to the PLL

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IV. SIMULATION RESULTS

Two different test cases [13] are considered for simulation. The αβPLL is implemented in Simulink and the PI controller gains are tuned using PSO. Integral gain is taken $K\,i$ = 15791.3 and only proportional gain K p is tuned using PSO. The simulation results are presented for best three $K\,p$ gain values.

A. *Test case 1*: Grid voltage experiences a phase-angle jump of +10 deg.
B. *Test case 2:* The grid voltage undergoes a frequency step change of +4Hz

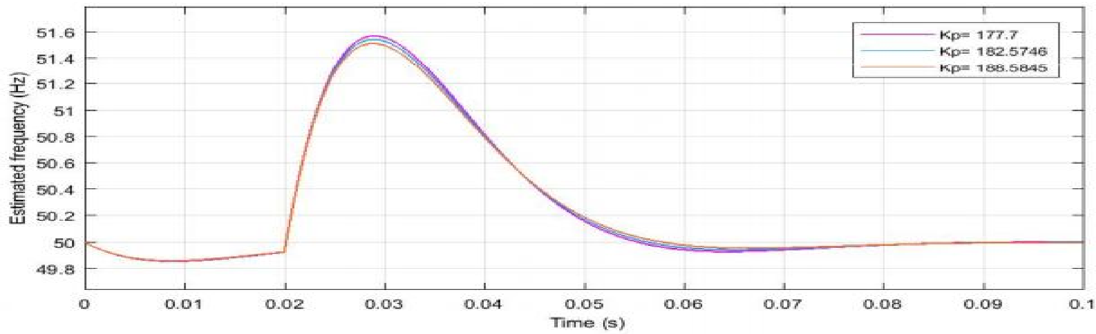

Fig. 3. Simulation results for test case 1.

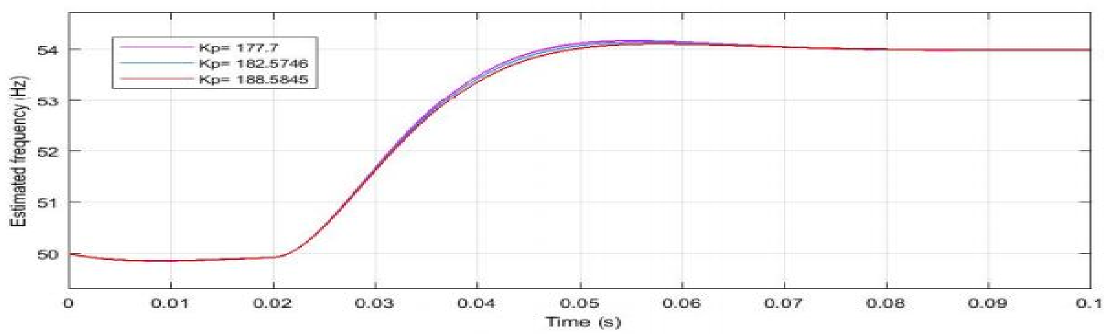

Fig. 4. Simulation results for test case 2.

For different $K\,p$ values the response of the Fig. 3 and 4 showing variation in terms of dynamic response and Peak overshoot. Though the peak overshoot minimized but the dynamic response getting slow.

V. CONCLUSIONS

The simulink model of αβPLL is implemented and the controller proportional gain ($K\,p$) is tuned for several simulations with PSO technique for 100 iterations. Best three results among them are presented. The best three gain values are $K\,p$ = 177.7, 182.5746 and 188.5845. Among the three gain values $K\,p$ = 177.7 is giving better dynamic response.

VI. APPENDIX

Grid voltage ,V= 1 pu, nominal frequency, $\omega_n = 2\pi 50$ rad/s, Ts = 1e-4, time delay, τ = 0.02.

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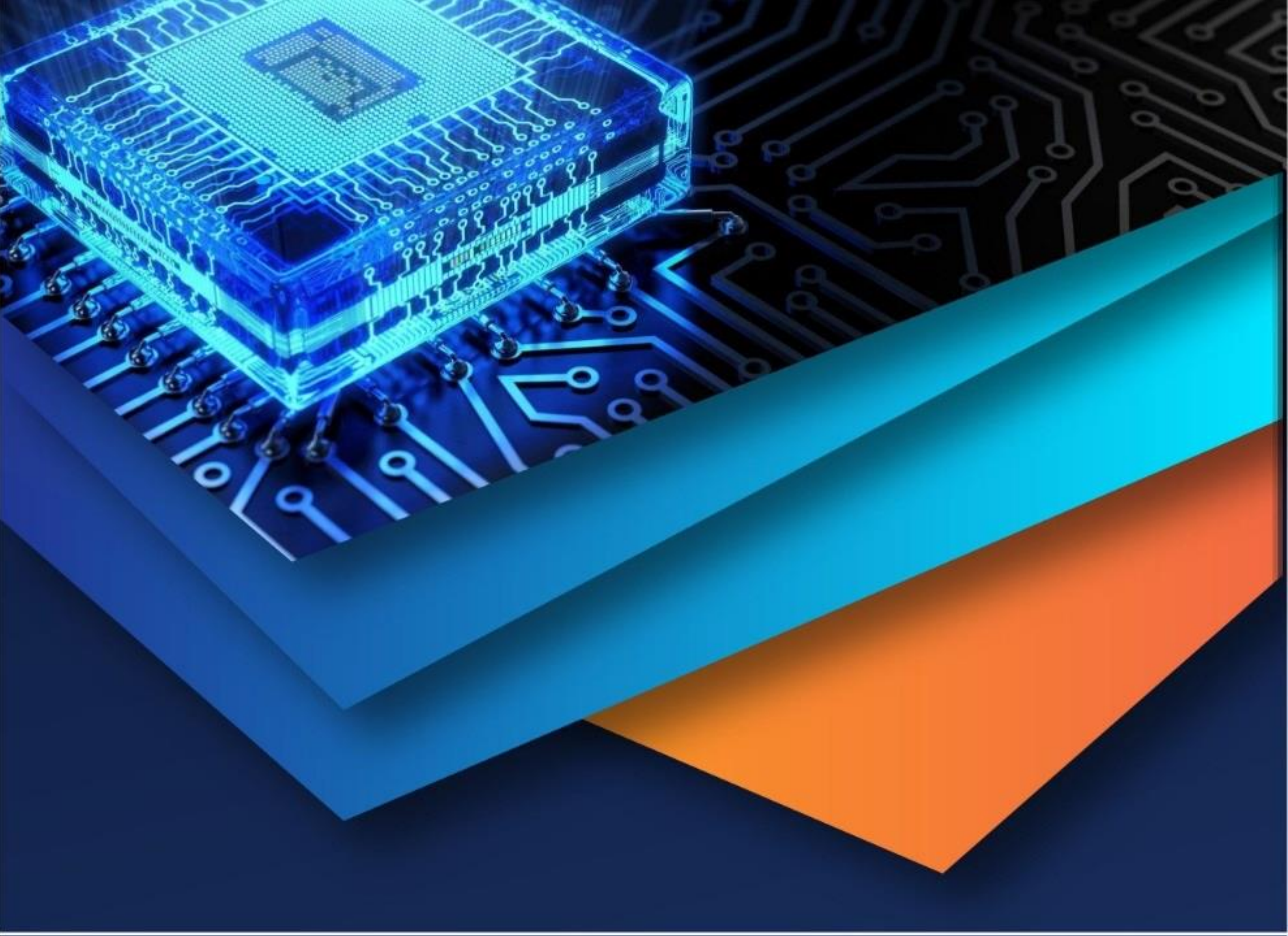

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