

**GRID VOLTAGE SYNCHRONIZATION FOR DISTRIBUTED GENERATION
UNDER UNBALANCED CONDITIONS**¹ Sangati.Rajeswari, ² M.Hema Chandra Reddy¹M.Tech Scholar, MJRCET,Piler,AP² Asst.Prof, MJRCET,Piler,AP

Abstract: This paper analyzes the synchronization capability of three advanced synchronization systems: the decoupled double synchronous reference frame phase-locked loop (DDSRF-PLL), the dual second order generalized integrator PLL (DSOGI-PLL), and the Genetic Algorithm based three-phase enhanced PLL (GAEPLL), designed to work under such conditions. Although other systems based on frequency-locked loops have also been developed, PLLs have been chosen due to their link with dq_0 controllers. Their performance, reliability of the amplitude and phase detection of the positive sequence of the voltage, under unbalanced and distorted situations, has been evaluated according to grid fault patterns.

Keywords: decoupled double synchronous reference frame phase-locked loop (DDSRF-PLL), dual second order generalized integrator PLL (DSOGI-PLL), Genetic Algorithm based three-phase enhanced PLL (GAEPLL),

I.INTRODUCTION

The power share of renewable energy-based generation systems is supposed to reach 20% by 2030, where wind and photovoltaic (PV) systems are assumed to be the most outstanding examples of integration of such systems in the electrical network [1]. The increased penetration of these technologies in the electrical network has reinforced the already existing concern among the transmission system operators (TSOs) about their influence in the grid stability; as a consequence, the grid connection standards are becoming more and more restrictive for distribution generation systems in all countries [2]–[3]. In the actual grid code requirements (GCRs), special constraints for the operation of such plants under grid voltage fault conditions have gained a great importance. These requirements determine the fault boundaries among those through which a grid-connected generation system shall remain connected to the network, giving rise to specific voltage profiles that specify the depth and clearance time of the voltage sags that they must withstand. Such requirements are known as low voltage ride through (LVRT) and are described by a voltage versus time characteristic [4].

Although the LVRT requirements in the different standards are very different, as shown in [5], the first issue that generation systems must afford when a voltage sag occurs is the limitation of their transient response, in order to avoid its protective disconnection from the network. This is the case, for instance, of fixed speed wind turbines based on squirrel cage induction generators, where the voltage drop in the stator windings can conduct the generator to an overspeed tripping, as shown in [6]. Likewise, variable speed wind power systems may lose controllability in the injection of active/reactive power due to the disconnection of the rotor side converter under such conditions [7], [8]. Likewise, PV systems would also be affected by the same lack of current controllability.

Solutions based on the development of auxiliary systems, such as STATCOMs and dynamic voltage regulators (DVRs), have played a decisive role in enhancing the fault ride through (FRT) capability of distributed generation systems, as demonstrated in [9]–[11]. Likewise, advanced control functionalities for the power converters have control solution, called droop control, also been proposed [12], [13]. In any case, a fast detection of the fault contributes to improving the effects of these solutions; therefore, the synchronization algorithms are crucial. In certain countries, the TSOs also provide the active/reactive power pattern to be injected into the network during a voltage sag; this is the case for the German E-on [2] and the Spanish Red Eléctrica Española (REE) [3]. This trend has been followed by the rest of the TSOs; moreover, it is believed that this operation requirement will be extended, and specific demands for balanced and unbalanced sags will arise in the following versions of the grid codes worldwide [14]. Regarding the operation of the distributed generation systems under balanced and unbalanced fault conditions, relevant contributions, such as [15]–[16], can be found in the literature.

These solutions are based on advanced control systems that need to have accurate information of the grid voltage variables in order to work properly, something that has prompted the importance of grid synchronization algorithms. In power systems, the synchronous reference frame PLL (SRF PLL) is the most extended technique for synchronizing with three-phase systems [17]. Nevertheless, despite the fact that the performance of SRF PLL is satisfactory under balanced conditions, its response can be inadequate under unbalanced, faulty, or distorted conditions [18]–[19].

In this project, three improved and advanced grid synchronization systems are studied and evaluated: the decoupled double synchronous reference frame PLL (DDSRF PLL) [20], the dual second order generalized integrator PLL (DSOGI PLL), [21] and the three-phase enhanced PLL (3phEPLL) [22]. Their performance, computational cost, and reliability of the amplitude and phase detection of the positive sequence of the voltage, under unbalanced and distorted situations, have been evaluated [23] and [24].

II. DESCRIPTION OF THE THREE SYNCHRONIZATION SYSTEMS

DDSRF PLL:

The DDSRF PLL was developed for improving the conventional SRF PLL. This synchronization system exploits two synchronous reference frames rotating at the fundamental utility frequency, one counter clockwise and another one clockwise, in order to achieve an accurate detection of the positive- and negative-sequence components of the grid voltage vector when it is affected by unbalanced grid faults. The diagram of the DDSRF PLL is shown in Fig.1.

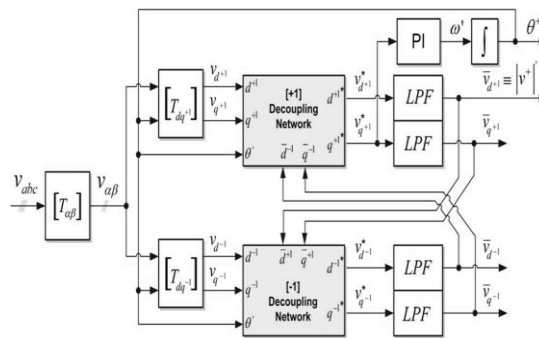


Fig.1 DDSRF-PLL block diagram

DSOGI PLL:

The operating principle of the DSOGI PLL for estimating the positive- and negative-sequence components of the grid voltage vectors is based on using the instantaneous symmetrical component (ISC) method on the $\alpha\beta$ stationary reference frame. The diagram of the DSOGI PLL is shown in Fig.2. As it can be noticed, the ISC method is implemented by the positive-sequence calculation block.

To apply the ISC method, it is necessary to have a set of signals, $V_\alpha-V_\beta$, representing the input voltage vector on the $\alpha\beta$ stationary reference frame together with another set of signals, $qV_\alpha-qV_\beta$, which are in quadrature and lagged with respect to $V_\alpha-V_\beta$. In the DSOGI PLL, the signals to be supplied to the ISC method are obtained by using a dual second order generalized integrator (DSOGI), which is an adaptive band pass filter based on the generalized integrator concept. At its output, the DSOGI provides four signals, namely, V'_α and V'_β , which are filtered versions of V_α and V_β , respectively, and qV'_α and qV'_β , which are the in-quadrature versions of V'_α and V'_β .

A conventional SRF PLL is applied on the estimated positive-sequence voltage vector, $V^{+}_{\alpha\beta}$, to make this synchronization system frequency adaptive. In particular, the $V^{+}_{\alpha\beta}$ voltage vector is translated to the rotating SRF, and the signal on the q-axis, V^{+}_q , is applied at the input of the loop controller. As a consequence, the fundamental grid frequency (ω') and the phase angle of the positive-sequence voltage vector (θ') are estimated by this loop. The estimated frequency for the fundamental grid component is fed back to adapt the centre frequency ω' of the DSOGI.

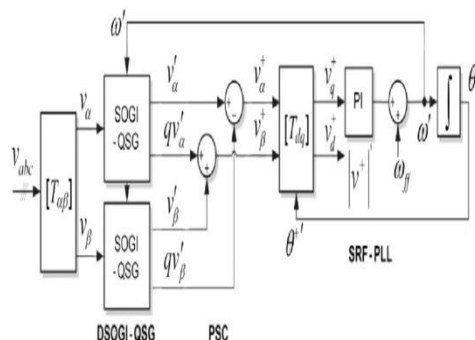


Fig.2 DSOGI-PLL block diagram.

GA THREE PHASE EPLL:

An EPLL is essentially an adaptive band pass filter, which is able to adjust the cutoff frequency as a function of the input signal. Its structure was later adapted for the three-phase case, in order to detect the positive-sequence vector of three-phase signals, obtaining the 3phEPLL that is represented in Fig.3.

Genetic algorithm is used for the calculation of PI controller parameters in EPLL.

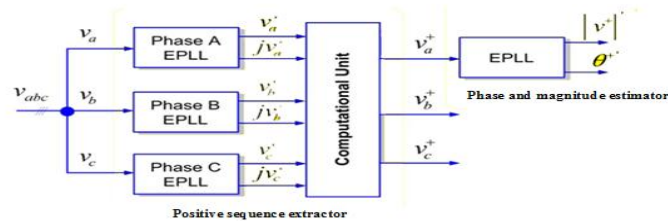


Fig.3 3phEPLL block diagram.

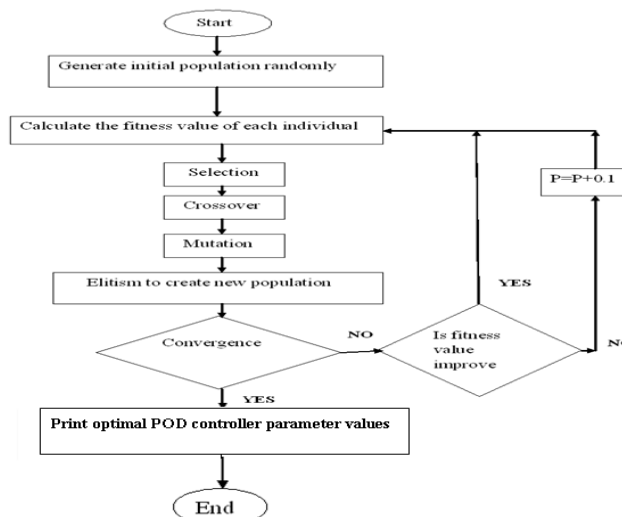


Fig.4 Genetic algorithm flowchart for optimization of PI parameters of EPLL.

III. SIMULATION DIAGRAM

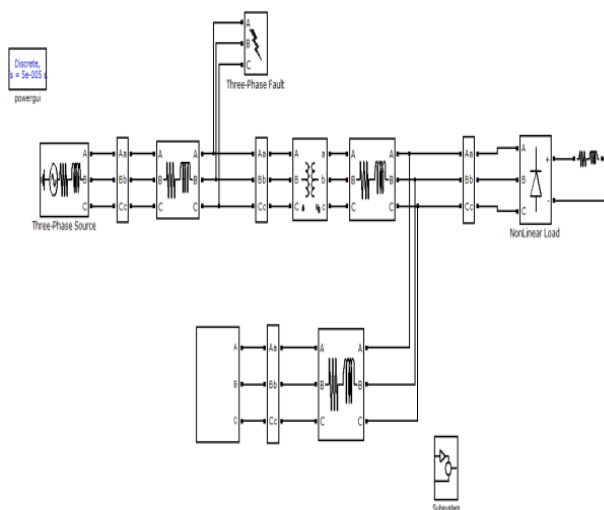


Fig.4 General Distribution system

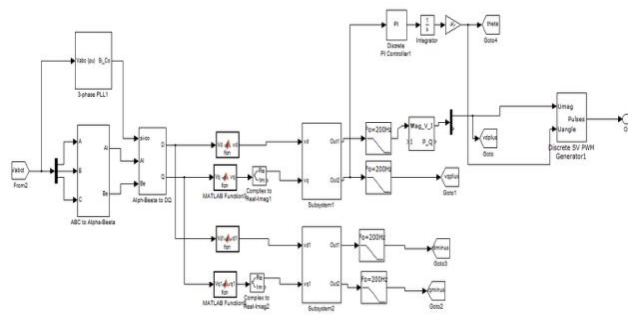


Fig.5 DDSRF PLL

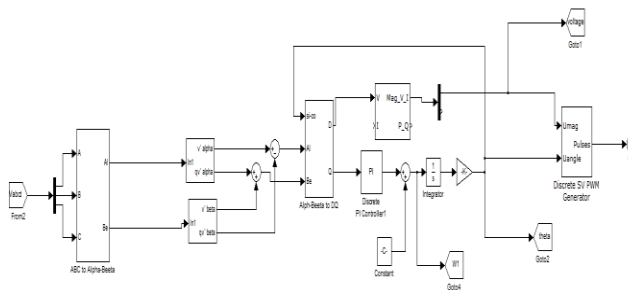


Fig.6 DSPGI PLL

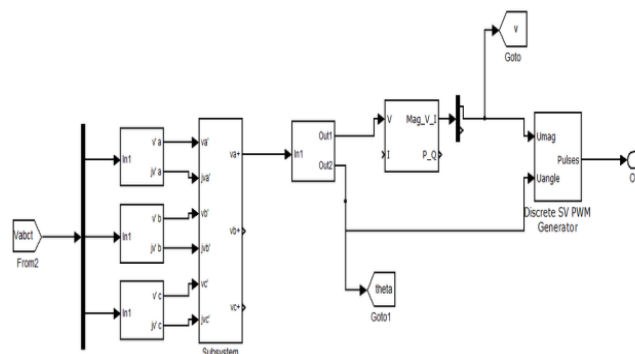


Fig.7 GA based Three phase EPLL

IV. SIMULATION RESULTS

TYPE A SAG:

This kind of distortion usually appears when a three phase fault occurs. The high currents generate a great drop in all voltage values, as well as phase jumps due to the change in the line impedance. This phenomenon can be also found when high power machines are suddenly connected to weak grids. As fig.8 shows the type A sag voltage. In Fig.8(a), shows the input signal for type A sag and (b) to (d) shows, amplitude and phase detection for the DDSRF PLL, DSOGI PLL and GA three phase EPLL and it will produces a good response, as both systems achieve a very fast detection (25 ms) of the positive-sequence components (less than two cycles).

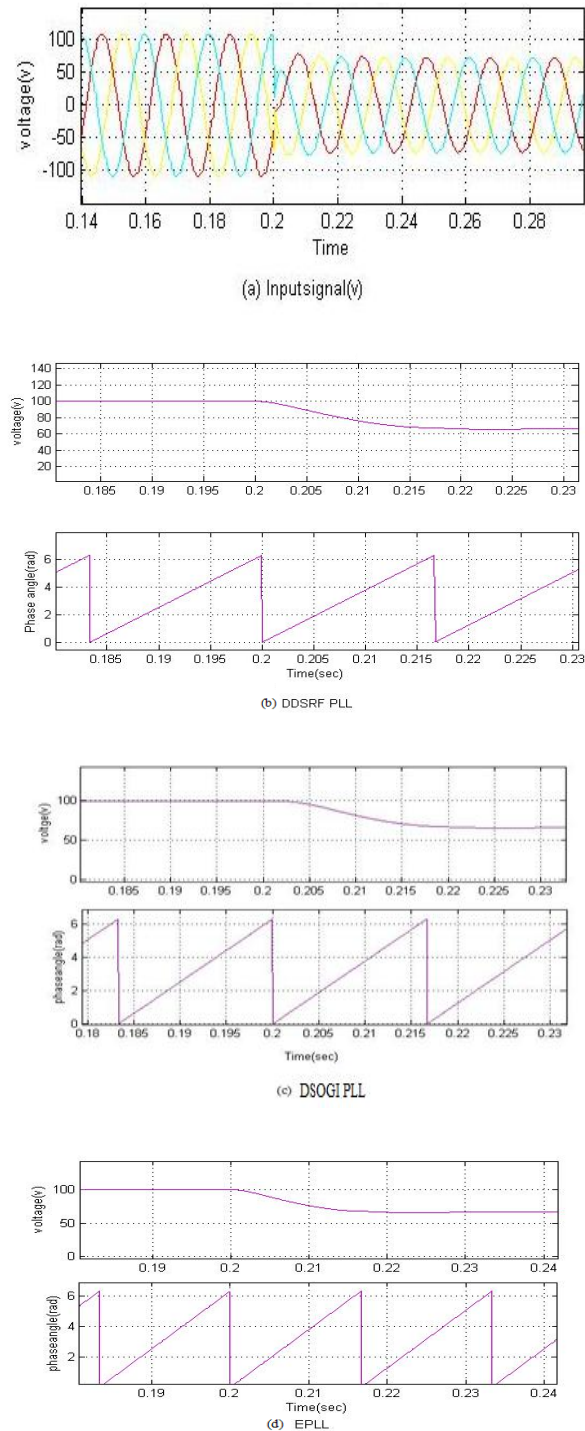


Fig.8 Amplitude (V) and phase (rad) detection for type A sag

TYPE A SAG:

This kind of fault permits analyzing the behavior of the PLLs under test in the presence of zero sequence components at the input. The Clarke transformation used in DSOGI PLL and DDSRF PLL to extract the $\alpha\beta$ components enhances the response of this synchronization system when the faulty grid voltage presents zero-sequence components. As the DSOGI PLL and the DSRF PLL are using $\alpha\beta$ components the dynamics of the positive sequence detection is not influenced by the homo polar one, even though in the 3ph EPLL this value is affecting the positive component estimation, so its dynamic is slower. However, this effect is attenuated by the 'computational unit' so finally the steady state is reached with no great delay. Their responses, as shown in Fig.9. On the other hand, the GA3phEPLL does not cancel out the zero-sequence component from the input voltage, something which may affect the dynamics of the positive-sequence estimation loop.

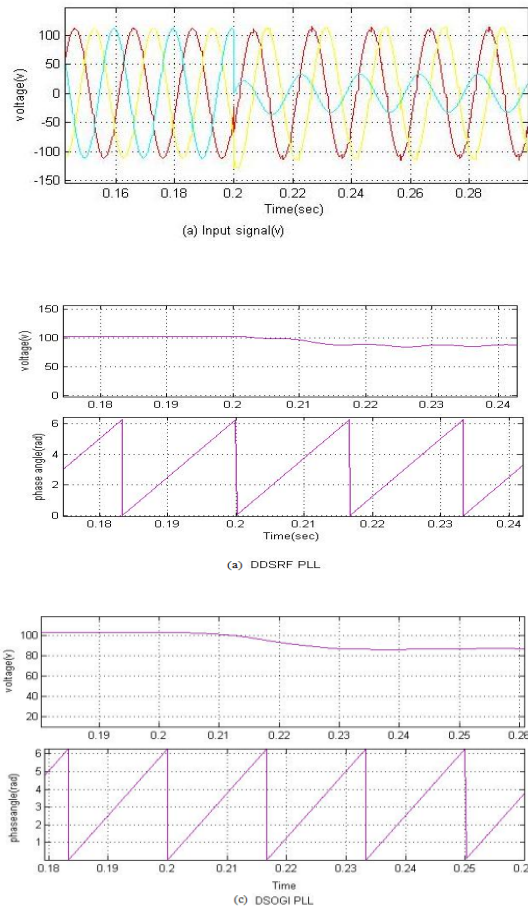
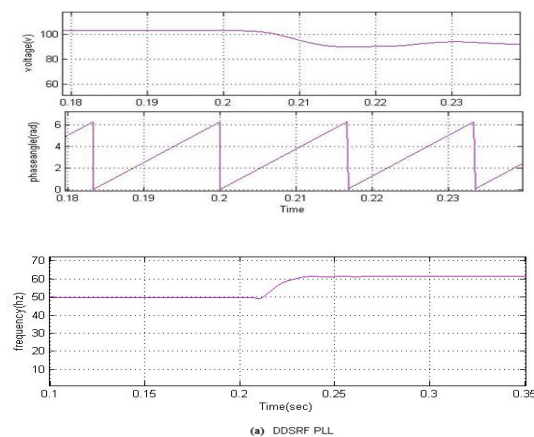


Fig.9 Amplitude (V) and phase (rad) detection for type B sag

Behavior of PLLs in Case of Frequency Changes (50–60 Hz):

As fig.10 shows the Matlab diagram for frequency changes from 50Hz to 60Hz, in this by using different PLL techniques the estimation of frequency, positive sequence amplitude and phase angle can be carried out. When the frequency changes the variations are shown in below fig. In this, similar results are obtained with the DDSRF and the DSOGI PLL, as can be seen in Fig.11. The low overshooting in the amplitude estimation in both cases assists the good phase and frequency detection. Likewise, the response of the GA 3phEPLL shows a similar settling time, as shown in Fig.11(c); however, the initial oscillation in the amplitude estimation of the voltage contributes to slightly delay the stabilization of the frequency magnitude, as displayed in Fig. 11.

Fig.10 General Distribution system when Frequency changes



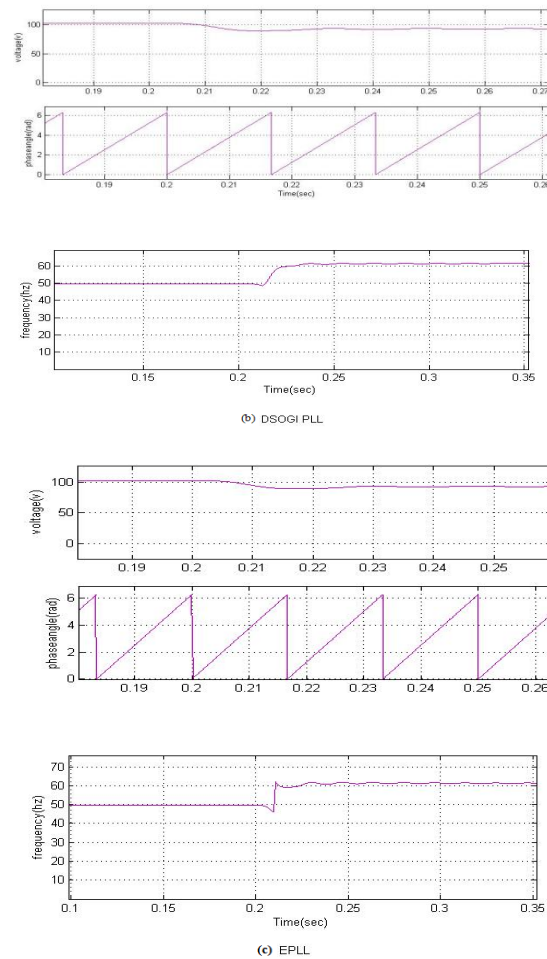


Fig.11 Amplitude, phase, and frequency estimation for frequency changes

Behavior of PLLs in Case of Polluted Grid:

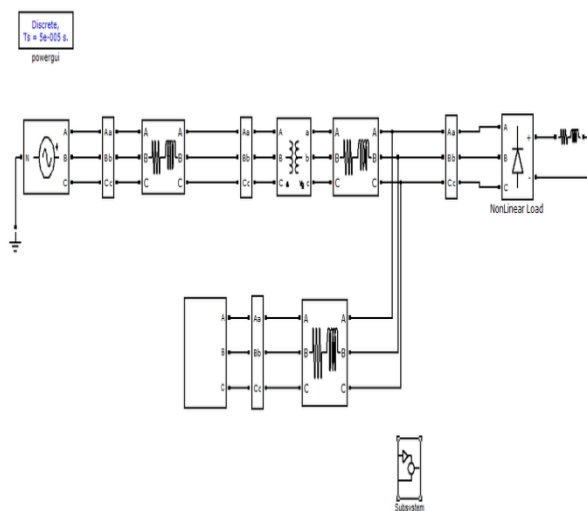
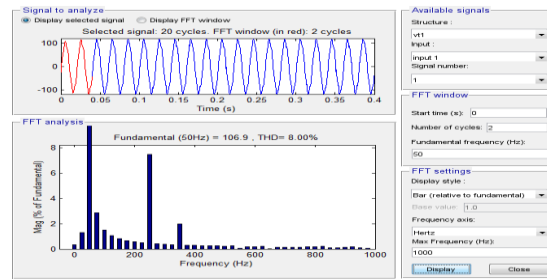
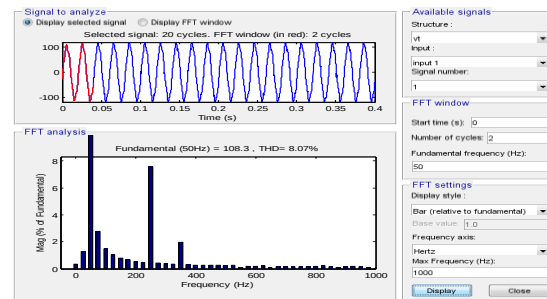


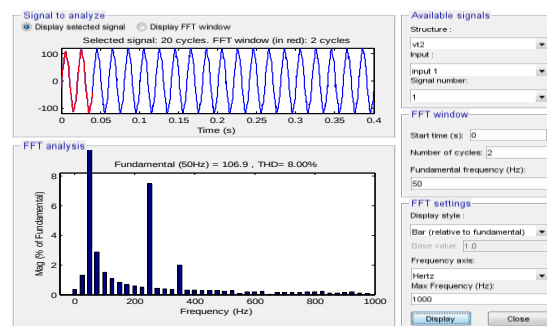
Fig.12 General Distribution system when polluted grid



DDSRF-PLL



DSOGI-PLL



Three Phase EPLL

Fig.13 Total Harmonic Distraction (THD) of polluted grid

V. CONCLUSION

The behaviors of three advanced grid synchronization systems were studied in this project. Their structures have been presented, and their discrete algorithms have been shown in detailed. Moreover, their performances have been tested. The DDSRF PLL and the DSOGI PLL allow estimating the ISCs of a three-phase system working in the $\alpha\beta$ reference frame, while the 3phEPLL uses the “abc” reference frame, thus working with three variables. It has been shown that, this feature simplifies the structure of the DSOGI PLL and the DDSRF PLL, which allows reducing the computational burden, as compared to the 3phEPLL, without affecting its performance.

The synchronization capability of the three PLLs under test has been shown to be fast and accurate under faulty scenarios, allowing the detection of the positive sequence of the voltage in 20–25 ms in all cases; however, the simpler structure of the DDSRF and the DSOGI affords an easier tuning of their control parameters and, therefore, a more accurate control of their transient response. The immunity of the analyzed PLLs in the possibility of a polluted network is better when using the 3phEPLL and the DDSRF, due to their greater band pass and low-pass filtering capabilities. Although the DSOGI also gives rise to reasonably good results, due to its inherent band pass filtering structure, its response is more affected by harmonics. Although all three have been shown to be appropriate for synchronizing with the network voltage in distributed power generation applications, mainly PV and wind power, the lower computational cost of the DDSRF PLL and the DSOGI PLL, together with their robust estimation of the voltage parameters, offers a better tradeoff between the presented systems, making them particularly suitable for wind power applications.

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