STUDY OF GRID SYNCHRONIZATION TECHNIQUES FOR DISTRIBUTED GENERATION SYSTEM CONSIDERING GRID UNDER ABNORMAL CONDITION

Veeresha K B[1] | Kumari Rashmi Gobbi[2]

[1](Asst.Professor, Dept.of EEE, JNN College of Engineering, Shimoga, Karnataka, India, veereshakb@jnnce.ac.in)
[2](M.Tech Student, Dept.of EEE, JNN College of Engineering, Shimoga, Karnataka, India, rashmigobbi@gmail.com)

Abstract-Increase in global electrical energy consumption, has led to increase in demand on power capacity, efficient production, distribution and utilization of energy. To meet this increased demand, reliable alternative is renewable energy sources like wind, solar, etc. Distributed power generation systems based on renewable energy resources needs to be controlled properly, otherwise, it will cause problems on grid side. Hence grid synchronization must be done before connecting these systems to utility network which is the most important issue. This paper discusses the best method (in terms of accuracy and fast response) of grid synchronization technique for power converter. From the results it can be seen that proposed synchronization method detects accurate phase angle and amplitude even under distorted condition than conventional synchronization method.

Keyword: ***global electrical energy, synchronization, grid, amplitude***

1.INTRODUCTION

Worldwide most of the generating systems are running on fossil fuels which are the major cause of environmental problems. Hence due to increased demand of power worldwide, alternative like renewable generation systems are growing rapidly.

This increased number of distributed power system connected to utility network may cause inability of these systems and grid itself. Most important issue with distributed power generation system is synchronization with the grid voltage vector. Synchronization algorithm should give phase of grid voltage vector and phase angle of utility voltage vector. This information is used to turn on/off the power devices, calculate and control the flow of active/reactive power or transform the feedback variable to a reference from a suitable for control purpose Algorithm should have the capability to keep the synchronization over short grid fault.

Existing converter synchronization improvement is needed because of rapid addition of distributed generation units to electric network.

2. EARLIER METHODS OF SYNCHRONIZATION

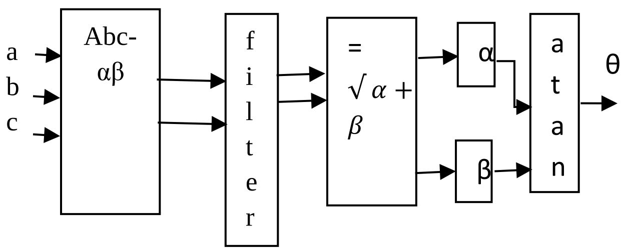
2.1 ZERO CROSSING METHOD (ZCD):

- It is the simplest method.
- It is used to obtain phase information using zero crossing of the utility voltages.

Thus, phase information can be found at every half cycle of utility voltage frequency only their dynamic performance of this technique is quite low.

For proper and accurate synchronization during grid disturbances, we need synchronization process to be updated not only at zero crossing point, but continuously over the fundamental period of signal.

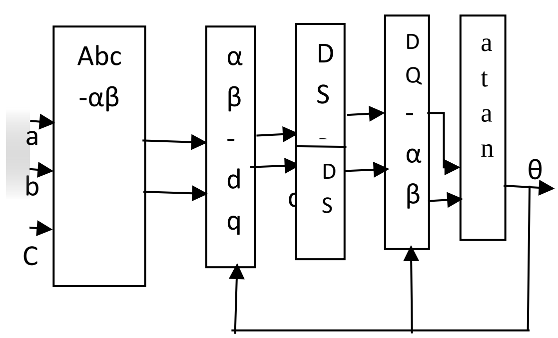
2.2 STATIONARY FRAME



Here, we obtain the phase angle of utility network in stationary reference frame using proper matrix transform. Later to both the components filtering is applied. But these filters introduce delay in the signal which is unacceptable in the case of grid voltage angle. So to compensate for this filter delay we can use a

1. PI controller, to monitor q component of voltage to correct the displacement introduced by filter or use
2. Band pass filter to obtain satisfactory results under unbalanced grid conditions.

2.3 DQ SYNCHRONOUS ROTATING REFERENCE FRAME



In this type, Ud and Uq components are DC variables and hence more filtering techniques like notch filter, low pass filter, band stop filter can be applied to obtain clear signal.

3. CONVENTIONAL TECHNIQUE FOR SYNCHRONIZATION

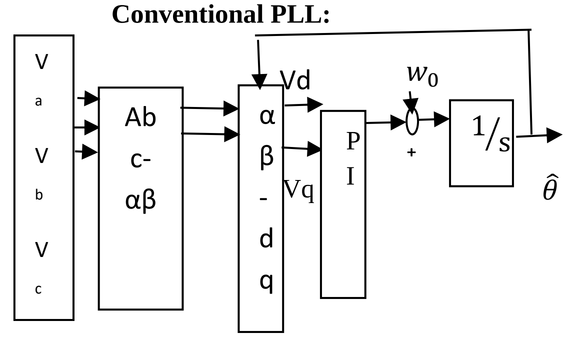
3.1 PLL (PHASE LOCKED LOOP)

PLL method is used to make synchronization system frequency adaptive. Some of the other method based on PLL technology is

a) EPLL (Enhanced phase locked loop)

It allows independent frequency adaptive synchronization without using synchronous reference frame.

Conventional PLL:



Here voltage vector is translated from abc natural reference from to αβ stationary reference frame by using Clark's transformation and then translated to dq rotating frame using parks transformation. Angular position of dq component is controlled by feedback loop by making q axis component equal to zero at steady state, thus d axis component will be the voltage vector amplitude

Under no harmonic distortion nor unbalance d, q component can be given by

$$\begin{bmatrix} Vd \\ Vq \end{bmatrix} = \begin{bmatrix} \cos\hat{\theta} & \sin\hat{\theta} \\ -\sin\hat{\theta} & \cos\hat{\theta} \end{bmatrix} \begin{bmatrix} U\cos\theta \\ U\sin\theta \end{bmatrix} = \begin{bmatrix} U\cos(\theta-\hat{\theta}) \\ U\sin(\theta-\hat{\theta}) \end{bmatrix} \quad (1)$$

Where

θ=phase of input signal

$\hat{\theta}$ = phase output from PLL

U=amplitude of input signal

Vd, Vq = Voltage of d and q axis component

From equation (1), it is clear that q axis component contains the information about phase error and d axis component will give voltage amplitude in steady state.

Under unbalance utility condition voltage vector can be generically expressed as

$$V = V_+ + V_- + V_0$$

Where +, -, o = represents positive, negative and zero sequence component

By using Clark's transformation voltage vector at α, β, γ, axis with zero component on γ axis is given by

$$V=\begin{bmatrix} V\alpha \\ V\beta \\ V\gamma \end{bmatrix} = T_{\alpha\beta/abc}\begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix}$$

When zero sequence components is considered on γ axis, it has no influence on parks transformation. Thus voltage vector on αβ plan is given by

$$V_{\alpha\beta} = T_{\alpha\beta/abc}(V_+ + V_-)$$

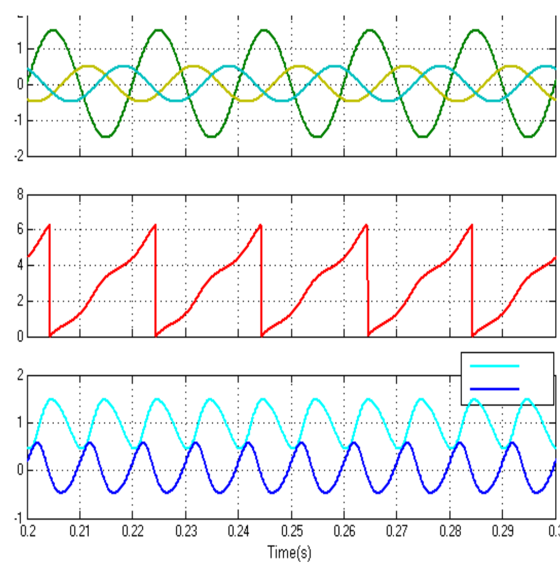
$$=2/3\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/2 & 1/2 & 1/2 \end{bmatrix}(V_+ + V_-)$$

$$=\begin{bmatrix} U_+ \cos\theta_+ & +U_- \cos\theta_- \\ U_+ \sin\theta_+ & +U_- \sin\theta_- \end{bmatrix} \quad (2)$$

From above equation, it is clear that voltage vector is no longer rotating with positive direction with neither constant magnitude nor constant rotating frequency under unbalanced grid condition.

After Park's transformation q axis component contains phase error information and 2ω repel. Large value of 2ω ripple makes it difficult get correct phase error and amplitude information.

Content of 2ω can be reduced by reducing the bandwidth of control loop but it results in deterioration of dynamic response as well as positive sequence voltages detected are distorted and unbalanced. From the below response it is clear that when conventional PLL is used to detect phase angle under unbalanced condition detected phase will be totally distorted.2ω ripple in d and q axis makes it difficult to get correct phase angle error and amplitude. Better response can be obtained by reducing bandwidth of control loop, but this significantly deteriorates dynamic response and detected positive sequence voltage are distorted and unbalanced.



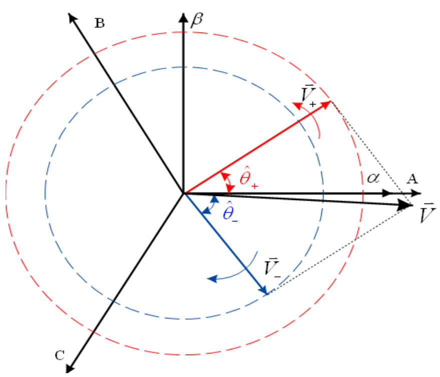
Response of conventional PLL under unbalanced condition

4. PROPOSED SYNCHRONIZATION METHOD:

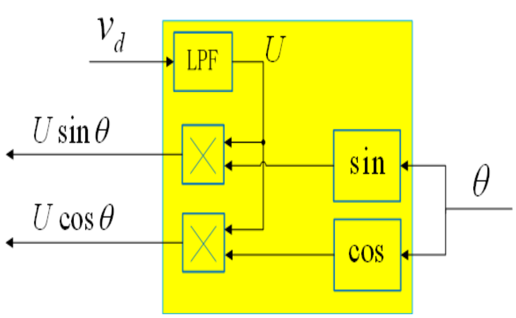
DSRF-PLL (double synchronous reference frame phase locked loop)

In the earlier αβ method both α, β components consisted of both positive and negative sequence component thus making positive sequence component detection difficult.

Here in DSRF-PLL voltage vector is decomposed into positive sequence phasor V_+ and negative sequence phasor V_- as in figure below

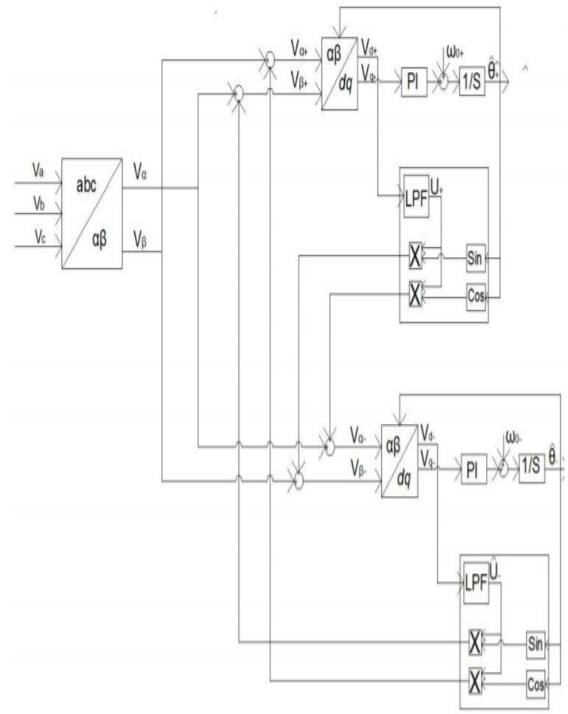


Synthesis circuit with 2 multipliers and 2 trigonometric functions and a low pass filter are used for decomposing the voltage vector as shown in figure below



The 2 orthogonal generated signals from synthesis circuit are used in decoupling the input signal positive and negative component.

Proposed PLL structure with 2 synthesis circuit is as shown below



This proposed PLL detects positive and negative sequence component at the same time. Input signals of each Park's transformation in V_α and V_β are calculated by subtracting the generated signals of other as shown in above figure. Thus after a transient process input signals of each PLL are cleaned up and distortion is cancelled at output of both PLL's. Thus even under distorted condition clean signal is extracted for proper synchronization. If $\omega_{o+}t$ is PLL's initial angular frequency to detect positive sequence component and $\omega_{o-}t$ to detect negative sequence component. Taking rotating reference frame rotating in positive direction equation (2) gives rise to equation (3)

$$\begin{bmatrix} Vd_+ \\ Vq_+ \end{bmatrix} = U_+ \begin{bmatrix}\cos(\theta_+ - \hat{\theta}_+) \\ \sin(\theta_+ - \hat{\theta}_+)\end{bmatrix} + U_- \begin{bmatrix}\cos(\theta_- - \widehat{\theta_+}) \\ \sin(\theta_- - \widehat{\theta_+})\end{bmatrix} \quad (3)$$

By setting $\hat{\theta}$ to $\omega_{o+}t$ equation (3) can be written as

$$\begin{bmatrix} Vd_+ \\ Vq_+ \end{bmatrix} = \begin{bmatrix} U_+ \quad + \cos(-2\omega o + t) \\ U\_\sin(-2\omega o + t) \end{bmatrix} \quad (4)$$

From equation (4) it can be seen that 2ω ripple is present in d axis component and hence a low pass filter is used to attenuate this ripple.

Thus low pass filter is used to attenuate 2ω ripple which means cutoff frequency of low pass filter, ω_c

$LPF(S)=\omega_c/S+\omega_c$

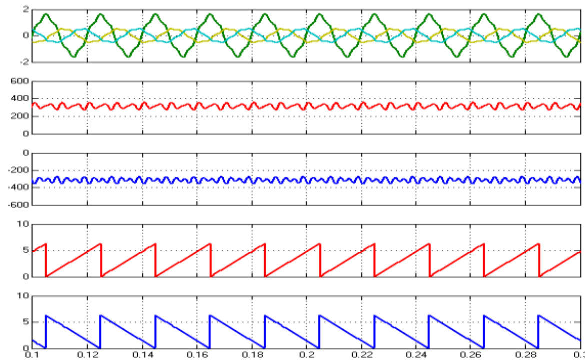
ω_c should not be bigger than 2ω for stable operation.

Bigger ω_c faster will be its congruence speed. Thus trade off will be between speed and stability to achieve desired behavior.

In the proposed circuit, low pass filter (LPF) is not included in closed loop of PLL so that its bandwidth does not affect the bandwidth of PLL.

LPF is only useful in dynamic process to help system get into stable state.

In steady state, when the PLL's input signals are balanced and no 2ω ripple occur then LPF only attenuate noise. In the below response we can see that we are to detect phase error and voltage amplitude more accurately when compared to other conventional methods.



Performance under distorted utility voltage

5. Conclusion

From the above discussion and results, we can conclude that proposed DSRF-PLL can accurately detect phase angle irrespective of grid conditions. DSRF PLL can track positive sequence component in a better way compared to conventional SRF PLL which fails the phase angle detection under unbalanced grid condition.

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