# A Novel To Model And Analyse Unbalanced Distribution System

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***Abstract*: This project develops an analytical model of an unbalanced radial distribution system consisting of a single-phase photovoltaic (PV), a three-phase induction machine load, a three-phase power factor correction capacitor (PFC), and a load. The analytical model is based on dynamic phasor (DP) for phases. The single-phase PV model includes inverter current control [proportional resonance (PR) controller], an L, or an LCL filter. The induction machine model is based on positive-, negative-, and zero sequence components' dynamic phasor. The sequence-based induction machine model was converted to the DP- reference frame and interconnected with other grid components. The developed analytical model is capable of small-signal analysis and can be used to identify variety of stability and/or harmonic issues in distribution networks, e.g., instability due to weak grid. Impact of unbalance on system dynamic performance can also be investigated using this model. The analytical model is benchmarked with a high-fidelity model built in Mat lab / Sim Power Systems where power electronic switching details are included. The small-signal analysis results are validated via Matlab/Sim Power Systems time domain simulations.**

## INTRODUCTION

The analysis of power distribution systems is an important area of research activities due to the vital role of distribution systems as the final link between the bulk power system and consumers. There are 3 type of power distribution namely loop, network and radial. Distribution system is highly radial in nature. Radial Distribution Systems is a system whereby power is received at the utility supply voltage level by a single, incoming substation. Through a series of step downs and splits, the power is converted for individual end-use equipment. Due to radial nature, there is consecutive increase in voltage drop from source bus to end buses.

In the last few years, generating electricity from clean and environment friendly resources is the world-wide trend to develop the future power grid. Photovoltaic (PV) power can be considered as a most promising and faster growing renewable source because of their low generation cost and minimum environmental impact. The PV system are planned and installed in distribution system to supply consumer directly. Therefore the distribution system is facing new challenge on its dynamic behavior with addition of PV. In addition induction machine based load are dominant in distribution system. The analytical model of such unbalanced distribution system provides the capacity to gain an accurate and deep understanding of the system. The objective of this dissertation is to model, analyze and simulate an unbalanced distribution system with both complex loads such as induction machine and also renewable such as inverter interfaced PVs. Proposed work improves the modeling strategy in two aspects and therefore tackle comprehensive dynamic phenomena of unbalanced distribution systems.

- A more comprehensive current control of PV inverter will be modeled. If current controls are ignored, interactions between the current controls of inverters and the grid can lead to resonances. Therefore, ignoring current controls of a grid connected inverter will lead to the omission of certain dynamics.
- Each source is modeled as a current source. The sources are then interfaced through network dynamics. Using this strategy, the network dynamics due to inductors and capacitors will not be omitted.

The dynamic performance of the unbalanced distribution system will be demonstrated with the three cases as follows:

- In the first case, step change in load torque is applied to the induction machine.
- In second case, effect of unbalanced level is investigated by applying ramp change in irradiance of the PV. This dynamic event emulates the cloud effect on a PV and distribution system.
- In third case, stability of the system is investigated by change in grid line length.

To demonstrate the above cases the study system will be built in Matlab/Sim Power Systems based on physical circuit connection.

## DESCRIPTION OF THE PROPOSED WORK

Our proposed technique involves investigates comprehensive modeling of unbalanced distribution systems using dynamic phasors. The system consists of a three-phase induction machine load, threephase resistive loads, a PFC and a single-phase PV system. The three-phase induction machine, will be modeled based on dynamic phasors and then be converted to phasors. A single-phase PV system at phase will be modeled in phase phasors. The entire system model will be obtained through a current source-based integration technique. The major contributionsof this paper include a comprehensive dynamic modeling approach for unbalanced radial distribution systems. Applications of the model will be demonstrated in small-signal analysis and fast and accurate simulation.

Methodologies:

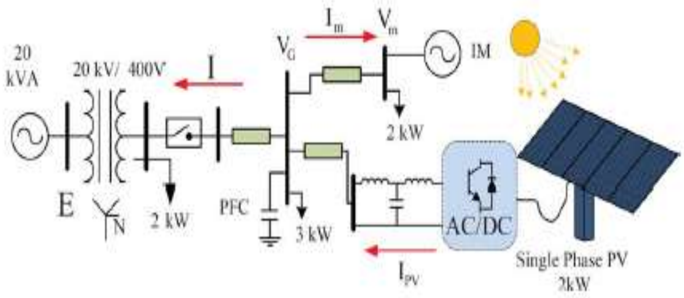


Fig: System fig

The parameters presented are utilized for the proposed study system shown in Fig. The distributed system consists of a single-phase PV station installed in phase othe system, a 3-phase induction machine, a 3-phase PFC, and a 3-phase load. Traditionally, two-stage converters (a DC-AC converter after a DC-DC converter) have been used for PV systems. Two-stage converters need additional devices compared with single-stage converters. Therefore, single-stage converters have been implemented in PV grid integration. The basic configuration of a single-phase PV is illustrated in Fig. The main elements of the single-stage PV are the proportional resonant (PR) current controller and the output filter.

The analytical model for the entire distribution system has been derived in Section III. The model was been builtinMatlab/Simulink. The nonlinear analytical model can be linearized based on a certain operating point using Matlab function “linmod”. Small-signal analysis can then be carried out for the linearized model. The same study system was also built in Matlab/SimPower Systems based on the physical circuit connection. TheMatlab/SimPower Systems model captures power electronic switching details and therefore is considered high-fidelity simulation model.

Three case studies have been carried out:

• In the first case, the analytical model in Simulink is benchmarked with the high-fidelity model in Sim Power Systems Dynamic simulation results are compared for the same dynamic event: a step change in load torque of the induction machine.

• In the second case, the effect of unbalance on the dynamic performance is investigated by applying a ramp change in irradiance of the PV. This dynamic event emulates the cloud effect on a PV and a distribution system

• In the third case, the effect of the grid-line length on stability is investigated. Small-signal analysis and time-domain simulation are carried out.

SYSTEM UNDER STUDY

Fig shows the basic configuration of an LCL filter in a single-phase PV. It is composed of two inductances and one capacitor connected to the grid through a single-phase transformer.

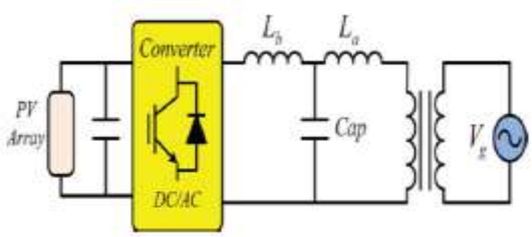


Fig :Basic configuration of PV system.

For unbalanced systems, frame-based dynamic models can be used for dynamic performance examination. Simulation packages such as PSCAD and Matlab/SimPower Systems [are based on simulation models with instantaneous variables, e.g., instantaneous voltages and currents in three phases. Conventional linearization at an operating condition cannot be applied to these models due to the periodic varying state variables. The necessary condition for small-signal analysis is to have constant values for state variables at steady state [7]. Transforming the models to a synchronous rotating reference frame is the most common technique utilized to overcome the above problem [7]. However the negative-sequence components presented in an unbalance system will be converted to 120-Hz ac variables in a -reference frame. Hence, -reference frame based models do not offer the capability of small-signal analysis under unbalanced topology and operating conditions.

OBJECTIVES

DP-based modeling can take into consideration of unbalance. For example, in [9], an induction machine (IM) model as well as a permanent magnet synchronous generator (PMSG) model in unbalanced conditions have been developed based on positive, negative, and zero (pnz) variables.
The objective of this proposed system is to
1. model, analyze and simulate an unbalanced distribution system with both complex loads such as Induction Motor
2. model, analyze and simulate an unbalanced distribution system renewable such as inverter interfaced PVs.

CONTROL STARTEGY

DP Model of a Single-Phase PV
Traditionally, two-stage converters (a DC-AC converter after a DC-DC converter) have been used for PV systems. Two-stage converters need additional devices compared with single-stage converters. Therefore, single-stage converters have been implemented in PV grid integration [20]–[23]. The basic configuration of a single-phase PV is illustrated in Fig. 2. The main elements of the single-stage PV are the proportional resonant (PR) current controller and the output filters. Fig. 2 shows the basic configuration of an LCL filter in a single-phase PV. It is composed of two inductances and one capacitor connected to the grid through a single-phase transformer. The simplified model of PV connected to the grid with an L or an LCL filter has been illustrated in Fig. 3. The output voltage of the DC-AC converter is, the filter inductances are and , and the grid side voltage is . Note that the transformer can be represented by an inductor Therefore and. Furthermore, for a PV connected to an L filter, if is used for the L filter inductance,

The time-domain equations of the system for the LCL filter

$$\begin{cases} L_1\frac{di_1}{dt} & = v_{c1} - v_G \\ L_2\frac{di_2}{dt} & = v_{con} - v_{c1} \\ C_1\frac{dv_{c1}}{dt} & = i_2 - i_1. \end{cases}$$

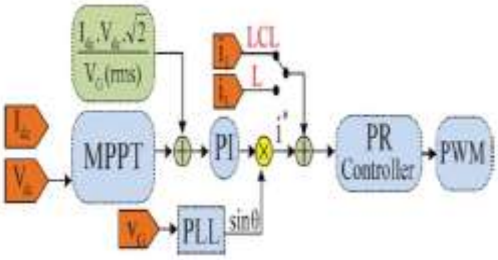


Fig 4. Basic control of a single-phase PV.

The dynamics of the PV system with LCL filter in DP is expressed as follows. It should be noted that only the first harmonic is considered for the derivation of dynamic phasor coefficients

$$\begin{cases} \dot{I}_1 & = \frac{1}{L_1}(V_{c1} - V_G) - j\omega_s I_1 \\ \dot{I}_2 & = \frac{1}{L_2}(V_{con} - V_{c1}) - j\omega_s I_2 \\ \dot{V}_{c1} & = \frac{1}{C_1}(I_2 - I_1) - j\omega_s V_{c1}. \end{cases} \quad (7)$$

A detailed control block diagram of the single-stage single phase PV is illustrated in Fig. 4.It is composed of a maximum power point tracking (MPPT) unit, a proportional resonant (PR) controller, a phase-locked-loop (PLL), and a pulse width modulation (PMW) pulse generation unit. In this paper, the effect of the MPPT dynamics and the PLL has been neglected for simplicity and special attention has been dedicated to the PR controller and the LCL filter.
1) DP Model of a PR Controller: PR control is used to track ac signals. The PR controller in Fig. 4 tries to provide unity power factor power from the PV. Therefore, the current referenceis synchronized with the grid voltage through a PLL. The dynamics of a PR controller considering only the fundamental harmonics can be expressed as:

$$\begin{aligned} v_{con} &= (K_p + \frac{K_r s}{s^2 + (\omega_s)^2})(i^* - i_1) \\ &= \left[K_p + K_r(\frac{0.5}{s + j\omega_s} + \frac{0.5}{s - j\omega_s})\right](i^* - i_1) \quad (9) \end{aligned}$$

where is the reference current comes from PV array. In the analytical model, the dynamics of PLL and MPPT are neglected for simplicity of analysis. is the grid current when the PV enhanced with LCL filter. In a case where the PV is interconnected with an L filter, will be replaced by , which is the grid current. The rest of the modeling part has considered the LCL filteronly. Define intermediate stat

$$\begin{cases} (s+j\omega_s)x_1 & = 0.5(i^* - i_1) \\ (s-j\omega_s)x_2 & = 0.5(i^* - i_1). \end{cases} \quad (10)$$

Rewriting (10) in time domain gives (11):

$$\begin{cases} \frac{dx_1}{dt} + j\omega_s x_1 = & 0.5(i^* - i_1) \\ \frac{dx_2}{dt} - j\omega_s x_2 = & 0.5(i^* - i_1). \end{cases} \quad (11)$$

Applying the characteristics of DP, the DP relationship can be derived

$$\begin{cases} \frac{dX_1}{dt} = & 0.5(I^* - I_1) - 2j\omega_s X_1 \\ \frac{dX_2}{dt} = & 0.5(I^* - I_1). \end{cases} \quad (12)$$

CONCLUSION

Dynamic phasor-based dynamic model would derived for an unbalanced distribution system consisting of a single-phase PV, a three-phase induction machine and a three-phase power factor correction capacitor. The model is capable of fast time-domain simulation and small-signal analysis. The model's accuracy in capturing time-domain dynamics has been validated by Matlab/SimPower Systems-based simulation. The model's capability of small-signal analysis was also demonstrated. The analysis results corroborate with time-domain simulation results in Matlab/SimPower Systems.

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