# Improving Power Quality Performance in Distributed Power Generation (Smart Grid)

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***Abstract*** — The voltage sag, swell, harmonics are the major power quality issues produced by the wind and solar system. In a distributed power system the focusing is on the improvements of these power quality issues. This can be achieved by the modified design of PI controller. The structure of designed controller consists of voltage control loop, current control loop, power control loop in dq0 reference frame. The operation of the controller is investigated for varying power demand with linear and non- linear loads from customer side and for varying smart grid impedance along with varying distributed generation source voltage. An increase in reactive demand at PCC (Point of Common coupling) would affect the system power factor at PCC. The conventional type PI controller for such change in consumer load and variation of the smart grid impedance do not exhibit a dynamic behaviour. Alternatively, the proposed controller simultaneously compute current dynamics and harmonics of the parameter for the generating control reference value to meet the additional reactive power requirement with reduced total harmonic distortion used as new reactive power reference value for the power controller . The design and modelling of photovoltaic cell, MPPT, DC/DC converter and inverter connected to the grid are done .The simulation for the proposed system is carried out using MATLAB 2010 Simulink software.

**Keywords - smart grid connected inverter, distributed generation, harmonic control, dq0 reference frame, PI controller, power control loop, voltage and current control loop**

## I INTRODUCTION

The combined solar and wind energy generation are several advantages for used as the distributed energy resourse.in earlier days some draw backs are there .this can be avoid by using the inverter and its controller circuit for PV based dg units. During the day and night times for improving the reactive power compensation and harmonic elimination on its neighbouring dg units and the grid by proper exchange of reactive power between the sources. For this approach the existing developed linear controller are PI and predictive control method. These two methods are more dominant in current error compensation. But in the case of conventional type pi controller normally do not have appropriate compensation from the inverter for grid connected application. The existing predictive control method is not superior for PV based DG units without dc-dc converter. This can be eliminated in SVPWM based PI controller. But this controller is insensitive to the system parameter since the algorithm does not include the system model. However the result is in the power imbalance between the generated power and load power due to grid impedance variation and can damage the capacitor and predictive device. The DVR with novel detection method [4] can compensate the voltage sag or interruption within 2-ms delay but this method additionally requires supper capacitor and power additional electronic devices. The existing control method are mainly focusing on voltage sag compensation and interruption at PCC.in this project a novel control strategy in dq0frame with communication interface its attempted to compensate

## II. BLOCK SCHEMATIC OF THE PROPOSED SYSTEM

The proposed model consists of a two different Distributed generating units (DG) comprises of PV array and wind power resource integrated to the grid through VSI and filter and control blocks as indicated in Fig. (1). the consumer loads are connected at PCC. The control block consists of abc – dq0 conversion block and voltage, current and power control blocks. Measuring instruments (voltage and current transformers are connected at the point of common coupling) to measure the currents flow through the VSI, induction generator, grid, customer demand.

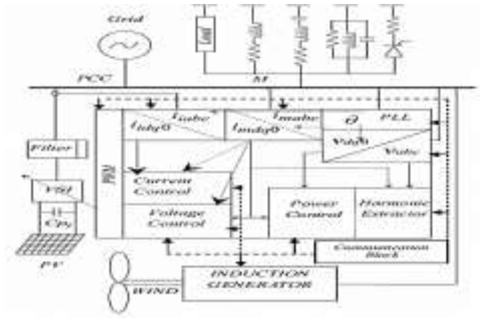


Fig 1: block diagram

This two units are supply's the local load and the surplus power is injected to the grid simultaneously PV sourced VSI is used for reactive compensation at PCC for avoid the voltage swell and sag. In order for communication between measured units and DG control units through DSC, embedded kit is used.

## III . MODELING OF 3Ø SELF EXCITED INDUCTION GENERATOR

The d-q axes equivalent circuits of an induction generator (IG) in synchronously rotating reference frame are shown in Fig. 2. The complete dynamic equations of IG, taking saturation into account, in synchronously rotating reference frame [2], [3] are represented in matrix form as follows

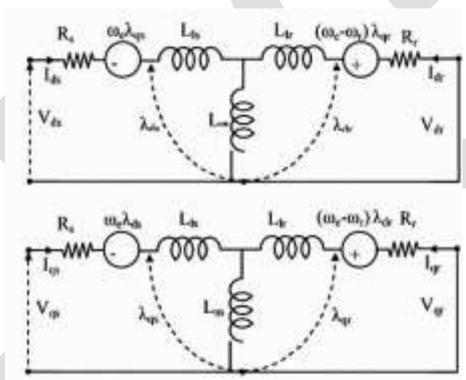

Fig.2- Equivalent circuit of lG - d-q model (a) d-axis (b) q-axis

These are represented in matrix form as follows

$$\frac{d}{dt}\begin{bmatrix}\lambda_{ds}\\ \lambda_{qs}\end{bmatrix}=\begin{bmatrix}V_{ds}\\ V_{qs}\end{bmatrix}-R_S\begin{bmatrix}i_{ds}\\ I_{qs}\end{bmatrix}-\omega\begin{bmatrix}0 & -1\\ 1 & 0\end{bmatrix}\begin{bmatrix}\lambda_{ds}\\ \lambda_{qs}\end{bmatrix}$$

$$\frac{d}{dt}\begin{bmatrix}\lambda_{dr}\\ \lambda_{qr}\end{bmatrix}=\begin{bmatrix}V_{dr}\\ V_{qr}\end{bmatrix}-R_r\begin{bmatrix}i_{ds}\\ i_{qs}\end{bmatrix}-(\omega-\omega_r)\begin{bmatrix}0 & -1\\ 1 & 0\end{bmatrix}\begin{bmatrix}\lambda_{dr}\\ \lambda_{qr}\end{bmatrix}$$

Where,

Rs = Per-phase stator resistance

Rr = Per-phase rotor resistance referred to stator

iqs = Stator q-axis current, ids = Stator d-axis current

iqr = Rotor q-axis current, idr = Rotor d-axis current

Yqs= Stator q-axis voltage, Yds= Stator d-axis voltage

Yqr= Rotor q-axis voltage, Ydr= Rotor d-axis voltage

ωe = Arbitrary reference frame speed

ωr = Rotor speed in rad/sec

λqs = Flux linkages of stator in q -axis

λds = Flux linkages of stator in d- axis

λqr = Flux linkages of rotor in q-axis

λdr = Flux linkages of rotor in d-axis

LIs = Stator Leakage reactance

Llr = Rotor Leakage reactance

Lm= Magnetizing inductance of inductance generator

## IV . MATHEMATICAL MODELLING OF THE PROPOSED SCHEME

In grid connected mode, both DGs are utilized for supplying pre specified power to load to minimize the power import from the grid. The simplified equivalent circuit of VSI integrated to grid in current control mode is indicated in Fig.3.

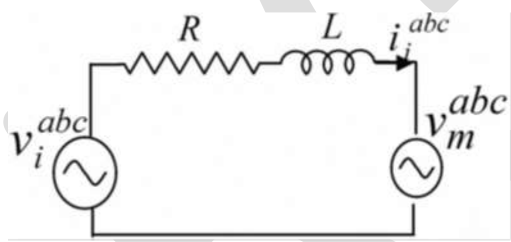


Fig 3: Simplified equivalent model of current control scheme for proposed system

The Vma, Vmb, Vmc &Via, Vib, Vic are the three phase ac voltage at the point of common coupling and voltage on inverter side, the subscripts m and i denote at the point of common coupling and inverter .The input to the inverter is a three phase voltage and is given by

$$V_{ia} = V_{max} \sin \omega t \quad (1)$$

$$V_{ib} = V_{max} \sin \omega t - \frac{2\pi}{3} \quad (2)$$

$$V_{ic} = V_{max} \sin \omega t + \frac{2\pi}{3} \quad (3)$$

Where Vmax and $\omega$ are the maximum phase voltage and angular frequency of the inverter respectively.

The voltage and current control model of the grid connected are implemented in [4] [5] for voltage and power controls. This developed controller model mostly concentrates only voltage sag and voltage interruption because the system model is not included in the controller. Accordingly the inverter output voltage is obtained as in eqn. (4)

$$[\begin{bmatrix} \frac{di_{id}}{dt} \\ \frac{di_{iq}}{dt} \end{bmatrix} = \frac{1}{L}[\begin{bmatrix} -R & \omega L \\ -\omega L & -R \end{bmatrix}\begin{bmatrix} i_{id} \\ i_{iq} \end{bmatrix} + \begin{bmatrix} v_{id} \\ v_{iq} \end{bmatrix} - \begin{bmatrix} v_{md} \\ v_{mq} \end{bmatrix}] \quad (4)$$

The injected active and reactive power components, p and q, can be represented in terms of the d- and q-axis components of the supply voltage at the Point of Common Coupling and the injected currents as follows:

$$p_{inv} = \frac{3}{2}(v_{id}i_{id} + v_{iq}i_{iq})$$

$$q_{inv} = \frac{3}{2}(v_{iq}i_{id} - v_{id}i_{iq})$$

To compensate for this filter-capacitor current component and the inductor current references are calculated by adding a simple feed-forward compensation term as follows in this proposed model

## V. CONTROL FUNCTION

One of the main objectives of the voltage controller is to achieve fast and accurate generation of the reactive current reference for regulating the voltage at PCC. To achieve this objective, the principle of voltage sag and swell mitigations along with harmonic reduction of DG sourced voltage source inverters are to inject a current into the PCC in order to keep the load voltage at its rated value. Using the voltage-oriented control, the active and reactive power injection can be controlled via a current-controlled VSI.

### 5.1 POWER CONTROL LOOP

$$Q_S(v) = Q_0(\frac{v}{v_0})^{\beta s} \qquad (5)$$

$$P_t(v) = P_0(\frac{v}{v_0})^{\alpha t} \qquad (6)$$

$$Q_t(v) = Q_0(\frac{v}{v_0})^{\beta t} \qquad (7)$$

With this arrangement, the dynamics of the system changes rapidly in the case of instantaneous load varying situations. A flexible control strategy is required to be developed to handle this dynamics. The proposed multilevel controller comprises of power control loop (external level control), voltage control loop (middle level control) and inner or current control loop. Outer loop creates reference for inner loop as indicated in Fig.4..

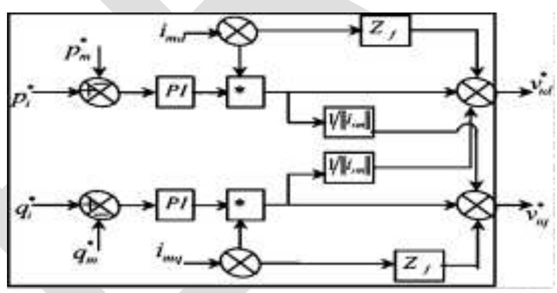


Fig 4: power control loop

$$\begin{bmatrix} L_S + \frac{K^2}{C_S} & \omega_0 L \\ \omega_0 L & L_S \end{bmatrix} \begin{bmatrix} i_{pn}(S) \\ i_{rn}(S) \end{bmatrix} = \begin{bmatrix} v_{pn}(s) \\ v_{rn}(s) \end{bmatrix} \qquad (8)$$

$$v_{pn}(t) = v_n \cos(n-1)\, t\omega_0 t \qquad (9)$$

$$v_{rn}(t) = -v_n \sin(n-1)\, t\omega_0 t \qquad (10)$$

$$\left(L_S + \frac{K^2}{C_S}\right) i_{pn}(s) + i_{rn}(s)\omega_0 L = V_{pn}(S) \qquad (11)$$

$-\omega_0 i_{pn}(s) + L_s i_{rn}(s) = V_{rn}(s)$ for harmonic analysis.

$$i_{rn}(t) = v_n A \sin(n-1)\, \omega_0 \mathrm{t} \qquad (12)$$

$$i_{rn}(t) = v_n B \cos(n-1)\, \omega_0 t \qquad (13)$$

$A = -\frac{n-1}{D}, B = \frac{1}{D}[(n-2) - \frac{\omega_n{}^2}{\omega_0{}^2(n-1)}]$

$D = X_L[\frac{\omega_r{}^2}{\omega_0} - n(n-2)]$ ;

$X_L = \omega_0 L$ , $\omega_r = \frac{K^2}{LC}$, $K = \frac{\sqrt{6}}{\pi}$

### 5.2 VOLTAGE AND CURRENT CONTROL LOOP

The inverter terminal voltage Vi is calculated and the compare to Vi* . An error signal is produced and then fed to a PI controller. The instantaneous values of the three-phase ac bus voltages in the dq0 reference frame permits to design a simpler control system than using abc components. The current control loop following the voltage control loop and this loop controls the real and reactive power independently and good response of the system dynamics and harmonics are ensured due to the inclusion of system modelling and inclusion of instantaneous grid impedance variation due to load variation.

One is active power control mode (P-CM) and the voltage control mode (Q-CM) and reduce the harmonic at PCC . In this paper voltage mode control is employed. In this mode, the current reactive power value is measured at point (qm) m this value of qm is compared with qi and error value is fed to the PI control for error minimization and the output of this controller gives dq0 voltage reference value (Vid *, Viq *J. These variables are fed to the voltage controller for generation of current reference. The change of reactive power requirement with respect to change of grid impedance value and local loads results in voltage drop across the filter.

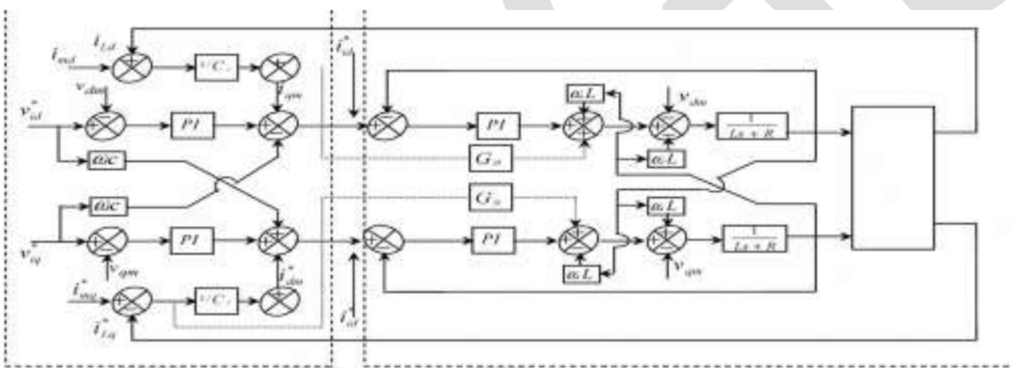


Fig 5: voltage and current control loop

## V. OPERATION THEORY OF PROPOSED CONTROLLER

This paper focuses on the control of reactive power for maintaining the rated voltage at PCC. The principles of voltage swell and sag mitigation during the change of local or grid impedance variation is identified by measuring the value of reactive power flow at PCC (qm). This amount of reactive power requirement is compared with the reactive power from the inverter (qi) and the error is used by the controller to balance the present reactive power requirement at PCC for voltage swell and sag. The conventional controllers mostly concentrate on voltage sag and interruption but the proposed controller also compensates the voltage swell by absorbing the Var during this period real power supplied by the inverter is affected by small value absorbing and reduce the values by extracting the harmonics but the power factor is maintained unity at PCC.

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## CONCLUSION

This report presents analysis and improvement of power quality (voltage sag, swell and harmonics) performance of smart grid connected inverter used in distributed generation. The developed controller controls the real and reactive power supplied by the DGs at the PCC. The controller is designed to deliver current at unity power factor at PCC. An increase in reactive power demand and harmonics at PCC due to change of load and grid impedance variation, would affect the system voltage at PCC. To study the dynamic behaviour of the proposed scheme, the state space model in dq reference frame has been developed for the entire hybrid scheme with the controller for validating the proposed with existing conventional SVPWM PI controller through simulation. The developed controller has been designed with outer power control loop, middle voltage control loop and inner current control loop. The performance of the developed controller model is evaluated through MATLAB/Simpower platform .Simulation have been carried out and the results are presented for both varying local power demand and grid impedance variation to evaluate the performance the proposed controller.

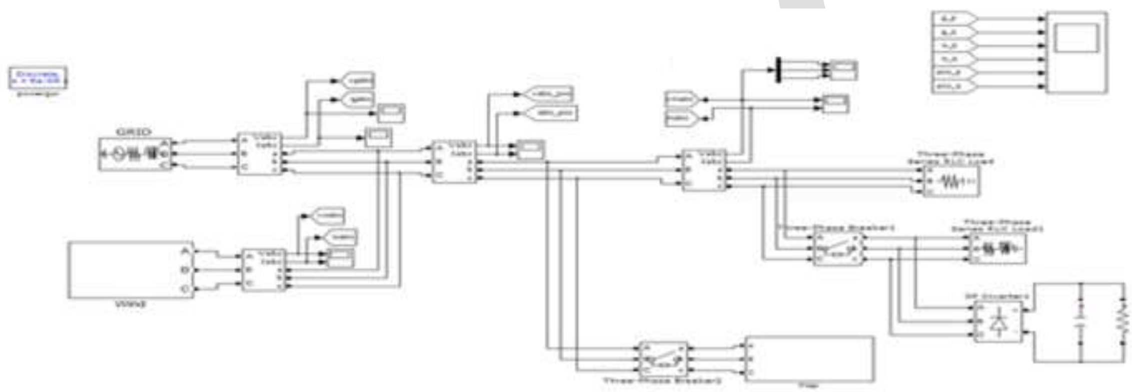
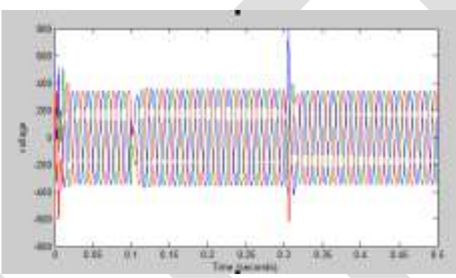


Fig 6: simulation diagram



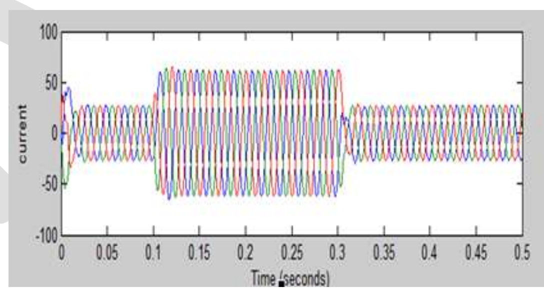
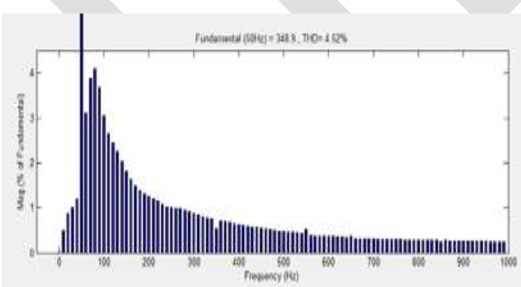



Fig 7 : Grid voltage

Fig 8: Grid current



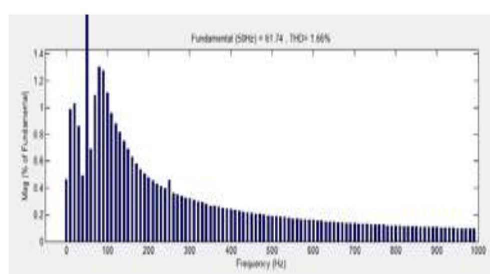


Fig 9: THD calculation of input voltage.

Fig 10:THD calculation of input current.

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