Interface of Inverter with Grid

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***Abstract*— The main scope of this paper is to interface of inverter with grid by using control techniques. The Current reference computation, PI controller, Current loop control, Phase Locked loop are used for control of inverter in this paper. The simulations for Line Voltage and current waveform are performed in MATLAB.**

***Keywords*— Inverter Control, voltage source converter, SPWM Technique, Phase locked loop, Micro grids, PI Controller**

I. INTRODUCTION

The requirement of reliable and flexible power system with modern control and communication system and power electronics has led to development of smart grid concept. Power electronics are enabling technology to convert classical power systems into smart grids. They allow controlling the power flows and bus voltages in the milliseconds.

Inverters based on Insulated-Gate Bipolar Transistors that provide fast switching and modulate any desired voltage. The Converters called Voltage Sourced Converters (VSC). They Control independently active and reactive power. They provide black start capability and injected reduced harmonics Currents allowing to use lighter filters.

Inverters based on thyristor called line commutated converters which can control active power while consuming non controllable reactive power, require the grid to be operated and require large filters for the harmonic current they generate. The main advantage is they are available for higher voltage and power and they produce less losses.
There are various control techniques useful for active and reactive power control of grid connected distributed generation systems.

II. SYSTEM DESCRIPTION

The model of Interface of Inverter with grid shown into figure 1.

The connection between grid and converter is also shown in figure 1.

In the control system use of current reference computation, Current loop control, Phase locked loop, Sinusoidal pulse width modulation (SPWM) technique.

The gate signal to IGBTs are given by using SPWM technique in Control of inverter.

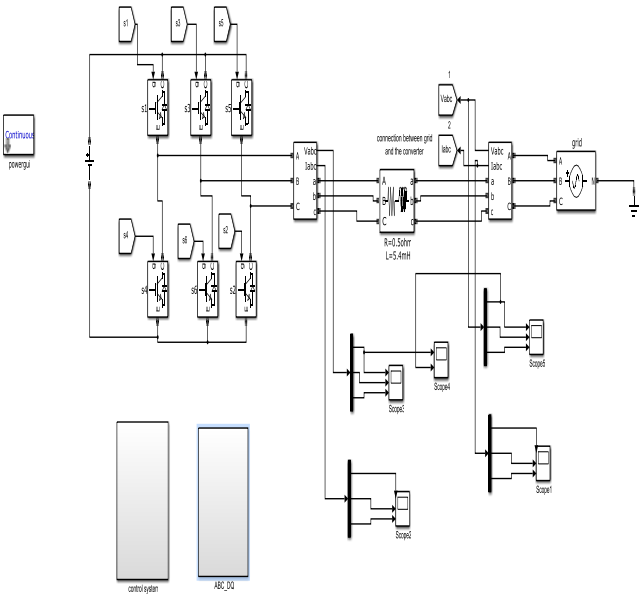

Fig. 1 Interface of Inverter with grid model

A. *abc to dq0 Transformation*

First the conversion of abc to dq transformation for voltage and current shown in figure 2. It is useful for easy solution of equation.

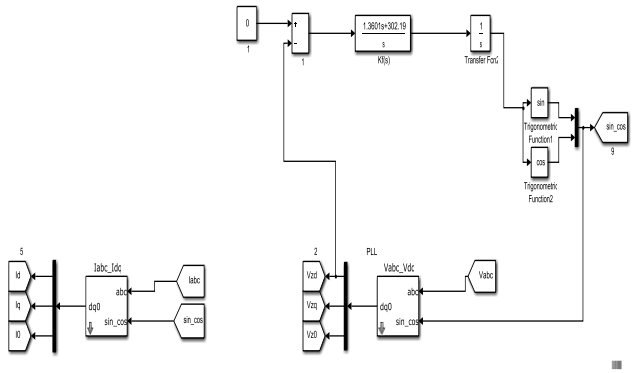

Fig. 2 abc to dq0 Transformation

III. CONTROL OF INVERTER

A. *Current reference computation*

The current references $i_d{}^*$ and $i_q{}^*$ to obtain the desired active and reactive powers $P^*$and Q^*can be obtained from the instantaneous power theory

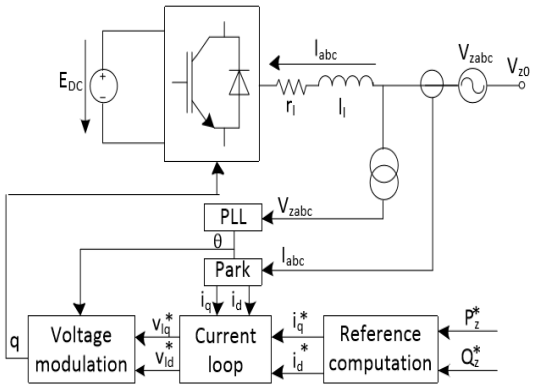

Fig. 3 Grid converter control general scheme for storage generation systems

$$P^* = \frac{3}{2}\left(v_{zq}\, i_q{}^* + v_{zd}\, i_d{}^*\right)$$

$$Q^* = \frac{3}{2}\left(v_{zq}\, i_d{}^* - v_{zd}\, i_q{}^*\right)$$

$$v_d = 0;$$

The current references can be derived as,

$$i_q{}^* = \frac{2}{3}\frac{P^*}{v_{zq}}$$

$$i_d{}^* = \frac{2}{3}\frac{Q^*}{v_{zq}}$$

B. *PI controller*

A PI controller can be used for the controller G_{cDc}

$$G_{cDc\,(s)} = K_{PDc} + \frac{K_{iDc}}{s}$$

The closed loop Transfer Function is computed as

$$\frac{W(s)}{W^*(s)} = \frac{sK_{PDc} + K_{iDc}}{\frac{1}{2}s^2C + sK_{PDc} + K_{iDc}}$$

Which is form of

$$\frac{W(s)}{W^*(s)} = \frac{2s\xi_E\omega_E + {\omega_E}^2}{s^2 + 2s\xi_E\omega_E + {\omega_E}^2}$$

The PI controller gains can be calculated as,

$$K_{PDc} = C\xi_E\omega_E$$

$$K_{iDc} = C\frac{{\omega_E}^2}{2}$$

where ξ_E is the desired damping ratio of DC voltage loop, and ω_E is the desired angular velocity of the voltage loop.

C. *Current loop Control*

The voltage equation with $v_{zd} = 0$

$$\begin{bmatrix} v_{zq} \\ 0 \end{bmatrix} - \begin{bmatrix} v_{lq} \\ v_{ld} \end{bmatrix} = \begin{bmatrix} r_l & l_l\omega_e \\ -l_l\omega_e & r_l \end{bmatrix}\begin{bmatrix} i_q \\ i_d \end{bmatrix} + \begin{bmatrix} l_l & 0 \\ 0 & l_l \end{bmatrix}\frac{d}{dt}\begin{bmatrix} i_q \\ i_d \end{bmatrix}$$

The q and d components can be decoupled using,

$$\begin{bmatrix} v_{lq} \\ v_{ld} \end{bmatrix} = \begin{bmatrix} -\hat{v}_{lq} + v_{lq} - l_l\omega_e i_{ld} \\ -\hat{v}_{ld} + l_l\omega_e i_{lq} \end{bmatrix}$$

where $\hat{v}_{lq}$ and $\hat{v}_{ld}$ are the outputs of the current controllers and v_{lq} and v_{ld} are the voltages to be applied by the converter.

The voltage equation,

$$\begin{bmatrix} \hat{v}_{lq} \\ \hat{v}_{ld} \end{bmatrix} = \begin{bmatrix} r_l & 0 \\ 0 & r_l \end{bmatrix}\begin{bmatrix} i_q \\ i_d \end{bmatrix} + \begin{bmatrix} l_l & 0 \\ 0 & l_l \end{bmatrix}\frac{d}{dt}\begin{bmatrix} i_q \\ i_d \end{bmatrix}$$

Applying the Laplace transformation, the transfer function between the controller voltages and converter currents can be derived as,

$$\frac{\hat{v}_{lq}(s)}{i_{q\,(s)}} = \frac{1}{l_l s + r_l}$$

$$\frac{\hat{v}_{ld}(s)}{i_{d\,(s)}} = \frac{1}{l_l s + r_l}$$

The controller can be designed using the Internal Model Control technique

$$G_{ciq}(s) = G_{cid}(s) = \frac{K_{Ps} + K_i}{s}$$

The constants;

$$K_P = \frac{l_l}{\tau}$$

$$K_P = \frac{r_l}{\tau}$$

where τ is the closed loop time constant of the electrical system. This constant must be chosen considering the converter physical restriction

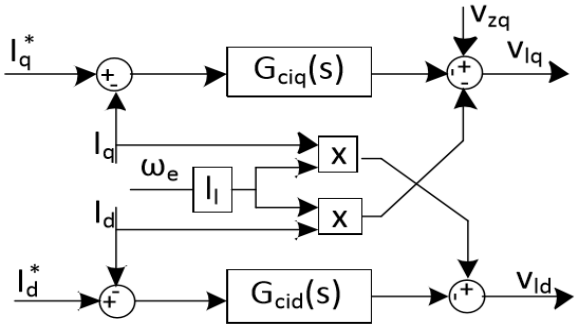

Fig. 4 Current Controller

D. Phase Locked Loop

A phase locked loop (PLL) is used to determine the angle and the angular velocity of the electrical network. A three-phase PLL consists in a feedback of the d-axis voltage component filtered by a PI controller. The output of the controller corresponds to the angular velocity ω_e of the electrical grid and the integration of this signal corresponds the grid angle θ_e.

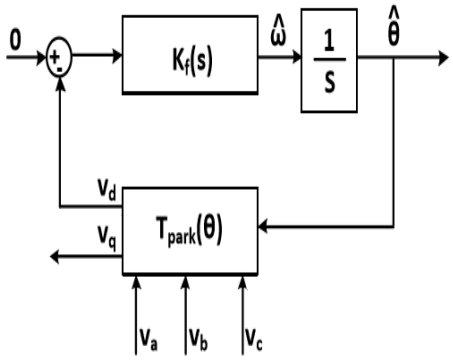

Fig. 5 Phase Locked Loop

To study the design of the PLL controller, the system can be linearized by assuming the angle error to be small. The following second order system is obtained.

$$\frac{\hat{\theta}_s}{\theta_s} = \frac{2\xi\omega_n s + {\omega_n}^2}{s^2 + 2\xi\omega_n + {\omega_n}^2}$$

where $\hat{\theta}_s$is the estimated grid angle and $\theta(s)$ is the real grid angle

The PLL controller can be defined as

$$K_{f(s)} = K_P\left(\frac{\frac{1}{\tau_{PLL}} + s}{s}\right)$$

where τ_{PLL} is the PLL time constant

The controller parameters $K_P$and τ_{PLL}can be computed using expressions.

$$\omega_n = \sqrt{\frac{K_P E_m}{\tau_{PLL}}}$$

$$\xi = \frac{\sqrt{\tau_{PLL} K_P E_m}}{2}$$

where E_m is the admitted peak voltage value,ξ is the damping ratio, ω_n is the electrical angular velocity.

E. Sinusoidal pulse Width Modulation (SPWM)

In multiple-pulse modulation, all pulses are the same width. Vary the pulse width according to the amplitude of a sine wave evaluated at the centre of the same pulse.

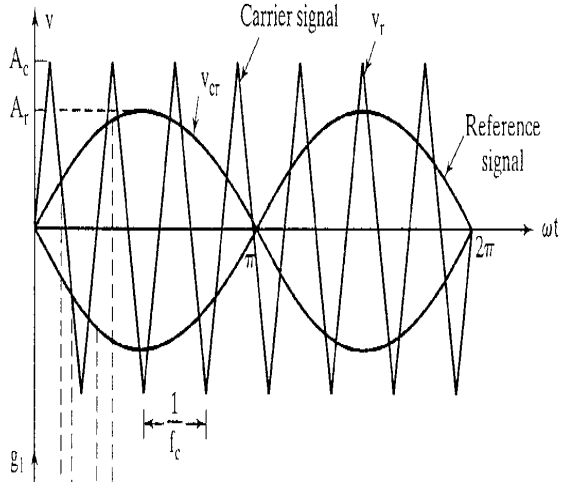

Fig. 6 Generate the gating signal

Comparing carrier and the reference signal

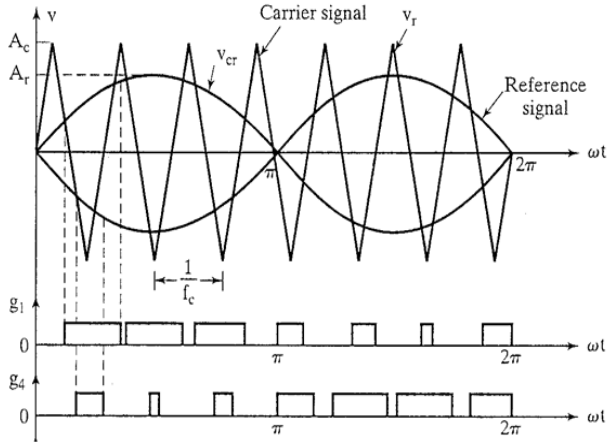

Fig. 7 Comparison of carrier and reference signal

Generate g_1 signal by comparison with V_r.Generate g_4 signal by comparison with $-V_r$

In SPWM technique a high frequency triangular carrier wave V_c is compared with Sinusoidal reference wave V_r of desired frequency. The intersection of V_c and V_r waves determines the switching instants and commutation of modulated Pulse.

IV. SIMULATION

A. Control Circuit of Inverter

The difference of reference and i_d& i_q are given to the transfer function. Then use of current controller and as shown

in simulation there is dq0 to abc transformation and then by using SPWM we get the gate signal for inverter.

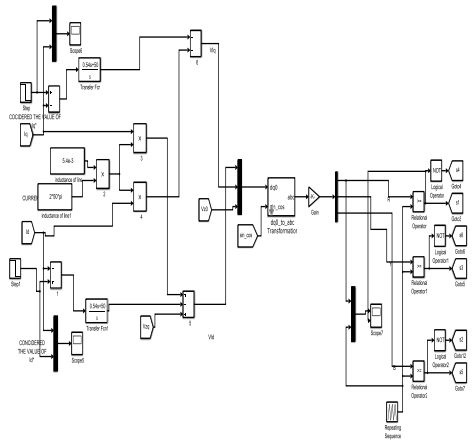

Fig 8. Control circuit of Interface of Inverter with Grid

B. *Control Circuit Waveform*

In control circuit waveform real and reference value of I_q and I_d are considered As shown in figure. If any changes in reference value according to that real value is also change.

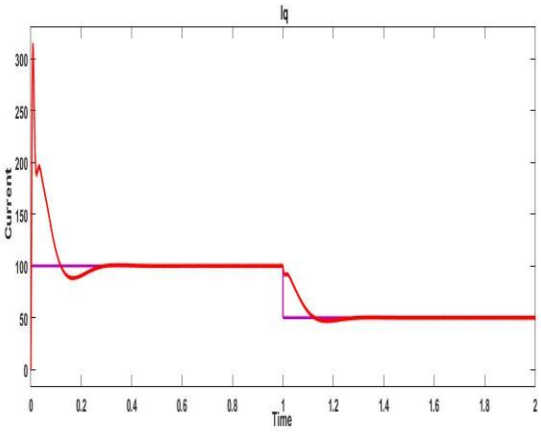

Fig 9. Waveform of Iq

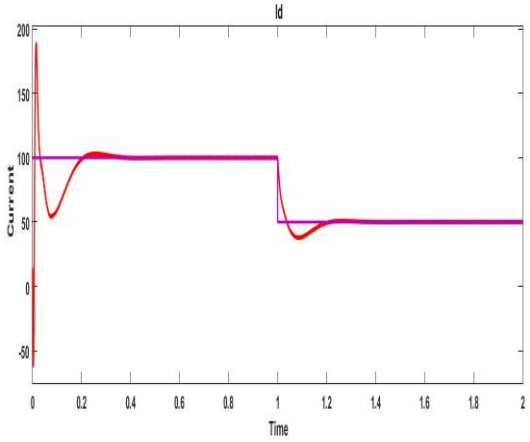

Fig 9. Waveform of Id

C. *Output Waveform*

The Output waveform of interface of inverter with grid inform of line voltage is shown into figure.I_{abc} is also shown in waveform.

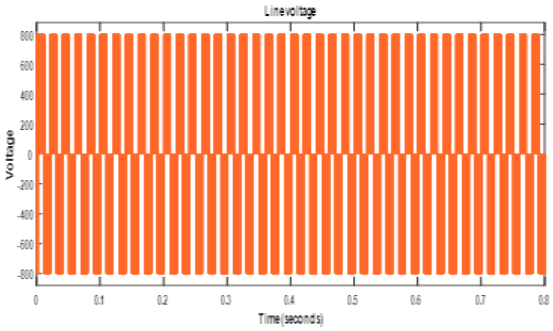

Fig 10. Line Voltage Waveform

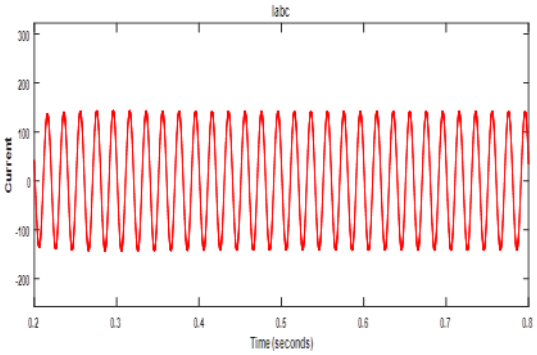

Fig 11. Current Waveform

V. CONCLUSIONS

The simulations are performed in MATLAB shows that by using control techniques for interface of inverter with grid real and reference value of I_q and I_d shown in waveform if changes in reference value according to that real value is also change. If Grid frequency is change according to that our inverter system frequency is also change.

ACKNOWLEDGMENT

I would like to express my special thanks and gratitude to my Guide Prof. NILAY. A. PATEL for his guidance, motivation, patience and his support and suggestions throughout the work.

I would like to thank my Head of the Department Dr. PRAGNESH BHATT for their support and understanding.

I would like to thank my family for their endless love, support, patience and encouragement throughout my all education.

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