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Synchronization ofIslandedSystem withInverter Interfacing With Grid

Jay R.Ray[1], Nilaykumar A.Patel[2]
1 M&V Patel Department of Electrical Engineering, Charusat, Changa, Gujarat, India
2 M&V Patel Department of Electrical Engineering, Charusat, Changa, Gujarat, India
Corresponding author:Jay Ray

Abstract: *In This Paper, Synchronization Of Island System With Inverter Interface With Grid Is Considered. The Different Control TechniquesLike Current Reference Computation, Phase Locked Loop, Current Loop Control, Sinusoidal Pulse Width Modulation Are Used For System Control. Inverter Control In Islanding Is Also Given In This Paper. The Change In Voltage, Current Of Inverter System And Grid During Before And After Islanding Are Considered In This Paper. The Simulation Is Performed In MATLAB.*

Keywords*—Inverter Control, Islanding, Phase Locked Loop, SPWM Technique, Current Controller, Smart Grid, Frequency Control*

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I. INTRODUCTION

The Importance Of Power Electronics And Devices Are More In Modern Power System. Now A Days Power Electronics Devices Made Power System More Reliable and Flexible. In The Smart Grid Concept These Devices Control Power Flows and Bus Voltages in Milliseconds [1], [2].

The First Mercury-Arc Valves Were Used As Power Electronic Devices In Power System. But Because Of Its Limitation They Replace By Semiconductor Switching Devices Like Diodes, Thyristors And Transistors. Power Electronics Is Very Important In High Voltage DC Transmission (HVDC), Flexible AC Transmission Systems (FACTS), Static VAR Compensator (SVC) For Active And Reactive Power Flow Control [2], Industrial Process Control With Variable Frequency Drives For Improving Productivity And Quality Of Products.

In HVDC System Inverter Is Useful At Receiving End Side To Convert DC To AC. In The Early Twentieth Century, Vacuum Tubes And Gas Filled Tubes Were Used As Switches In The Circuit Of Inverter. Inverters Made By Insulated-Gate Bipolar Transistors That Provide Fast Switching And Modulate Any Desired Voltage. The Converters Called Voltage Sourced Converters (VSC) [2]. Inverters Made By IGBT Provide Control Independently Active And Reactive Power. They Provide Black Start Capability And Injected Reduced Harmonics Currents Allowing To Use Lighter Filter. Inverters Made With 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 Which Are Useful For Active And Reactive Power Control Of Grid Connected Distributed Generation Systems. Whenever Grid Frequency Is Changed According To That Inverter Frequency Should Be Change. This Can Be Achieved By Using Control Technique For Interface Of Inverter. [1]

II. SYSTEM DESCRIPTION

The Model Of Synchronization Of Island System With Inverter Interface With Grid Is Shown In Figure 1. The Connection Between Inverter And Grid Is Also Shown In Figure. Three Phase Breaker Is Connected Between Grid And Inverter Systemfor Island Purpose. In Normal Condition Inverter System Provide Supply To Load As Well As Grid. The Phase To Phase Voltage Of Load Is 415V. The Inverter Control During Islanding Is Also Considered In This Paper.

First The Conversion Of abc To dq Transformation For Voltage And Current. The Conversion Of V_{abc} IntoV_{zd},V_{zq}, V_{z0} By Using Transfer Function andTrigonometric Function. [1]It Is Similarly Used For The Conversion Of i_{abc} Intoi_d,i_q,i_0.It Is Useful For Easy Solution Of Equation.

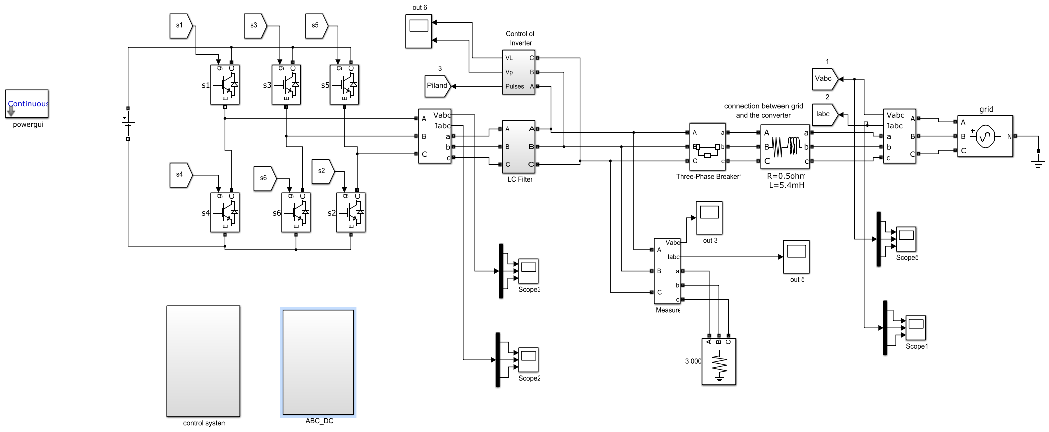

Figure1: Model of Synchronization of Islanded System with Inverter Interfacing With Grid

III. Control System

3.1 Current Reference Computation

The Current References $i_d{}^*$ And $i_q{}^*$ To Obtain The Desired Active And Reactive PowersP^*andQ^*Can Be Obtained From The Instantaneous Power Theory. [2]

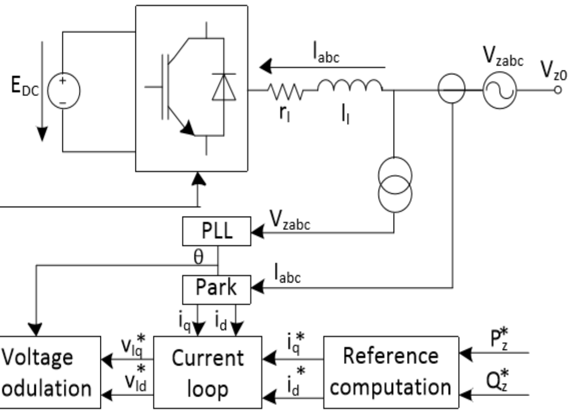

Figure2: Grid Converter Control General Scheme for Storage Generation Systems

$$P^* = \frac{3}{2}\left(v_{zq}\, i_q{}^* + v_{zd}\, i_d{}^*\right) \quad (1)$$

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

The Current References Can Be Derived By Equations Given Below.

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

$$i_d{}^* = \frac{2}{3}\frac{Q^*}{v_{zq}} \quad (4)$$

3.2 Current Loop Control

The Voltage Equation With $v_{zd} = 0$

$$\begin{bmatrix} v_{zq} \\ 0 \end{bmatrix} - \begin{bmatrix} v_{lq} \\ v_{ld} \end{bmatrix} = \begin{bmatrix} r_l & l_l\omega_e \\ -l_l\omega_e & r_l \end{bmatrix}\begin{bmatrix} i_q \\ i_d \end{bmatrix} + \begin{bmatrix} l_l & 0 \\ 0 & l_l \end{bmatrix}\frac{d}{dt}\begin{bmatrix} i_q \\ i_d \end{bmatrix} \quad (5)$$

The Q and D Components Can Be Decoupled Using,

$$\begin{bmatrix} v_{lq} \\ v_{ld} \end{bmatrix} = \begin{bmatrix} -\hat{v}_{lq} + v_{lq} - l_l\omega_e i_{ld} \\ -\hat{v}_{ld} + l_l\omega_e i_{lq} \end{bmatrix} \quad (6)$$

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,

$$\begin{bmatrix} \hat{v}_{lq} \\ \hat{v}_{ld} \end{bmatrix} = \begin{bmatrix} r_l & 0 \\ 0 & r_l \end{bmatrix}\begin{bmatrix} i_q \\ i_d \end{bmatrix} + \begin{bmatrix} l_l & 0 \\ 0 & l_l \end{bmatrix}\frac{d}{dt}\begin{bmatrix} i_q \\ i_d \end{bmatrix} \quad (7)$$

By Using the Laplace Transformation, the Transfer Function Between The Controller Voltages And Converter Currents Can Be Derived As,

$$\frac{\hat{v}_{lq}(s)}{i_{q(s)}} = \frac{1}{l_l s + r_l} \quad (8)$$

$$\frac{\hat{v}_{ld}(s)}{i_{d(s)}} = \frac{1}{l_l s + r_l} \quad (9)$$

The Controller Can Be Designed Using The Internal Model Control Technique,

$$G_{ciq}(s) = G_{cid}(s) = \frac{K_{Ps} + K_i}{s} \quad (10)$$

The Constants;

$$K_P = \frac{l_l}{\tau} \quad (11)$$

$$\frac{r_l}{\tau} \quad (12)$$

Where τ Is The Closed Loop Time Constant Of The Electrical System. This Constant Must Be Chosen Considering The Converter Physical Restriction.
The Basic Block Diagram Of Current Controller Is Shown In Figure 3.

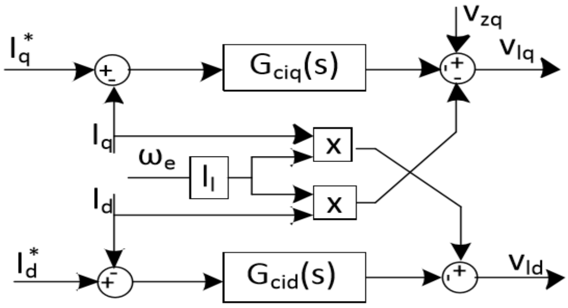

Figure3:Current Controller

3.3 Phase Locked Loop

A Phase Locked Loop (PLL) Is Used For 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.

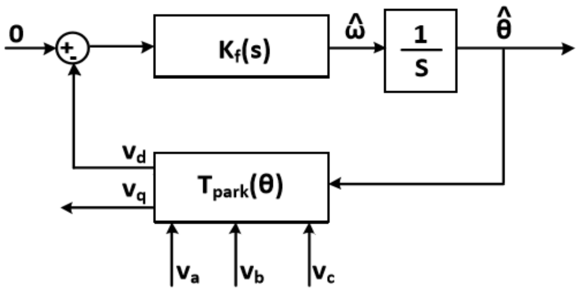

Figure4: Phase Locked Loop

ForThe Design Of The PLL Controller, The System Can Be Linearized By Assuming The Angle Error To Be Small. Thefollowing Second Order System Is Obtained.

$$\frac{\hat{\theta}_s}{\theta_s} = \frac{2\xi\omega_n s + \omega_n^2}{s^2 + 2\xi\omega_n + \omega_n^2} \quad (13)$$

Where $\hat{\theta}_s$ Is The Estimated Grid Angle And $\theta(s)$ Is The Real Grid Angle.
The PLL Controller Can Be Defined As,

$$K_{f(s)} = K_P\left(\frac{\frac{1}{\tau_{PLL}} + s}{s}\right) \quad (14)$$

Where τ_{PLL} Is The PLL Time Constant.

The Controller Parameters K_P And τ_{PLL} Can Be Computed Using Expressions.

$$\omega_n = \sqrt{\frac{K_P E_m}{\tau_{PLL}}} \quad (15)$$

$$\xi = \frac{\sqrt{\tau_{PLL} K_P E_m}}{2} \quad (16)$$

Where E_m Is the Admitted Peak Voltage Value, ξ Is the Damping Ratio, ω_n Is The Electrical Angular Velocity.

3.4 Sinusoidal Pulse Width Modulation (SPWM)

In Sinusoidal Pulse Width Modulation There Is Comparison Of Sine Wave And Triangular Wave.The AmplitudeOf Sine Wave Is Less Than Triangular Wave. [1]

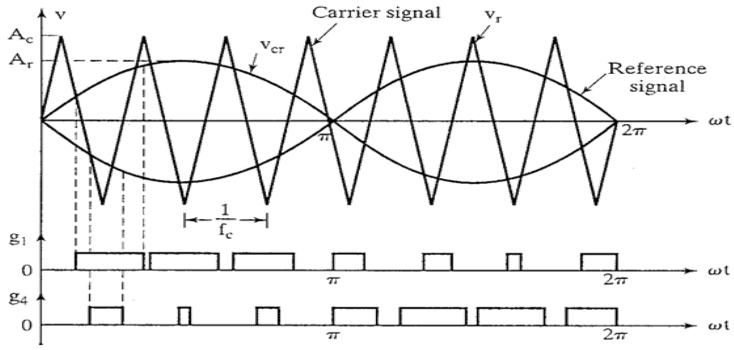

Fig. 5 Comparison Of Sine Wave And Triangular Wave

IV. SIMULATION

4.1 Control Circuit ofInverter System

The Difference ofReference and i_d & i_q Are Given To the Transfer Function.In Control Circuit Real And Reference Value Of I_q And I_d Are Considered. If Any Changes In Reference Value According To That Real Value Is Also Change. Which Indicate That If Any Changes in Reference Value according To That Our System Match the Value .The Current Controller Shown inSimulation. There Is dq0 To abc Transformation And Use Of Switch For The Islanding Mode. By Using SPWM Technique Gate Signal Are Given To Igbts Of Inverter. The Circuit Breaker Time Is 1 Second So Before Islanding The SPWM Signal Are Given As Gate Signal To IGBT And After Islanding The Signal Are Given By Inverter Control In Islanding. The Control Circuit Of Inverter Is Shown In Figure 6.The Breaker Is Used To Make System Operate In With And Without Islanding Mode.

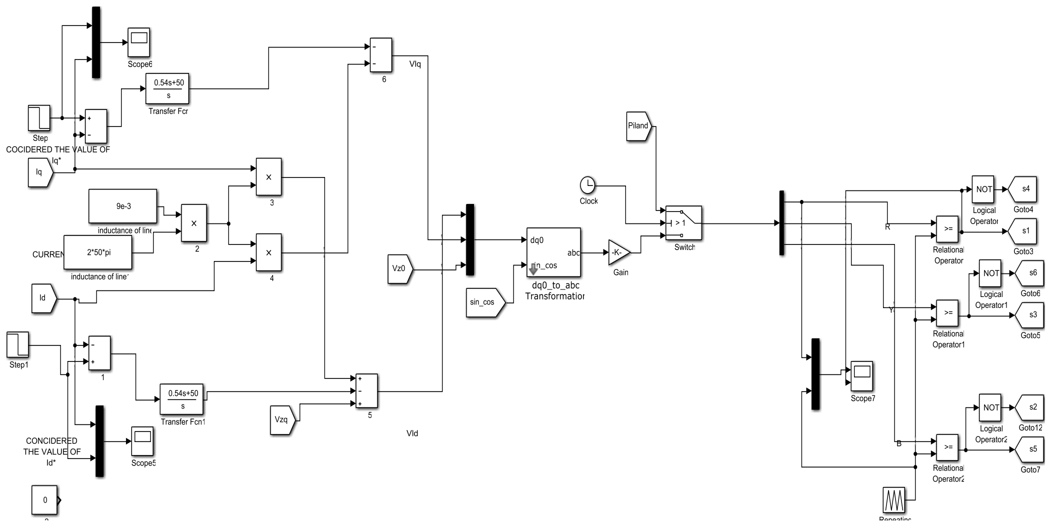

Figure 6: Control CircuitofInverter System

4.2Inverter Control In Islanding

Three Phases Are Shown In Figure 7. There Is Conversion Of Line Voltage Into Phase Voltage In Subsystem 1. By Using Three Phase Voltage We Get Pulses Which Are Useful As Gate Pulses For IGBT's During Islanding Mode. The Description Of Pulses Is Explained In Detail In Topic 4.2.1.

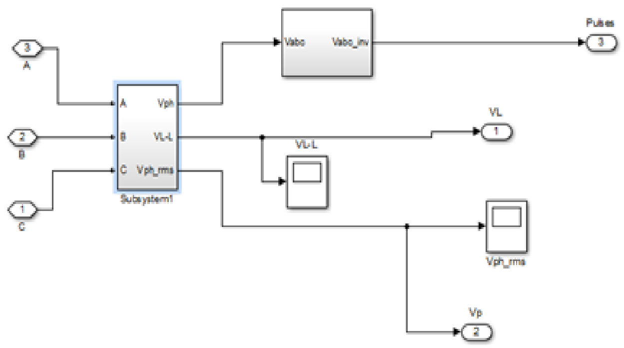

Figure 7: Inverter Control inIslanding

4.2.1 Pulses For Inverter After Islanding

As Shown In Figure 8, Phase Voltage Is Divided By Base Value So There Is Per Unit Conversion.The Base Value Of The Line Voltage Is 230V.In Sub-System by UsingequationSin(ωt),Sin($\omega t - \frac{2pi}{3}$), Sin($\omega t + \frac{2pi}{3}$) We Get Wave Shape. Use Of PI Controller For Error Solves And By Use Of ProductWe Get Pulses For Inverter. Then Pulses Which We Get They Are Gate Pulses Of Inverter During Islanding Mode.

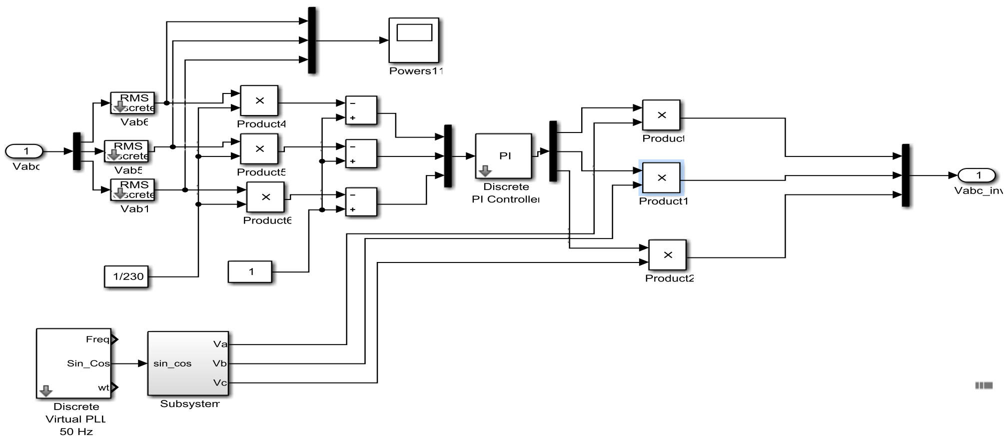

Figure 8: Pulses for Inverter afterIslanding

4.3 Output Waveform ofInverter System

The Output Waveform Of Voltage And Current Are Shown In Figure 9 &10. The Voltage Is SPWM Which Is Gate Signal For Igbts Of Inverter. The Circuit Breaker Time Is 1 Second. Our Inverter System Also Provide Supply To Load After Islanding. The Variation in Current of Inverter after Islanding Because Of Load.

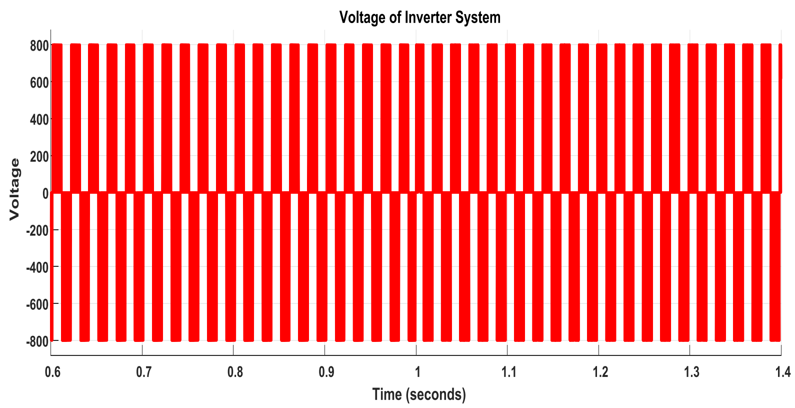

Figure 9: Waveform of Inverter System Voltage

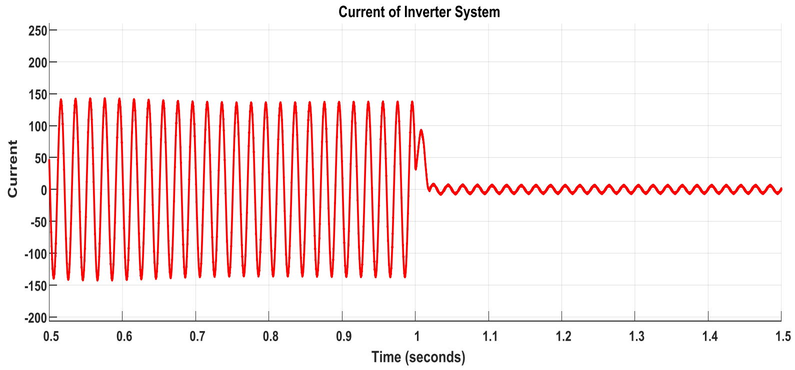

Figure 10: Waveform of Inverter System Current

4.3 Waveform of Grid Voltage and Current

Waveform Of Grid Voltage And Current Are Shown In Figure 11&12. In The Comparison of Frequency of Grid Voltage and Inverter System Voltage Is Same. During Islanding Grid Is Disconnected From The System. After Islanding Grid Current Is Zero Shown In Waveform.

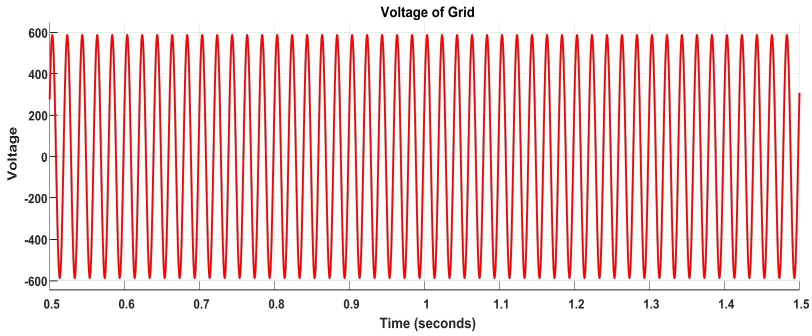

Figure 11: Waveform ofGrid Voltage

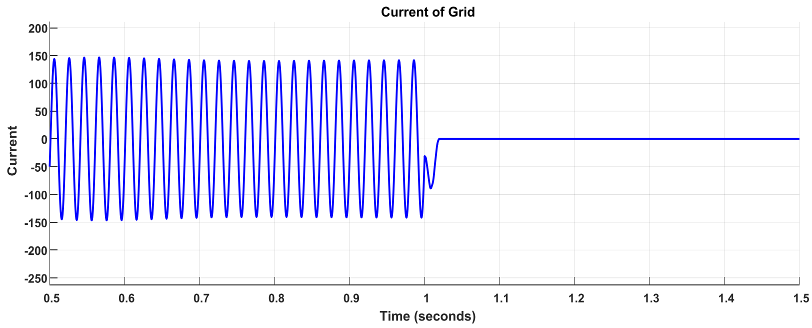

Figure 12: Waveform ofGrid Current

4.4 Waveform ofLoad Voltage andLoad Current

The Waveform Of Load Voltage And Load Current Are Shown In Figure 13&14. They are Phase toPhase Voltage.

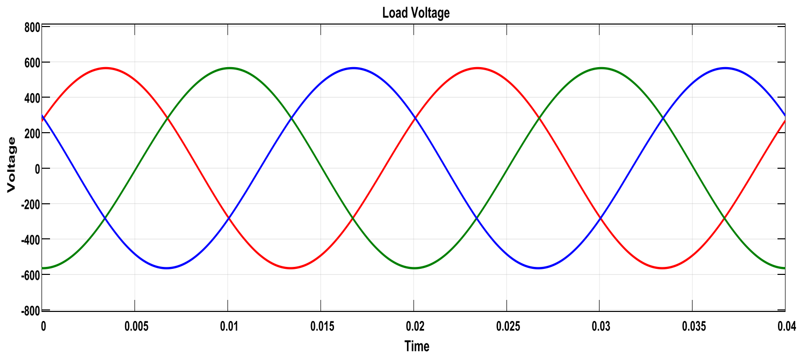

Figure 13: Waveform ofLoad Voltage

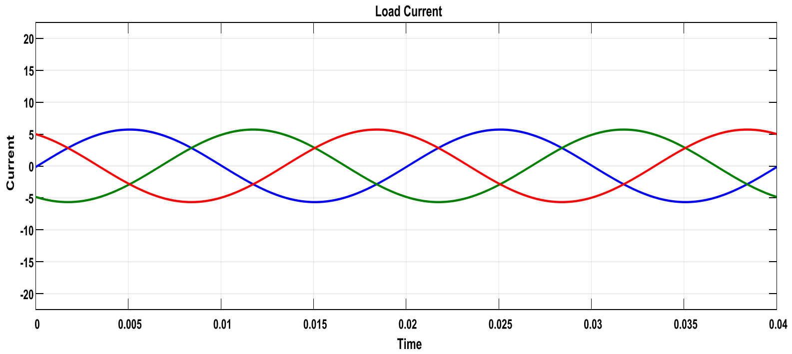

Figure 14: Waveform ofLoad Current

V. CONCLUSION

The Simulation Is Performed In MATLAB Shows That By Using Control Techniques Like Phase Locked Loop (PLL), Current Reference Computation, Current Loop Control, SPWM Technique We Match The Frequency Of Inverter System And Grid. If Grid Frequency Is Change According To That Our Inverter System Frequency Is Also Change. In Islanding Mode That Means After The Disconnection Of Grid The Voltage 230V Is Maintained. Before Islanding Mode The SPWM Signal From Control System Use As Gate Signal For Inverter. After Islanding Pulses From Inverter Control In Islanding Use As Gate Signal To Inverter.

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Jay R. Ray Received Bachelor ofEngineering Degree in Electrical Engineering From Gujarat Technological University In 2016. He Is Currently Pursuing Master Of Technology In Electrical Power System From Charotar University Of Science And Technology, Changa. His Main Field Of Interest Include Electrical Power System, HVDC Systems, Facts Devices, Power System Protection.

Nilaykumar A. Patel Received Bachelor Of Engineering Degree in Electrical Engineering From B.V.M., V.V.Nagar In 1994 And Master Of Engineering Degree In Electrical Power System From B.V.M., V.V. NagarIn 2010. He Is Currently Pursuing His Phd From Charotar University Of Science And Technology, Changa. He Is Now Assistant Professor In Electrical Engineering Department ofCharotar University Of Science And Technology. His Main Field Of Interest Includes Power System Protection, Electrical Machines, HVDC System.

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