Middle-East Journal of Scientific Research 25 (4): 864-870, 2017
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2017.864.870

Synchronization Control of Grid Connected Photovoltaic System

[1]*A. Angela Sheril* and [2]*M. Ramesh Babu*

[1]Department of Electrical and Electronics Engineering,
St.Joseph's College of Engineering, Chennai, India
[2]Department of Electrical and Electronics Engineering,
St.Joseph's College of Engineering, Chennai, India

Abstract: Integration of renewable energy sources to utility grid depends on the scale of power that is being generated. The main aim of this paper is to analyze the grid interfacing behavior, its control performance and operation when connected to a Renewable source. A Current Fed-Dual Active Bridge (CF-DAB) is used since high frequency Alternating Current has to be maintained in the Grid. This type of converter also provides electrical circuit protection from stray currents. The Maximum Power Point of the Solar Panel is estimated using Incremental Conductance Algorithm (ICT). Phase Locked Loop is used to synchronize the inverter's voltage and current and that of the grid and hence the entire system is operated synchronously. The Grid here is represented as a Nine Bus System where three sources are used in order to meet the load one being Renewable form of source namely, Solar Energy. The entire system is operated at a voltage of 11kV. The model has been described with reference to and implemented in MATLAB/SIMULINK software. Comprehensive simulation results are presented at the end of the paper and hence analyzed to validate that the proposed simulation model is effective.

Key words: Response surface and parameter dual methodologies · Central composite design · Liposomes · Wool dyeing · Color strength (K/S)

INTRODUCTION

Renewable Energy also referred to as the Non-Conventional type of Energy is the source that is continuously used by natural phenomena. The various types of Renewable energy include solar energy, bio-energy - bio-fuels, wind energy, ocean energy, tidal energy, hydropower etc. A renewable energy system converts the energy that is present in sunlight, geothermal heat, falling-water, wind, sea-waves or biomass into a usable form that is heat energy or electrical energy. The majority of the renewable energy comes either directly or indirectly from sun and wind and can never be exhausted and therefore they are called Renewable Energy.

Photovoltaic cells are made of special materials called semiconductors namely silicon. PV cells are connected in series on a panel to form a PV module for obtaining high power. Cells when connected in series enhance the current and when connected in parallel increase the voltage. Cells when connected together forms module and when modules are connected together forms Array. The PV Array generates DC power because of which power electronics converters are essential. Actually power electronics converters are required to convert the DC power to AC power and to achieve the Maximum Power Point (MPP).This power can be fed to the Grid. The Maximum Power Point Tracking (MPPT) for a PV connected Grid is evaluated using Incremental Conductance Algorithm [3, 2]. The converter used here CF-DAB is highly efficient with Grid interconnection [5]. With the use of Phase Locked Loop PLL the inverters voltage and current and that of the grid are maintained and operated synchronously. There are different ways in which the PLL can be designed [4].

General Block Diagram of the System: The Intended Grid Connected Photovoltaic System (GCPS) consists of a Solar Panel, Converter, Inverter, PLL connected to Grid 2 and two other AC sources connected to Grid 1 and Grid

Corresponding Author: A. Angela Sheril, Department of Electrical and Electronics Engineering,
St. Joseph's College of Engineering, Chennai, India.

3.The input to the Solar Panel is Temperature and Solar Irradiance, in other words DC input. This DC input is fed to a Converter. The converter then boosts the voltage level depending on the type of Converter that is being used. In this system, a Current Fed Dual Active Bridge Filter is used. The DC output is then fed to a three phase inverter which provides an Alternating Current (AC). The voltage and current from the panel is sensed by a controller Unit. An MPPT (Maximum Power Point Tracking) Controller is used to sense the voltage and current and provide the required Duty Cycle to the Converter. Phase Locked Loop (PLL) is used to match the inverter's voltage and frequency with that of the Grid. The system used here for implementation is an 11kV System.

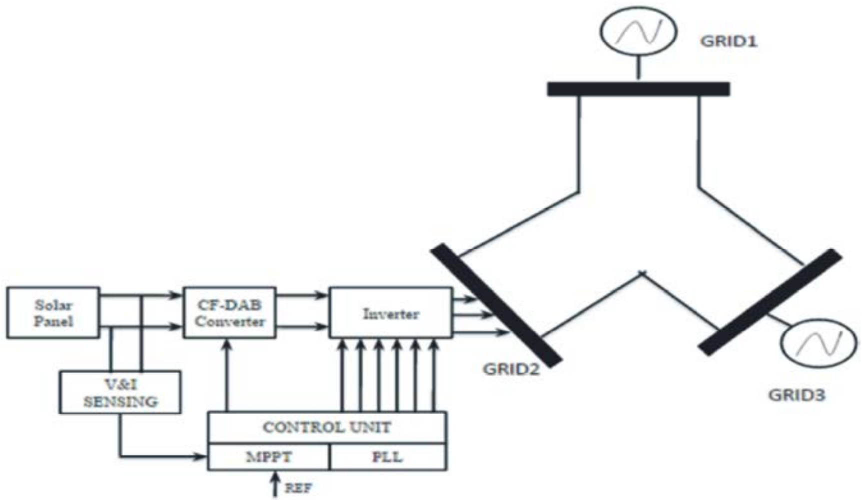

Fig. 1: Block Diagram of A GCPS

Solar Panel: A number of PV cells are connected in series circuits on a panel to form a PV module for obtaining high power. Modeling is basically described with the reference to a PV module. The equivalent circuit of a Solar Module consists of an ideal current source, a diode connected in parallel with the current source and a series resistor. When the cells are exposed to sunlight and the energy from each photon (light particle), which is hitting the silicon substrate liberates an electron and a corresponding hole. If this happens within the range of the electric field's influence, then the electrons will be sent to the N side and the holes to the P side, resulting in yet further disruption of electrical neutrality. This flow of electrons signifies the flow of current and the electrical field in the cell produces a voltage and the product of these two is power.

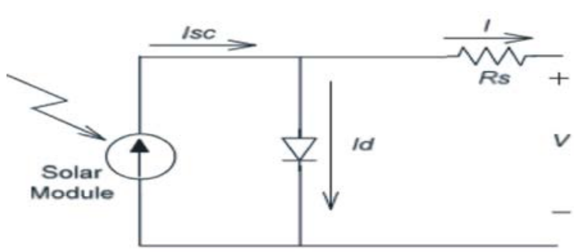

Fig. 2: Equivalent Model of a PV Array

where,
V is the terminal voltage of the Module
Rs is the resistance of the Module
I_{SC} is the short circuit current of a module under a given solar irradiance
I_d is the diode current

The input to the solar panel is temperature and irradiance. A temperature of 25◎ and irradiance of 1000 (W/◎◎^2) was taken. Applying the required equations a voltage of 10.5 kV with 50A of current was generated which was fed to the converter.

Current Fed – Dual Active Filter: The Dual Active Bridge DC-DC converter is known because of its high-recurrence galvanic separation(to prevent direct conduction path), delicate exchanging trademark and bidirectional force stream [5]. In this way, the PV framework can attain high unwavering quality and high effective most extreme force point following. CF-DAB converter is mainly used for PV application on a dc distributed system. Because of the high-frequency isolated dc–dc converters the PV system can be directly connected to the high-voltage ac grid without bulky line-frequency transformer and hence the converter output voltage is scalable due to it's the modular structure. The dc–dc module is interfaced with segmented PV arrays having independent MPPT; therefore, the solar energy harvesting can be maximized. The dc-link capacitance is mainly determined by the allowed voltage ripple on the dc-link in specific system.

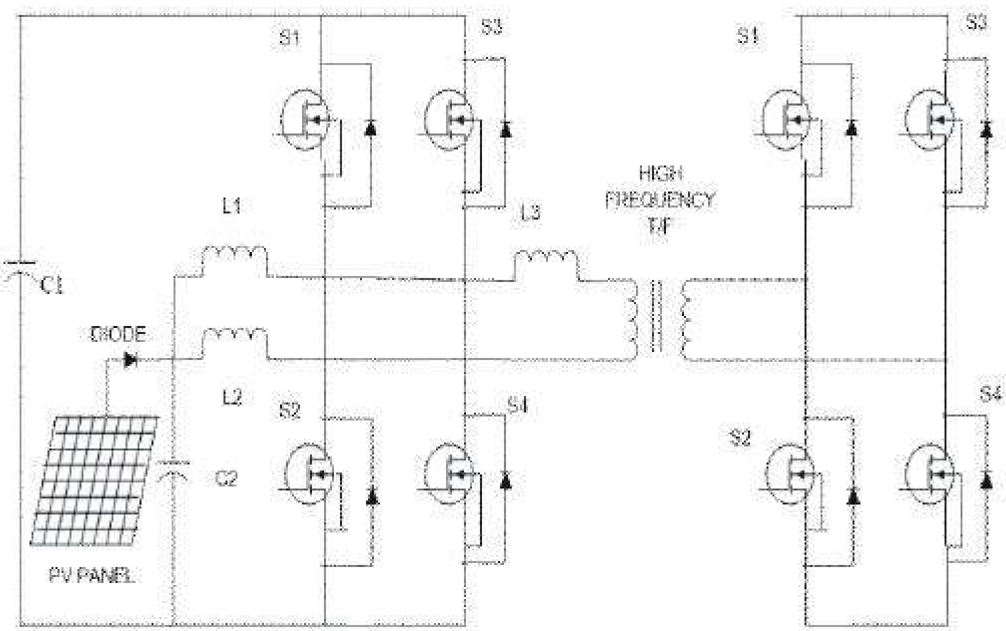

Fig. 3a: Current Fed - Dual Active Bridge Converter

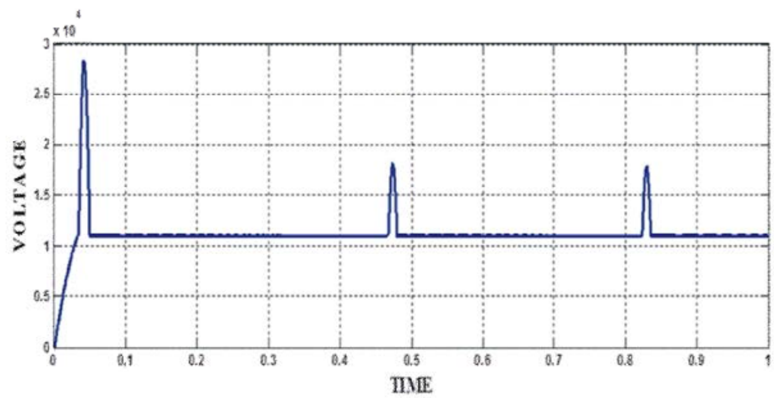

Fig. 3a: Current Fed - Dual Active Bridge Converter Output

Maximum Power Point Tracking: Maximum power point tracking technique is used to ameliorate the efficiency of the solar panel. In the source side we are using a CF-DAB converter connected to a solar panel in order to enhance the output voltage. By changing the duty cycle of the CF-DAB converter appropriately the source impedance can be matched with that of the load impedance. In this paper, Incremental Conductance Algorithm is used. Here two sensors namely the voltage and the current sensors are used to sense the output voltage and current of the PV array. The use of ICT Algorithm helps in sensing Voltage and Current so as to sense the output voltage and PV array current. Irradiance is taken into consideration and also the error due to irradiance is eliminated as Voltage and Current are sensed simultaneously. The present and previous values of Voltage and Current were determined. The controller measures incremental changes in PV array current and voltage to predict the effect of a voltage change. It aids in providing the duty cycle to the switching device.

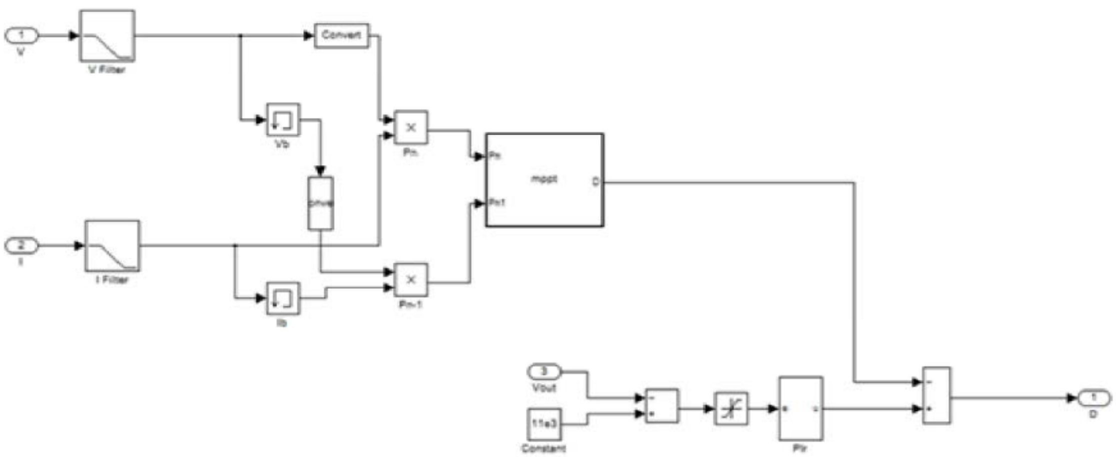

Fig. 4: MPPT-ICT Algorithm

Conditions for Synchronisation: There are five conditions that must be met for the synchronization process to take place. They are the source (generator or Sub-network) must have the same Line voltage, Frequency, Phase sequence, Phase angle and Waveform to which the system is being synchronized.

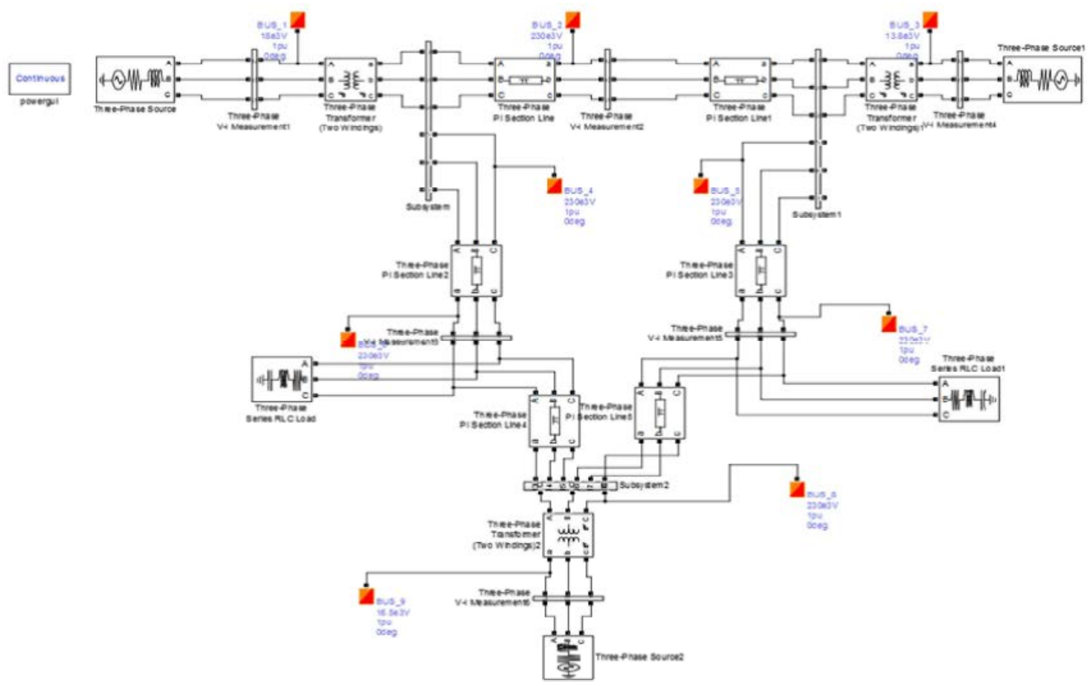

Fig. 5: Nine Bus System

A grid-connected photovoltaic power system or grid-connected PV power system is electricity generating solar PV power system that is connected to the distribution section. A grid-connected PV system consists of solar panels, one or several inverters, a power conditioning unit and grid connection equipment. Figure 5 represents a nine bus system.

Synchronisation Control: Phase Locked Loop (PLL) is a control system that produces an output signal in phase/reference with that of the input signal. PLL when used in Grid interfacing matches the Grid parameters like voltage, current, frequency with that of the Inverter. Only when the Voltage, Current and that of the frequency and phase of the three sources are maintained the same, will there be synchronism maintained.

The phase locked loop maintains the voltage constant throughout the system. The reference value of voltage is compared with inverter voltage and the error is computed. Similarly the current value is determined. The quantities of stationary reference frame is converted to rotating reference frame using Park's transformation and vice-versa using Inverse Park's Transformation. The PLL helps to maintain the inverter and the grid in synchronism and during any faulty condition it brings it back to synchronism.

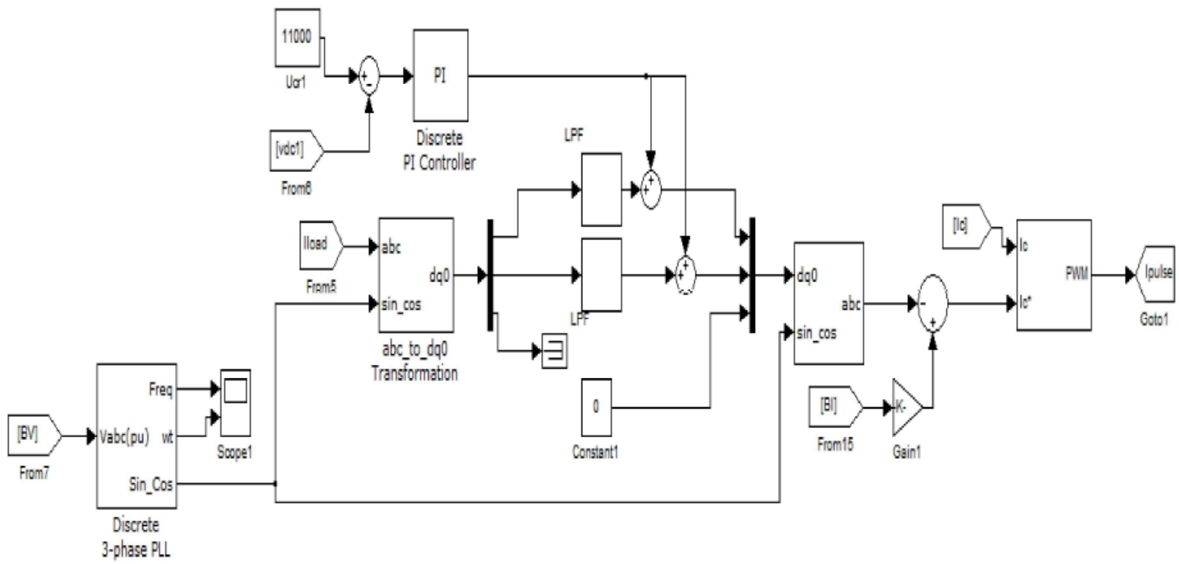

Fig. 6: Synchronization Control

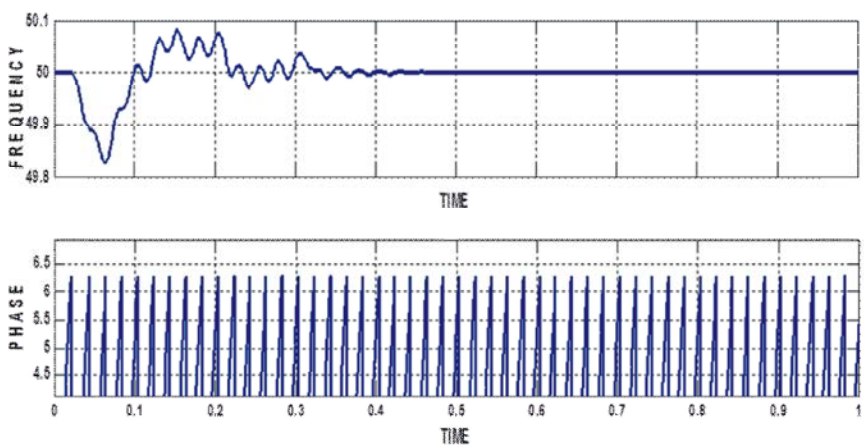

Fig. 7: Synchronized Frequency and Phase Waveforms

The quantities of stationary reference frame is converted to rotating reference frame using Park's transformation and vice-versa using Inverse Park's transformation. The PLL helps to maintain the inverter and the grid in synchronism and during any faulty condition it brings it back to synchronism.

As shown in Figure 8, an 11 kV system, when all the three sources have the same voltage level, the current through the inverter and the two sources are in phase.

As seen in Figure 9, for an 11 kV system, when all the three sources have the same voltage level that is 11kV, a waveform as below is obtained.

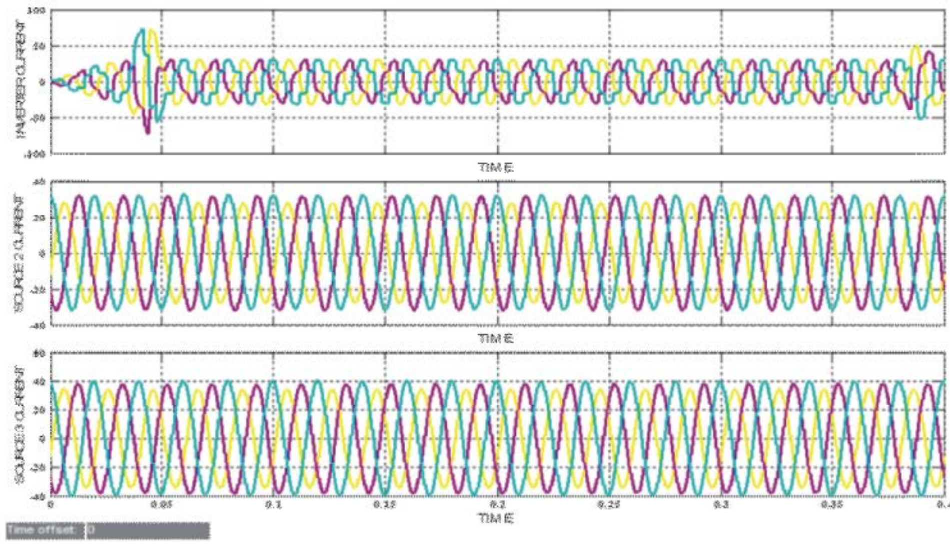

Fig. 8: Synchronized Current Waveform

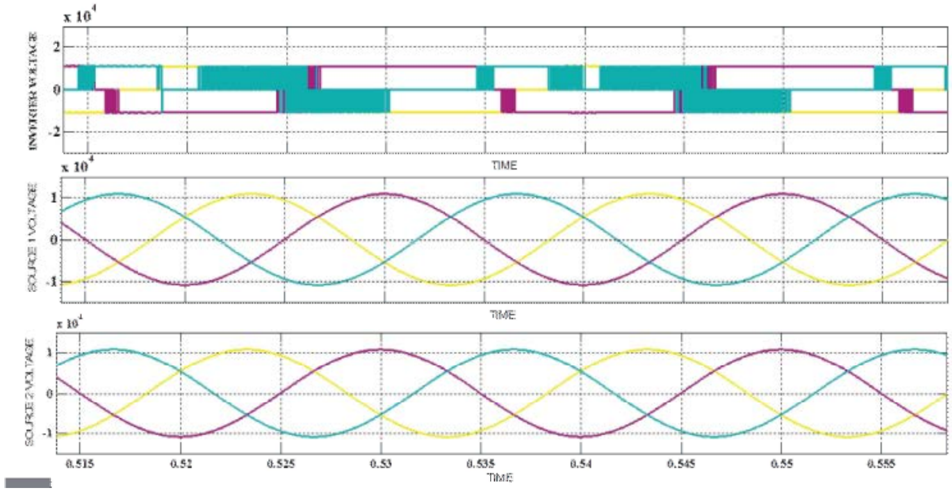

Fig. 9: Synchronized Voltage Waveform

CONCLUSION

A model of a Grid connected Photovoltaic system was presented for synchronization analysis. The simulation model included detailed representations of the PV system circuits and its controllers. The design implementation was based on SIMULINK/MATLAB. Various simulation results were presented to provide the clear understanding of grid based PV systems. The model could provide a detailed control design and performance evaluation of GCPS. The model can be designed with Wind as another source of energy also can the system be analyzed for transient faults and hence the behavior and control performance can be studied.

REFERENCES

1. Maris, T.I., S. Kourtesi, L. Ekonomou and G.P. Fotis, 2007. Modeling of a single-phase photovoltaic inverter, IEEE Sol. Energ Mat. Sol. C, 91: 1713-1725.
2. Esram, T. and P.L. Chapman, 2007. Comparison of photovoltaic array maximum power point tracking techniques, IEEE T. Energy Conver, 22(2): 439-449.
3. Seul Ki Kim, Jin Hong Jeon, Chang Hee Cho, Eung Sang Kim and Jong Bo Ahn, 2008. Modelling and Simulation of a Grid Connected PV Generation System for Electromagnetic Transient Anlaysis, IEEE Sol Energy, pp: 83-664-679.

4. Karuppanan, P. amd Kamala Kanta Mahapatra, 2010. PLL with PI,PID and Fuzzy Logic Controllers based Shunt Active Power Line Conditioners, IEEE T Power Electr, pp: 978-1-4244-7781.

5. Yuxiang Shi, Rui Li, Yaosuo Xue and Hui Li, 2015. High Frequency Link Based Grid Tied PV system with small DC Link Capacitor and Low Frequency Ripple Free Maximum Powre Point Tracking, IEEE Power Electr, pp: 31-1-0885-8993.