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Three Phase Grid Connected Solar PV System Modelling for Micro Grid

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Abstract: To address the problems of existing grid systems, the new micro grid idea provides a superior alternative by allowing for the incorporation of sustainable power. The biggest issue with renewable energy generation is that it is intermittent and depends on the weather. This nature resulted in substantial voltage swings. Rapid adjustment is becoming increasingly important for energy transmission and distribution networks. Already, numerous solutions have been described to address the challenges that are limited to a single transmission line. However, for multi-line power flow regulation, a new type of device known as GIPFC was implemented for the hybrid micro grid. As a step-by-step approach for implementing the respective suggested system, all of the various hybrid micro grid elements are first modelled, and the proposed system is then implemented at the grid connected end. The paper's key contribution was to simulate the PV system in the MATLAB/Simulink environment to analyze the three phase outputs.

Key words: PV system, MPPT , P&O technique, Boost Converter, 3ph Inverter, Filters.

Introduction:

Every day, over half a billion people worldwide lack access to electricity. The majority of people in rural India do not have access to electricity since connecting to the grid (macro grid) is challenging. A substantial percentage of India is comprised of villages. Electricity has great power. To realize the benefits, the amount of electricity in the system must match actual consumption needs. Because of the growing demand and popularity of technological advances such as electric vehicles, power grid operators face a number of challenges, including an increase in renewable energy sources, transmission losses, and frequency of power outages, electro mobility, grid modernization, cyber-attacks, and revolutionary attacks. Micro grids provide an environmentally friendly method of supplying electrical energy. To achieve the minimal requirements, a micro grid must use dispersed generation, such as renewable energy sources, and sustain electrification for local loads.

All kinds of energy accessible today, including renewable energy sources, should be employed as distributed generators to electrify communities with local loads. This micro grid allows for the electrification of isolated places that are difficult to reach. Recent developments in micro grid technology enable the inclusion of RES while simultaneously providing a dependable power supply for neighboring consumer loads.

Global warming threatens humanity, and the depletion of fossil resources adds to the risk, given the world's expanding demand for electricity. Toxic emissions from traditional power sources threaten biodiversity. Natural resources are depleted and the environment is harmed in the name of progress, resulting in social injustice. On the other hand, green energy, such as RES, supplies humanity with the power it requires without damaging the environment. Non-conventional renewable energy sources (RES) are less capable of producing power and are not appropriate for long-distance transmission; as a result, they are best suited for dispersed generation in a micro grid. The schematic representation of the Micro grid is shown in the fig.1.1. It consists of all the type of domains. The development and use of RES distributed generators has two advantages: first, it produces clean, emission-free electricity; second, it meets local load requirements and prevents transmission line losses. Electricity has tremendous strength. In order to reap its benefits, the quantity of electricity in the grid must correspond to real consumption needs. Due to the growing demand and popularity of technological advances such as electric vehicles, power grid operators encounter a number of challenges, like growing amount of renewable energy sources, transmission losses, frequency power outages, Electro mobility, Grid modernization, threat of cyber-attacks, Threat of revolutionary attacks. To resolve all of these problems, then MICROGRID appeared.

Power electronics now play a crucial part in distributed generating and PES integration with the grid. The interface between RES and the power grid is made up of power electronic equipment. Because these devices generate

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harmonics into the system, they distort source voltage, increase losses, and may cause protective relays, mains, and other control units to malfunction. As a result, it's important to keep the system's THD within acceptable limits (Huang et al., 2011).

The Micro grid is a collection of several DGs, including biomass, diesel, gas turbines, photovoltaic, wind and solid oxide fuel cells (SOFC). Due to its ecologically favourable properties, the micro grid has drawn significant interest in the electric power system (Huang et al., 2011).More power quality problems arise when loads are moved to islanded mode from the grid (Moghaddam et al., 2014). Introduction Due to an increase in the use of sensitive machinery and non-linear loads in both the home and industrial sectors, of additional harmonic enters the grid (Xiaozhi et al., 2011). The degradation of fossil fuels has led to an increase in the use of renewable energy. As a result, more research on RES has been conducted to lower the cost and use renewable energy sources. By taking into account the aerodynamic power and control with the non-linear, fuzzy, and predictive methodologies, Arturo Soriano et al. (2013) modelled a wind turbine.

Particularly in recent years, the use of renewable energy sources has gained momentum. The need for alternative energy and distributed production is driven by rising energy demand, quick technological advancements in energy production, and growing public concern for environmental protection. For applications with modest installed capacity, a hybrid structure with an effective photovoltaic (PV) system and a wind energy system can be built utilising a variety of control systems. Reactive power compensation is an emerging requirement for stable operation of a hybrid system because renewable energy sources like wind alone and hybrid Wind/PV are not totally safe in satisfying the demand for the load. All energy systems must compensate for reactive power. Concerns with reactive power are related to various power quality issues as well as rising power losses. Synchronous condensers and fixed mechanical switching capacitors have long been employed as a solution to this problem. This kind of compensations have some drawbacks, including big dimensions, substantial losses, and long response times. These issues make integrating these sources into the traditional grid more difficult and complicated. Reverse power flows, transient modes of micro grid operation, economic and supply demand uncertainties of micro grid will become challenging tasks.

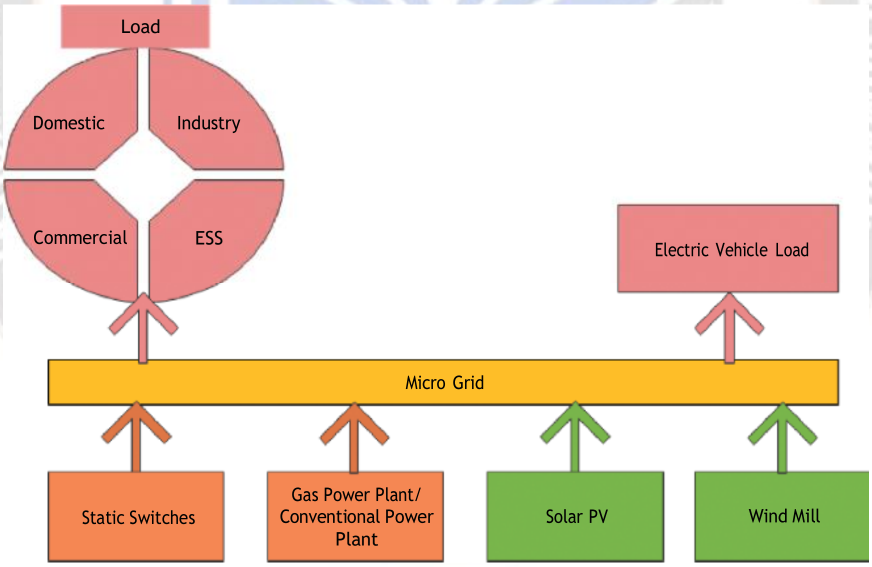

Fig. 1.1 schematic representation of a micro grid.

In this paper, the grid-connected PV system was modelled. The first PV module was chosen, and to increase the voltage level, a boost converter was installed, followed by a three-phase inverter to connect it to the external grid. Figure 1.2 depicts the block diagram for the grid-connected PV system.

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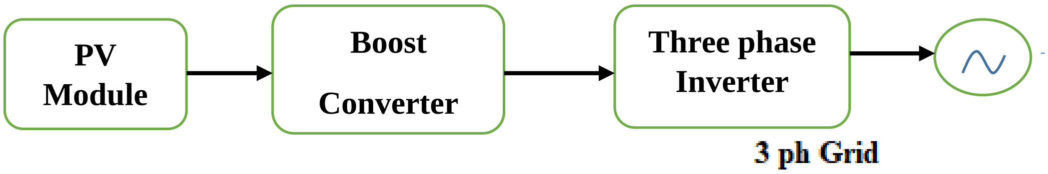

Fig 1.2: Block Diagram of the grid connected PV System.

2. Grid Connected Solar PV system:

The basic modelling block representation of the proposed circuit was as shown with reference to [9].

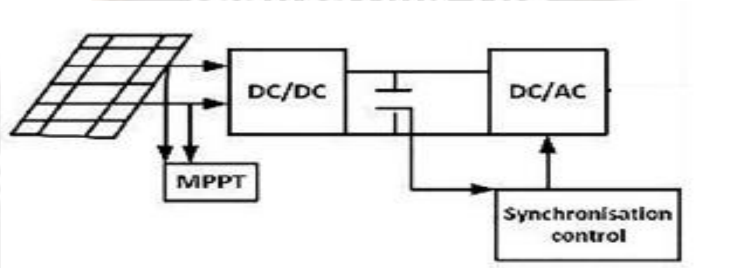

Fig 2.1: Schematic representation of grid connected PV system

2.1 Equivalent circuit of the solar cell:

An analogous circuit model is a theoretical circuit diagram that depicts a device's electrical characteristics. It is important to note that the components shown in the model are not physically present in the devices themselves. Instead, these models assist us visualize and simplify computations about the cell's behavior. These models are extremely useful for understanding underlying device physics, describing specific events, and assisting in the design of more efficient devices.

A solar cell's equivalent circuit consists of an ideal current generator in parallel with a reverse-biased diode, both of which are linked to a load. The generated current is proportional to light intensity. This demonstrates how critical it is to correctly recreate the solar spectrum while testing solar cells, and why solar simulators are an essential piece of equipment in this situation. Although the quantity of current produced fluctuates with light intensity, solar cells have other constraints that reduce their efficiency. The circuit's other components indicate these limits. The equivalent circuit of the solar cell is as shown in fig 2.2.

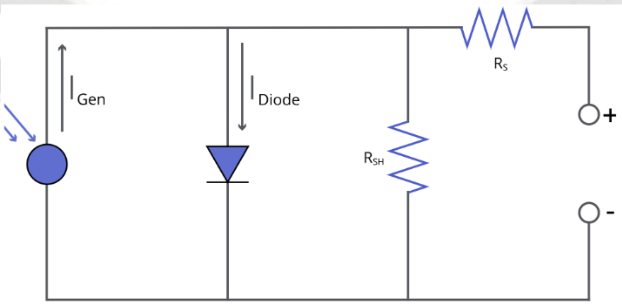

Fig 2.2: equivalent circuit of the solar cell.

If the resistance across the load exceeds that of the diode, the diode will draw current, raising the potential difference between the terminals while decreasing the current directed through the load. Alternatively, if the diode's resistance is greater than the load's, electrons can readily pass through the load, resulting in a higher current. However, the possible variation between the terminals will be rather small. This demonstrates a fundamental restriction with solar cells: optimizing current frequently implies compromising voltage. There is a sweet spot, or maximum power point, when both

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voltage and current are optimized, resulting in maximum power production.

You can also use similar circuit diagrams to depict device losses. The accompanying ideal circuit diagram of a solar cell has components that represent series resistance and shunt resistance. Shunt resistance accounts for all losses caused by electrons moving directly across terminals, such as shorts in the device. It is thus represented by a resistor running parallel to the ideal current generator, and you should try to raise shunt resistance as much as feasible. This implies you should do everything possible to keep your terminals apart, with no pinholes or flaws.

The last component in the diagram indicates series resistance, which accounts for all current losses caused by poor charge transfer between or within layers of your device. The analogous circuit schematic shows this as a resistor in series with the ideal current generator. You should do everything possible to reduce series resistance so that electrons can flow smoothly through the device. The PV system modelling with equations was given here[1].

2.2 Defining the equations:

We may use this ideal circuit design to obtain equations that characterize and model solar cells. This also allows us to define some of the most essential metrics used to describe solar cells. To put it simply, current through the load equals the amount of current created minus the current that travels through the diodes and the current lost due to shunt resistance.

$$I = I_{Gen} - I_{Diode} - I_{sh} \qquad (2.1)$$

where I is current extracted, I_{Gen} is the generated current, I_{Diode} is diode current, and I_{SH} is current lost to shunt resistance.

Where I = Current Extracted

I_{Gen} = Generated Current

I_{Diode} =Diode Current

$I_{SH=}$ Current lost to Shunt Resistance.

Ideal Diode equation I_D is:

$$I_D = I_0 \left\{exp\left[\frac{qv}{nkT}\right] - 1\right\} \qquad (2.2)$$

Where

I_0 is the reverse saturation current
n is the diode ideality factor
q is the charge constant
k is the Boltzmann constant
T is absolute temperature.
Therefore, the overall current equation can be written as:

$$I = I_{Gen} - I_0 \left\{exp\left[\frac{qv}{nkT}\right] - 1\right\} - I_{sh} \qquad (2.3)$$

This equation gives us the characteristic current-voltage graph shape we see for solar cells.

3. Boost Converter:

The boost converter is a DC-to-DC converter that performs step-up conversion on the provided DC input. The supplied fixed DC input is boosted (or enhanced) to an adjustable DC output voltage in a boost converter, which means that the output voltage is always greater than the input voltage. A boost converter is also known as a step-up converter or chopper. It is called "boost" because the produced output voltage is greater than the supplied input voltage. It reverses the behaviour of the buck converter[2][3], converting higher DC input into lower DC output.

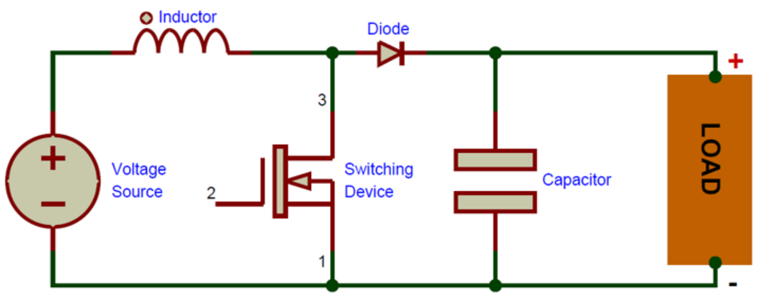

Fig 3.1: Boost Converter Basic Circuit

The boost converter is used to increase an input voltage to a greater level as required by the load. The boost converter performs step-up conversion by storing energy in the inductor and releasing it to the load at a higher voltage.

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There are at least two semiconductors (diode and transistor) and at least one energy storage element (inductor, capacitor, or both). Other semiconductor devices, such as power MOSFET, power BJT, and IGBT, are employed as switches in boost converter circuits. Thyristors are not commonly utilized in DC-to-DC converters because they require an additional external communication circuit. The PV interconnected boost converter with the control circuit and its control mechanism [4] is as shown in the fig 3.2.

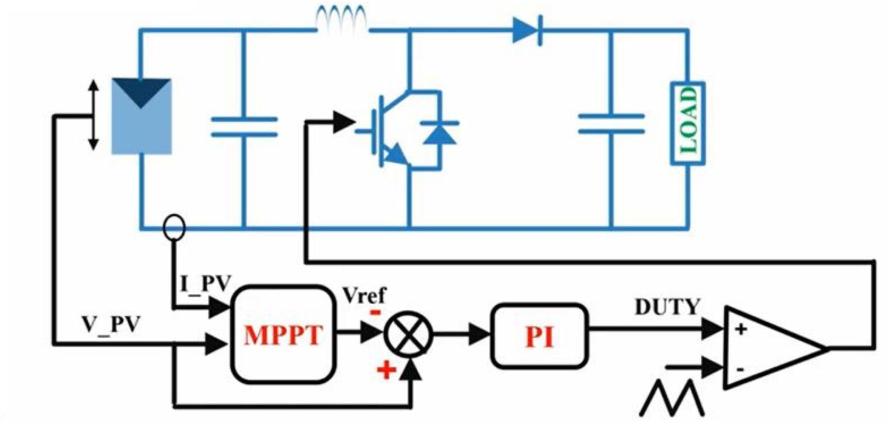

Fig 3.2: PV connected Boost Converter with Controller Circuit.

4. DC to AC Converter:

The three-phase bridge VSI with square wave pole voltages has been investigated. This inverter's output is intended to power a three-phase balanced load. The figure below depicts the three-phase inverter's power circuit. This circuit consists of three single-phase half-bridge inverter circuits connected via a common dc bus. The individual pole voltages of a 3-phase bridge circuit are the same as the square pole voltages produced by single-phase half bridge or full bridge circuits. The three pole voltages of the three-phase square wave inverter are time-shifted by one-third of the output period.

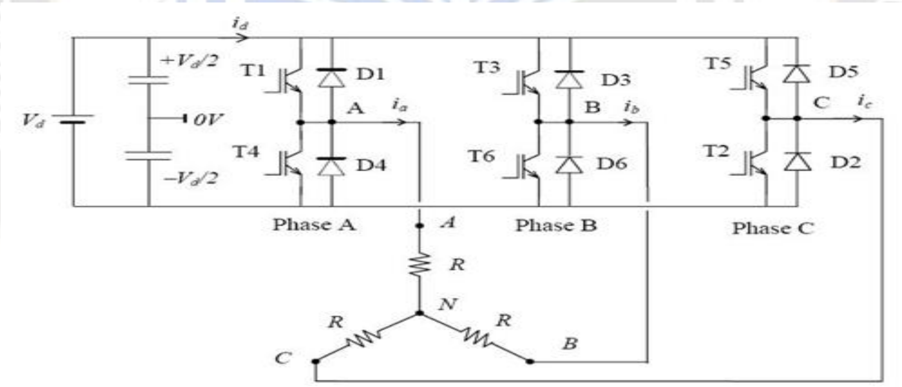

Fig: 4.1 Three phase inverter

Switches on each leg of the three-phase inverter, like those in a single-phase square-wave inverter, work in tandem. When the top switch of a leg is turned on, the lower switch must block the entire DC bus voltage, and vice versa. Thus, the switches must be rated to block the worst-case instantaneous magnitude of dc bus voltage. Consequently, the switches must be rated to withstand the peak projected magnitude of instantaneous load-phase current.

For a non-unity power factor load, the diode connected in anti-parallel to the switch will conduct some of the switch current. The load power factor at the operating frequency determines how current is distributed between the diode and the controlled switch. In general, both the diode and the controlled switch should be rated to handle the peak load current. In addition, these diodes must block a peak reverse voltage equivalent to the worst-case voltage across the switches. The three phase switching operation with the control circuit was clearly given in the reference papers [5][6][7].

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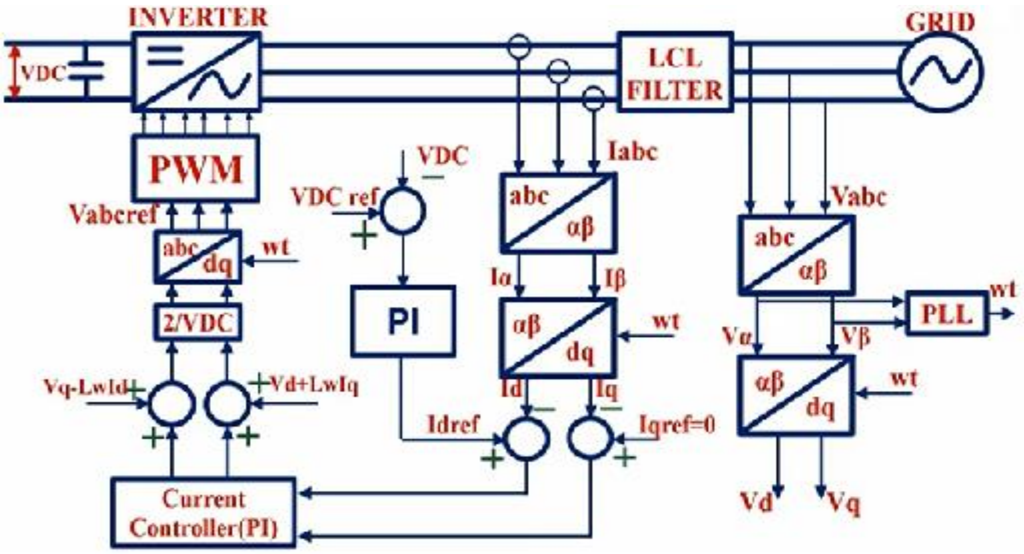


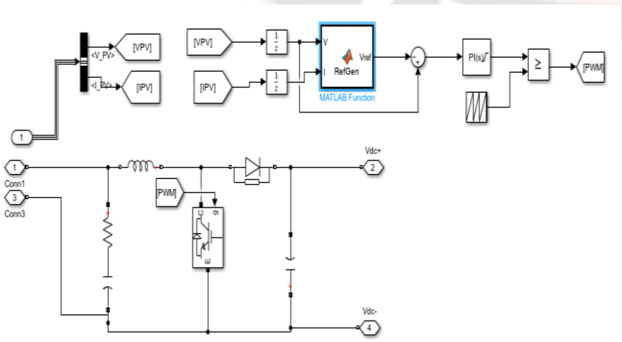
Fig: 4.2 Grid connected Inverter control circuit

5. Simulation and Results:

The designed grid connected system was tested with the following parameters.

S.NO	ELEMENTS	PARAMETERS
1	PV system	V_{oc} = 363V V_{mppt} = 270-300V
2	Boost converter	Switching Frequency=5Khz L=1.45mH C=3227μF Peak to Peak Vdc= 600V
3	Inverter	Switching Frequency=10Khz IGBT/Diode connected switch
4	LC Filter	L=500μH C= 100µF
5	$V_{LL,}$ Rated Power	400V rms, 100KW

Modelling of the boost converter and its controller , 3ph inverter circuit with the controller was modelled as shown in the fig 5.1 & fig 5.2.



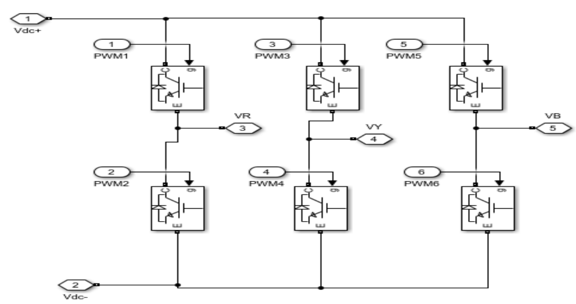


Fig 5.1 Modelling of Boost Converter **Fig 5.2** Three phase inverter with IGBT/Diode

Basic reference for the modelling of the system was clearly explained in the Jawairia Atiq's paper[8] .

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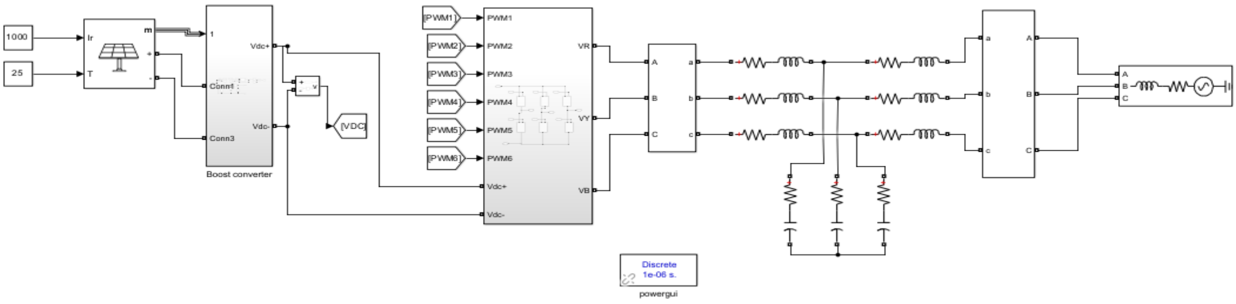

Fig 5.3 Complete Modelling of grid connected PV system

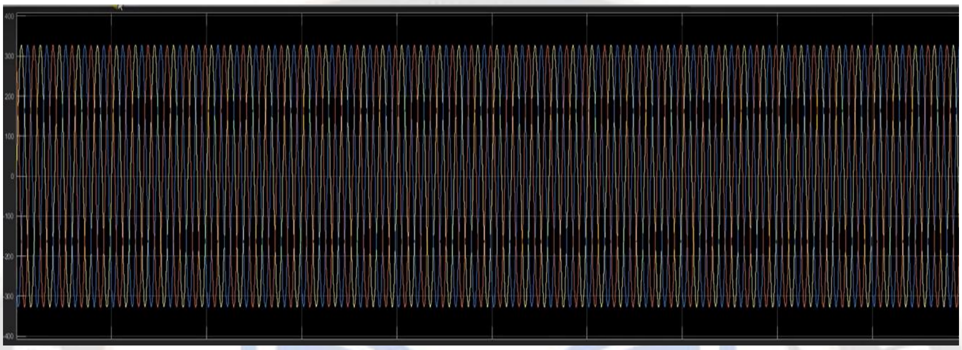

Fig 5.4: Voltage output Vabc

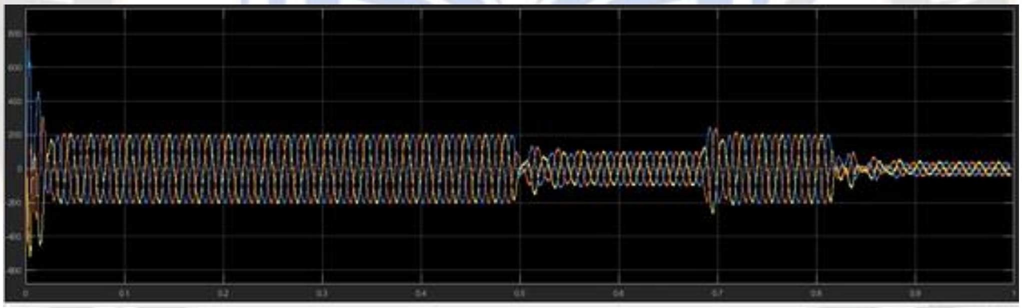

Fig 5.5 current Output Iabc

Matlab code for the boost converter was also developed and used in the modelling process. The outputs Vabc and Iabc are displayed in the waveforms in Figures 5.4 and 5.5. Figure 5.5 clearly shows the difference in current levels for different irradiance values, i.e., 1000 W/m2, 500 W/m2, and 200 W/m2.The DC Voltage was plotted as shown in the fig 5.6

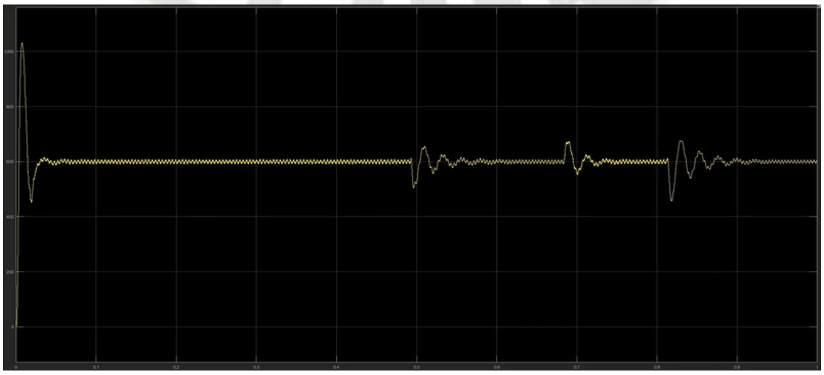

Fig 5.6 V_{DC} Output Voltage

6. Conclusion:

The paper proposed the modelling of a grid connected PV system. The detailed modelling of the components in the system was discussed in detail. PV system was considered with 47 parallel strings and 10 series connected Modules. To maximize the output of the PV system the boost converter was modelled with the Perturb & Observer Algorithm. A DC to AC PV inverter with an LC filter was created to convert DC voltage and current to AC values. Reference signals for inverter IGBT switches were generated using a controlled PWM modulation approach.

The system was tested under various temperature and solar insolation conditions. Solar irradiation has been found to have a greater effect on system output power than temperature variation. The model described here can be used to investigate system output characteristics under any temperature or solar irradiance conditions.

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