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Micro-Grid Simulation and Integration with GRID using 13 Level Inverter

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Abstract: *The need for renewable energy systems (RES) continues to grow, and research into wind and solar systems has accelerated in recent years. At the moment, the world's energy requirements are heavily reliant on fossil fuels, which are on the verge of extinction. Renewable energy demand will skyrocket in the next years. Our study demonstrates a robust energy generating system that utilises photovoltaic MPPT and a 13-level inverter system in MATLAB simulink to maximise the output of the solar panel. To optimise the advantages of such network interface distribution systems, a control approach is developed. The inverter is programmed to perform several purposes, including active power filtering. Thus, the inverter may be employed as a power converter to power the network's renewable energy sources. The MATLAB / Simulink simulation is used to execute and verify all of the analyses by subjecting the system to dynamic load conditions.*

Keywords: *Photovoltaic System, Maximum Power Point Tracking (MPPT), Grid Subsystem, PID Controller, MATLAB*

I. INTRODUCTION

There are undoubtedly various problems that must be overcome in order to fulfil future generation energy needs. The first is a scenario of competing demand and supply, in which growing demand combined with continued reliance on combustible fossil fuels as a key source of electricity resulted in fast resource depletion. Fossil fuels are the primary source of carbon emissions; they destroy the ecosystem, and their continued depletion results in geological imbalance, a grave ecological hazard. Fossil fuels are inefficient; rising fuel costs have stymied the economic growth and industrial advancement of the twenty-first century. The essential task is to transition to a dependable alternative fuel [1]-[2]. Because renewable energy is plentiful, replenish able, eco-friendly, and cost-effective, power production based on it would be a viable choice for addressing the aforementioned difficulties. Renewable energy sources now meet around 16-17 percent of worldwide demand. Microgrids are being used globally to facilitate the development of renewable energy-based electricity production.

Microgrids are a concept that focuses on integrating renewable energy sources, namely distributed generating systems. Solar, wind, geothermal, Biomass and Fuel cells are all examples of renewable energy sources [3]-[4]. Additionally, battery systems may be added to this system. Microgrids operate independently, with the sole issue being the system's security and the operator's attention to assure continuous power production [5]-[6]. Microgrids may be powered by a various types of renewable energy sources [7]. Thus, Microgrids include diverse and separated sources of energy that may be utilized alone or in conjunction with the grid. When a microgrid is linked to numerous sources, it is often connected to a bus bar, which may then be utilized for different loads in addition to the grid or supplied into the grid. These loads might be numerous residences or charging stations for emerging electric cars, for example [8].

The paper is organized as follows. Section 2 gives modelling of PV system, MPPT model and Incremental Conductance. In Section 3 the simulation of microgrid consisting of PV model with DC-DC converter connected to grid and load system is described. The results and discussions from the Simulation are given in Section 4. Section 5 provides conclusions.

2.1 PV System Equivalent Model

Solar cells are fundamentally p-n semiconductor junctions. When an object is exposed to light, it generates a direct current. Solar irradiation has a linear relationship with the produced current. The photovoltaic cell's conventional equivalent circuit is seen in Figure 1.

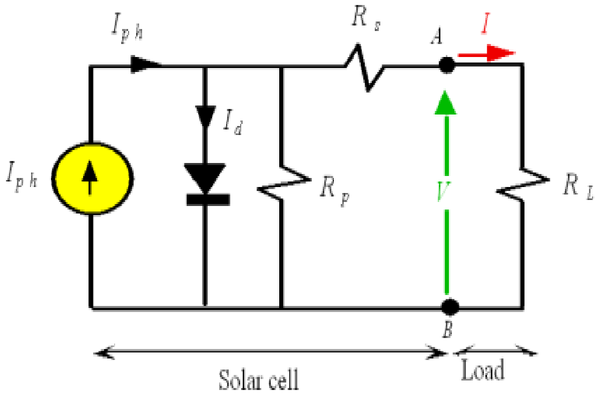

Figure 1 Equivalent Model of PV

The following equation is the fundamental equation that explains the (V-I) properties of the photovoltaic model.

$$I = I_L - I_0\left(e^{\frac{q(V+IRs)}{kT}} - 1\right) - \frac{V+IRs}{IRp} \qquad (1)$$

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Where I cell current (A),I_L light generated current (A),I_0 diode saturation current,q free charge of electron =1.6x10-19 (coulombs),K Boltzmann constant (J/K) ,T cell temperature (K) ,R_S and R_P cell series and shunt resistance (ohms) ,V Cell output voltage (V).

Solar panels use to convert photons into electricity emitted by the sun when they strike with panel surfaces as a defined voltage and current. The output of the solar panel may be plotted voltage vs. current graph called an I-V curve. We express a current in amps and voltage in volts. The resultant line on the graph indicates the panel's current output for each voltage setting. Figure 2 illustrates a certain light intensity and temperature. The current is constant until it reaches higher voltages, at which point it quickly decreases. I-V curve is can be used for all solar panels electrical output.

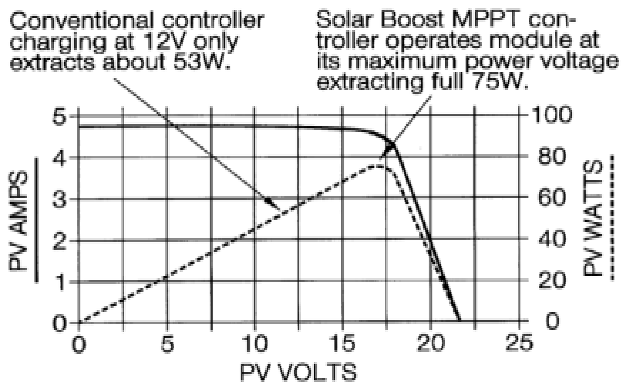

Figure 2 V-I curve with MPPT

2.2 PV System MPPT model

MPPT [9] [11] is an acronym for Maximum Power Point Tracking, which is used to extract the maximum amount of energy feasible from them under defined environmental, position and structural conditions. MPPT is an automatic electronic control device which is regulate the electrical load. This section describes the algorithms developed and implemented in the design and operation of on- and off-grid specialised converters / inverters to be used between solar cells and load centres. The primary reasons for searching for MPPT are temperature, environment and irradiance-related. As the temperature increases, the output power drops by up to 22% for 50 degrees, as illustrated in Figure 2.

The reasons of this temperature impact are as follows:

- Increased temperature causes electrons in the outer band to acquire energy. As a result, the effective band gap decreases.
- The majority of parameters are influenced by a reduced band gap energy, which results in a less output voltage and power output. Generally, it is the open circuit voltage.

Solar irradiation is affected by environment condition, geographical location, rainfall patterns throughout time, and other factors. However, if used successfully, an MPPT may increase the power consumed under certain conditions by up to 5% [6] [7].

Now, each photovoltaic panel now has its unique I-V pattern due to the following factors like Deposition of dust, Manufacturing tolerances, Angle of rotation in the mounting position and Shading differences

Maximum power may be equal to the knee point in the V-I curve for a given panel with a set environmental state. Now, to perform it in an automated manner, different techniques applied are Perturb & observe (P&O), parasitic capacitance (PC), Incremental conductance (IC), Current based peak point tracking (IPPT), Voltage based peak point tracking (VPPT)

We will propose the IC MPPT method for our implementation for unidirectional error, P&O is appropriate for rapidly approaching the peak point and incremental conductance adopting for avoiding fluctuation and remaining at the peak point.

2.3 Incremental Conductance

Incremental Conductance approach determines the P–V curve slope, while the MPP is determined by looking for the P–V characteristics peak. MPPT is accomplished by using the instantaneous conductance I/V and the incremental conductance dI/dV This relationship can be expressed in (2)–(4), and help to determine the location of the module's operating point on the PV curve, i.e., (2) show that the PV-module operates at the MPP, whereas (3) and (4) show that the PV module operates on the right and left sides of the MPP, respectively.

$$\frac{d_i}{d_v} = -\frac{1}{V} \qquad (2)$$

$$\frac{di}{dv} > -\frac{I}{V} \qquad (3)$$

$$\frac{di}{dv} < -\frac{I}{V} \qquad (4)$$

The equations (1) – (4) are described from the concept, where the slope of the P–V curve at MPP is equal to zero, i.e.:

$$\frac{dp}{dv} = 0 \qquad (5)$$

Equation (5) can be written as:

$$I + V\frac{di}{dv} = 0 \qquad (6)$$

As per standard of incremental conductance approach, (6) can be used to identify the MPP, and the MPPT controller measures the voltage and current of PV Modules. If equation (3) fulfilled, the converter duty cycle must be lowered; if (4) is satisfied, the duty cycle does not need to be changed; and if (6) is satisfied, no duty cycle adjustment required [10].

II. METHOD

The Proposed complete simulation model with the best possible combination of proficient techniques at several levels of the PV based power plant is simulated and results are presented.

The PV panel with smart switching MPPT algorithm, boost dc-dc converter and Thirteen Level inverter with current controlled hysteresis control strategy with PLL for the integration of GRID. PV system simulation is present in figure 3. Figure 3 illustrates the simulation model with five major subsystems. The first subsystem depicts the PV panel of 8KW capacity with soft switching MPPT and boost dc – dc converter combination. The second subsystem is of the 13- level multi- level inverter with neutral point clamped arrangement.

The third subsystem is of the LOAD setup where in two different loads 13KW and 24KW are used to switch the load in run time and show the dynamic stability of the system under varied load conditions. Fourth subsystem is of the GRID the infinite source of energy.

PLL is used to get the angle and the magnitude of the GRID in order to synchronise the PV system with it. The fifth subsystem is of the control method where in the hysteresis current controlled method is used with PID to tune the Vdc and achieve the synchronisation with GRID by providing suitable gating pulses to inverter.

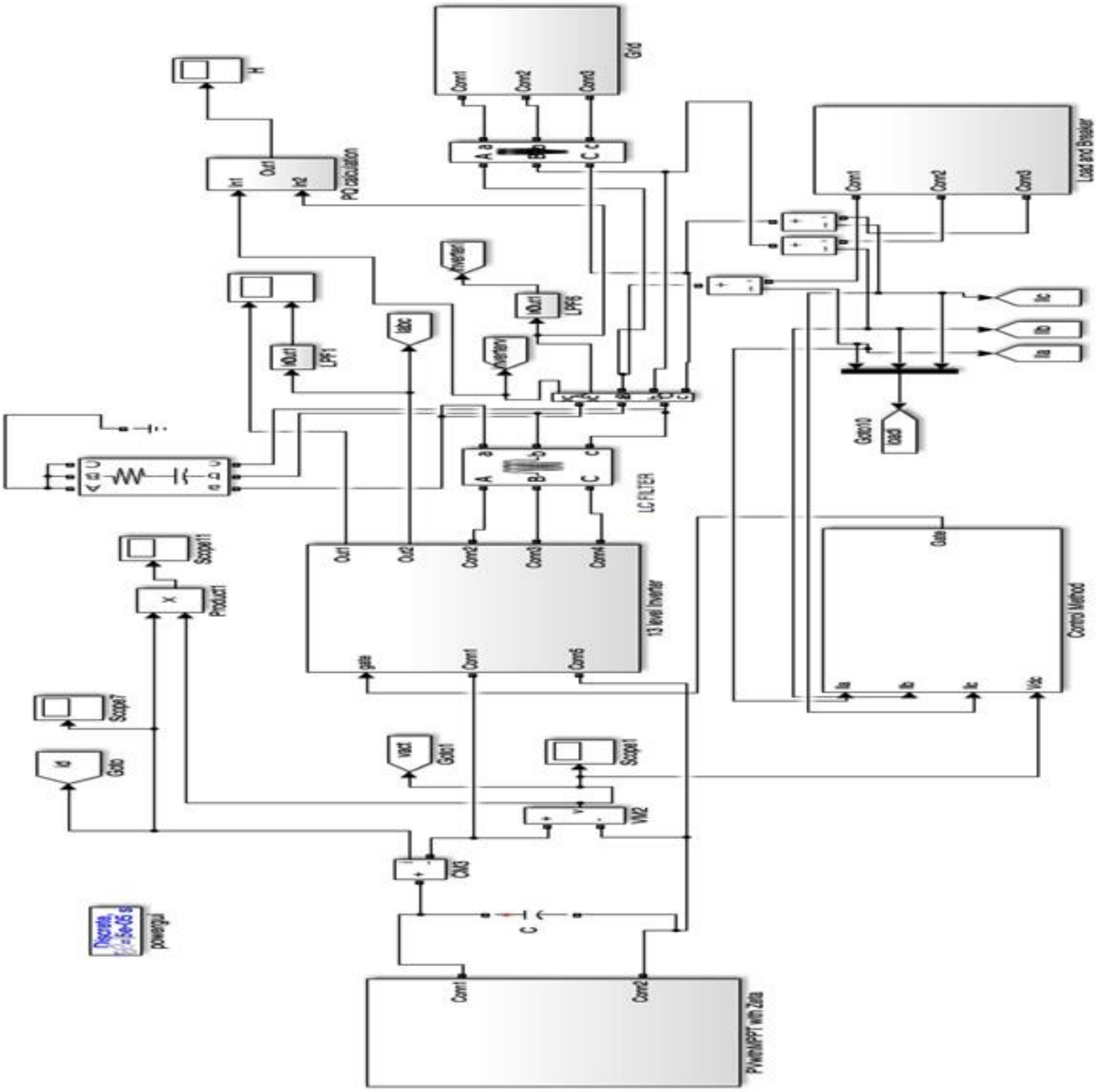

Figure 3: Complete Integration Module of Pv with On Grid System

3.1 PV panel with boost DC-DC converter Subsystem

The PV panels are varied as per sun irradiation and its maximum capacity is 8KW. The MPPT technique used is the smart switching IC MPPT technique. Boost converter is used in the final simulation to extract the maximum output/efficiency of the PV system.

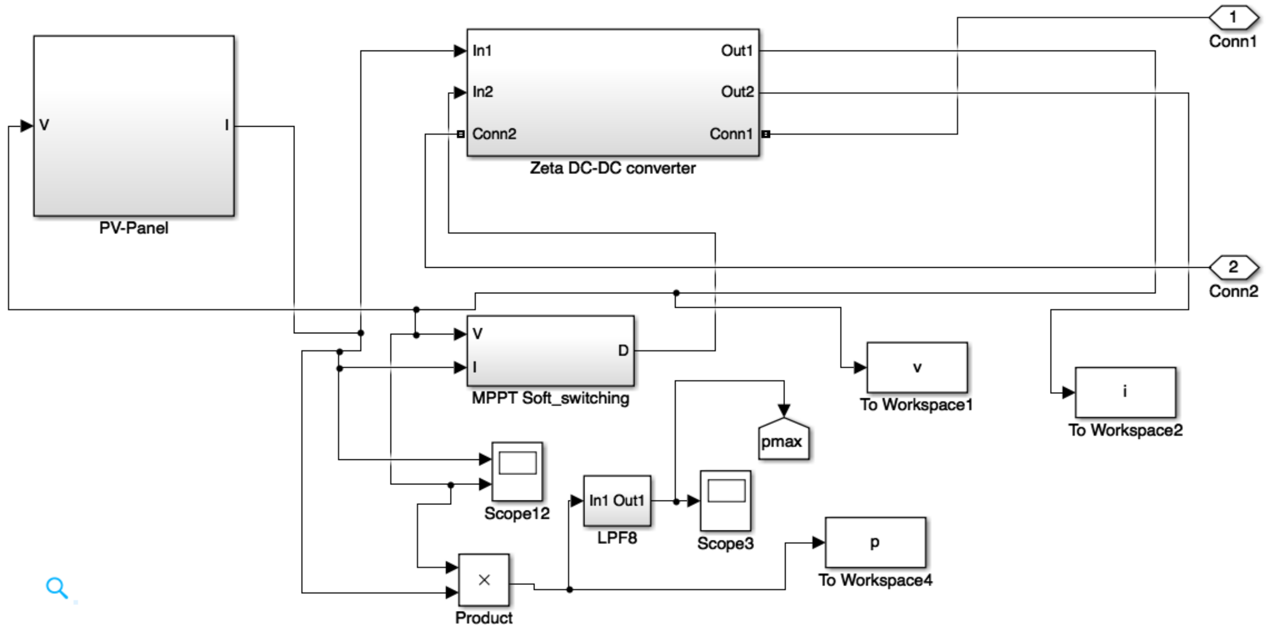

Figure 4 PV Panel with MPPT and Boost Converter Subsystem

3.2 Grid Subsystem

The Grid system is built using the three phase source in the MATLAB Simulink and shown in figure 5. The Grid is considered an infinite source of energy. The PLL subsystem is employed to get the information of the three phase current of the Grid. The sin and cos angle information of the grid is further utilised in the control strategy to synchronise the inverter I_{abc} &V_{abc} with the Grid I_{abc} &V_{abc}.

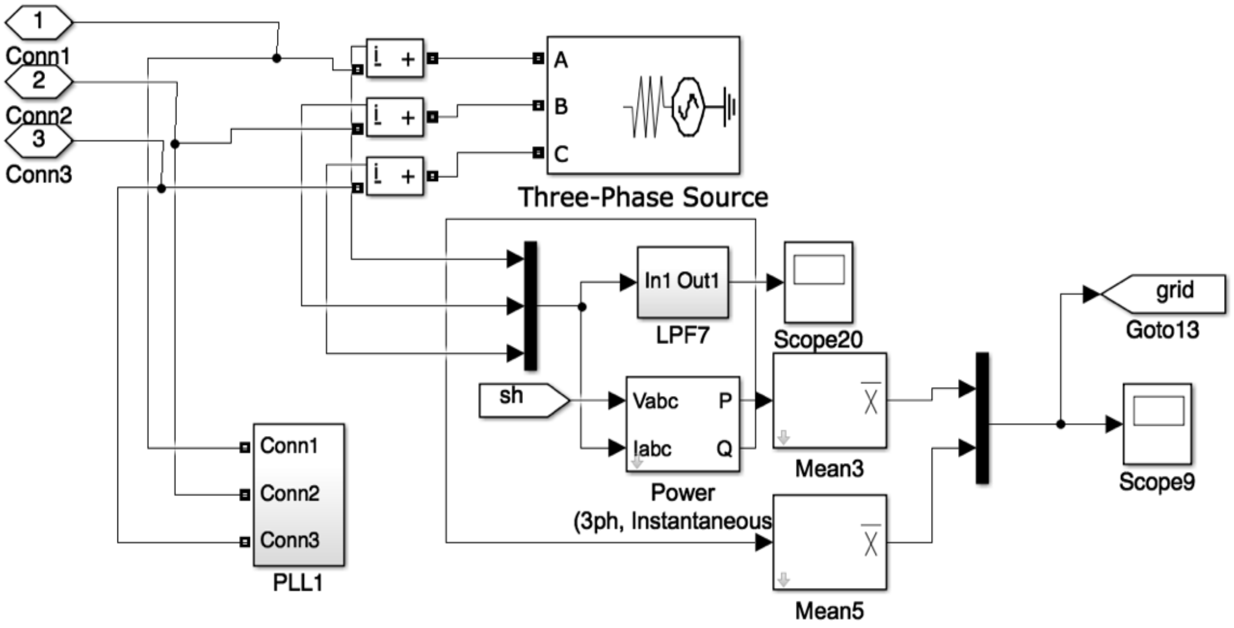

Figure 5 GRID subsystem

3.3 Control Strategy Subsystem

The PID controller is employed in order to tune the V_{dc} to desired level of the PV system. Furthermore, the hysteresis current control method is incorporated to get the suitable gating pulses for the thirteen - level inverter. The complete subsystem for the control method implemented of V_{dc} and Gating pulses shown in figure 6. The current inverter I_{abc} and current Grid I_{abc} both fed to the system as measured and reference values then it is subtracted to get the error value and then this error is tuned to zero and get both the current levels synchronised.

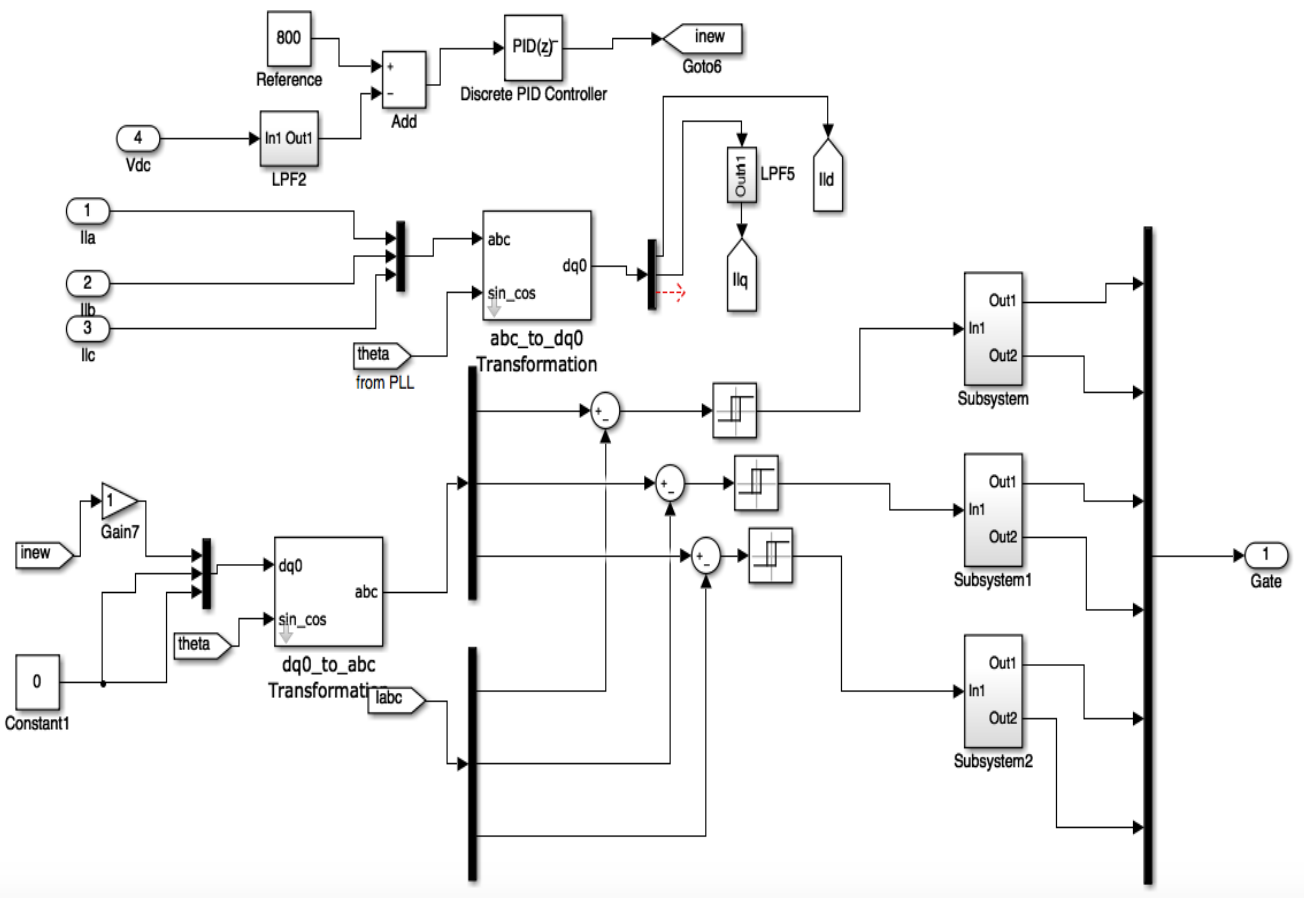

Figure 6 Control Strategy

3.4 Load Subsystem

Figure 7 illustrates the Load subsystem wherein a 15KW load as load1 is used and Load 2 is of 26KW. The load switching is controlled using circuit breaker 1 and breaker 2. The runtime switching is done at 0.2 and 0.5 second simulation time.

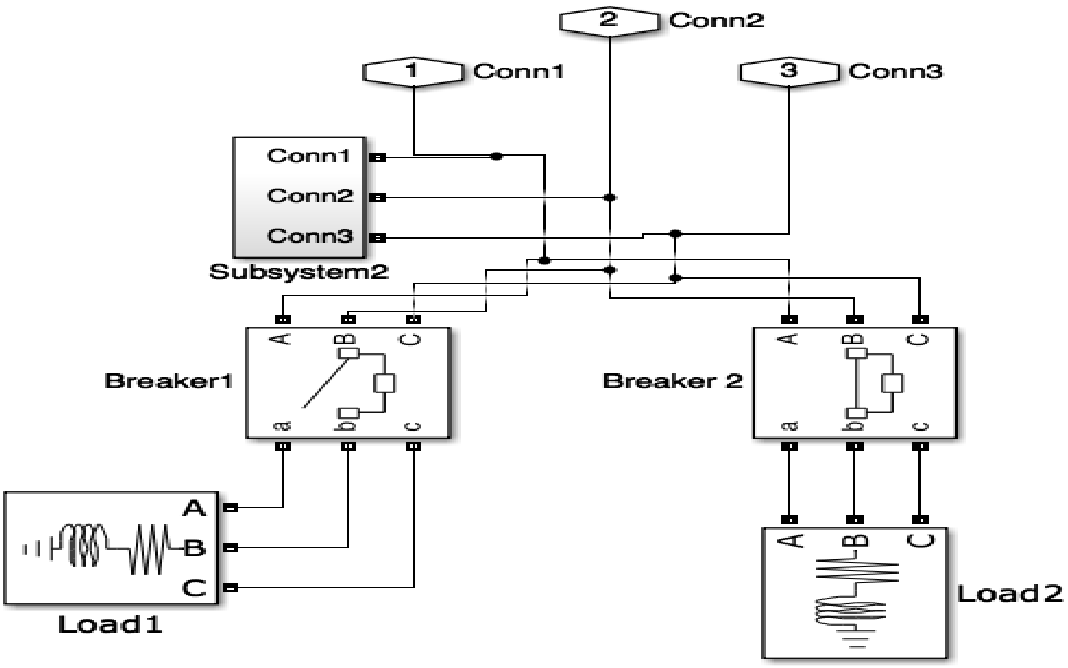

Figure 7 Load Subsystem

III. RESULTS AND DISCUSSION

All the results produced from the model are discussed in this section. The figure 8 is showing the tuned Vdc at 800Volts. The desired Vdc is attained using PID controller and has taken approximately 0.1 sec to reach to the 800V level.

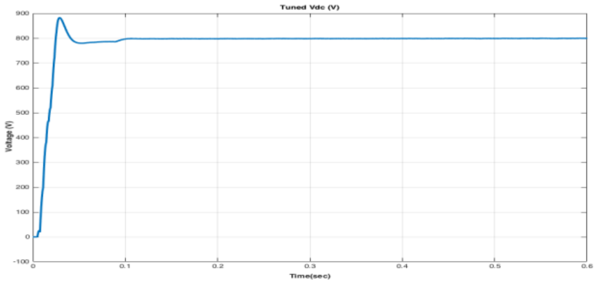

Figure 8 Tuned V_{dc}(v) of PV system

The maximum power attained form the PV panel using smart switching MPPT and boost converter switching is shown in figure 9. it can clearly be seen that at approximately 0.11 sec the 8000(W) mark is attained.

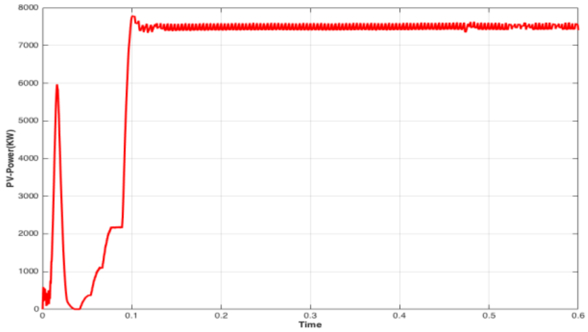

Figure 9 Max Power (KW) PV system

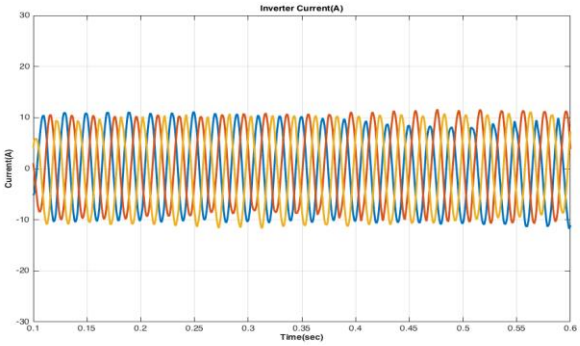

Figure 10 Inverter Current (I_{abc}) 3-phases

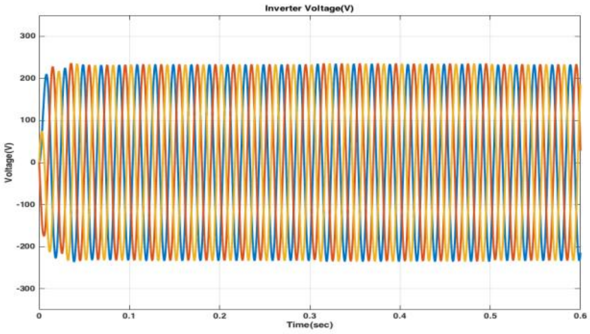

Figure 11 Inverter Voltage (V_{abc}) 3-phases

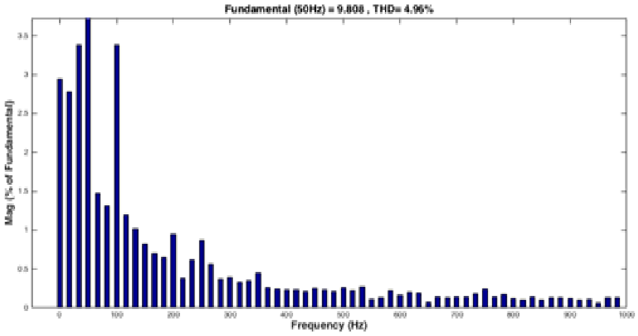

Figure 12(a) Phase 1: Current THD level

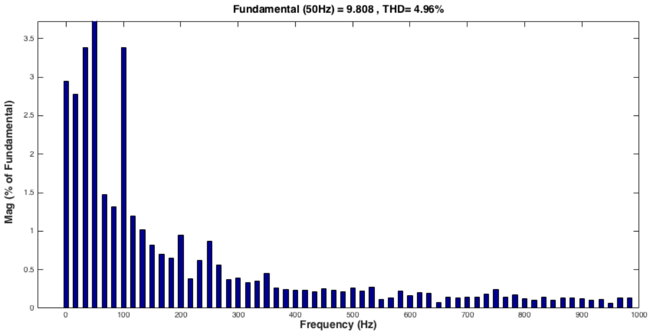

Figure 12 (b) Phase 2: Current THD level

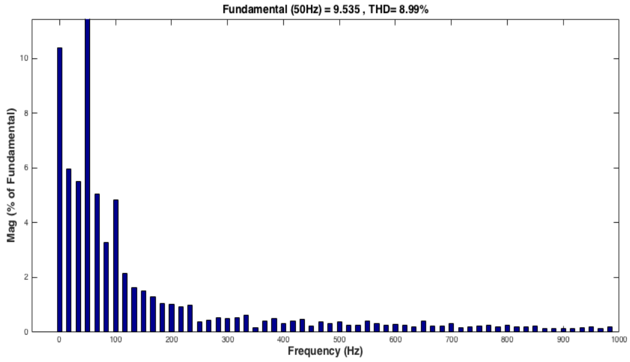

Figure 12 (c) Phase 3: Current THD level

Figure 10 and 11 illustrates the Inverter side three phase currents and voltages. The voltage and current both are stable and tuned using the hysteresis control. The total harmonic Distortion level of the inverter voltage and current is displayed in figure 12& 13 (a, b & c) phase wise. The current maximum distortion is 88.99% at phase 3 and minimum distortion is 4.96%. The voltage THD levels are on the lower side. The maximum THD is 1.26% at phase 3 and minimum THD is 1.24% at phase 1.

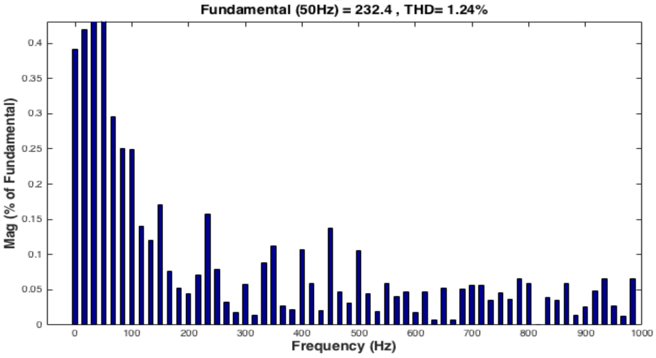

Figure 13 (a) Phase 1: Voltage THD level

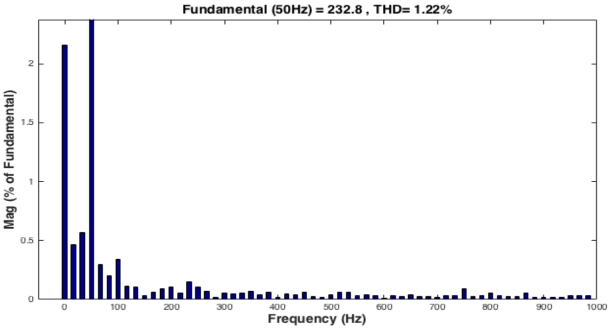

Figure 13 (b) Phase 2: Voltage THD level

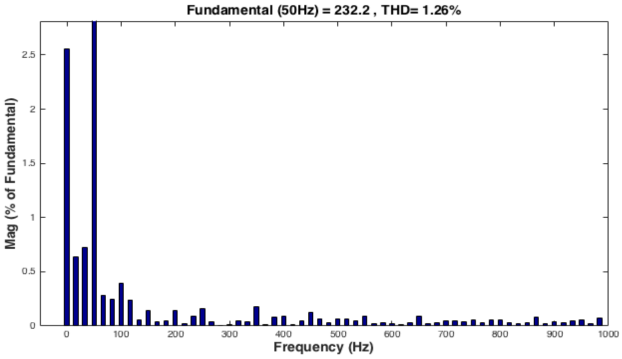

Figure 13 (c) Phase 3: Voltage THD level

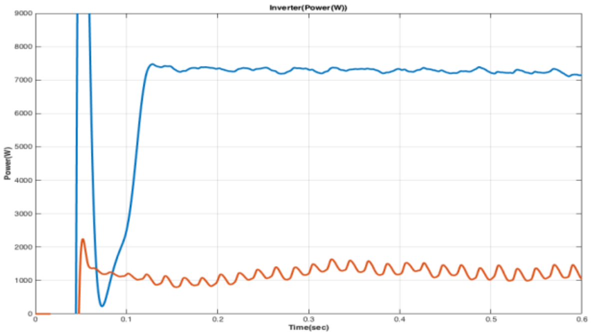

Figure 14 Power by the inverter to the Load

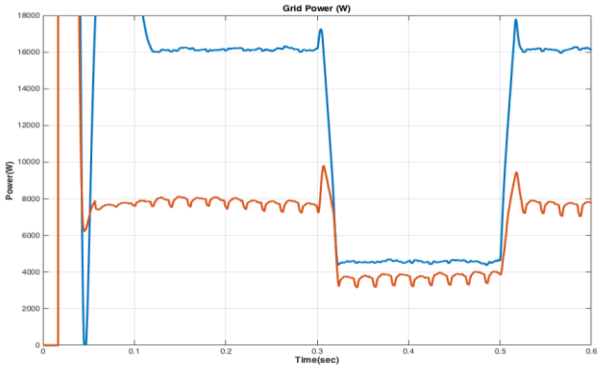

Figure 15 Powers by the Grid to the Load

Figure 14 and 15 are displaying the synchronisation of the grid and the PV power system. Two loads with various capacities are considered in the simulation. The first load in the system is 24KW from 0 secs to 0.3 sec. The second load is of 13 KW capacity and is available in the system from 0.3 sec to 0.5 sec then again 24KW load switched on. From figure 13 it can be seen that throughout the simulation the inverter is feeding the system exactly 8KW i.e. its maximum capacity. The remaining power is then provided by the grid which can be seen from figure 14. The figure 14 showing the grid power graph from 0sec to 0.3 sec the grid is delivering the remaining 16KW power. And from 0.3sec to 0.5 sec it is delivering remaining 5KW power to the load. Tabular form representation of the system is shown in table 1.

Table 1 Power from Grid and PV inverter on Load Variation

Time (sec)	Grid Power(KW)	Inverter Power (KW)
0-0.3	16	8
0.3-0.5	5	8
0.5-0.6	16	8

IV. CONCLUSION

In this research work a microgrid consisting of PV power system has been successfully implemented with integration of grid using PID controller based synchronisation. IC MPPT algorithm is incorporated to extract maximum output from PV micro grid and 13 level inverter applied to convert DC to AC and to reduce the THD levels. The THD level obtained 4.96% on the inverter current side and 1.24% on inverter voltage side showing the stability of the A.C. power generated. The system is designed in such a way that first the renewable source will be consumed and if the demand is more and PV is not providing sufficient power then the Grid will be utilised. The dynamic stability of the system is tested by varying the load in real time and increasing the load requirement with synchronisation of both PV and Grid systems.

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