

Effectual P and O (Perturb and Observe Algorithm) Based MPPT Control for Islanded Micro Grid

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ABSTRACT

According to scientific research a big concern for mankind that the atmospheric change caused by the utilization or the consumption of fossil fuels provides us a great opportunity to make the renewable energy concept one of the interesting research areas. The higher authorities of all the countries or nations encourage the society through a proper way (likewise seminars, conferences, printed media, etc) to utilize the renewable energy resources in a predetermined manner. Global warming also is a big concern for our mankind, we need to step up as early as possible in order to utilize natural resources so that we can get more and more benefits, but care must be taken in order to preserve our atmosphere. It has been found that renewable energy has recorded the most significant development around the globe. According to the survey report, about 24% of the world's electricity is produced by Renewable Energy resources, this implies that about $\frac{1}{4}$ th part of electricity is generated from REs's whereas 76% of latest renewable installation goes in favor of photovoltaic (PV) and wind turbine (WT) systems. Efforts are being made towards research on hybrid renewable resources that are used for purpose of microgrids. Renewable-based microgrids (DC) proposes a characteristic feature of utilizing natural resources with the help of energy management techniques. Stringent control is needed for hybrid type microgrids such as wind and PV based for harnessing maximum available energy, energy storage system like batteries demands efficient management and the DC bus voltage should remain constant. These above-based requirements are fulfilled by the MPPT control algorithm in our project, so it provides intelligence to the system and makes the microgrids reliable.

KEYWORDS: Solar cells, MPPT, STATCOM, Active power, Reactive Power

1. INTRODUCTION

For modern civilization electrical energy has become the main tool for the development of mankind. Different technologies such as electronics, telecommunication, and computers emerge as a result of the wide access to electrical energy. Thanks to the simulation capability the technology has grown from the last 20 years as it has created a revolution for the betterment of mankind. The more powerful the computers become and the faster the telecommunication infrastructure was achieved the more flexible and reliable power grids have been developed. At the same time, modern power electronics were developed and successfully employed in power system applications. Easy

communication by the Internet or other web resources has been essential in helping engineers around the globe to cooperate for the benefit of civilization. Photovoltaic power systems have increasing roles in the modern electric power industry due to the continuing decline in the world's conventional sources of energy.

A standalone photovoltaic power system is a complete set of interconnected components for converting solar irradiance directly into electricity and generally consists of the array, battery bank, charge controller, an inverter, protection devices, and the system load. The total solar irradiance that reaches the earth's surface varies with the time of day,

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season, location, and weather conditions. Different places on the globe experience different microclimatic conditions, therefore our location is a major factor that affects photovoltaic power system design in various ways. Today in modern day to day life Renewable based DC microgrid provides an upper hand for achieving rural electrification in developing countries especially in our country. Being an independent power system Dc microgrid involves several generating sources, storage devices, energy management techniques, and loads. This type of system may or may not be connected to the grid depending upon the requirement. To full fill, the need for electrification DC microgrid provides a better solution for fulfillment of energy scenarios in various rural and isolated regions. Since we know that in practical power systems the regions where grid-connected supply is available, they pay for the poor quality of supply also it has been found that the supply for such systems is also time-limited, so for such regions, this hampers the economic and social growth of that region. For urban areas where grid-connected supply is corporately stronger, load shedding and poor quality of supply make the grid. Noticing the limitations of the AC grid creates a need for localized power systems or DC microgrids, but care must be taken in order to focus on cost, efficiency, and reliability and also it must be kept into consideration that it should be environment friendly. Renewable-based microgrids utilize natural resources which are in abundance and free of cost. Due to losses that are faced in AC grids for severe transmission and distribution, DC microgrids utilize choppers or DC-DC converters having almost 95% efficiency and they reduce the need for AC/DC converters. For our test system, DC microgrid based on PV system have been proposed with various sections (which will be discussed in detail), this system has been simulated by using MATLAB/SIMULINK software. The test system uses a control strategy known as MPPT control which monitors and tracks the maximum power based on control circuitry, the type of control strategy which has been used in my project is simply the 'Perturb and Observe Algorithm'. The simulation results validate the feasibility of the microgrid, the storage system also provides an option of storing the surplus energy based on the Irradiance level. The storage system we have chosen is a simple Li-Ion battery which stores

the energy in chemical form. Li-Ion batteries perform both the functions of charging and discharging depending upon the state of charge, this provides an advanced feature to my project.

2. Background

Microgrids have a vast history based on research. As we know that the first Power Plant was constructed in 1882 named Manhattan Pearl Street Station, basically it was actually a microgrid as the Centralized grid was not yet been established. Up to 1886 the firm of Edison had already installed almost 58 microgrids (DC).

The knowledge of microgrids is seen in different books and also on the internet, but the main problem is which generating source we will choose, since various renewable energy sources are available which are of no cost, so we need to utilize them in order to fulfill the need. The source we have chosen is the Sun i.e we are using the Sun as a primary source of energy for the microgrid-based system. After studying various research papers, the definition of microgrids is important to know before moving on further, various definitions of microgrids are as under as recorded at the University of Wisconsin, Madison, USA:

1. An energy system which consists of the number of distributed energy resources and many electrical loads operating as a single or grid-connected either in parallel or in Islanded mode.
2. It consists of single power subsystems associated with a few numbers of distributed energy resources (DERs) both conventional and renewable sources like photovoltaic, wind power, gas turbine, hydrothermal, microturbine in collaboration with the number of loads.
3. The last but not the least definition is given by Dr. Robert H.Lasseter, Professor and Principle at the University of Wisconsin Madison based on CERTS (Consortium for Electric Reliability Technology Solutions) which says microgrid is actually a grid that gives an aggregation of loads and various micro sources operating as a single source providing both power and heat. These microsources may be power electronic-based in the majority to provide flexibility to ensure the operation as a single system.

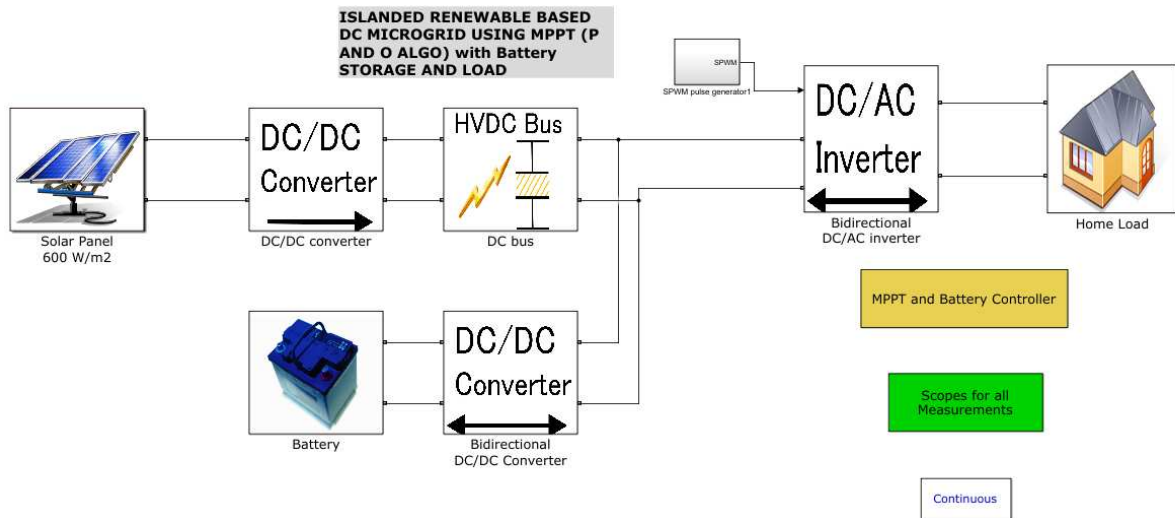


Fig- 1 MATLAB simulink of Islanded renewable based DC microgrid

3. Solar PV Panel:

After going through various research papers and studying the PV and VI characteristics of a Single Cell, Here we took the output of a ‘7.33 Kw Solar Installation Farm’ which consists of several panels each of 130watts where its VI characteristics are shown on the basis voltage and currents fed in the lookup table. I am using the ‘VI look table’ of the above system to feed into the circuit as shown in the given below diagram.

Lookup table is a table for which we give predetermined inputs and outputs and we notice the characteristics. As shown in above Fig 2 using a Controlled Current source which will drive the current forcibly in this circuit and voltage across the load is measured by using a voltmeter in place of a shunt resistor like in the case of a physical model.

Now this voltage is fed back in the look table as an input ‘V_pv’, to get the desired output as current I_pv. Initially, at zero voltage the current is 57.8Amp, and further as the current increases the voltage with increases up to which the peak point reaches wherefrom the graph shows the bend. At this point, the MPPT controller doesn’t allow the voltage to go beyond 200V.

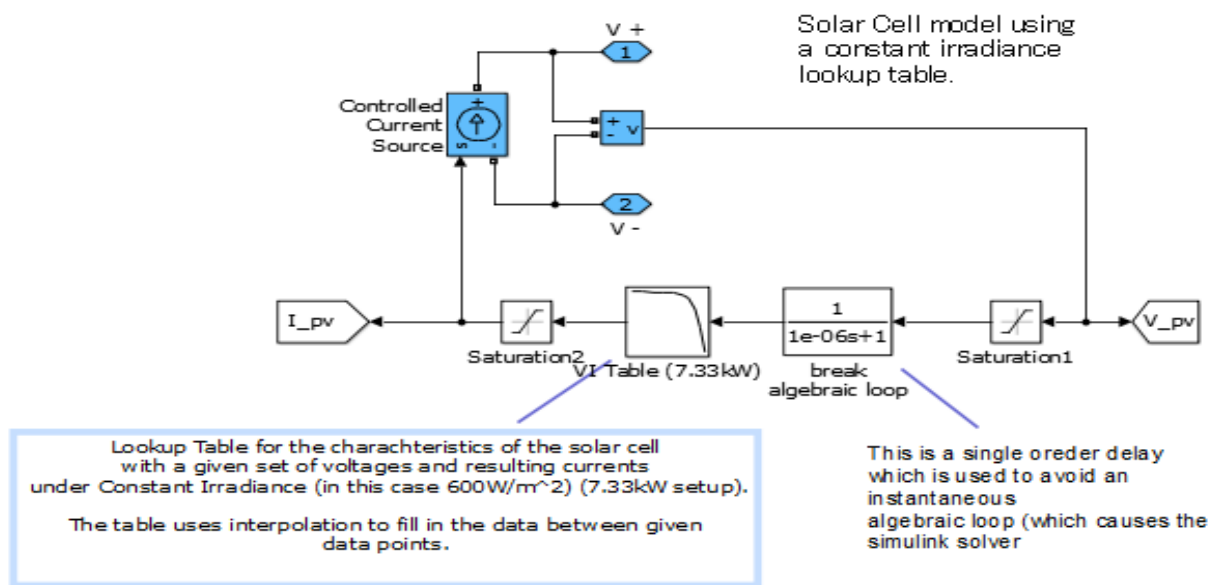


Fig 2-Model of a Solar Cell using a constant Irradiance Look up Table

Now this voltage is passed through the saturation block, the function of saturation block is that in case the load gets shorted very high current is drawn which will damage the system or the whole simulation is crashed. So in order to maintain continuity this block is used. Also, for practical purposes, this block comes into existence due to parasitic and internal resistances. It also reduces the spikes due to voltages and currents.

Break Algebraic Loop: This block is used as a single order filter which is used to avoid any instantaneous algebraic loop. This block simply removes any spikes to make the voltage stable.

VI look up Table: This table uses the VI characteristics of the '7.33 kW Solar Installation Farm' which consists of several panels of 130watts. As we can see from the above figure That initially the voltage is zero and the current is 57.8 Amp. As the voltage increases the current also increases till it reaches to the MPPT point where the voltage is not allowed to go beyond 200V, this is done by the MPPT controller.

Further, this voltage is passed through the saturation block where from further spikes are removed. Now the desired output i.e current is obtained as 'I_{pv}'

➤ **OBSERVATIONS DURING SIMULATION:**

The PV panel Installation (7.33kW) in the above Look up table during modelling can produce a maximum voltage and current as: **SHORT CIRCUIT CHAR BASED VALUES:**

V_{pvmax} = 280V. (Open circuit Voltage)

I_{pvmax} = 26.153A (Short Circuit Current)

P_{pv} = 5.0 kW (Solar power output)

➤ **MPPT CHAR BASED VALUES:**

V_{pv} = 200V.

I_{pv} = 20Amp.

4. DC BUS:

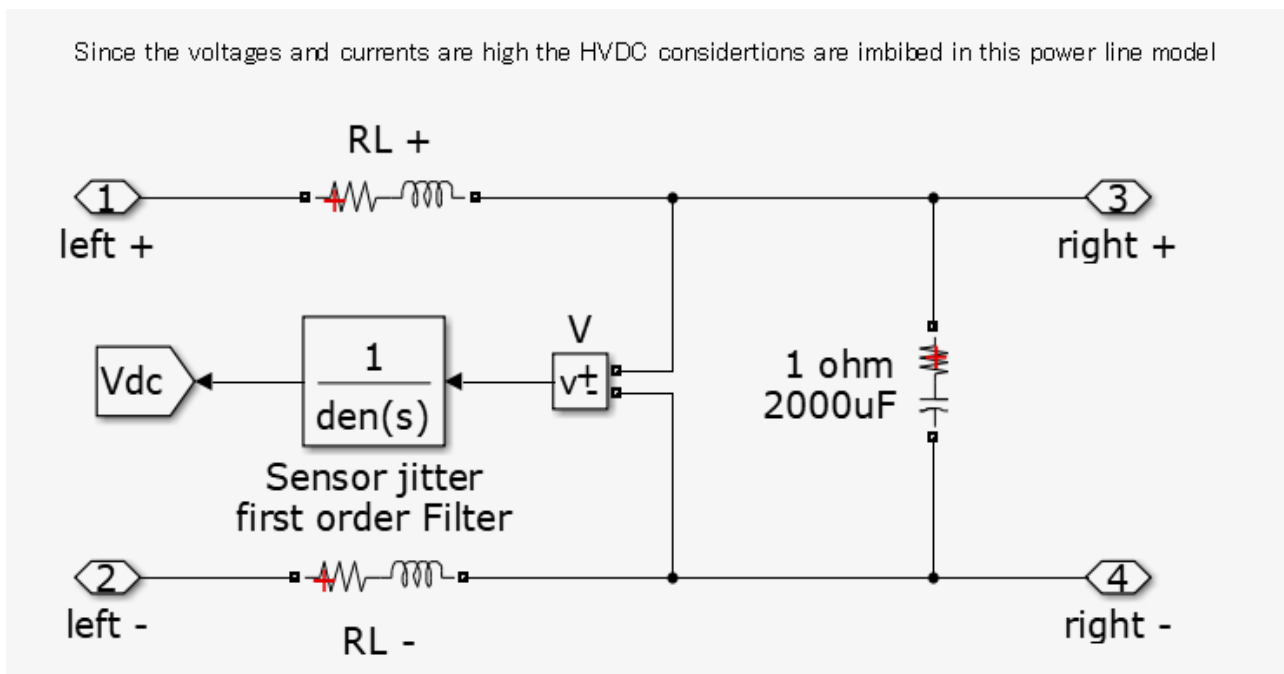


Fig 3- Schematic diagram of DC bus

Since the voltages and currents are higher (V_{dc} = 200, I_{dc} = 50Amp) the HVDC consideration are imbibed in this power line model. The schematic of the DC bus is shown below in Fig 3

5. Li-Ion Battery:

Battery is used to store the energy as well as to draw the energy from it during the high demand of the load. We have used a 'Li ion' battery in our project with a normal capacity of 200V. The state of charge of the battery is chosen as 80% means the battery is initially discharged.

The voltage, current, and power across the battery are seen on Battery status (scope). The schematic of the battery is shown below

As far as storage battery is considered we have chosen a Li-Ion battery, the operation of this battery will depend upon the components, it has three components viz a positive electrode which is connected to the positive portion/terminal of the battery, a negative electrode which is connected to the negative terminal of the battery. An electrolyte is the third component which is in between the two electrodes. Going to the construction part the positive electrode consists of lithium cobalt oxide (LiCoO₂), based on advanced technology nowadays LiFePO₄

is preferred. The negative electrode generally consists of carbon (graphite). The electrolyte changes from type one battery to another type.

During the charging process, the ions from the positive electrode (LiCoO₂) travel through the electrolyte towards the negative electrode (graphite), in this whole process, the energy is stored in the battery. During discharging mode, the Li-ions flow in opposite direction from the negative to the positive electrode. In both, the above cases the electrons flow in opposite directions to the respective ions around the outer circuit. Electrons in this process actually flow from the external circuit, not from the electrolyte. The movement of the two carriers i.e ions and electrons is important if either of the two stops the movement so does the other.

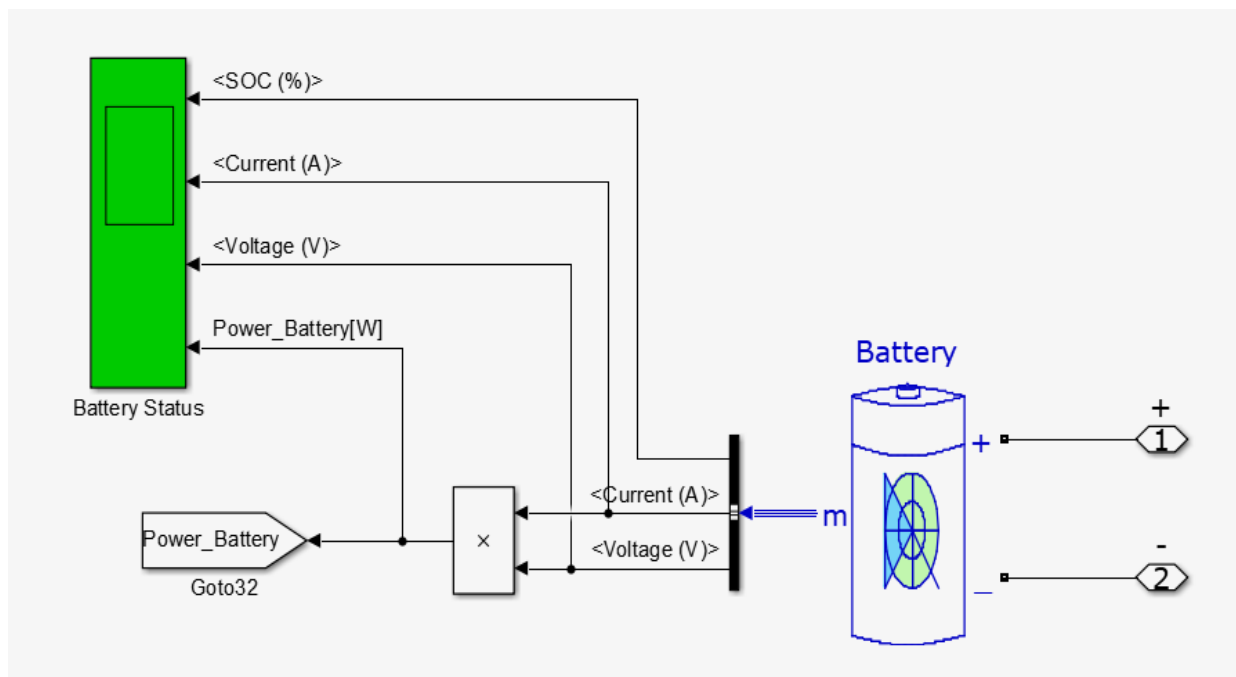


Fig 4 Li-Ion Battery

6. Methodology

CONTROL STRATEGY BY USING MPPT (P & O):

MAXIMUM POWER POINT TRACKING (MPPT): Maximum power point tracking is a technique used for extracting the maximum power from the Solar Photovoltaic system. In the case of PV modules, there is a single operating point where maximum power can be drawn, so we need to track this point in order to track the maximum power. The process of doing this by trying to maintain the operating point of the PV panel at the maximum power point (MPP) is called MPPT.

CONTROL LOGIC CIRCUITRY

The Control Mechanism of the simulated setup comprises of three parts. The MPPT controller, the battery controller, and the load controller.

6.1. The MPPT control

The power output of a solar panel varies based on the load and irradiance variation throughout the day. This is usually undesirable. To counter this many techniques have been devised to ensure that maximum power is drawn from the solar panel installation at all times. This is done by tracking the maximum power value on the solar PV curve, the main control variable being the voltage, V_{ref} . If the voltage is maintained at a value for which the power value is maximum, by techniques such as PWM control of a DC-DC regulator, this technique is called maximum power point tracking or MPPT. Many control techniques have been designed to perform this tracking task. Among the earliest of these was perturb and observe or P&O. This technique is still widely used today in entry-level controllers available in the market because of its simplicity, however more efficient options involving higher and different monitoring techniques and even machine learning have been devised. These more exquisite and complex techniques are mostly employed in medium to large-scale solar PV projects. This project uses P&O because of its simplicity and widespread use in the entry-level market. The following section briefly explains the perturb and observation technique.

6.2. PERTURB AND OBSERVE ALGORITHM

As the name suggests, the controller uses a voltage sensor and a current sensor on the PV installation output to monitor the voltage, current, and power output of the setup. The microcontroller (typically) is fed with all the parameters and it computes the power at a given sampling instant, but for our test system, we have used MPPT controller (PV). This instantaneous value of the power is stored as a variable, say 'Pa' then on the next sampling event a new value of power is computed, say 'Pb'. Then the following computation is performed;

$$\frac{P_b - P_a}{T_s}$$

Where T_s is the sampling interval. This equation effectively computes the slope of the power-voltage or PV curve at a given instant. Then after obtaining the information regarding the operating point of the system, i.e. the point at which power was computed in the previous step.

The controller then checks the voltage of the panel again, it keeps increasing or decreasing, until the slope of the power curve obtained is almost zero, at this point, the controller records the voltage at which this maximum power point MPP occurs. It then sets the set-point for the DC-DC converter to this voltage and provides the corresponding duty cycle control. This is how to perturb and observe works in their essence. For our test system, we have simulated a Flow chart for MPPT control which can be understood as shown below in Figure 5.

V_{pv} = voltage output of PV panel.

I_{pv} = Current output of PV panel.

P_{pv} = Output power of PV panel.

V_{ref} = Maximum voltage at which the peak power is tracked.

$dV = 0.5$ = perturbation.

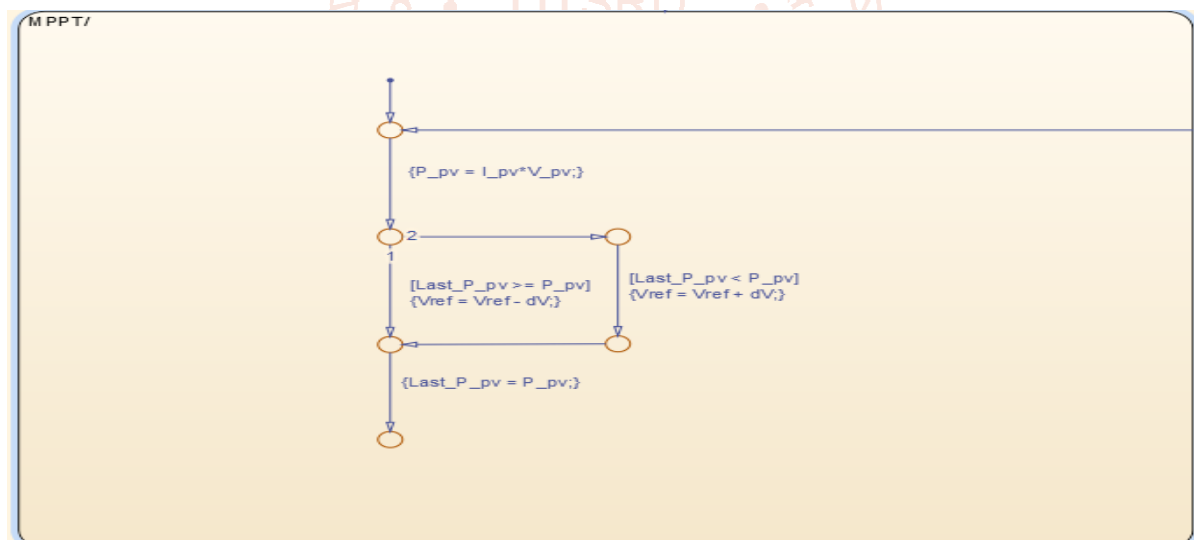


Fig 5 Flow chart based on P and O

6.3. The Battery controller

The battery controller is simple in construction. It involves a bidirectional buck/boost converter and complete isolation control. Apart from this, the battery is also monitored for its SOC or state of charge, voltage, and temperature, etc.

The isolation mechanism is controlled by the controller section which allows for manual control. The four isolation switches can be turned on (in simulation by a signal builder block) to enable the battery to both charging and supplying power to the load. In case of maintenance or when the load can be powered by the solar panels alone and the battery is fully charged, the battery can be disconnected from the system to avoid unnecessary stress on the system components including battery and switches. The control setup works on the given below simulated model as shown in Figure 6.

The bidirectional converter is controlled by a simple PID control mechanism, apart from the flow control which determines whether the system acts as a buck or boost converter based on the battery SOC and load status, and panel power output. The battery set-point is defined in the controller.

7. PHOTO VOLTAIC CONTROLLER:

The function of the PV controller is simply to generate the pulses which are used to feed to the gate terminal of the Boost converter in order to control the duty ratio. PV controller takes three inputs V_{pv} , I_{pv} , and V_{ref} .

Control mechanism:

The reference voltage is passed through saturation block which removes any spikes or surges, after that it is subtracted from the panel voltage, V_{pv} . An error is generated which is filtered by passing through a filter of the transfer function as shown below.

$$G(s) = \frac{1}{s+10^{-4}+1} \dots\dots\dots(4.1)$$

This filtered signal is passed through the PID which always tries to reach the signal to a set point. Now the reference signal is generated as I_{ref} . This signal is subtracted from the PV panel current, I_{pv} after that it is further filtered to remove the jitters.

Finally, a 2 level PWM generator is used to generate the pulses for duty ratio to vary automatically of Boost converter. A terminator simply terminates the duty varying from 0 to -1.

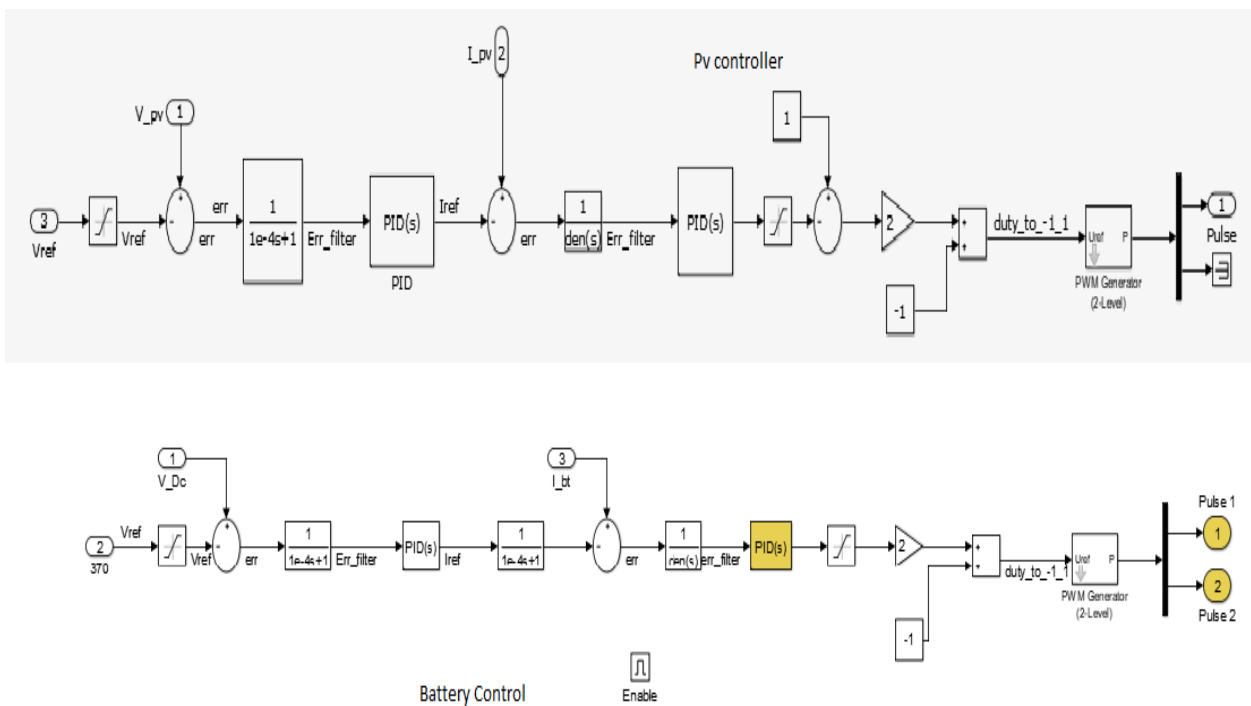


Fig 6- Battery and PV controllers (simulated view)

8. LOAD CONTROLLER:

This part consists of a signal builder block in Simulink to generate two non-conformal switching signals to simulate two different loads being operated at different times, like when the battery is enabled and not enabled to determine system performance under normal situations and stress.

The load is the most important component, so here the chosen controlled loads ‘RL’ loads that are typically in our homes for which the power factor is lagging. And modeled them in such a way likewise in our homes, loads are turned ON and OFF. Here the inserted two switches in series with the loads for which the control signals are generated from the signal builder set up. The schematic of the Simulink model will clearly show the arrangement in simulation.

Mechanism:

The loads are connected in parallel and the load voltage is noticed by using a voltmeter as shown below. The switches are used in order to turn ON and OFF of battery.

Now when the battery is off and the loads are connected to the solar PV panel in that case what happens is, if the loads are supposed to be 5KW, 6KW and the irradiance is also less, a small amount of current will be drawn from the PV panel, but loads are heavy so the small current will cause heating to the appliances which are connected to the PV panel, In other words, we can say the appliances will get damaged.

On the other hand, side, if the battery is connected to the system or battery, is ON, and also the irradiance is also high in that parasitic effects are also negligible. In that case, the current will follow the least resistance path as shown from the Schematic diagram. So here both battery, as

well as the PV panel, is supplying the current to the loads which are connected to the system. These loads are turned ON based on issuing pulses to the switches which are connected in series with the loads. The function of these switches is simply to connect the loads like in practical cases, likewise in our home. They are called as controlled loads because they are connected to the Inverter output on the basic commands given to the system.

As we can see we from the ‘Simulink Model’ (scopes and measurements block) where from load switching block, how the loads are connected practically turned ON and OFF.

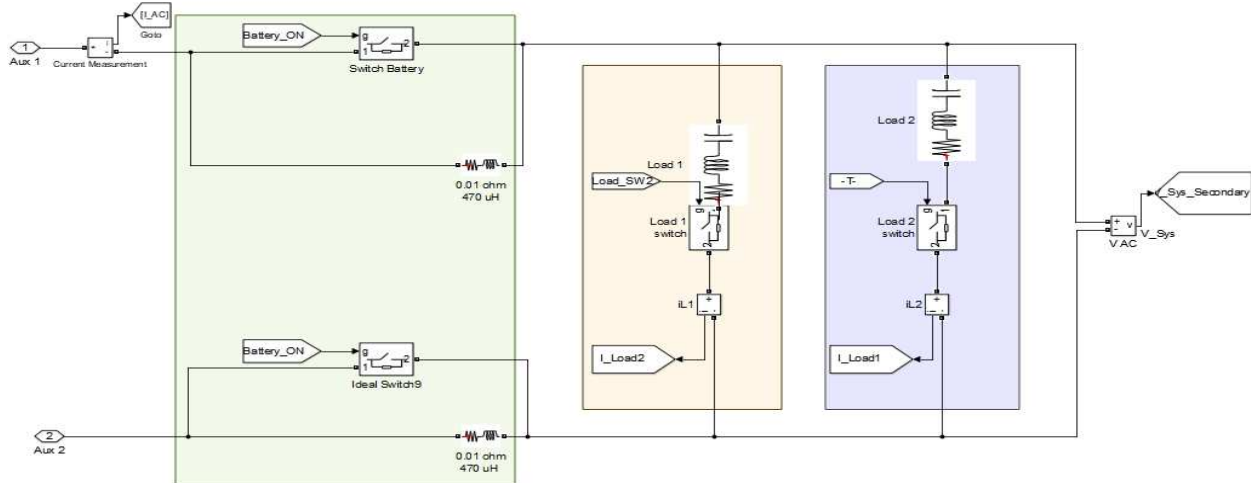


Fig 8- Schematic of Load arrangement

9. RESULTS

The Photovoltaic installation panel we have inserted in the loop is being monitored, the

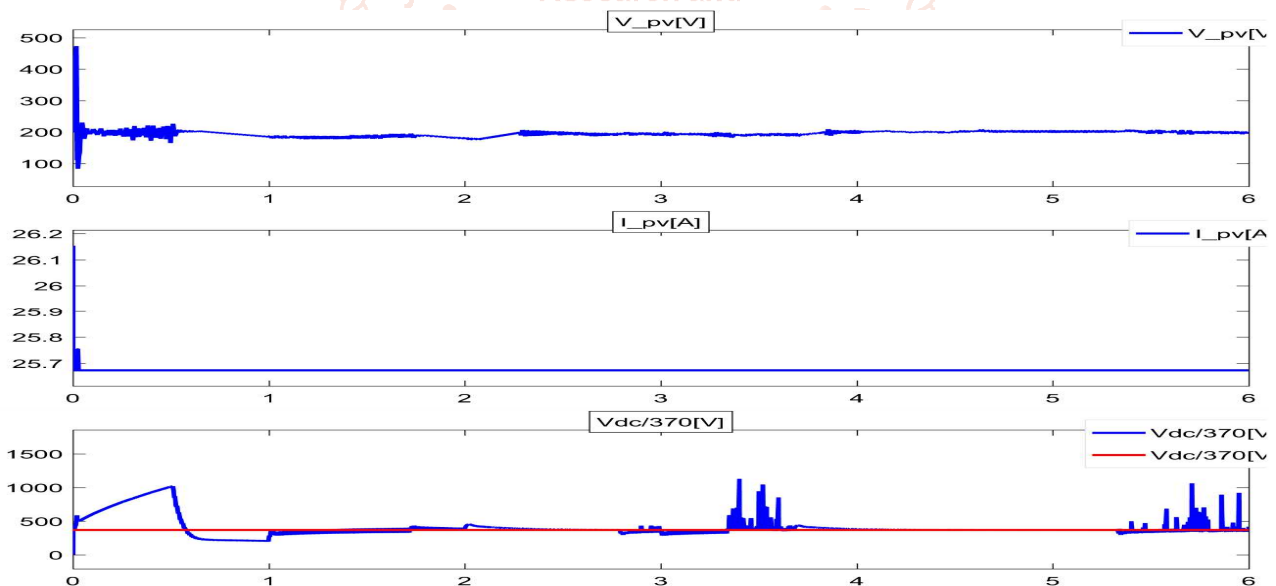


Fig-9 PV voltage, PV current, DC bus voltage

PV outputs like V_{pv} , I_{pv} and V_{dc} (370V), in order to charge the battery based on battery’s nominal voltage) are shown in the PV panel scope as shown below.

Fig -9 Photovoltaic panel parameters during installation

Now the 2nd case arises on the basis of irradiance available, if the irradiance is low in that case the current is very low since we have taken lagging loads for our system, these loads will get overheated due to the low value of current, which we have done is connect a battery to the system which draws a current which is favorable for the

loads. The loads and battery are turned ON on the basis of commands given (can be seen in signal builder block), the same is the case for battery, fig 10 below will show the scenario.

During observations, different types of powers such as Battery power, Solar power, Load_1 power, and Load_2 power are shown below in the plot based on the MPPT control mechanism.

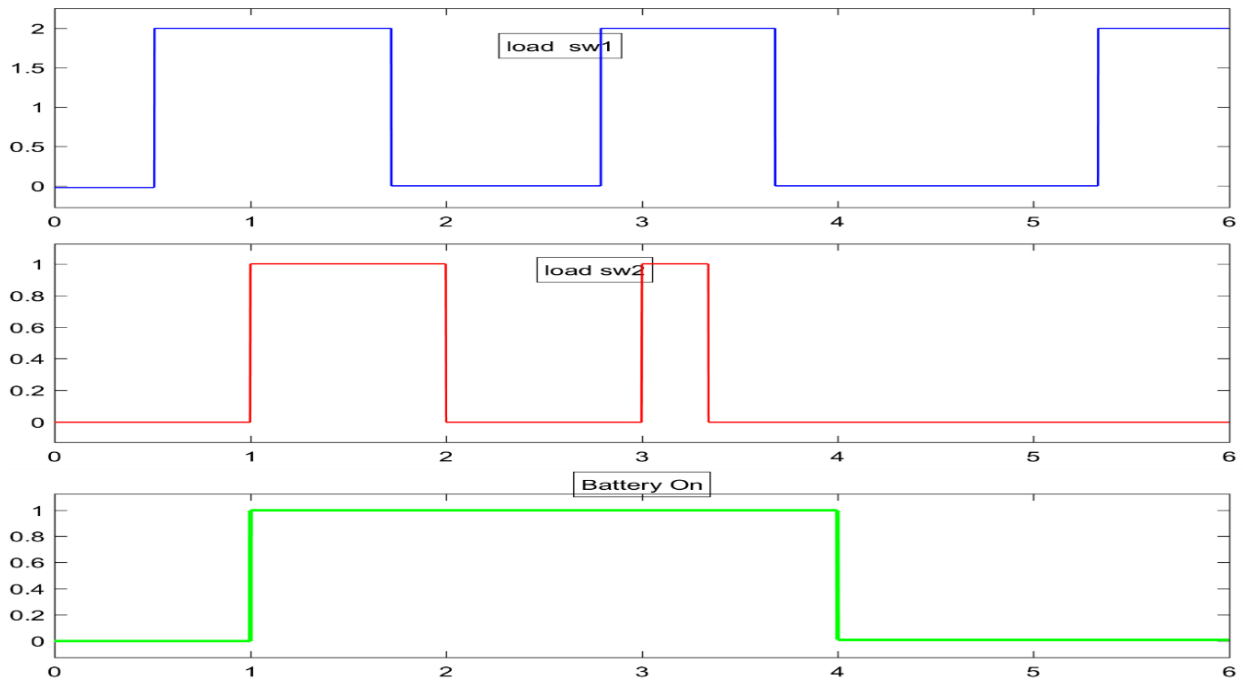


Fig10 Battery and load switching arrangements

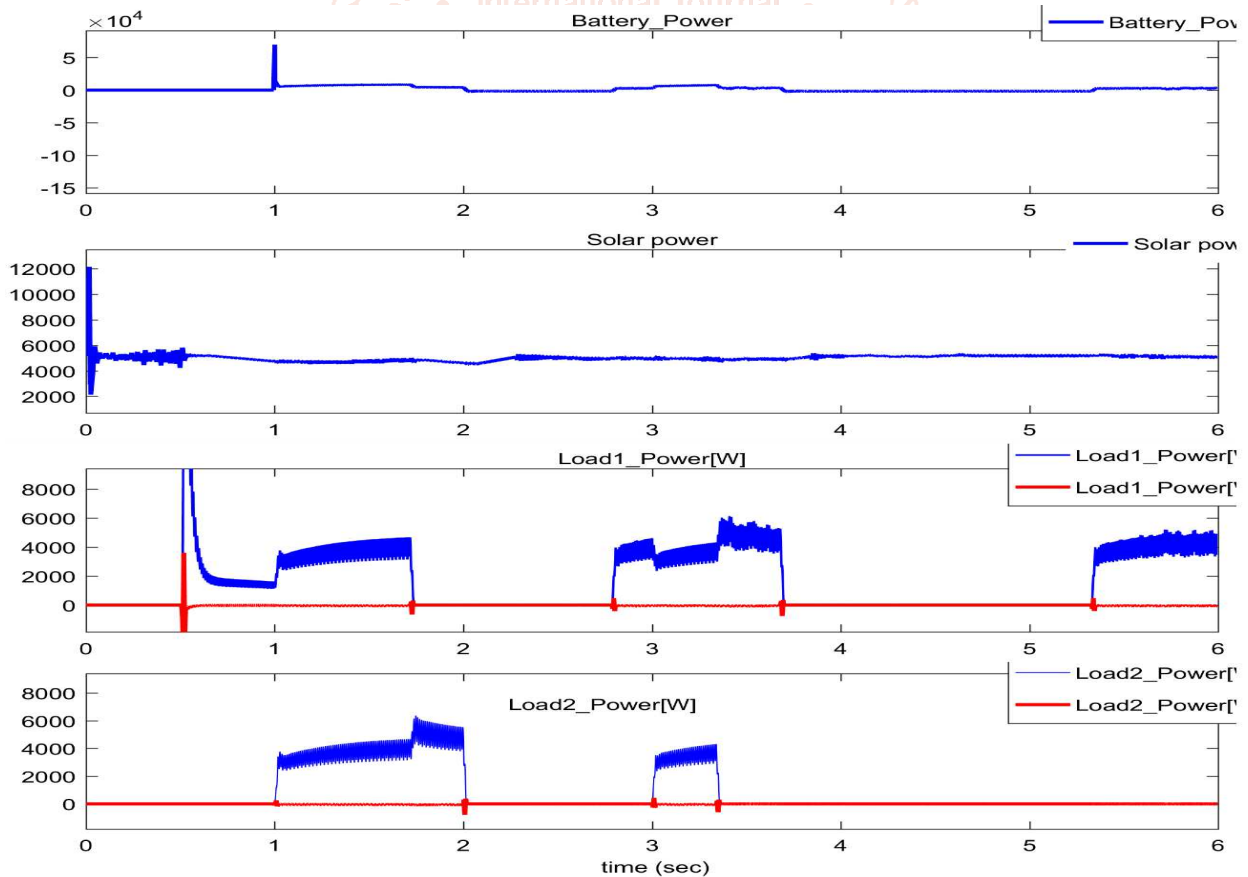


Fig 11 Power outputs for 4 different systems

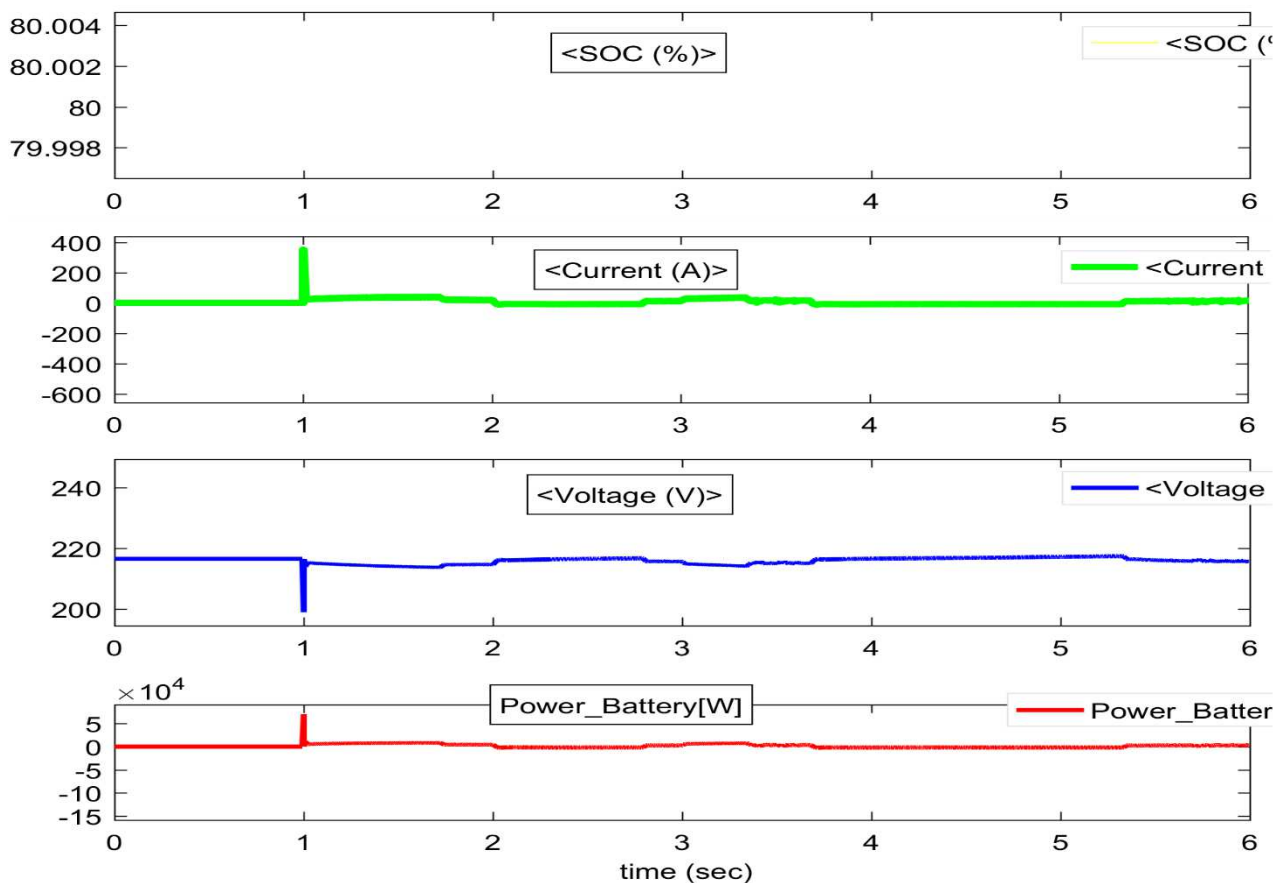


Fig 12 Battery status (Battery parameters)

10. CONCLUSION

In this study, the MATLAB/Simulink environment was used to simulate a simple Photo Voltaic Installation Farm where its characteristics were seen that they remain the same as a single-cell PV system. In this test system, we are tracking the maximum power from the arrangement by using the MPPT control ('Perturb and Observe Algorithm'). Further, we have also modeled the system in order to store the surplus power and also to provide the power to the commercial loads by using the standard mechanism shown in the Simulink model. The DC bus voltage we have obtained needs to be utilized both for charging purposes as well as for commercial loads, for that purpose we have chosen a single-phase Full bridge SPWM inverter which converts this Dc bus voltage into ac in order to use this voltage for practical commercial systems (Home loads). Finally, we have chosen Home Loads as RL loads (controlled) in order to see the performance of power flow from source to load, these loads were taken in order to observe the behavior of such loads for a practical real-world scenario. The various plots of the above system can be seen on the Scope measuring block.

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