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PV System Multiple Source Single Inverter

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ABSTRACT- Renewable energy has gotten a lot of attention because of environmental issues like climate change, as well as political and economic reasons including decreased reliance on foreign energy imports and high oil costs. The fastest-growing renewable energy industries are wind and solar power. As advances in renewable energy are developed, the cost of power generated by renewable energy decreases. Renewable energy technologies are excellent for dispersed power generation as well as solving climate change and reducing reliance on foreign energy imports. Renewable energy may deliver power without expensive and intricate grid infrastructure in distant, there are really no power sources in remote areas, or the expense of installing distribution networks is prohibitive.

Power capacity built worldwide reached 227 gigawatts (GW) in 2015, enough to need 1% of total electricity generation. Thermal power plants may be located in northern Argentina, with the largest being the 392 MW Ivanpah Solar Electric Generation System in Arizona.

This paper describes and analyses a micro-grid system that includes different and independent PV sources connected to a shared DC bus, as well as localized battery storage and power monitoring and protection devices.

KEYWORDS- Solar Energy, Thermal Energy, Power Protection, Microgrid.

I. INTRODUCTION

The growth of renewable energy has received a lot of attention in recent years. Furthermore, because renewable energy sources such as solar energy are employed in homes and offices, generation is spread out. The notion of micro-grid is highly valuable in making dispersed generation relevant to the nearby neighborhood community of such generation canters. The goal of this project is to simulate and present the results of a distributed solar photovoltaic system with a common DC bus and a single point of DC energy storage in the form of a battery, in which the energy being taken and provided to the localized DC grid is monitored for consumer supply and consumption of energy generated in the system. In addition to the aforementioned goals, a general design for microgrid-solar-integration protection.

Renewable energy has gotten a lot of attention because of natural issues such as global warming, as well as social -financial grounds including decreased reliance on foreign oil supplies and high oil costs. The extremely fast renewable electricity industries are wind and solar power. As advances in sustainable energy are developed, the cost of power generated by renewable energy decreases. Wind turbines are excellent for dispersed generating electricity as well as solving climate science and reducing reliance on foreign energy imports. Solar power may deliver power without complex and intricate generation capacity in distant places where there are no coaxial cables or the cost of establishing power systems is excessive[1].

As per International Energy Agency, renewable energy producers might have the majority of wind energy for around 50 years. Agency, lowering greenhouse gas emissions that hurt the environment. "Photovoltaic and solar-thermal plants may fulfill the majority of the world's demand for electricity by 2060, and half of the total energy demands, with wind, hydropower, and biomass plants contributing much of the remaining output," said. Senior expert in the IEA's clean energy section, Cedric Philibert "When photovoltaic and concentrated solar power is combined, they have the potential to become the primary source of electricity." Wind energy output is also quickly increasing, accounting for roughly 5% of global power use. Installed photovoltaic capacity reached 227 gigawatts (GW) in 2015, enough to provide 1% of global energy demand. The 392. MW Ivanpah Solar Electric Generating System in California is the largest solar thermal energy station in the United States and Spain[2]

II. LITERATURE REVIEW

Micro-grids offer technological advantages by adopting renewable power to increase system service grade and electric system performance [3-4]. Sub also have the key characteristics:

- A sub might be used to meet increased market by offering more generation capacity
- A sub might be used to meet increased market by offering more generation capacity as a consequence, system changes that would be required to satisfy the growing market can be delayed or minimized. This means that micro-grid DGs would be used in the existing substation.
- Micro-grid functions such as instantaneous reactive power supply, current sag remedies, and overall differential modifications are performed by generators [5-7].

The first stage in building a solar system is to figure out how much energy will be provided. If PV storage is necessary, the quantity of the battery pack is determined once consumption has been analyzed. Once a bank has been specified, the size of both the Photovoltaic (PV) array must be estimated. [8-11] The mechanical components are then selected, namely electrical networks, amplifiers, and MPPT Controller controllers. Lastly, hardware for the rebalancing of the system (BOS), such as element mount, wiring, controls, timers, fuel rooms, and suppression systems, are selected. Calculated and the results for load measurement and power electronics are described in. One of the major difficulties that PV supply systems face is the storage of electricity production. [11-13]

III. GENERAL OVERVIEW

Because it combined numerous PV energy sources using DC-DC converters and then used storage mechanisms and inverters to store and supply energy in AC form, the setup described in this project is highly simple and practical for small-scale deployment as a micro-grid. The following renewable energy sources are combined: solar photovoltaic, and battery storage. To make the system more redundant, the batteries are employed as energy buffers. This section aims to provide a basic understanding of how solar cells and power electronic converters function.

A. Solar Photovoltaic Cells

A photovoltaic panel, also characterized as a solar panel, is an electronics method of converting produce electricity via the PV effect.

A photovoltaic (PV) cell must have three essential characteristics in order to function:

- Light absorption, which as a result, particles called excitons are formed.
- Valence electrons with conflicting types of charges are split.
- Directly extracting the carriers to an electrical current. PV cells are made of photovoltaic systems and cell assemblages that produce power from sunlight.

To provide the most electricity at any given time, solar photovoltaics employ MPPT (Maximum Power Point Tracking).

Figure 1: Solar panel farm

A solar PV (photovoltaic) farm is seen in Fig. 1. Each panel is made up of numerous smaller tiles (black squares), which are made up of smaller strips or individual solar cells linked by silver conductors. To avoid degradation, the panel's surface is comprised of either glass or UV-resistant epoxy. Solar cells may survive up to 25 years on average, however, their performance degrades significantly with time. The mathematical model of the solar PV-cell, as well as the mathematical equations, are shown in Figure 2.

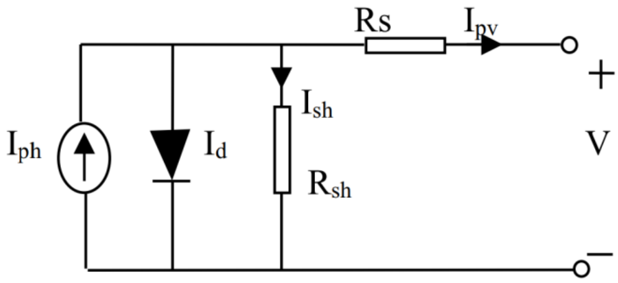

Figure 1: Model of a PV-cell

A solar cell is an electronic system that collects and transforms optical energy from sunlight. In the ideal solar cell system, the values associated with cell warming and emissivity, such as Rsh and Rs, are exceptionally challenging to measure. Small solar providers give observable basic characteristics such as the current of a static shock ISC, the potential of a short circuit current VOC, the voltage level point Vm, the Vmpp current Im, and the Mppt Pm.

$$Ipv = I_{Ph} - I_d - \frac{V + IR_s}{R_{sh}}$$

B. Boost Converter

A power supply is a DC to DC got converted whose voltage drop is positive. It's also known as a step-up transformer. The phrase process is a multi-converting comes from the fact that, like a process is a multi-rectifier, the voltage output is decided to step up to a level higher than the input signal. As per the ideal gas law, the motor speed must equal the output power.

The voltage output (Pin) equals the input power (Pin) (Pout)

Because Vin Vout is smaller than Vout in a voltage source inverter, the total power is much less than the input current. As a result, Iin boost converters

$$V_{in} < V_{out} \text{ and } I_{an} > I_{out}$$

1) Principle of Operation of The Boost Converter

Boost translators work because the resistor inside the primary winding resists rapid changes in input power. Only when the switch is open off, does the form of magnetic field information in the form of random energy and discharges this when the valve is switched on. The frequency in the transmitter coil is designed to be substantial enough so the duty cycle of the final stage's RC circuit appears high. The large time factor gives a consistent output voltage particularly linked to that same commutation period. Vo(t) = (constant)

2) Circuit Diagram of the Boost converter

The voltage source inverter circuit schematic is given in the below figure 3.

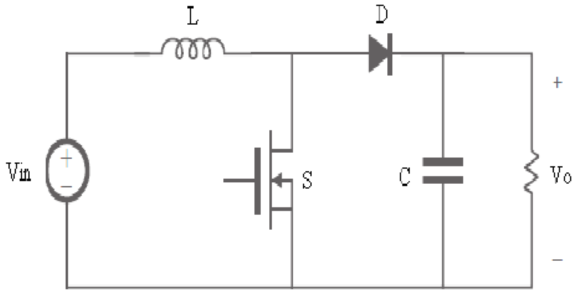

Figure 2: Circuit Diagram of Boost Converter

Modes of function for boost converters

- The boost translator has two modes of operation: a) Incremental conductance style, in which the current is never minimal and thus the inductor half discharged before the changeover cycle starts.
- Multimode mode, in which the flux density is zero somewhere at end of the half-cycle, indicating that the inductor has been completely charged.

3) Circuit Analysis of Boost Converter

Pretend that the inductor's present variation (from lowest to the highest amount) and indeed the capacitor's charge movement are both exceptionally large. small, and that they fluctuate linearly throughout the study. This is to make the analysis easier, and the answers we'll obtain from it will be rather accurate when compared to real-world numbers.

4) Continuous Conduction Mode

This is the first occurrence when switch S is switched on.
Since this n part of such diode is at a dc speed than with the p side, which again is damaged to the floor by flip, the diode will include programs when the transfer is switched on.
The input current and expenses both increase in this state. The river is moving forward. through the inductor is calculated as follows:

$$I_L = (1/L) * \int V * dt$$

Say also that circuit is I'L, off, before the device is turned. Because the voltage output is fixed,

$$I_{L,off} = (1/L) * \int (Vin) * dt + I'_{L,off}$$

Imagine the switch is open for D*Ts years, where D represents the clock frequency and Ts represents the changeover period. Following that, of the switch-on state, the current through the inductor is given as

$$I_{L,on} = (1/L) * Vin * D * Ts + I'_{L,on} \text{(Equation 1)}$$

Hence ΔIL = (1/L) *Vin*D*Ts.
instance 2: When the light is turned off
Once the switching is switched off, the bulb will software glitch, and the multilevel inverter wire may be rebuilt as such.
The RC & diode combination is now used to destroy the ferrite. Assume that even before the lever is closed, the current in the inductor is I''L, off. The following formula is used to compute the present traveling through the capacitor:

$$I'''_{L,off} = -(1/L) * \int (Vin - Vout) * dt + I''_{L,off}$$

The coil is recharging, as indicated by the negative value. Let the switch is closed for toff seconds, which is (1-D) * Ts, where Ts is the toggling timespan and D is the duty cycle. At the conclusion of the changing state, the value and through the resistor is given as

I'''L, off = – (1/L) *(Vin-Vout) *(1-D) *Ts + I''L,

Since the current flowing does not change drastically, it should also be comparable at the completion of the shift on cycle and or the ends of the shift off state in a full-employment scenario. Furthermore, the flows at the beginning of the shift off state and the potential at the end of the switch-on state should be the same. Consequently

I'''L, off =IL, *on*, also

I''L, off =I''L, *off*

Using the equations, we get

(1/L) *Vin*D*Ts = – (1/L) *(Vin-Vout) *(1-D) *Ts

Vin*D=- (Vin-Vout) *(1-D)

Vin* (D-1+D) = Vout*(1-D)

Vout/Vin = 1/ (1-D)

Since D < 1 Vout > Vin. Assuming no losses in the circuit and applying the law of conservation of energy

Vout*Iout = Vin*Iin

As a result, Iout/Iin = (1-D), and Iout Iin. The output. As the duty cycle increases, the voltage rises and the output current decreases. Nonetheless, due to neurological aspects in the bulk sections resistor, collector, and circuit, the step-up ratio Vout/Vin decreases with rising duty cycles and gradually decreases at the unit circuit.

C. Discontinuous Conduction Mode

As previously stated, when the converter is run in a parallel connection, the inductor's potential glycogen is completely depleted just before the turning cycle is finished. The voltage level waveforms of a voltage regulator in a PFC converter are shown in the diagram below.
The transistor releases much of the flow it gathered during the charging interval from the same cycle in ccm mode. The following formula is used to compute the present boost inductor:
:

$I_L = (1/L) \int V_L * dt$ = (1/L) *(area under the curve of voltage v/s time)

Hence, Vin*D*Ts = -(Vin-Vo) *δ*Ts (negative sign signifies that the inductor is discharging)

Vout/Vin = (D+ δ)/ δ

and the ratio of output to input current from the law of conservation of energy is Iout/Iin = δ/ (D+ δ).

IV. DESIGN OF SETUP

This section describes the construction of the simulation (figure 4)

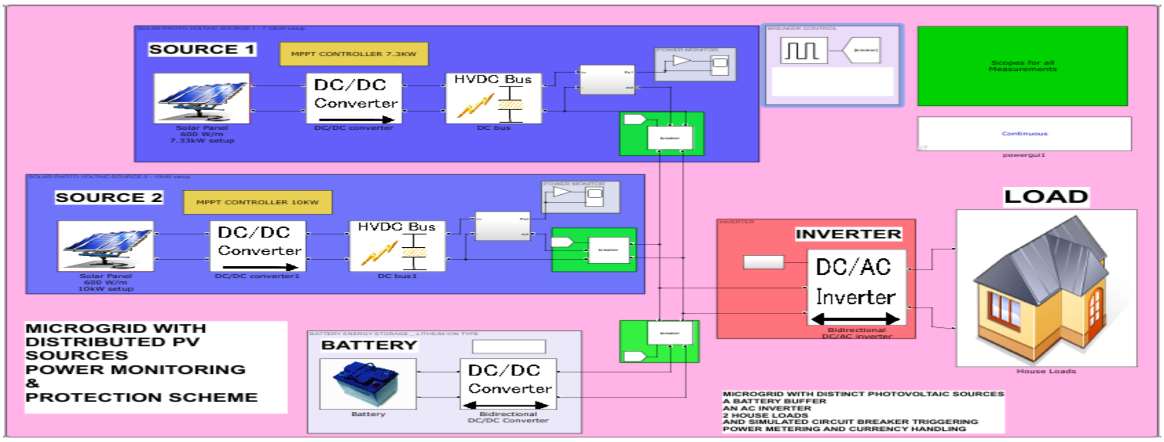

Figure 3: Construction of Simulation

A. Solar Photovoltaic Setups

The design of the Solar panel coupled to the Boost converter is shown in this section. Simulink is used to design the setup in MATLAB. The system consists of a 7.33kW and a 10kW PV system, each running independently under 600W/m2 irradiance and in a 23-to-30-degree Celsius ambient temperature range. Look-up tables with real-world data are used to replicate the installations. Each of the panels in both sets is rated at 130 watts. The PV system's output is routed to a boost converter, which raises the panel's output voltage to 200V while performing MPPT on the electricity generated by the panels this scenario, the Perturb and Observe method is applied. The DC bus utilized in this design has a voltage of 200V as well. A boost converter is used to achieve and maintain the desired bus voltage. The PV installations and their construction are depicted in the accompanying diagrams.

Each PV system is treated as a distinct source, with its own set of independent components. A power meter, a cost calculator, and a 2-pole circuit breaker are all included in each device (figure 5).

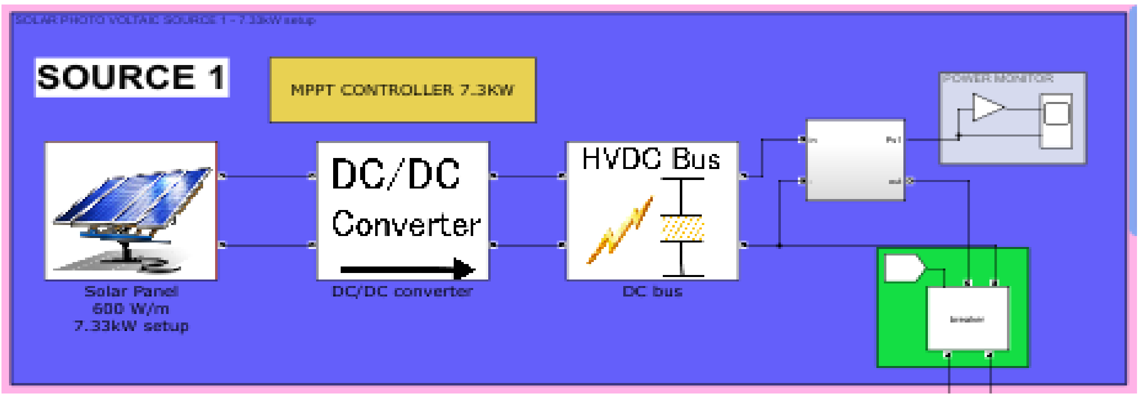

Figure 4: Solar photovoltaic Setup

The PV installation is to the left of the 7.33KW system. Then there's a DC-DC MPPT boost converter, a parasitic parameter emulator for the high voltage DC-bus, and a buffer capacitor. The power and energy metering system is on the right, while the circuit breaker is on the lower right (green) (figure 6).

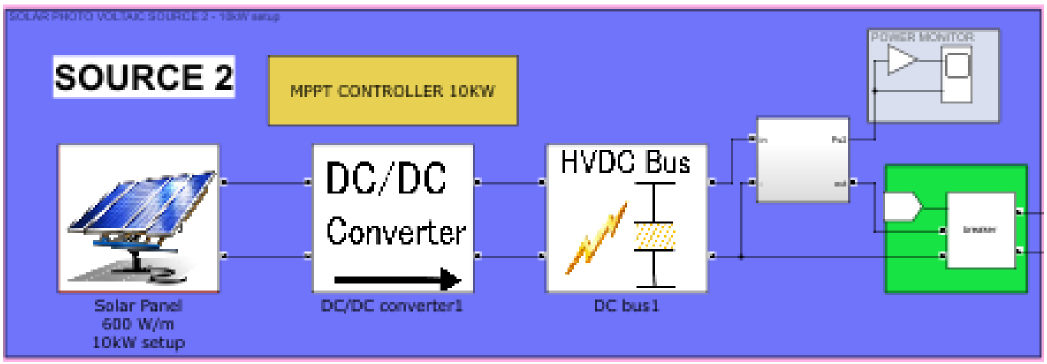

Figure 5: Photovoltaic setup source 2

The PV installation is on the left of the 10KW system. Then there's a DC-DC MPPT boost converter, a parasitic parameter emulator for the high voltage DC-bus, and a buffer capacitor. The power and energy metering system is on the right, while the circuit breaker is on the lower right (green).

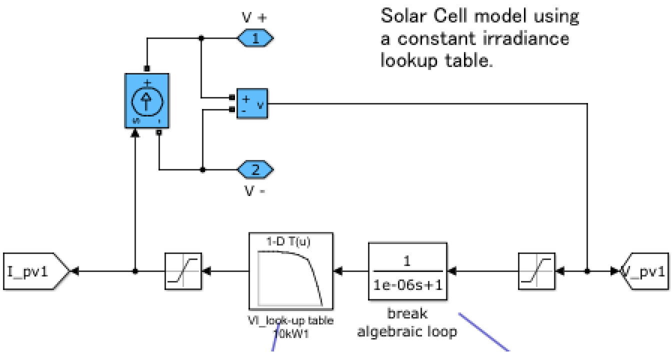

Figure 6: Solar cell model using a lookup table

Design for a solar PV system based on a look-up table (both the 7.33- and 10-kW systems) (figure 7). The data from a look-up table in the bottom middle is used by the top left controlled current source. The first order delay in the break algebraic loop block prevents race conditions in the simulation.

B. Boost Converter

To safeguard the PV panels, this is a basic DC-DC boost converter with reverse protection diodes. This converter's job is to increase the voltage to the bus voltage and perform MPPT (maximum power point tracking). This is accomplished by controlling the IGBT with PWM (pulse width modulation). The MPPT block provides the control signal 'Pulse PV.' The design is seen in the below figure 8.

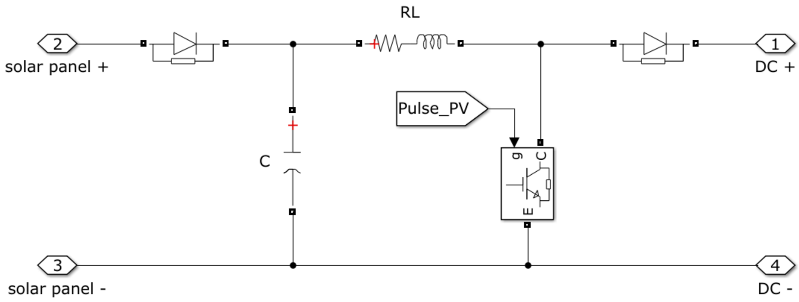

Figure 7: Buck-boost Converter

C. DC BUS

This is a basic two-wire simulation with resistance and inductance incorporated to account for their impacts in high-voltage operating zones. The construction is depicted in the diagram below. The capacitor serves as a ripple filter as well as a decoupler. To reduce controller instability, the voltage measuring block employs a second-order filter to eliminate jitter (figure 9).

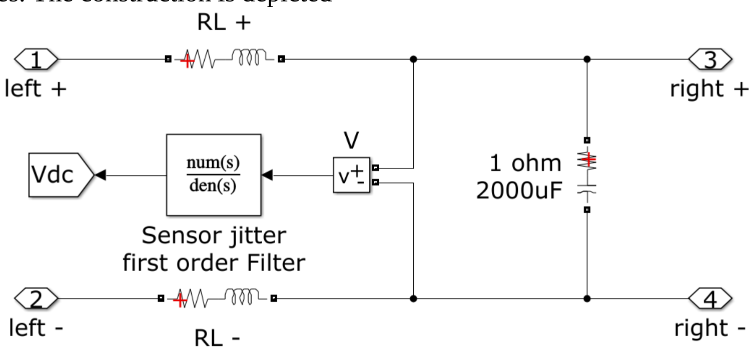

Figure 8: DC Bus

D. MPPT

Maximum power point tracking, often known as P&O, is a control approach for power electronic converters that ensures that the generation of power for a PV system is constantly at maximum. There are numerous strategies for this, such as P&O, Incremental Conductance, and so on.

However, P&O is used in this project because of its ease of use and efficiency in the simulation environment. The blocks below demonstrate how to build a P&O control system in Simulink (figure 10).

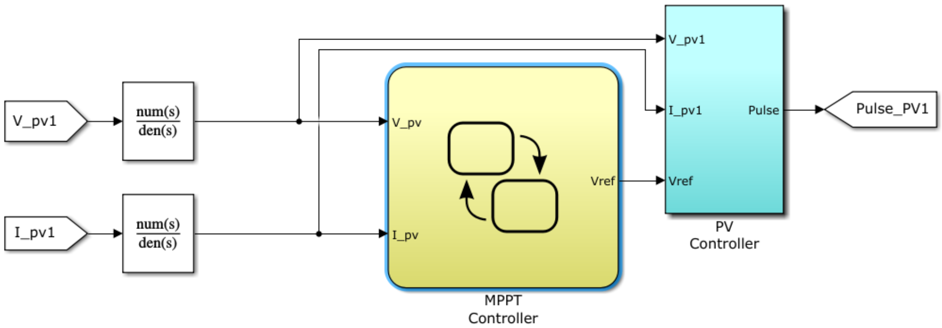

Figure 9: MPPT

On the left, you'll find the control settings. They're filtered before being given to the MPPT controller, which provides a reference voltage that's cleaned and optimized before being used to generate the PWM control signal for the boost converter IGBT (figure 11).

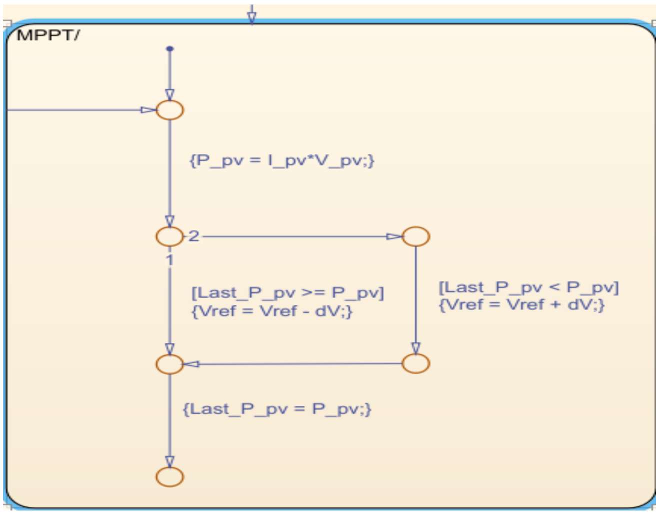

Figure 10: This is the state-flow implementation of the P&O MPPT algorithm

E. Battery Storage

To provide energy storage and redundancy a lithium-ion battery storage system that is centralized is included in the simulation The controller can engage and disengage the battery based on a manual or automated control signal, and the battery may be isolated by using four isolator switches on the battery charger.

The battery charger is a bidirectional buck-boost converter in and of itself. It features a separate control system and employs complementary switching.

For further information, see the below figures 12,13 and 14.

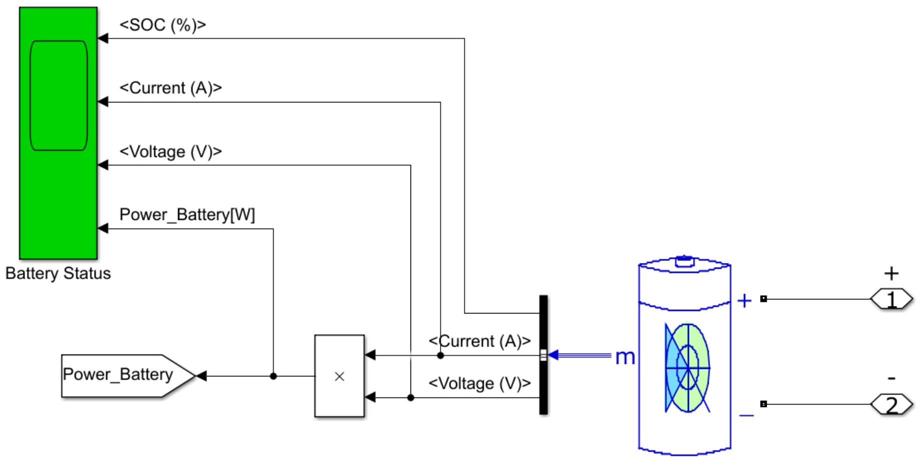

Figure 11: Battery and its monitoring setup

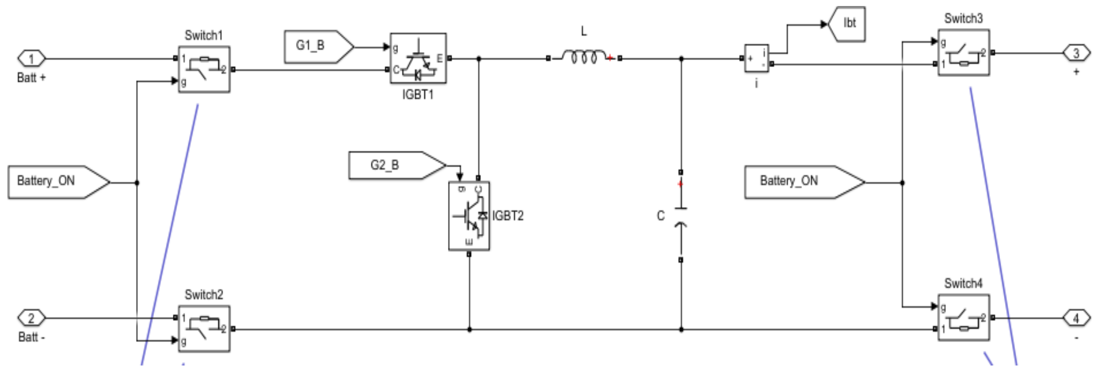

Figure 12: Battery charger

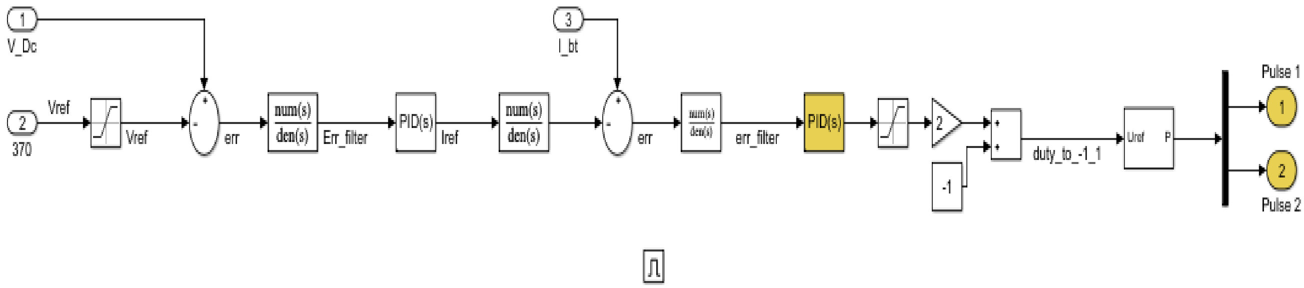

Figure 13: Battery charging controller

F. Power Metering

This section of the simulation merely monitors the solar PV sets' power output to the DC bus and computes the instantaneous power and energy provided to the DC bus. This may be used to allow business installations to get compensation for any energy they supply to the grid. This function is depicted in the following figure 15 and 16.

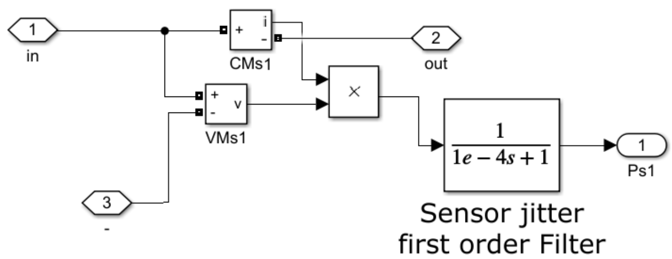

Figure 14: Power Meter

The following figure 16 shows the processing of the output of the power meter;

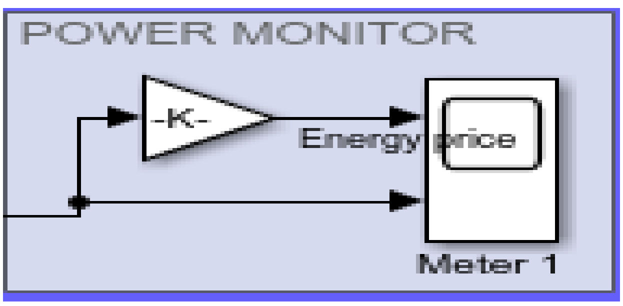

Figure 15: processing of the output of the power meter

The top connector provides the energy currency equivalent value after multiplying it by an appropriate gain. The lower connector provides, instantaneous power being delivered to the DC bus

G. Protection Systems

The electricity must be disconnected in the event of faults, malfunctions, or repairs on the microgrid, grid, or transmission infrastructure. This type of architecture has several power sources, including grid-integrated electricity and power from its PV sources. All power connections must be unplugged, and the system must be certified safe for in-contact human usage. A global control for the breakers will be employed in this scenario. To keep the simulation time and hardware constraints in mind, the breaker is activated via a timed event rather than a fault simulation. The protective strategy is depicted in the diagrams below figure 17. In the simulation, it is activated at 0.7s.

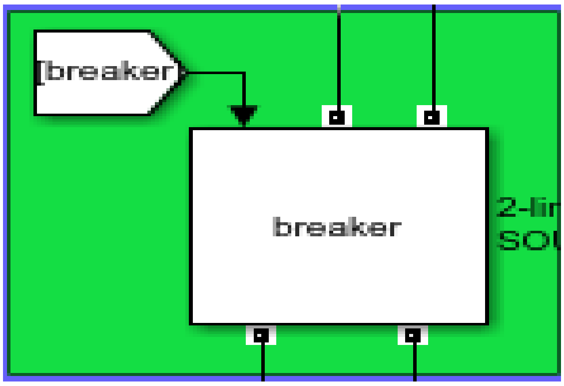

Figure 16: Breaker Block

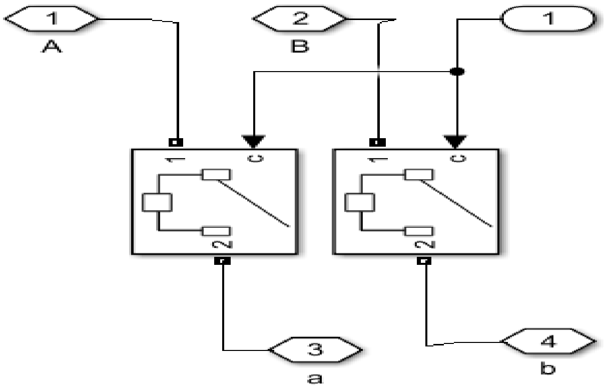

Figure 17: Inside Breaker Block

Inside Breaker Block are two independent breakers for each DC wire in this 2-wire DC bus system (figure 19).

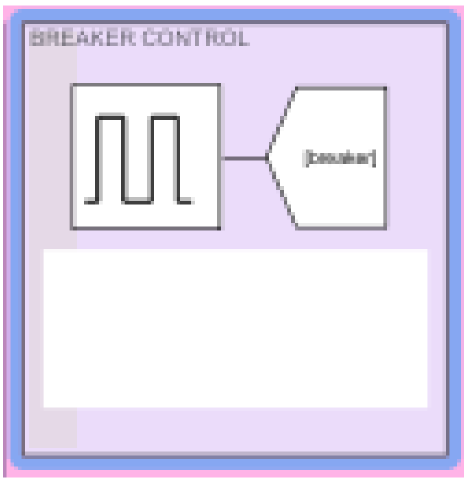

Figure 18: Breaker control signal

H. DC-AC Inverter

The single-phase DC to AC inverter used here is controlled by an SPWM (Sinusoidal PWM) signal. If grid integration is used, it is bidirectional. As a result, it can convert AC to DC by dumping power into the DC bus via its flyback diodes, but this must be properly controlled. The inverter is seen in the below figure 20 and 21. Switching is controlled by a single control signal, which is utilized to produce four control pulses for four switches using NOT logic.

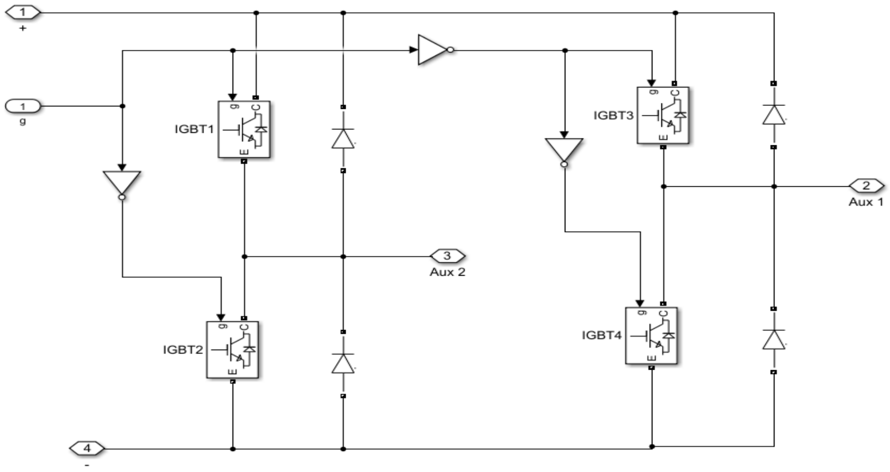

Figure 19: DC-AC bidirectional inverter

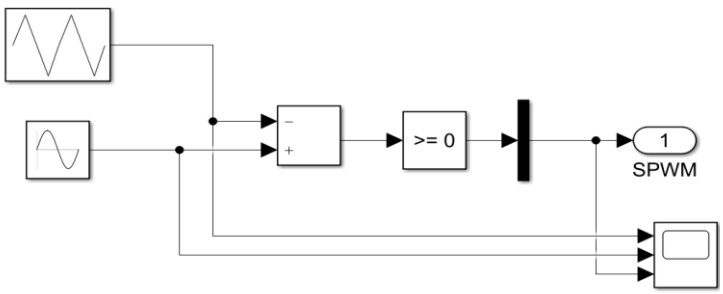

Figure 20: SPWM generation

I. House Loads

With some adaptive power consumption, the typical residential load is around 4kW. They are independently controlled and replicate workload changes.

The loads are mostly resistive, but they are also inductive and use reactive power, albeit in modest amounts. At separate times, each load is turned on. Load-1 is turned on for a brief time starting at 0.3s, and Load-2 is turned on at 0.5s and stays on throughout. All systems, and hence all loads, lose power when the breaker trips at 0.7s(figure 22).

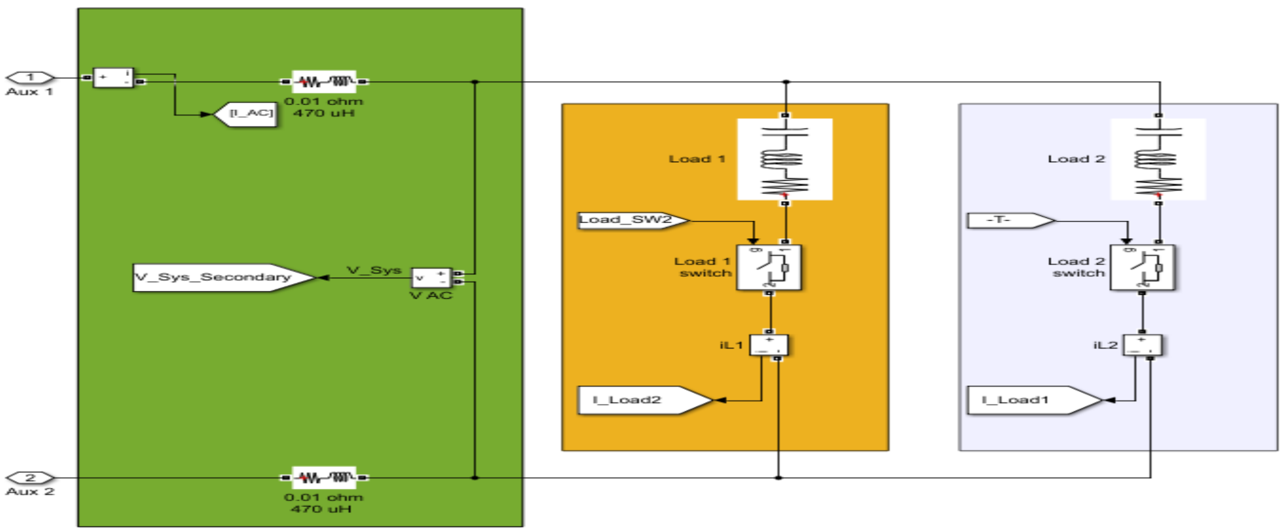

Figure 21: Inside House load; Load1 – Orange; Load2 – Silver

J. Control Mechanism

The modeled setup's Mechanism is made up of three elements. The Mppt algorithm, the batteries regulator, and the load controller are all part of the same system.

1) The MPPT Control

A solar panel's power production varies during the day, depending on the load and irradiance fluctuations. This is almost never a positive thing. To overcome this, several strategies have been devised to ensure that the solar panel installation is always pulling the maximum amount of power. The maximum power value on the solar PV curve is the control variable. Maximum power point tracking or the voltage is the most important factor to be watched. MPPT is a method that uses techniques like PWM control of a DC-DC regulator to keep the voltage at a value where the power value is at its maximum. A number of control techniques can be used to carry out this tracking activity. Disturb and observation was one of the first of these. This strategy is still often used in entry-level controllers on the market today because of its simplicity; however, more efficient alternatives have been developed, including higher and more diversified monitoring approaches, as well as machine learning. These more sophisticated and complicated methods are more likely to be used in medium to large-scale solar PV systems. P&O is employed in this project because of its simplicity and widespread use in the entry-level market. In the next part, we'll go through the perturb and observe the method in more detail.

2) P&O

As the name indicates, the controller uses a voltage to monitor the price, current, and current generated from PV installation, a power source, and photodiodes are installed on the PV activation output. The CPU gets all of the data and does the calculations. the power at each sampling moment. This instantaneous power value, Va, is recorded, and a new power value, Vb, is computed on the next sampling event. After that, the following computation is performed:
Ts (Vb – Va) denotes the primary filter. This algorithm is used to compute the steepness of the control or PV curve at a particular time. Collect information at the operating point of the system, that is where capacity was calculated in the earlier stages. The management then measures this same panel's voltage again, increasing or decreasing the gamepad's PWM again until the slope of the – voltage profile has been almost zero, at which point the microcontroller stores the number at which the MPP transpires. The schedule of the Rectifier is then adjusted to this voltage, and the frequency response is controlled appropriately. This is essentially how disturb and observer work.

3) The Battery Controller

The battery controller is made of basic materials. A bidirectional buck/boost converter is used, as well as total isolation control. Aside from that, the battery's SoC (state of charge), voltage, and temperature are all monitored.
The isolate technique is controlled by the computer piece, which offers precise control. The four isolated circuits can be turned on to allow the bank to pack and supply electricity. To reduce the added burden on major systems, such as the batteries and actuators, the charger can be disconnected from the equipment during vacation or servicing, but when the load can be sustained only by the photovoltaic panels and the charger is fully loaded.
Aside from control valves, which detect yet if the system operates as a buck or dc-dc converter based also on battery SoC, load status, and grid output current, the multimodal condition is achieved using a basic PID control approach. The power set-point is determined by the computer.

4) Load Controller

This section contains a Simulink pulse handyman block that generates two single gate pulses to simulate multiple opposite loads being handled at different points in time, such as when the battery is permitted and disabled, in determining software quality under normal and stressful conditions

V. RESULTS

After the simulation, the following results were obtained (figure 23).,

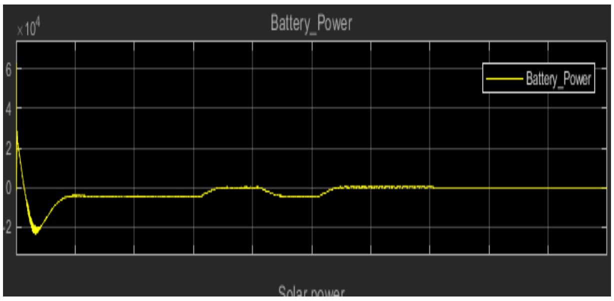

Figure 23: SPV

The battery is active for 0.5s and feeds power to the grid during the first startup phase to compensate for inrush and other related impacts. Because the PV arrays are more than capable of servicing the demand, the Battery begins charging as soon as the Buses stable. The battery does, however, contribute a modest amount of power from 0.5s to 0.7s. It should be noted that the vertical scale is 104(figure 24).

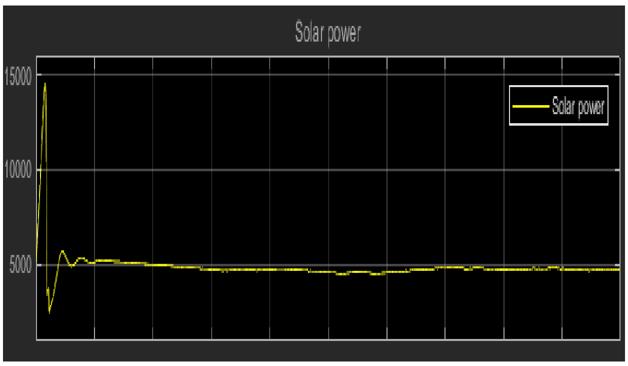

Figure 24: DC Bus Voltage

This is the power supplied by SOURCE-1 after MPPT (figure 25).

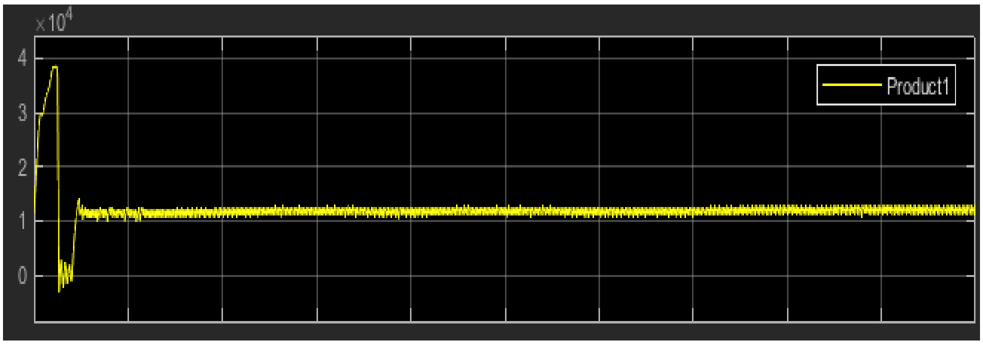

Figure 25: MPPT

This is the power supplied by SOURCE-2 (note that it is 10^4 or 10kW) (figure 26).

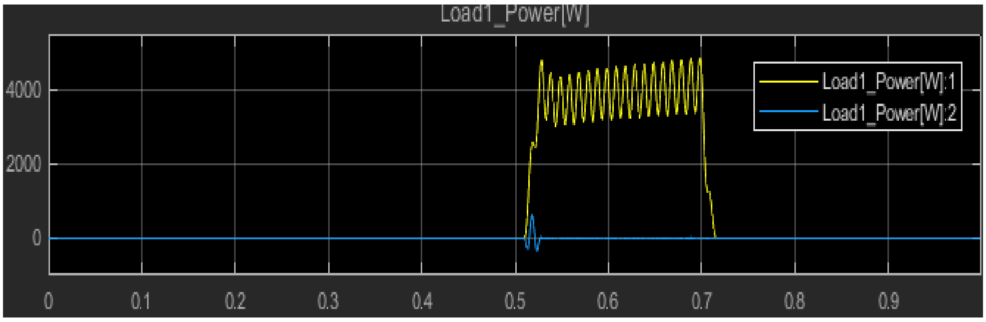

Figure 26: Power Source 2

This is the power consumed by LOAD-1 (Real – Yellow; Imaginary – Blue), around 4kW(figure 27).

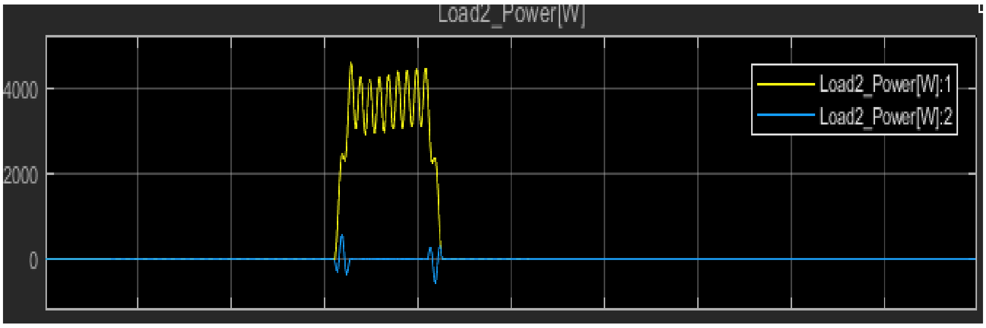

Figure 27: Consumption By Load-1

This is the power consumed by LOAD-2 (Real – Yellow; Imaginary – Blue), around 4kW(figure 28).

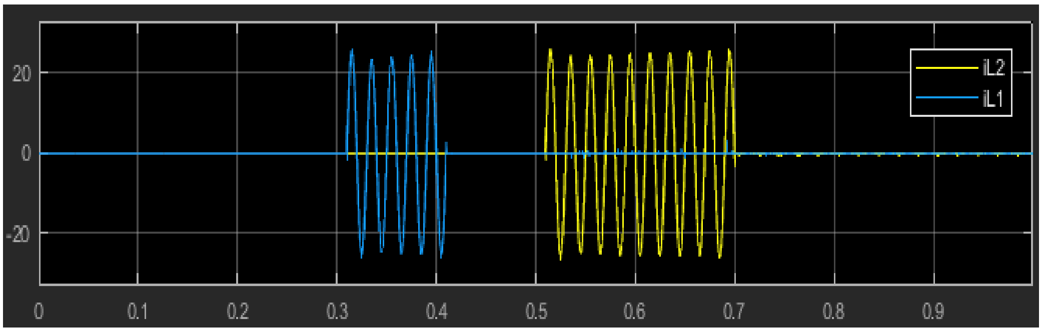

Figure 28: Consumption by Load-2

These are the load currents where; yellow is for LOAD-2 and blue for LOAD-1(figure 29).

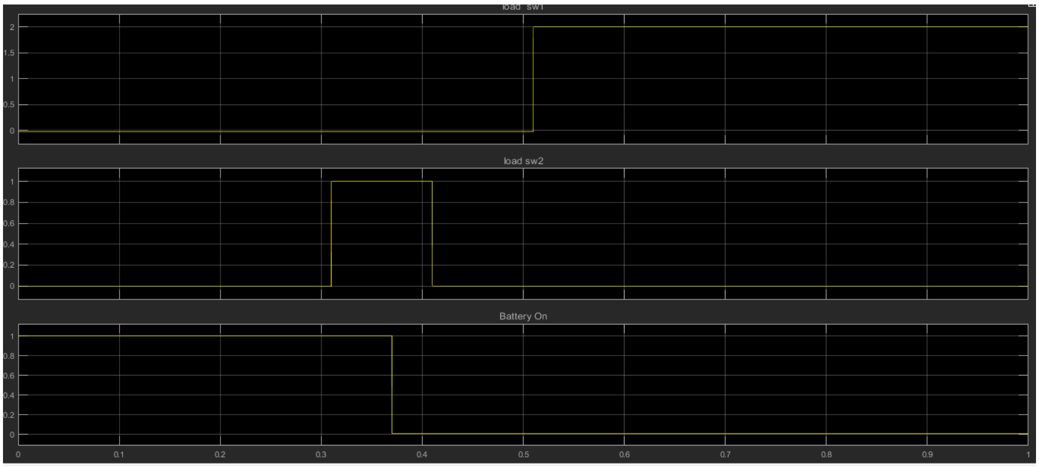

Figure 29: Load Currents

These are the control signals for the loads and battery to engage and disengage(figure 30).

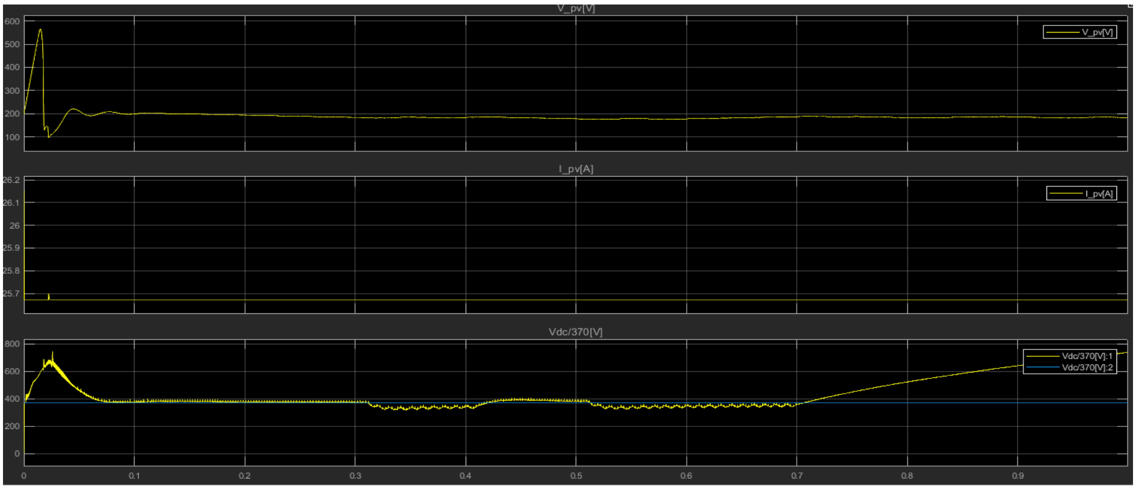

Figure 30: Control Signals

These are the voltage, current, and DC bus characteristics of SOURCE-1. As can be noted MPPT voltage hovers around 200V and the setup current around 24A. The yellow graph below is for DC-bus voltage and after 0.7 seconds is effectively open-circuit voltage. OR zero volts on the actual DC link(figure 31)..

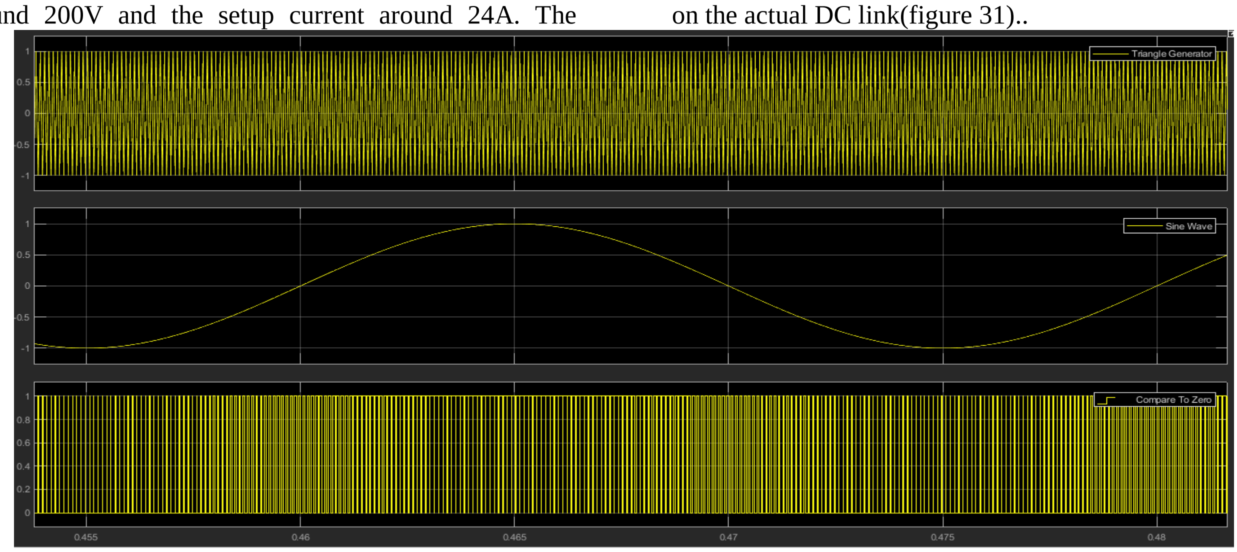

Figure 31: DC Bus Voltage

This is the SPW generation scheme. Top; carrier (triangle wave 10kHz), Center; reference sine wave (50Hz), Bottom; output SPWM(figure 32).

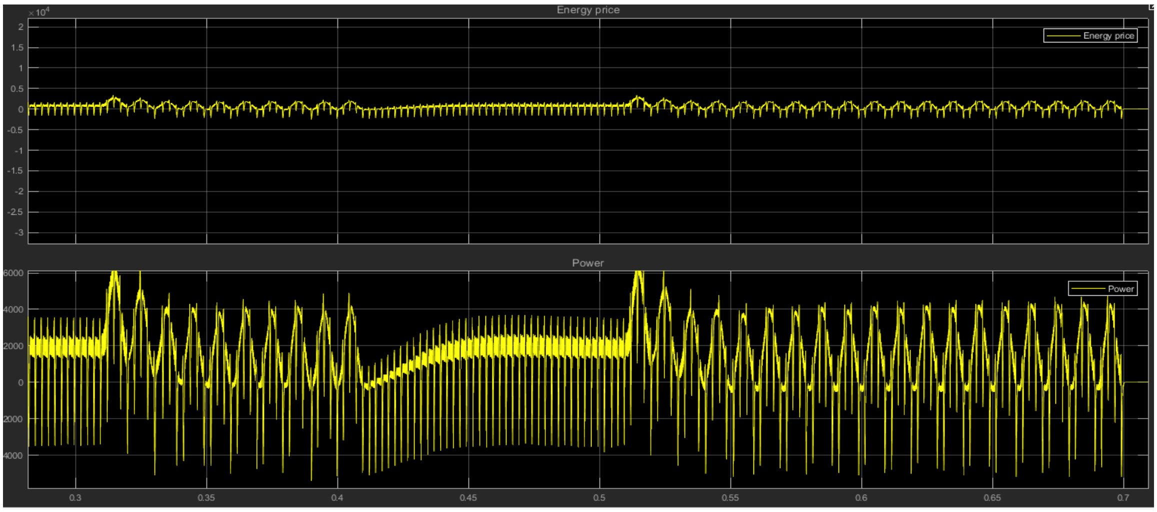

Figure 32: SPW

The output of the power meter. Ignore the spikes as they are caused by low decimation in the simulation. Follow the thick yellow line (figure 33).

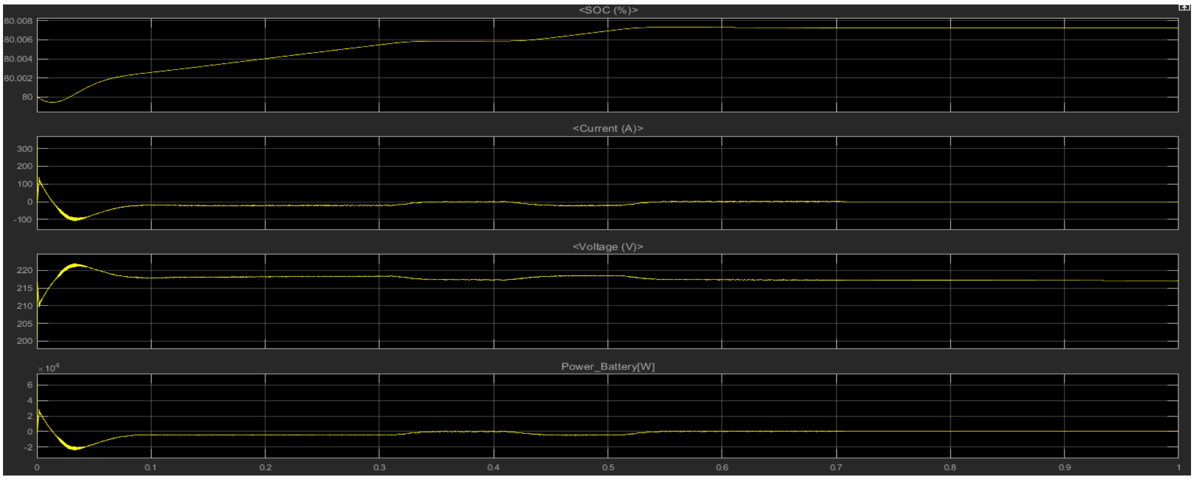

Figure 33: Power Meter

Characteristics of the Battery from its monitoring system(figure 34).

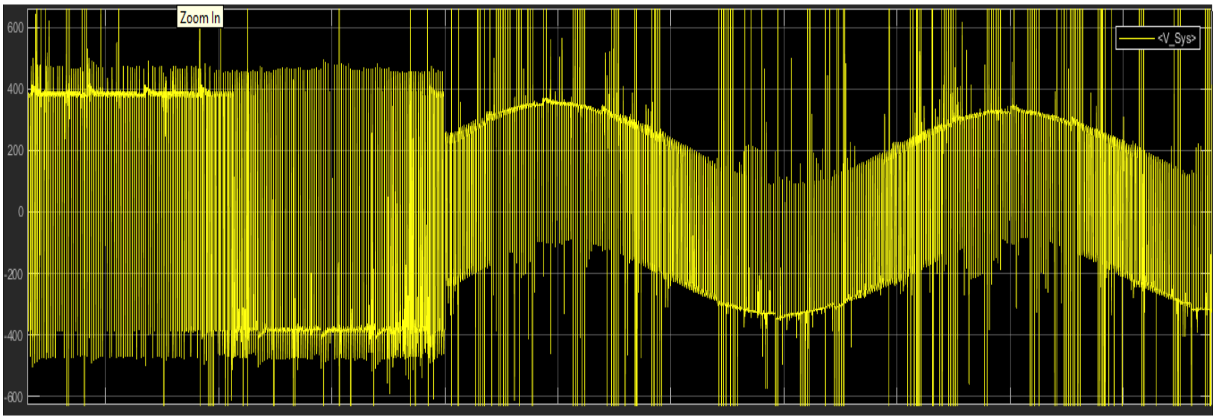

Figure 34: Battery

The inverter output voltage ignores the spikes as they are caused by low decimation. As the load is switched on the voltage begins to become apparently sinusoidal.

VI. CONCLUSION

The findings obtained after simulating and evaluating a micro-grid arrangement suggest that the theory and ideas employed were valid and that such a system has viability in practical implementation, as stated in the introduction. The DC bus connection likewise functions as predicted, and the system's stability is unaffected by the presence of two independent MPPT controllers attempting to manage Bus Voltage. The circuit breakers stop power supply and consumption, but the sources continue to create a voltage that is viewed as open-circuit voltage in the scopes, for example, the DC bus voltage increases after the breakers trip, indicating that the sources are not loaded.

Further work can be carried out by integrating the system with AC grid/infinite bus etc. It should be further noted that the protection system also works as expected and the same is reflected in the simulation.

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