A Study of Energy Scheme to Improve the Sustainability in Island Village

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About 70 percent of India's energy consumption comes from conventional sources. Only a few important areas are responsible for generating all of this power. After being transmitted to far-flung stations by India's massive grid, the energy is delivered to consumers via a new, distributed system in place. As a result of this, a large amount of energy is squandered. There are frequent power outages and low power quality in places with rough topography, putting location's reliability at danger.AC and DC generators, as well as loads that can run on both AC and DC electricity, are all part of a microgrid's infrastructure. Alternatively, it might be any of the above-mentioned microgrid configurations. It was a microgrid in this sense because initial electric power plant was a single powerhouse that only served a few hundred loads at best. If you're using current terminology, a microgrid is an electrical network with its own sources and loads, which is independent from the main electric system. In this case, the microgrid is a preferable option for decreasing transmission and loss across long distances. In the future years, grid stress will be exacerbated by electric vehicles and significant loads on the grid. These resources are dispersed across large areas and can be found in cities. Renewable energy sources include photovoltaics, wind turbines, and a buffer energy source like a battery.In some cases, a non-island microgrid, which requires a grid connection, is also used. It is covered in the simulation design chapter, along with components' functions. MATLAB software is used to study the micro gird. Providing adequate amounts of electric power to remote or difficult-to-reach areas in order to maintain reliability is tough. Geographically, they aren't suitable for grid power. This study uses the island village of Dharma dam, in Kerala, as a case study.

Keywords: Consumption, Generators, Infrastructure, Renewable, Solar, Grid Power, Island Village.

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1 Introduction

A micro-grid, as defined by the definition, is a small electrical network with its own local energy sources and sinks. Because the sources are local or close to the loads, this is a micro-grid. Solar thermal, solar photovoltaic, roof-mounted wind turbines, diesel generators, and micro hydropower are among the most common. Solar photovoltaic is the only alternative because it produces electricity, although solar thermal may not provide the same benefit.

In this micro-grid interconnection region, sources and loads are connected via a local transmission network, which can comprise AC/DC sources and/or loads. A large-scale wind or solar farm can be connected to the existing grid infrastructure that relies on remote generation. An "interconnected micro-grid" is a smaller network (micro-grid) that is connected to a larger infrastructure that already exists. That's because it can take energy from both local and large-scale sources, and it can even supply electricity to the main electric network, which is also known as the electric grid.

This paper simulates solar photovoltaic (SPV) power for a fixed light input of 600W per square meter. The final output voltage of a DC regulator operating as a power tracker is around 150V, depending on the load. Because they are commonly utilized in low- to medium-power devices, N-channel MOSFETS were utilized as switching devices. As with the maximum power point tracking arrangement, the perturb and observe (P and O) approach is also applied (MPPT). A PID controller, which stands for proportional, integral, and derivative constituent components, is used to compare the running estimate of maximum power to the current control voltage.

The wind turbines for typical microgram applications are induction type and typically are medium power range >100kW. But the system presented here is very small application <50kW system. For such an application the wind turbine being inductive type is impractical owing to the requirement of external capacitor banks. For that reason the use of PMSG was done, since it does not rely on external excitation. This however is a problem since we cannot connect varying amplitude and varying frequency source to our common low voltage DC bus or LVDC bus. For that reason the output of the turbine is rectified using a passive rectifier and then is regulated using 2 cascaded DC-DC converters to achieve the desired bus voltage.

The wind turbine in this case is also static and the nacelle cannot swivel as that would be too expensive for such a low power design, instead the AC-DC conversion allows for turbine to spin in reverse which is also simulated in the system presented. This is currently a topic of exploration in current research the behavior of the solar PV system should be as realistic as possible. A lookup table was built based on the current-voltage (IV) characteristics of a real-world system, and interpolation was used to fill in the gaps. This technique takes into account our temperature swings and irradiance changes as well.

2 Literature Review

Multiple smaller units or cells are combined into a larger panel unit, which is then connected in series-parallel fashion to attain the required voltage and power ratings. These devices work by using incident photons to create pairs of holes and electrons that are then forced through an externally linked load since they cannot recombine because of the barrier voltage. This is the photo current. An average silicon cell generates 0.7V, hence it must be paired with other silicon cells. They are made of doped silicon, which is either crystalline or amorphous - the former being more efficient in generating power. They can also be made of chemically deposited films, some of which are even being investigated as a building finish.

The silicon-based substrate makes the cells extremely sensitive and brittle, therefore mechanical damage is a worry. Water entry can disturb the crystal structure, hence humidity is a worry. The module that houses these cell assemblies is made of high-grade plastic or a similar material, allowing it to withstand the elements for a long time. The product of the panel's voltage and current rating determines the module's wattage. These voltages and current ratings are normally listed on the underside of the panel; however, they are computed for ideal lab settings and may not always correspond to real life weather situations [1].

Fuse panels, reverse protection diodes, and panel monitoring systems are all housed in a terminal box with MC4 high voltage connectors on the panel's underside. In addition, some small panels may include a USB power regulator, which can be used to power small electronics. The panels are connected in parallel to achieve the desired current rating, and in series to achieve the desired voltage. The parameters are set so that the overall interconnected result behaves like a huge PV panel when viewed from the top down. A vast array of wires is possible with the wires. Partially shady panels are sometimes equipped with bypass diodes, which can prevent the entire plant's capacity from collapsing if a panel or area is shaded. Mirrors, lenses, and cooling systems are used in some designs of SPV systems to increase the intensity of light or energy per unit area and generate more energy as a consequence. Observe that a commercial solar cell is sensitive to yellow-green (540nm) radiation and hence works regardless of other colors or radiation levels such as infrared [2].

3 Objectives

India currently has the world's largest grid system. This is essential for the survival of the majority of India. True, grid power isn't always reliable or cost-effective, but it isn't available everywhere. Geographically, they are unsuitable for grid supply because to their geographical characteristics. Dharma dam in Kerala, which is the topic of this study, is one such island village. As a result of its location below the cancer tropics, the selected site receives a lot of sunshine. Wind pressure at the site is light throughout the year because to its proximity to Kerala's eastern shore.

Solar PV, wind, batteries, and the grid are all explored in this study. Micro grid is then connected to main grid. The grid integration also performed using PLL control.

The objective of this paper is the viability of employing such a model for a small business operating on the site will be evaluated.

To make power supply more reliable and cost-effective, this paper aims to optimize the system. Original work is the integration of small wind turbine using PMSG, which is synchronized to a common LVDC bus by using rectifier and dc-dc converters. The active integration of battery and prevention of backflow into sources. The battery is actively used to supply energy deficit on DC bus instead of passively supplying power when the main sources are not generating energy, this is one of the original works presented since this type of battery support is only being explored in conventional grids at large scale and not in cases like island micro grid systems.

4 Design of Simulation

Aluminum frames are used to mount solar PV panels in order to keep the overall weight low. Some of the features of these aluminum supports include the ability to modify the angle, mounting brackets, and tacking motors. Sun-tracking devices are devices that direct payloads toward the Sun. Solar panels, parabolic troughs, Fresnel reflectors, lenses, and heliostat mirrors are common payloads.) As a trade-off, mechanical complexity and maintenance costs will rise [3-4].

4.1 Cost of Solar

Since 2012, the price of solar electrical power has dropped to the point where it is now cheaper than traditional fossil fuel electricity from the grid in many countries, a phenomenon known as grid parity (Grid parity (or socket parity) occurs when an alternative energy source can generate power at a levelized cost of electricity (LCOE) that is less than or equal to the price of power from the grid [5].

4.2 Electrical parameters of SPV

As noted in datasheets, while developing an SPV system or a micro-grid that uses one, the following electrical parameters must be considered**.**

- Maximum Power — the result of multiplying OCV and SCC.
- A panel's terminals are subjected to test conditions that result in an open circuit voltage (OCV).
- When a panel's terminals are short-circuited, a short circuit current (SCC) flow from the panel. Plot load-curves with this tool.
- MPPV stands for Maximum Power Point Voltage, and it refers to the maximum voltage that can be generated utilizing MPPT procedures by the panel under test settings and test illumination.
- When applying MPPT procedures, the maximum power point current (MPPC) can be generated.
- Amount of electricity that can be created from a given amount of light. This varies based on the type of silicon utilized, the production process, and the material used.

Standard test conditions are used to measure these parameters (STC): 1000 W/m2, 25 °C, and 1 atm Under STC, the maximum power is delivered, however in the actual world, the maximum power fluctuates dramatically as the light incident varies. These situations are extremely rare in the real world [6].

Radiation from the sun should be directed towards the panel or array at a 90-degree angle for best power output. The direction and inclination to achieve orthogonality vary depending on the region, such as mountains or plains, and the location, such as a city or village. The mounting settings can be calculated with commercial software tools such as PVsyst. Alternatively, sophisticated equations can be used to calculate this by hand [7].

4.3 Efficiency and Performance

The electrical output for incident direct radiation is measured by efficiency. Spectrum, materials, temperature, reflection and resistance all have an impact on the efficiency of SPV panels. As manufacturing techniques improve, solar cells are reaching their theoretical limit. Since they only respond to a single energy band, the real efficiency is still quite poor [8]**.**

Fig. 1. Efficiency curves of solar photovoltaic energy over the time

Figure 1 illustrates the key milestones in enhancing the efficiency of solar photovoltaic. The most efficient commercial cells, however, run at roughly 24 percent efficiency.

4.4 PV cells IV and Power curves

A PV cell's power characteristics show a flat tendency before dropping to zero at OCV. Current and voltage are combined to generate a hump with maximal power just around the voltage where the voltage on the IV curve begins to fall off. Knee voltage is the term used to describe this type of current.

4.5 Fill Factor

Assumes a maximum power of 100 watts, this is a measure of how close the harvestable power product is to the ideal power product in terms of performance. Getting closer is always better. The manufacturing technique and the materials utilized determine the price.

$$Fill\ Factor = \frac{P_{max}}{V_{oc} \times I_{sc}} = \frac{U_{mpp} \times I_{mpp}}{V_{oc} \times I_{sc}}$$

There is a high probability that commercial SPV cells will have an F-factor greater than 0.7. For major installations and projects, it is not suggested to employ cells with an FF below 0.7.

4.6 PV cell equivalent circuit

The mathematical model created from the nodal analysis of SPV equivalent circuit is a crucial component for SPV studies, simulators, and even for the design of large commercial installations to understand the performance of PV modules and their working.

The single diode model for the SPV cell is shown in Figure 2. The current source simulates the current created by light. The diode simulates the voltage across a single cell by using a single transistor. Internal resistance loss is represented by Rsh or shunt resistors, whereas internal contact resistances and terminal and wire resistances are represented by Rs or series resistors, respectively.

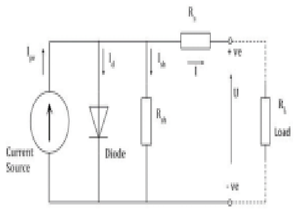

Fig. 2. SPV equivalent Circuit

Equation of a PV module: The following basic equations can be derived from the analogous circuit:

$$I = I_{pv} - I_d - I_{sh} \qquad U_{sh} = U + IR_s$$

current flowing through the shunt branches (U). Sum of terminal voltage and resistance drop across internal series resistor. That's the difference between Rsh and diode D. It's possible to calculate Rsh's current using the formula;

$$I_{sh} = \frac{U_{sh}}{R_{sh}} = \frac{U + IR_s}{R_{sh}}$$

In order to describe the voltage more correctly, Shockley's equation calculates the current through a diode:

$$I_d = I_0\left[e^{\frac{Ush}{nVT}} - 1\right]$$

and

$$V_T = \frac{kT}{q}$$

The PV cell (module) characteristic equation is obtained by combining the previous equations:

$$I = I_{pv} - I_0\left[e^{\frac{U+IRs}{nVT}} - 1\right] - \frac{U + IR_s}{R_{sh}}$$

4.7 Phenomenon of Irradiance

It is important to consider how and what type of radiation interacts with the cell while designing SPV systems.

Solar radiation: SPV systems are driven by solar power, hence it is required to briefly explain the interactions.

Direct Radiation: This is the radiation that reaches the cell directly from the sun, without any reflections or refractions. After a minor loss in the atmosphere, this type of irradiance retains the majority of its energy.

Diffuse Radiation: As the sun's rays travel through the atmosphere, they reflect off of surfaces and disperse. Upon reaching the cell, this radiation is dispersed and has lost much of its energy.

There are two ways to measure irradiation: in Watts per meter square and in square kilometers. Light dependent resistors (LDRs), calibrated solar cell sensors (bolometer), and many other sorts of sensors are used to measure this type of radiation. Despite the fact that they work on separate principles and have various qualities, they accomplish the same task.

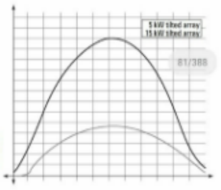

Fig. 3. Irradiance on a sunny day

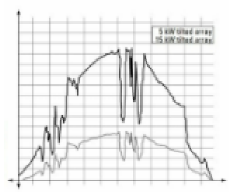

Fig. 4. Irradiance on a cloudy day

From dawn to dusk, a 24-hour period is recorded on the horizontal scale. A smooth light curve (vertical axis, W/m2) can be seen in Figure 3 because the day was sunny and clear.

Figure 4 shows intermittent clouds in the morning, followed by clear sky until midday, when a second heavy cloud cover appeared, followed by intermittent clouds. As a result, there is no doubt as to what has transpired in the first scenario, the panel performed better, whereas in the second situation, it did worse. Low irradiance during cloudy weather indicates poor energy photons, which translates to low current output and, therefore, low overall power production [9-11]

4.8 Maximum Power Point Tracking

As the amount of light varies during the day, so does the amount of energy that SPV cells get. In a similar way as incident radiation, current output changes. The power curve is distorted due to this variation. Using a DC-DC regulator system, we can, nevertheless, follow the maximum power point MPP to extract maximum power at any given time. MPPT or MPP tracking is the term for this.

A micro-grid configuration that uses DC or an inverter with no input regulation can still get maximum power using this strategy, but now the output voltage changes, making it less practical. The net output voltage must be stabilized by using a second cascaded DC-DC converter. Figure 5 illustrates the basic IV and Power curve, whereas Figure 6 shows the varied IV curve for different irradiances. Black line displays MPP points and direct region under reveals voltage path for tracking MPP [12-13].

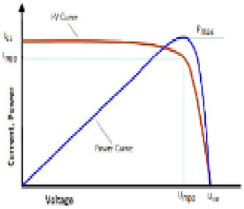

Fig. 5. IV and power curve (general)

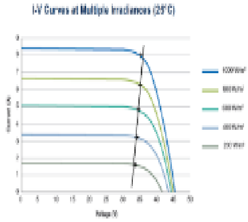

Fig. 6. IV and power curve (different irradiance)

4.9 P&O method

For MPPT, perturb and observe is a typical control strategy. To detect which side of the power curve the voltage is ON, this programme tracks the power coming from the panel output and computes the derivative of the power. Whenever the derivative is positive, the controller instructs the DC-DC converter to increase the duty cycle and output voltage in incremental increments, increasing the processing power at each step. This implies that the controller has passed the hump when the slope turns to zero or a negative number. When the hump is reached, the controller begins to oscillate around the hump. To filter them, use buffer capacitors [14].

5 System Analysis

In the micro-grid simulation, the SPV component includes an MPPT controller, a DC-DC converter, and a voltage regulator as well as output scopes. For the SPV system, the maximum power rating is 7.33kW and the MPP is roughly 5.3kW (using P&O). Fill factor is 5.3/7.33 = 0.72 in this situation. Use of modern MPPT techniques can improve this system, which is a decent system.

Real-world data is used to create a lookup table, and interpolation is used to fill in the gaps. Figure 7 displays a closed feedback current source with an algebraic delay to prevent a race condition in the simulation, whereas Figure 8 demonstrates the working inside a PV array (photovoltaic array)[15].

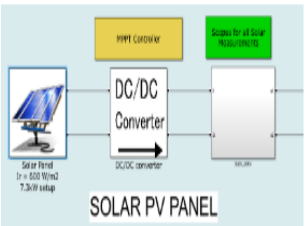

Fig. 7. Current source in a closed feedback

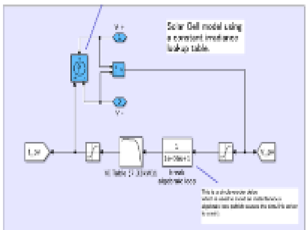

Fig. 8. Inside PV array

5.1 MPPT controller and PV controller

Both Vpv and Ipv are fed into the mppt state flow block via two first-order filters whose transfer function is determined by numerator and denominator coefficients. Figure 9 shows an MPPT controller. As a result, vref, which stands for or reference voltage value, is output. Input of PV controller, which is a simple Feedback controller.

In PV controller, reference voltage created by mppt output flows via saturation blocks, which makes the system BIBO stable.... the difference between vpv (voltage output of the PV plant) and v-ref (voltage reference) is then sent as a negative input to a Sumer block (reference voltage generated by mppt). PID controller may be shown in Figure 10, where the output represented by error is routed via an error filter before being given as input. An IGBT switch in a boost converter receives a pulse from the PV controller as input. The boost converter outputs 200 volts, which must be stepped down to 150 volts by way of a buck converter to complete the circuit.

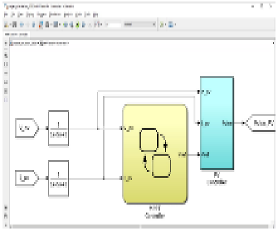

Fig. 9. MPPT Controller

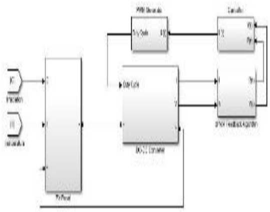

Fig. 10. PV Controller

5.2 Boost Converter

Two diodes, in addition to the regular components of the boost converters, prevent the backflow of power in our system. Filters input for jerks and noises using a capacitor as indicated in figure 11, a booster controller is used. In order to achieve 100 percent smooth output, the switch employed is an IGBT, whose inputs are provided by both the mppt and the PV Controller. Modeling an inductor with a tiny resistance is done so that MATLAB doesn't crash. As a result, these inductors have an ESR model (Equivalent series resistance) Scope "DC-DC conv solar" receives the output and input voltages of the boost converters.

5.3 Buck Converter

To power the buck converter, you'll need 200 volts of power. These include a MOSFET switch (whose duty ratio is provided by a PWM generator that has input as a step function), a switch diode, and an inductor with a low resistance model (equivalent series resistor ESR). The duty cycle is set to make the output approximately 150v. There's an example of one in Figure 12. On the scope, we utilized a basic resistive load (R) to measure the output.

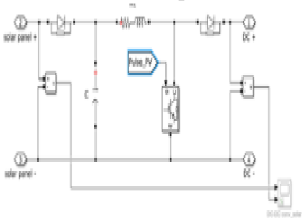

Fig. 11. BOOST converter

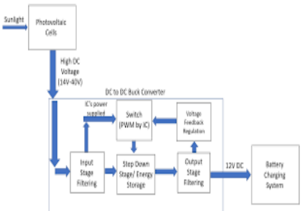

Fig. 12. BUCK converter

5.4 Wind Generation and Battery Storage

When simulating wind turbines, they are based on a permanent magnet synchronous generator PMSG, which is rectified and regulated using DC-DC converters in order to maintain the voltage at a DC_ synchronization bus level for the multiple sources in the micro-grid arrangement. It can be seen in figure 13, a wind profile generator. Here, it's 150V. One kilowatt of power can be generated by the machine's configuration. In order to create a realistic wind speed pattern, many modulated sine waves are added together [16-17].

An additional buffer storage battery has been included in the simulation, which has been chosen to be Lithium ion due to its better energy density, however lead acid batteries can also be employed. The battery has a nominal voltage of 200 volts (V). "Battery Controller" controls the charging and discharge of the battery to the common DC synchronization bus using a bidirectional DC-DC converter. Figure 14 illustrates the battery storage.

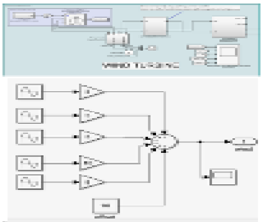

Fig. 13. Wind profile Generator

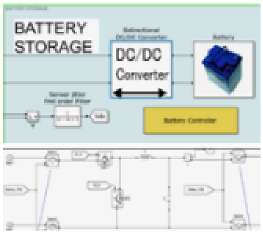

Fig. 14. Battery storage system

5.5 Grid Connection Simulation

Microgrids are often self-sufficient, which is one of their biggest advantages. Microgrid stress can be mitigated in a metropolitan setting using grid power. Microgrids can be connected to the grid to power equipment on days when the wind and solar PV systems aren't producing enough power as seen in Figure 15. Another element of the simulation involves simulating a grid-connected microgrid for this purpose as well. As part of this, regulated voltage sources are combined to mimic an emulated DC synchronisation bus with load-caused power supply voltage regulation. House has loads and is connected to the grid in such a way that the output of the inverter is synchronised to the grid AC utilising Phase locked loop and then through a transformer to the utility distribution voltage of 11kVll or 6.6kVp.

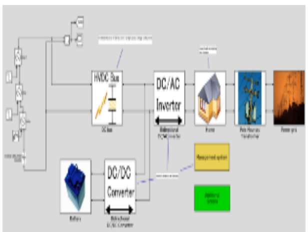

Fig. 15. Grid Integration

6 Results and Observations

In the DC-synchronization bus, the unloaded voltage output of the DC-DC regulators is 200V. The output of the SPV system is shown below in red. After the tracker has stabilized the voltage, the current pulled from the SPV regulator continues at 25.7A. As with MPPT, controllers aim to maintain constant values to cause any jitter or variations in parameters. When the jitter is high, the controller maintains the general output at roughly 5 kW. When using the P&O algorithm, the voltage step can be minimized, albeit at the cost of reaction speed. As a result, the simulation duration is longer when the voltage step is lower. Figure 16 displays the voltage and current at the output of the system. Loaded DC bus voltage is maintained at 150 volts. Under no-load conditions, the voltage can reach 200V. As a result, the controllers have a defined dynamic operating range. Without the controllers, 200V may be reached (unlikely case). In addition, the battery is able to compensate for short-term outages and small overloads. The battery system is meant to maintain a continuous flow of electricity in the event of interruptions, not a complete power failure. Figure 17 shows the electricity generated by battery and solar PV systems. In order to keep the simulation time within practical and reproducible constraints, this simulation is maintained separate.

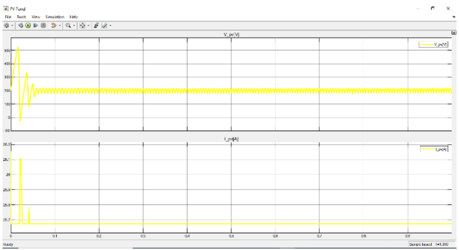

Fig. 16. SPV output voltage and current

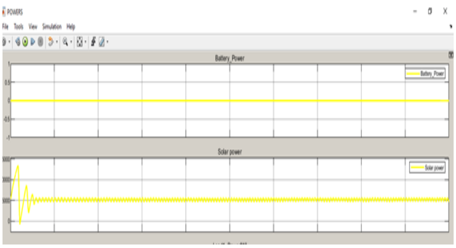

Fig. 17. Power from Battery and Solar PV system

Due to controller overshooting and hunting for the MPPT, the initial big transients with wide spacing occur. After stabilizing at 5kW, it returns to its original value.

Changing wind speed affects the AC output of wind turbines. Currents are represented by the RYB (red yellow blue) waveform in figure 18, whereas turbine speed, torque, etc. are represented by the other waveforms in the image.

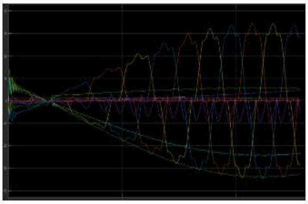

Fig. 18. Wind turbine AC output

There's a phase change just at the beginning, where the whole system crosses over. This is due to the turbine's nacelle not having a swivel here. Rotor rotates in opposite direction because of wind speed, causing phase shift.

Figure 19 shows the simulation's power consumption from the battery, SPV, and loads. There is a time limit of 1.5 seconds for simulation. Fig. 20 illustrates the on and off state of the loads and the battery level. A simulation of grid integration is shown in Figure 21, and Grid connection voltage and current are shown in Figure 22**.**

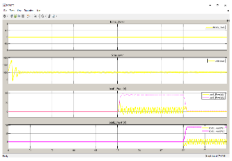

Fig. 19. Power in the simulation of the battery SPV and loads

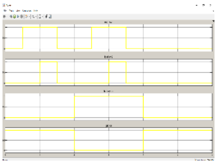

Fig. 20. Control signal for turning on and off loads and battery

Fig. 18. Powers in the simulation of Grid integration

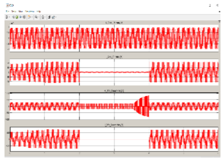

Fig. 19. Grid connection voltages and currents

7 Conclusion and Future Scope

For an industrial load, a hybrid PV-Wind Grid system is explored in this paper. Inspiring outcomes have been obtained thus far. According to the study's findings, the system's output and reliability both raise with the addition of a battery, as do the power resources included in the study's analysis. By testing protection strategies, fault analysis, etc., the micro-grid can be further analysed. Thirdly, we can use batteries. On the dc bus, we can link it to a bidirectional DC–AC single phase inverter, and then connect it to the home load, which includes both linear and nonlinear loads.

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