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Enchancing the Energy Management System of Hybrid sources based Microgrid

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ABSTRACT: An efficient energy management system for a small-scale hybrid wind-solar-battery based microgrid is proposed in this paper. The wind and solar energy conversion systems and battery storage system have been developed along with power electronic converters, control algorithms and controllers to test the operation of hybrid microgrid. The power balance is maintained by an energy management system for the variations of renewable energy power generation and also for the load demand variations. This microgrid operates in standalone mode and provides a testing platform for different control algorithms, energy management systems and test conditions. A real-time control is performed by rapid control prototyping to test and validate the control algorithms of microgrid system experimentally. The proposed small-scale renewable energy based microgrid can be used as a test bench for research and testing of algorithms in smart grid applications.

I. INTRODUCTION

The uses of energy have evolved as humans have changed patterns of energyconsumption. Although renewable sources such as wind, water and biomass were the first sources of energy tappedtoprovideheat,lightandusablepower,itwasthe energystoredinfossilfuelsandmore recently, nuclear power that fueled tremendous expansion of the industrial, residentialandtransportsectors.Butthefossilfuelcons umptionhasincreased,andmostofthe industries are started moving towards renewable energy systems. The conventional energy sources such as coal, diesel oil, petroleum gases, hydropower and nuclear power are getting limiting in our nature day by day. It is necessary to have an immediate action to find the possible ways of alternative energy sources to balance the demand and supply. Therefore, a certain path is required to stabilize the demand and supply. Here, in this project, power is generated by solar, wind and also by a backup battery supply. But by using Solar and Wind, we cannot acquire the power all the time. There will be some shading conditions in solar panels and no wind can be obtained all the time. During these times, the power cannot be acquired. Here we use the backup power form the battery. Here we use PID controller to produce high power continuously. The work in this project is mainly focuses on integration and control technique. The main objective of this project is to extract maximum power and to maintain power quality to a satisfactory level from the varying condition from the hybrid system with different irradiation and shading conditions. To capture the maximum power from the hybrid system, a PID based MPPT controller is applied for the system and this proposed model offers increased stability and efficiency of the system. The effectivenessofproposedmodelwithcontroltechnique sareverifiedinMATLAB/SIMULINK environment.

The proposed work is Enhancing the energy management system of Hybrid sources based microgrid. The Hybrid system is the combination of the Solar, Wind and the Battery. This technique is used to obtain the maximum power and also continuouspower.Theoutputcharacteristicsofphotov oltaic(PV)model and wind systemarenon-lineardueto shading conditions and irradiance. Therefore, PID based MPPT controller is needed to maximize power extraction from PV model under allconditions. And also, PID controller is needed to obtain the maximum power from the wind turbine. A bi-directional battery backup is also added in this proposed model to ensure continuous power supply. Thework in this project is mainly focuses on integration and control technique. The main objective of this project is to extract maximum power and to maintain power quality to a satisfactory level from the varying condition from the hybrid system with different irradiation and

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shading conditions. To capture the maximum power from the hybrid system, a PID controller is applied for both solar and wind system and this proposed model offers increased stability and efficiency of the system when compared to other control techniques.

II. OBJECTIVES

- To design the Solar PVmodel, Wind and Battery storage system.
- To develop a PID based MPPT controller for solar system.
- To develop the control algorithm based on PID controller for windmodel.
- To analyze the performance of the proposed model with controltechnique.

III. PROPOSED MODEL

The pictorial representation of the proposed system is shown as schematic in Figure 3.1. This hybridmodelconsists ofPVpanels, wind turbine and battery are connected in parallel.Thisblockdiagram is simplified to explain the process clearly. The PV panels, wind turbine and the battery are connected in parallel to obtain the maximum power from the combined hybrid system. Solar module consists of a Solar panel (PV), MOSFET, Resistor, Conductor areconnected in Boost converter. The proposed model consists of photovoltaic array and boost converter. PID basedMPPTcontrollerisusedtogetmaximumpowerfr om thesolarmodule.Solargeneration system is one of the trending types of research fields now adays. Solar system can reduce emission rate by maximizing the use of renewable energysources. Itisoneofthemostavailabilitiesoffreeresources.Them aintenancecostofSolarsystemislow whencomparedtoconventionalgenerators.Fuelisnotu sedanditdoesn'trequireanyfrequent services. Solar system is very highly efficient due to no usage of fuel. Ultimately, lower power costs for consumers can beprovided. Wind module consists of Wind turbine connected with the rotating shaft to the Permanent Magnet Synchronous Generator (PMSG). Further, the Wind turbine consists of MOSFET, Resistor, and Conductor areconnected in Boost converter. Wind power is a popular, sustainable, renewable energy sources that has a much smaller impact on the environment than burning fossil fuels. The Battery Storage System consist of a lead acid battery and a bidirectional DC-DC buck-boost converter. This converter is responsible in maintaining the DC bus voltage through a PI controller. The battery operates in two modes. They are charging and discharging modes, this depends on the power generated by both solar and wind. The battery also operates in these two modes based on the energy constraints which are determined by the SOC limits,

$SOCmin \leq SOC \leq SOCmax$

3.1 SOLAR MODULE

The solar module consists of photovoltaic (PV) panels, by-pass diodes and boost converter. This solar energy conservation system generates power from the solar energy with the help of PV panels and boost them using DC-DC boost converter. This solar module is one part of the hybrid system.

Let the solar module working and block used in the solar module will explained in detail.

3.1.1 SOLARPANEL

The PV module is the interface which converts light into electricity. Modeling this device, necessarily requires taking weather data (irradiance and temperature) as input variables. Photovoltaic (PV) panels are used to produce electricity directly from sunlight. PV panels consist of a number of individual cells connected together to produce electricity of a desired voltage. Photovoltaic panels are inherently DC devices. To produce AC, they must be used together with an inverter.

Figure 3.1 Photovoltaic panel

Single PV cell unit is not enough to extract sufficient power for satisfying for fulfilling the different demands. Many PV cells are stacked in parallel and series combination to obtain the maximum energy for utilization. This architecture of cells is called PV module, they have the capability to produce power as per the demand.

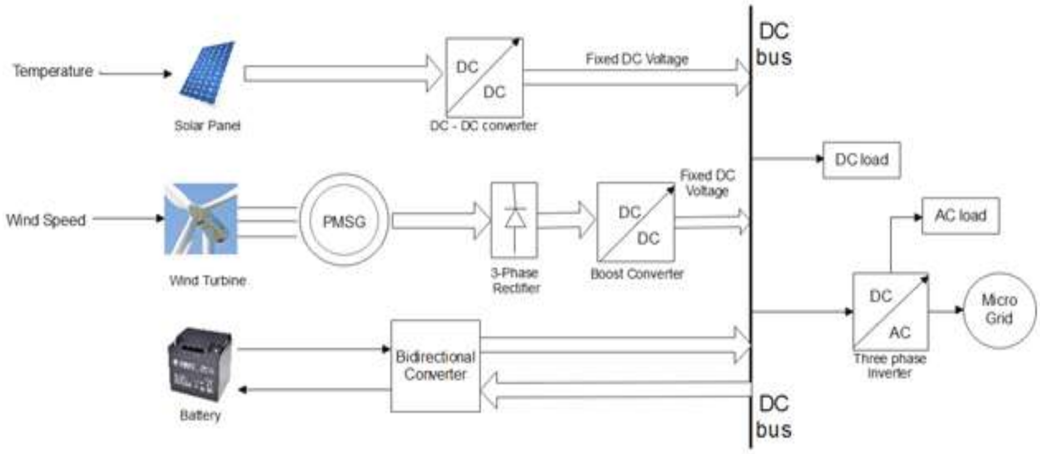

Figure 3.2 Block diagram of proposed model

3.1.2 BY-PASS DIODE FOR PV SYSTEM

When the models are installed some of the portion of the modules might get covered by clouds tall buildings Shadow of other PV Panels one over another, shadows from trees, etc. This might cause less current supplied by the PV cell which are covered than those which are non-covered.ContrarytothissolarcellmusthavesamecurrentforallbranchesofPVmodels. Iftheoutputofthecellisclosetozeroorzerothiswillcausethecelltoworkinnegativeregion of voltage. Consequently, the voltage of the entire outlet will reduce. This will cause a hotspot as the cells now start absorbing power and will heat up. Result of this is lot of power will be consumed and most of the power of shaded PV array will be condensed with significant amount.

To reduce these self-heating effects of the modulus bypass diodes are connected crosswisewiththearray.ThePVtrajectoryestablishes manymaximaorpeakanddisplaysthe difference of maximum power point in themodels.

3.1.3 BOOST CONVERTER

AboostconverterisaDC-DCstep-uppowerconverterthatstepsupvoltagefromitsinput to its output. It consists at least two semiconductors (a diode and a transistor) and at least one energy storage element. The storage elements are capacitor, inductor or two in combination. To reduce voltage ripple, filters made of capacitors are normally added to such a converters output andinput.

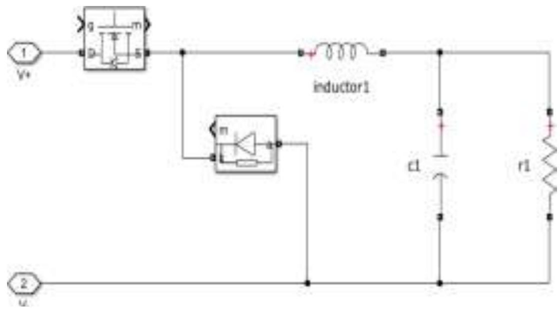

Figure 3.3 Boost converter

3.1.4 PID BASED MPPT CONTROLLER

An MPPT (Maximum Power Point Tracker) is an electronic DC to DC converter that optimizes the match between the solar array (PV panels) and the battery bank or utility grid. To put it simple, they convert high voltage DC output (load) for the solar panel down tolower voltage needed to chargebatteries.

3.2 WIND MODULE

3.2.1 WIND TURBINE

A wind turbine is a device that converts the wind's kinetic energy into electrical energy. Wind energy is economic option in comparison with other types of renewable energy resources.

Although wind turbine's initial cost is higher than other types of renewable energy resources, its long life and higher efficiency of power production can compensate its initial cost and leads to higher economic benefit. Modern wind turbine consists of several main components.

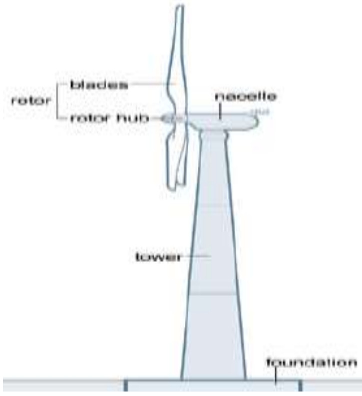

Figure 3.4 Wind turbine

Rotor Blades - The rotor blades of a wind turbine operate under the same principle as aircraft wings. One side of the blade is curved while the other is flat. The wind flows more quickly along the curved edge, creating a difference in pressure on either side of the blade. The blades are "pushed" by the air in order to equalize the pressure difference, causing the blades to turn.

Nacelle – The nacelle contains a set of gears and a generator. The turning blades are linked to the generator by the gears. The gears convert the relatively slow blade rotation to the generator rotation speed of approximately 1500 rpm. The generator then converts the rotational energy from the blades into electrical energy.

Tower – The blades and nacelle are mounted on top of a tower. The tower is constructed to hold the rotor blades off the ground and at an ideal wind speed. Towers are usually between 50-100 m above the surface of the ground or water. Offshore towers are generally fixed to the bottom of the water body, although research is ongoing to develop a tower that floats on the surface.

3.2.2 PERMANENT MAGENT SYNCHRONOUS GENERATOR

A permanent magnet synchronous generator is a generator where the excitation field is provided by a permanent magnet instead of a coil. The term synchronous refers here to the fact that the rotor and magnetic field rotate with the same speed, because the magnetic field is generated through a shaft mounted permanent magnet mechanism and current is induced into the stationary armature. Synchronous generators are the majority source of commercial electrical energy. They are commonly used to convert the mechanical power output of steamturbines, gas turbines, reciprocating engines and hydro turbines into electrical power for the grid. Some designs of Wind turbines also use this generator type.

3.2.3 RECTIFIER

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The reverse operation is performed by the inverter. The process is known as rectification, since it straightens the direction of current. Rectifiers have many uses, but often found serving as components of DC power supplies and high-voltage direct current power transmission systems. Rectifications may serve in roles other than to generate direct current for use as a source of power.

3.3 BATTERY ENERGY STORAGE SYSTEM

This Battery model is used to maximize the accuracy of the model. It includes the effect of the coulomb's coefficient and the double layer diffusion. The battery equivalent circuit is considered as a DC voltage source connected in series with the internal resistance, which represents the ohm resistance and two parallel branches connected in series to represent electromagnetic effects.

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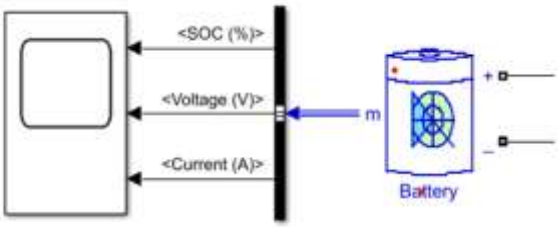

Figure 3.5Battery System

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In lithium battery, SOC%, remaining useful life, and degradation are the main important parameters when discussing the battery as well as some other parameters like Battery parameters detection, Charge control, and Battery safety control and alarm.

IV. SIMULATION WORKS

The Simulation of Enhancing the Energy management system of Hybrid sources based Microgrid is done using MATLAB/SIMULINK and its simulation is carried out.

The output of this hybrid system is connected to the DC bus and then to the transmission system or to the microgrid which will be developed further in the upcoming phase of the project.

4.1 SOLAR MODULE

The solar module consists of a solar PV panel, a DC-DC boost converter and an MPPT controller as shown. Depending on state of charge of the battery storage system, the MPPT is operated under MPPT mode or under off-MPPT mode of operation. The gate pulse is given to the MOSFET with the help of PID controller. The gate pulse is given in correspondencewiththeMPPT.

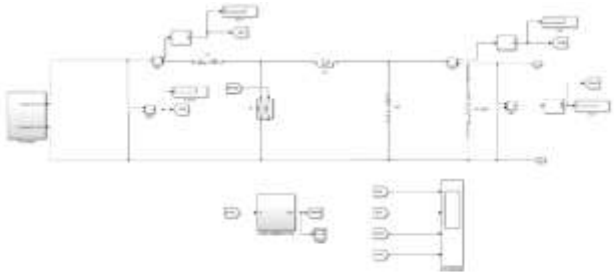
Figure 4.1 Solar simulation module

The output from the solar panels is connected to the DC-DC boost converter to boost up the output power from the PV panels. And then, the output from the boost converter is connected in parallel connection with the hybrid system modules.

4.1.1 PV ARRAY SIMULATION

In this system, four solar panels are connected in series with the solar radiations and the module temperature. Each solar panel will receive different solar radiations and module temperature to ensure the shading conditions of the solar panel.

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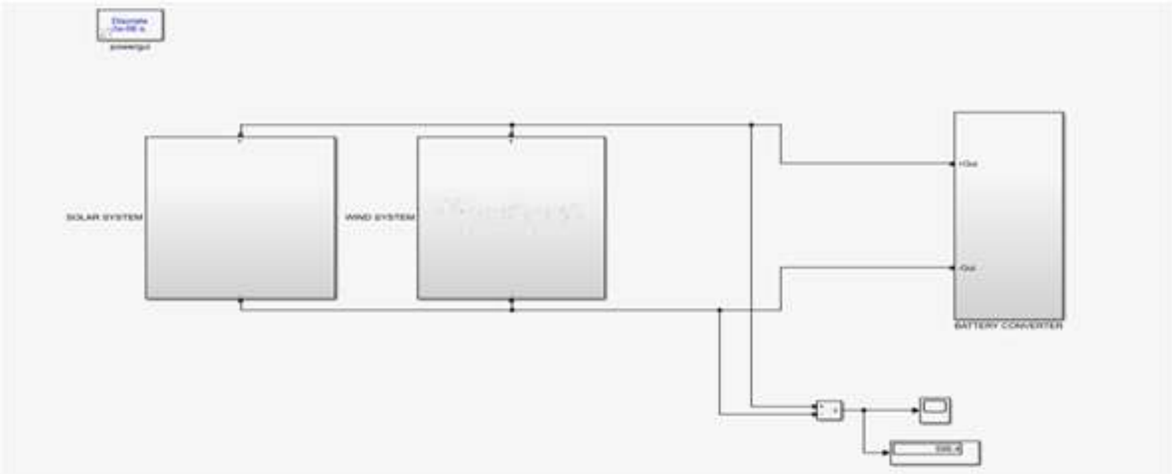

Figure 4.2 Overall Simulation

Here the bypass diodesareconnectedinparallelwiththePVmoduletoneglectthepowerreturnanditwillalso prevent the panels from being damaged. All the bypass diodes are connected in series and cumulatively they are connected in parallel to the PV modules.

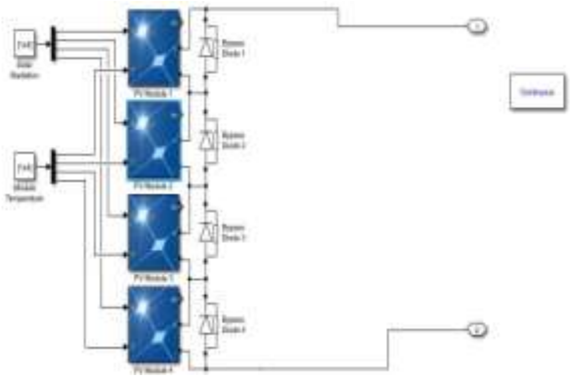

Figure 4.3 PV array (subsystem) simulation

The function of by-pass diode istoeliminatethehot-spotphenomenawhichcandamagethePVcells.ThePV canevencause fireifthelighthittingthesurfaceofthePVcellsinamoduleisnotuniform.Theby-passdiodes are usually placed on sub-strings of the PVmodule. The solar radiations and module temperature are typically inputs for the PV module. The solar radiations may be varied due to shading conditions. During shading conditions, all solar panels cannot get the input. So, in the solar radiation block the assumption inputs are varies randomly. Assumed solar radiation values are 500, 800, 900 and 1000W/m2. Subsequently, the module temperature will also be assigned as 28°C, 26°C, 25°C and 26°C.

4.1.2 VI CHARACTERISTICS OF PV PANEL

The voltage-current characteristics of the PV panel are plotted with two conditions. At one condition, the temperature will be constant at 25°C. And at another condition, the irradiations will be constant at 1000W. The characteristics waveform is plotted for voltage-current and voltage-power of the solar characteristics.

The VI and VP characteristics of the PV panel at constant temperature of 25°C. When temperature is constant, the output from different irradiation levels will have a constant current at variable voltage. At different irradiation level, the

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voltage will be changed by having the current values as constant.

From the voltage-power characteristics, it is shown that when voltage increases, the power also increases at constant temperature. From figure 4.4, it is clearly explaining that voltage is directly proportional to the power. The power from different irradiation levels is plotted clearly.

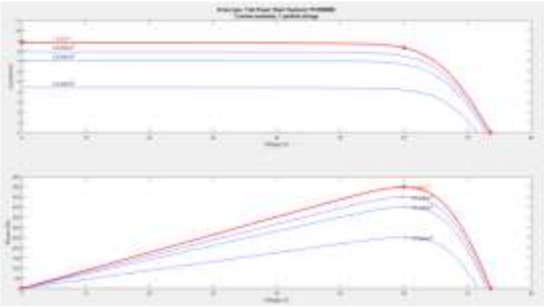

Figure 4.4 Characteristics of Solar panel
(temperature constant at 25◦C)

From the voltage-power characteristics, it is shown that when voltage increases, the power also increases at constant irradiation level. It is clearly explaining that voltage is directly proportional to the power.

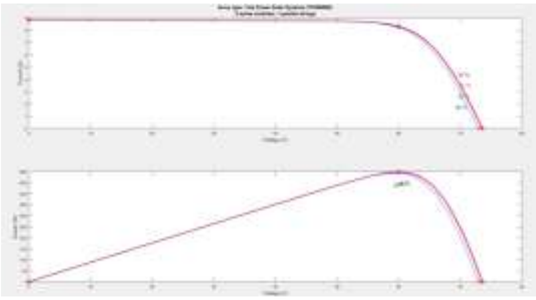

Figure 4.5 Characteristics of solar panel
(irradiations constant at 1000W)

4.1.3 INPUT WAVEFORM

Input voltage and current to the boost converter (output from the PV array) is measured by using the scope.

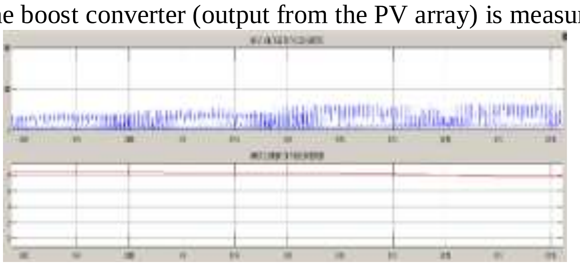

Figure 4.6 Input waveform of solar module

The input waveform of the voltage and current. As per the formula, thepoweriscalculatedinthesimulation.Powerismultipleofthevoltageandcurrentbyusing product block insimulation. The input waveform is nothing but the PV array output waveform. The PV array output is given to the DC-DC boost converter and boosted up. The input voltage waveform is acquired with some ripples. This ripple can be neglected by doing the energy management or by using efficient converter. Though boost converter is one of the basic converters, any other converter rather than boost converter can be used to reduce the ripples.

4.1.4 GATE PULSE WAVEFORM

The gate pulse waveform given to the MOSFET. The gate pulse will remain constant even in shading conditions because of the MPPT values are coded in the PID controller. The PID

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controller is the main block to provide the gate pulse to the MOSFET of the solar module. Here, in this PID controller, the output voltage is compared to the reference voltage of 700V and then to the relation operator block. Thus, it is given to the MOSFET as the gate pulse for the solar module.

Figure 4.7 Gate pulse waveform for Solar

4.2 WIND MODULE

The wind module consists of a wind turbine, a PMSG, a DC-DC boost converter and controller. The power extracted from the wind. The wind is necessary to drive the wind turbine. The wind turbine will give the necessary power to drive the Permanent Magnet Synchronous Generator (PMSG).

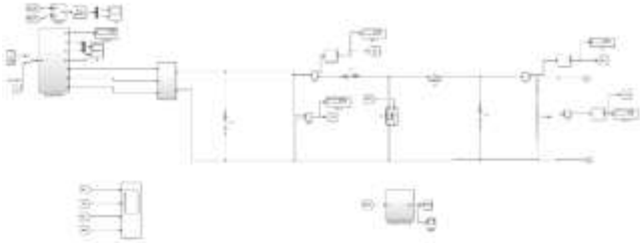

Figure 4.8 Wind simulation module

The output the PMSG will be the AC current. Then it is connected to the rectifier. This rectifier concerts the AC current from the wind turbine as the DC current and then to the boost converter to boost up the power.

4.2.1 WIND TURBINE SIMULATION

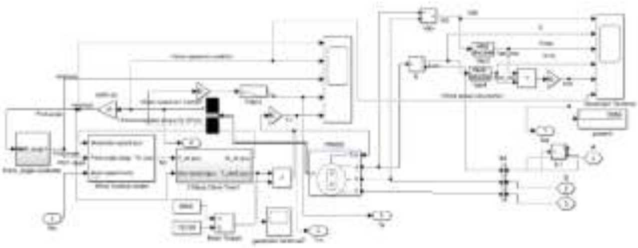

Figure 4.9 Wind turbine simulation

A permanent magnet synchronous generator is selected for its low maintenance and low operational cost. The generator output is dependent on the wind speed.

4.2.2 CHARACTERISTICS OF WIND TURBINE

A variable speed wind turbine is used in this system. The characteristics of the wind turbine for various wind speeds at different pitch angles. A permanent magnet synchronous generator is selected for its low maintenance and low operational cost. The generator output is dependent on the wind speed. The three-phase output of the generator is rectified using a diode rectifier and then the voltage level is increased with the help of a DC-DC boost converter.

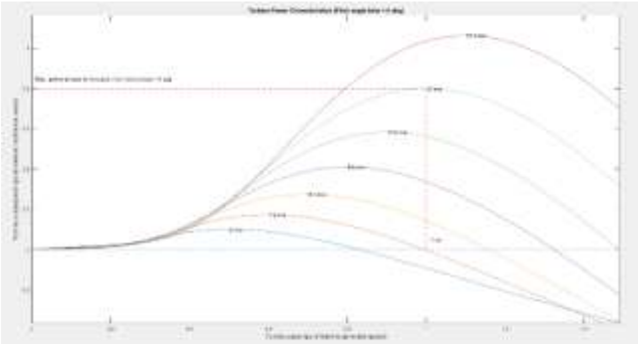

Figure 4.10 Wind turbine characteristics

The performance characteristics of the Wind turbine shows the waveform for wind speed, rotor speed, pitch angle and torque.

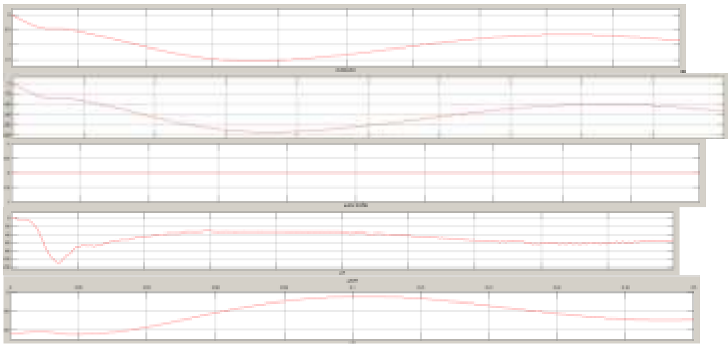

Figure 4.11 Wind turbine performance waveform

The performance characteristics of wind turbine. In port 1, the wind speed is measured. It shows that there is a change in wind speed. In port 2, the rotor speed is measured. The rotor speed is directly proportional to the wind speed. It also changes when the wind speed change. In port 3, the pitch angle is measured. The pitch angle is kept at 0. In port 4 and 5, the electrical torque and mechanical torque are measured.

4.2.3 INPUT WAVEFORM

The input waveform is the waveform from the wind turbine subsystem which is given as the input to the boost converter. Depending on state of charge of the battery storage system, the PID controller is operated in with reference to the voltage.

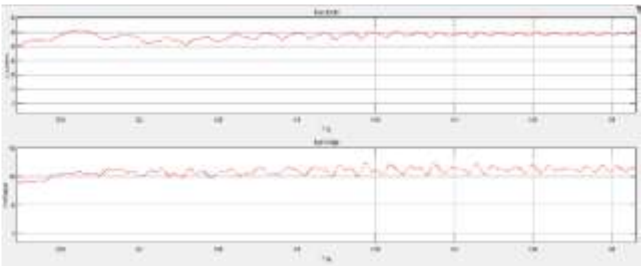

Figure 4.13 Input waveform of wind module

The obtained output waveform from the wind turbine subsystem is given to the boost converter. Here in wind module, the output from the wind turbine is the input of the system. The output from wind turbine is AC current. It is converted into DC current by using the three-phase rectifier. Thus, the input waveform is acquired. The input current is a DC current with some ripples. So, the input voltage also has some ripples.

4.2.4 GATE PULSE WAVEFORM

The gate pulse waveform given to the MOSFET. The gate pulse will remain constant

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even there is a change in wind speed, because of the MPPT values are coded in the PID controller. The PID controller is the main block to provide the gate pulse to the MOSFET of the solar module.

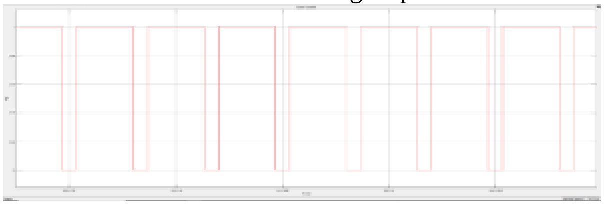

Figure 4.14 Gate pulse waveform for Wind

Here, in this PID controller, the output voltage is compared to the reference voltage of 700V and then to the relation operator block. The gate pulse block in wind is similar as the gate pulse block in the solar module. Thus, it is given to the MOSFET as the gate pulse for the wind module.

4.3 BATTERY STORAGE SYSTEM

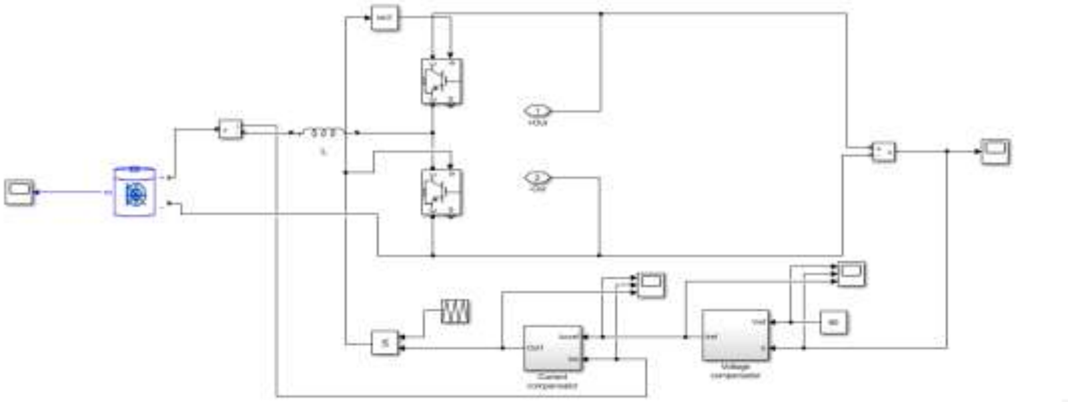

Figure 4.15 Battery Simulation

The Battery Storage System consist of a lead acid battery and a bidirectional DC-DC buck-boost converter. When there is a demand in the power generation from the solar and wind, the BSS will work as the backup system. The voltage will discharge from the battery. The system works on the buck converter. The when the power from the sources are attained at full strength, the battery will charge. At that time, the system works on the boost converter.

Thus, the system works in the alternating condition with respect to the wind speed and the solar irradiations and temperature.

4.3.1 INPUT WAVEFORM

The input waveform of the battery storage system is obtained. This waveform is the general waveform obtained from the battery.

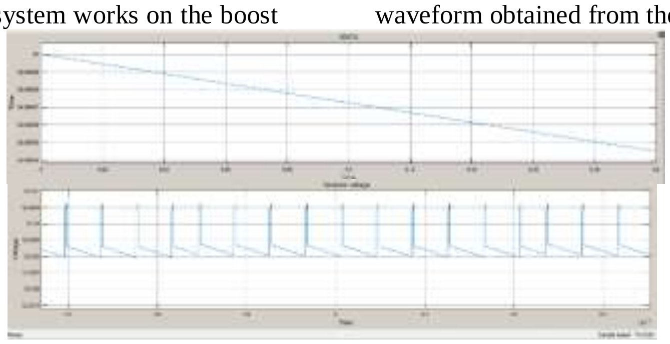

Figure 4.16 Input waveform of battery storage system

4.3.2 GATE PULSE WAVEFORM

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Figure 4.17 Gate pulse waveform for battery

The gate pulse is obtained by the voltage compensation and the current compensation. After that, it is given as the gate pulse to the converter. But here the NOT gate is used. The gate pulse is directly given to the MOSFET when it is operated in the boost mode.

V. RESULTS AND DISCUSSION

To evaluate the efficiency and reliability of the suggested methodMATLAB/Simulink is used. The Simulation of Enhancing the Energy management system of Hybrid sources based Microgrid is done. Here, the output voltage, current and power waveform is shownbelow.

5.1 SOLAR MODULE WAVEFORM

Figure 5.1 Output voltage and current waveform (PV)

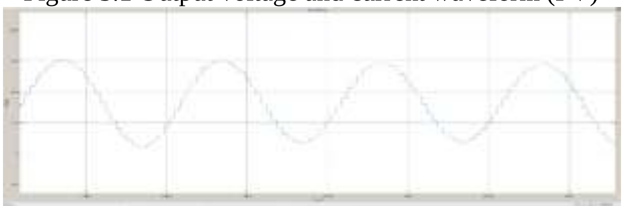

Figure 5.2 Output power waveform (PV)

The output waveform of voltage, current and power. From the above waveform, it clears that the output voltage didn't drop to 0 (zero). In some linear algorithms like P&O algorithm, the output voltage drops to zero due to shading conditions. And output power cannot provide continuously. So, we move on to PSO algorithm. And it clears that, in PSO algorithm is very efficient than other linear algorithms.

5.2 WIND MODULE WAVEFORM

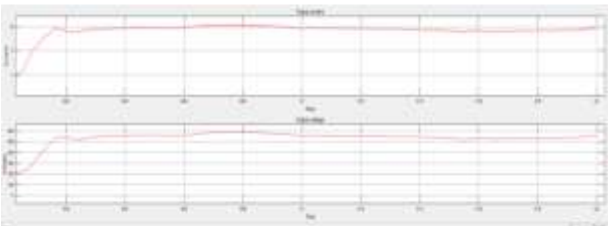

Figure 5.3 Output voltage and current waveform (Wind)

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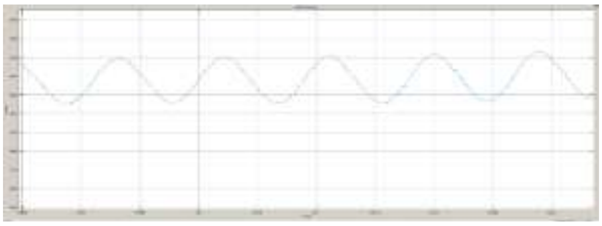

Figure 5.4 Output power waveform (Wind)

5.3 OVERALL WAVEFORM

Thewaveformofthereferencepower(calculatedoutputpower)and the output waveform from the simulation. The output waveform will not exceed the reference calculatedpowervalue.Thus,thepowerwillnotexceed thereferencepowerandalsothepower doesnotdroptozero.Thepowerwillbeprovidedcontinuouslyevenintheshadingconditions by changing the duty cycle value with the help of algorithm coded in the functionblock.

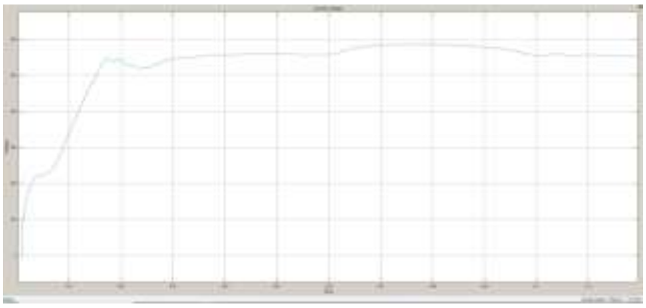

Figure 5.5 Overall scope

Theoutputpowerwillnotexceedthereferencepowervalue.That reference power value is called as the "Maximum Power Point'value.

5.4 DISCUSSION

We can conclude that PSO algorithm is much better than an efficient and other linear algorithm. The output waveform will not exceed the reference calculated powervalue.Thus,thepowerwillnotexceedthereferencepowerandalsothepowerdoesnot drop to zero. The power will be provided continuously even in the shading conditions by changing the duty cycle value with the help of algorithm coded in the functionblock.

VI. CONCLUSION

ImplementationofPSObasedMPPTControllerforSolarsystemhasbeenevaluated.Other algorithms like P&O cannot detect maximum power when it is subjected to changing irradiations and partial shading conditions. When compared with other linear algorithms like P&O algorithm, fuzzy algorithm, the PSO algorithm is much efficient and continuous power can be acquired.

Therefore, PSO algorithm is employed for extracting maximum power of a PVsystem.ForimprovingtrackingspeedPSOmethod wasusedwhichinitializestheparticles so as to search the new MPP which resulted in a better and dynamic response as can be seen from the resultoutput.

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