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Modeling and Simulation of Hybrid Wind/Photovoltaic for Improvement of Reliability of the DC Microgrid

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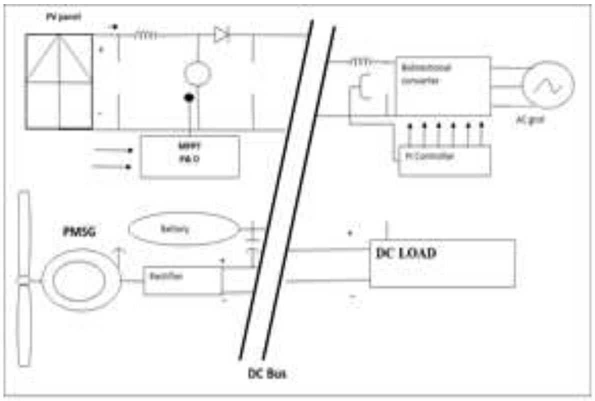
Abstract: This paper presents modeling and simulation of an autonomous DC microgrid in Matlab Simulink environment. The proposed microgrid system consists of a wind turbine, solar PV array ac grid and DC loads. The wind turbine &Ac grid is interfaced to the microgrid with a rectifier and a buck converter which are controlled to maintain a constant DC bus voltage. While the PV array is connected via a boost converter which extracts maximum power from the circuit. the microgrid system also consists of a Energy Storage System (ESS) which is connected via a bidirectional buck-boost converter. The overall stability of the microgrid is maintained by the control action of the ESS. DC microgid system have been analyzed and simulation done using Matlab.

Keywords: — DC microgrid; Maximum Power Point Tracking (MPPT) ;Distributed Energy Resources (DERS) ;Low Voltage Converter(LVC); State of Charge(SOC) Energy Storage System (ESS)

1. INTRODUCTION

Economic, technology and environmental incentives are changing. The face of electricity generation and transmission. Centralized generating facilities are giving way to smaller, more distributed generation partially due to the loss of traditional economies of scale. To realize the emerging potential of distributed generation one must take a system approach which views generation and associated loads as a subsystem or a "micro grids'. During disturbances, the generation and corresponding loads can separate from the distribution system to isolate the micro grid's load from the disturbance (and thereby maintaining service) without harming the transmission grid's integrity.

This paper proposes the design and analysis of a DC microgrid which is implemented with a Battery Energy Storage System (ESS). In terms of energy generation, the microgrid system consists of a small wind turbine and an array of solar PV modules. The sources are interfaced with appropriate converters in order to supply power to the microgrid. The load of the microgrid is considered as a small group of houses or a residential building. And in order to achieve a smooth control of the overall microgrid the centralized battery unit is employed with a bidirectional converter. Firstly, the models of each of the components of the microgrid are prepared in Matlab Simulink. After this, a control objective is set in order to achieve a stable operation of the microgrid under various conditions of generations and load.



A DCMG operates in various modes.

i) Grid connected – uncontrolled mode: An AC grid balances power in the DCMG. Further, it charges battery in case of surplus power than demand. The DC-AC converter connected to grid i.e., Grid- voltage source converter (G-VSC) regulates voltage in DCMG and it is to be noted that, the power transfer through AC-DC converter does not exceeds its maximum power limit.

$P_L = P_{GRID} + P_{PV} + P_{WP} + P_B$ (1)

where PPV, PWP, PB, and PGRID are power input to DC bus from PV, wind, battery and AC grid respectively. PL is power required by load (AC/DC or both).

ii) Grid connected controlled mode: In this mode, converter connected between DC link and grid does not take part in controlling DC link voltage. This may be due to the power flow from AC grid which exceeds maximum power rating of converter or fault occurrence in AC grid which causes its voltage dip. The DC link voltage cannot be regulated by grid converter. In such condition, battery regulates DC bus voltage shifting from charging mode to discharging mode.

$P_B = P_L - P_{PV} - P_{WP} - P_{GRID}$ (2)

iii) Isolated mode: In this mode, AC grid is disconnected and load power is supplied by DERs and battery. Battery regulates DC bus voltage. In case of less solar radiation and less wind speed, battery gets discharged to reduce DC link voltage. In case of more radiation and high wind speed, the battery gets charged, however the overcharging of battery is avoided. The DERs to be operated in derated mode.

$P_B = P_L - P_{PV} - P_{WP}$ (3)

2. LITERATURE SURVEY

[1] In this paper, loss of a dc microgrid system for residential complex is compared with loss in an ac system. Each system has a PV system, a gas engine cogeneration and 20 residential houses. The losses are calculated from measured load data and PV output data which was estimated from global solar radiation and temperature of a PV panel. The operation of the gas engine cogeneration is determined from the heat demands. As house loads, we consider an air conditioner, a refrigerator, a washing machine and a liquid crystal display (LCD) in each house. The loss calculation result shows the total losses in the dc system are around 15 % lower than the losses in the ac system.

[2] This blog explains that with the decreasing cost of electricity generated by photovoltaics and wind turbines, DC microgrids may be the most efficacious way to provide electrical energy to those who have none. Just as cell phone use in the developing world exploded without the prior installation of landlines, DC microgrids could leapfrog over the traditional system of centralized AC generation. The market for microgrids in the developing world could be huge, and the benefits they would bring to what are now grossly underserved regions are monumental

[3] In this paper, a comprehensive survey on microgrid to improve the power quality parameters is taken as the main objective. Furthermore, the detailed investigations are explored in this paper for the enhancement of power quality issues with the help of an optimization technique, filters, controllers, FACTS devices, compensators, and battery storage.

[4] In this model it is also critical to be able to use the waste heat by placing the sources near the heat load. During disturbances, the generation and corresponding loads can separate from the distribution system to isolate the microgrid's load from the disturbance (providing UPS services) without harming the transmission grid's integrity. This ability to island generation and loads together has a potential to provide a higher local reliability than that provided by the power system as a whole. This implies that a unit can be placed at any point on the electrical system as required by the location of the heat load

3. OBJECTIVE

1-To make a solar and wind hybrid energy system that can make use of the complementary nature of various sources, which increases the overall efficiency of the system and improve its performance (power quality and reliability).

2-To increase the overall efficiency or the response of an energy source with slower dynamic response (e.g. wind) by the addition of a storage device with faster dynamics to meet different types of load requirements

3-To achieve lower emissions by designing solar and wind hybrid energy systems to maximize the use of renewable resources, resulting in a system with lower emissions.

4-To enhance flexibility of Solar and wind hybrid energy systems in terms of the effective utilization of the renewable sources.

PV MODULE MODELLING:

PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I. A simple equivalent circuit of PV cell is shown in Fig. 6.

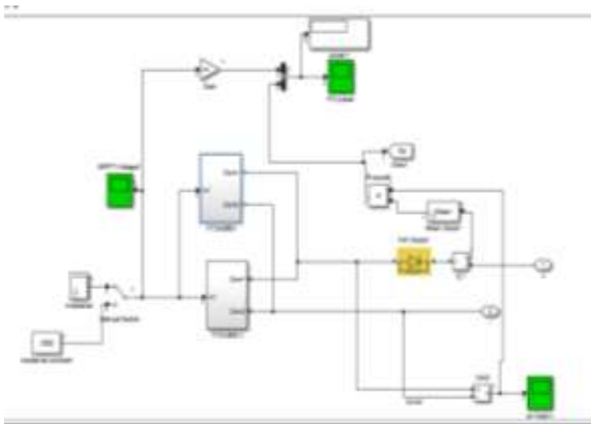


Figure 1: Modeled solar system

A cell series resistance (Rs) is connected in series with parallel combination of cell photocurrent (I_{ph}),exponential diode (D), and shunt resistance (R_{sh}) , I pv and Vpv are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s\left(e^{q(V_{pv}+I_{pv}*R_s)/nKT} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

Where:

I ph - Solar-induced current

Is - Diode saturation current

q - Electron charge (l.6e-l9C)

K - Boltzmann constant (l.38e-23J/K)

n - Ideality factor (l~2)

T - Temperature K

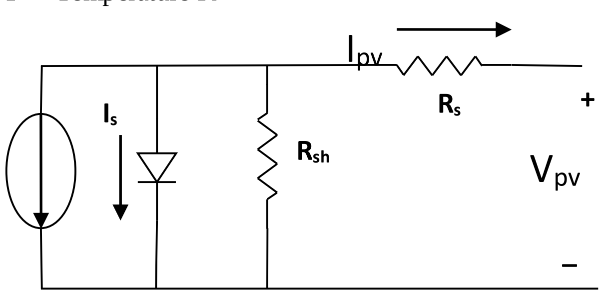


Figure 2: Equivalent circuit of solar PV cell

4. BATTERY MODE

The battery can exchange between charge and discharge mode in order to maintain DC bus power balanced. If the energy storage unit reaches the capacity limitation, it keeps the DC bus power balanced by exchanging a power to/from the AC grid.

Table 1 : Battery modeling parameters	
Nominal voltage (V)	300
Rated capacity (Ah)	6.5
Initial state-of-charge (%)	60
Battery response time (s)	30

5. GRID SIDE MECHANISM

The power supply from solar PV supply to the DC-microgrid is unifacial. The energy storage smoothes the power balances of the DC-microgrid by charging and discharging and therefore the power flow between the battery and therefore the microgrid is two-way. once the battery is in state of full charge or discharge, the excess/deficient power is equipped to or provided from AC network to the load. The battery realizes that a power balance supported the varying load demand and thus it makes continuous secured power supply to the load as attainable as in every condition.

$$P_B = P_{pv} - P_L$$

$$P_g = P_{pv} - P_B - P_L$$

Model of wind turbine

with PMSG Wind turbines cannot fully capture wind energy. The components of wind turbine have been modelled by the following equations [8-10].

Output aerodynamic power of the wind-turbine is expressed as:

$$P_{Turbine} = \frac{1}{2}\rho A C_p(\lambda, \beta) v^3$$

where,ρ is the air density (typically 1.225 kg/m3), *A* is the area swept by the rotor blades (in m2),*CP* is the coefficient of power conversion and *v* is the wind speed (in m/s).

The tip-speed ratio is defined as:

$$\lambda = \frac{\omega_m R}{v}$$

where ω_m and *R* are the rotor angular velocity (in rad/sec) and rotor radium (in m), respectively.

The wind turbine mechanical torque output *m T* given as:

$$T_m = \frac{1}{2}\rho A C_p(\lambda, \beta) v^3 \frac{1}{\omega_m}$$

$$P_{Turbine} = \frac{1}{2}\rho A C_{p_{max}} v^3$$

The above equation shows the power output of the turbine

6. RESULTS

The modeled system consists of two renewable energy resources making the system more reliable. The results of the analysis have been discussed below in two cases.

(1) CASE 1 describes the system with only solar energy resource supplying a DC load.
(2) CASE 2 is the hybrid model of wind energy system and solar energy system, together feeding the DC load.

7. CASE 1: MODEL WITH SOLAR ENERGY SYSTEM ONLY

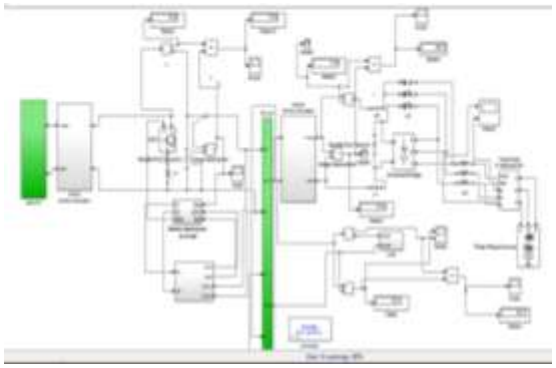


Figure 3: MATLAB model of solar energy syatem

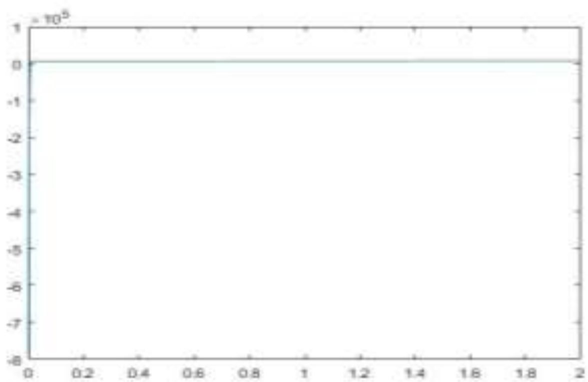


Figure 4: Power Output from Solar System

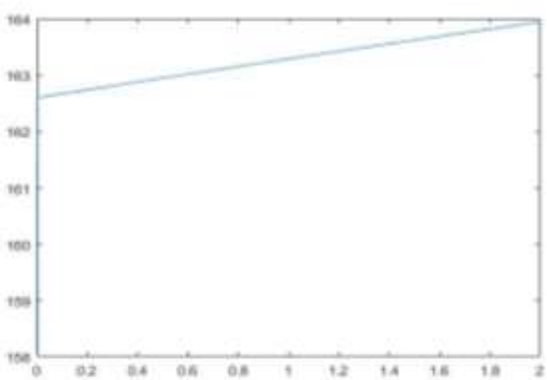


Figure 5: Voltage of Battery

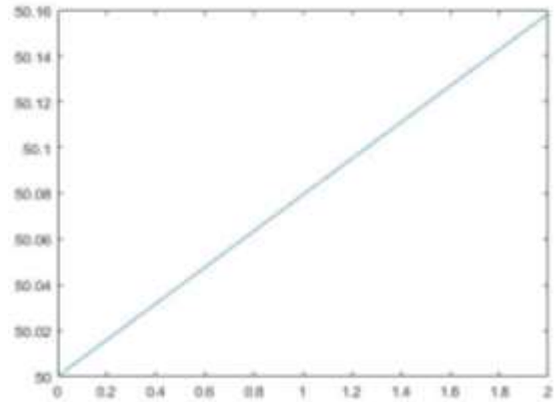


Figure 6: SOC of Battery

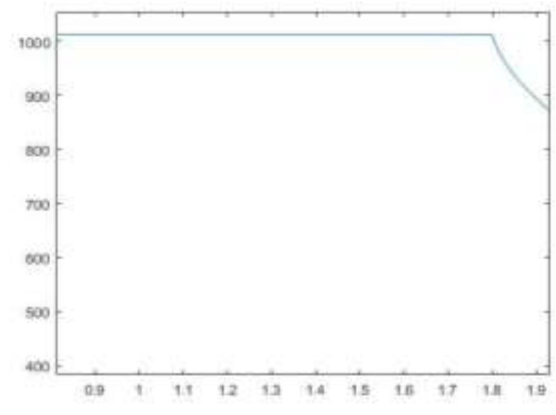


Figure 7: Power Output at Load Terminal

8. CASE 2: HYBRID MODEL WITH BOTH SOLAR AND WIND ENERGY SYSTEMS

The system has been modeled with a wind energy system along with solar in order to serve in the situations of fault/ maintenance of one system. The fig: shows the hybrid modeled system feeding the DC load.

The switching between solar and wind system has been obtained by using a IGBT switch having forward voltage V_f = 400 Volts.

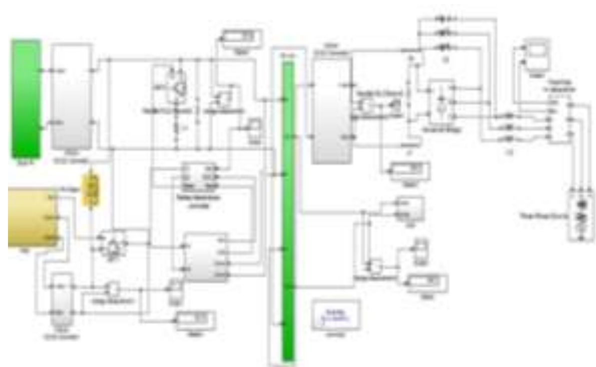


Figure 8: MATLAB model of hybrid energy system

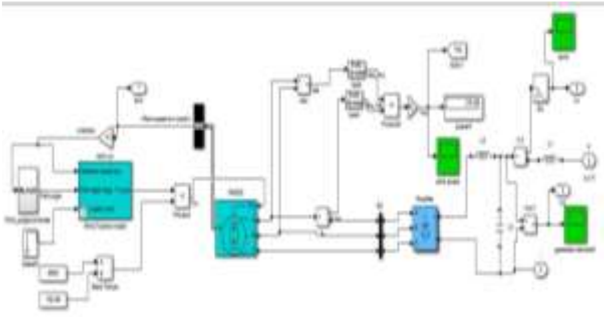


Figure 9: Modeled wind energy system

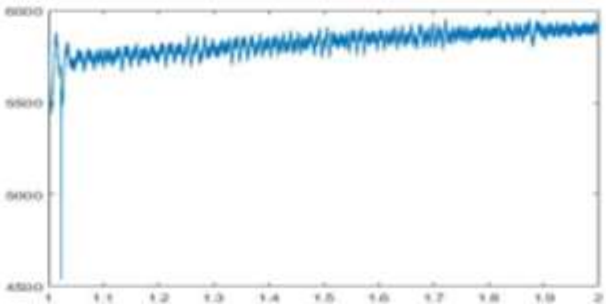


Figure 10: The DC power output from the wind energy system

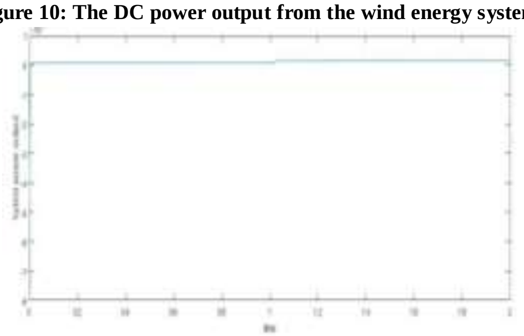


Figure 11: Power Output from hybrid system

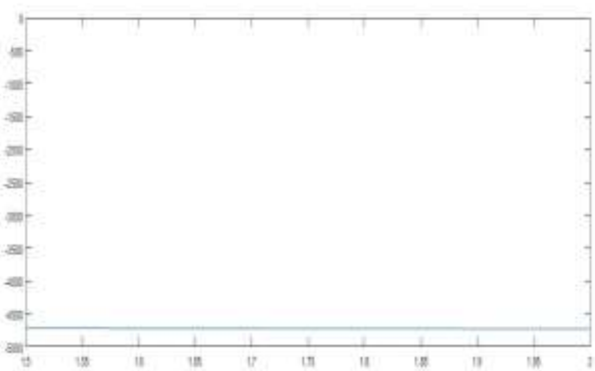


Figure 12: Battery Power Output

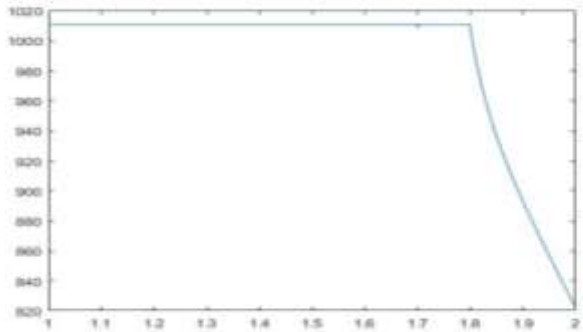


Figure 13: Power output at load terminal

9. VALIDATION

The red waveform is the power drawn from the solar only system and green waveform is the power drawn from hybrid system. The power feeding into the grid is considerably larger than the system having only solar power.

P_{solar}= 7640 watts

P_{hybrid}= 13550 watt

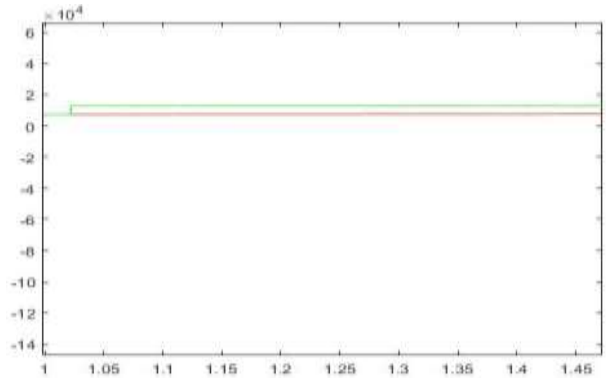


Figure 14: Combined power output from two systems

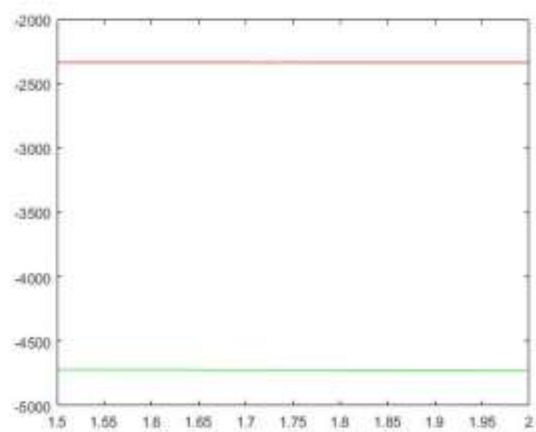


Figure 15: Power outputs from the battery in two cases

The battery is getting charged from the residual power of the hybrid system. The negative power of the battery system represents that battery has received some power from the hybrid energy resources as well as from the system having only solar system.

However there is considerable difference in the power being fed to the battery from the renewable energy resources. The amount of power going into the battery in case of hybrid system is more than the amount of power going into the battery from solar only system

$P_{solar,battery}$= -2335 watts

$P_{hybrid,battery}$= -4726 watt

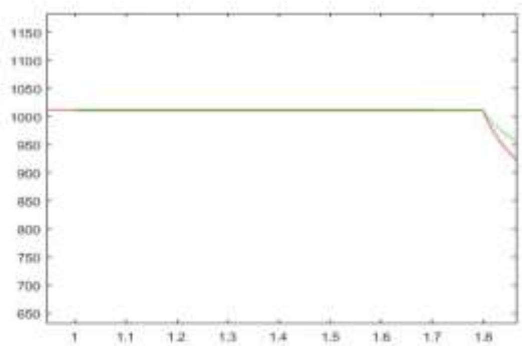


Figure 16: Power output from load terminal

10. Conclusion

- Micro grid for renewable power integration has been proposed. The operational optimization and power-electronics based voltage–power control was developed, and the functioning was demonstrated through simulation.
- A method to quantify the uncertainty affiliated with the forecast of aggregated wind and PV-based power generation was created and used to quantify the energy reserve of the battery energy storage system
- Power electronics is a key enabling technology in connecting all energy resources to the dc bus.
- The above results show that the value of voltage of the load connected to the DC link is receiving same amount of voltage from the system that is 269.2 Volts.
- In accordance with the micro grid paradigm, operation is also supported in autonomous mode to support the system when the connection to the main grid is unavailable. During such periods, fast charging is not supported, as the priority shifts to supplying critical local loads.

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