Grid Integration of Renewable Power (PV-Wind) With Incremental Conductance MPPT Controlled BUCK-BOOST Converter and Battery Storage

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Abstract

The Electric Power generation using renewable energy sources like sun and wind are rapidly increasing day by day. This paper mainly concerns about the grid integration of photovoltaic (PV)-Wind system along with battery storage. The main objective of this work is to meet the real power demand of the load in an efficient manner and injection of excess power into grid from power sources and charging and discharging of battery whenever it is needed. Proposed System Consisting of a PV System of 12KW and a wind turbine of 8.5KW fitted to three phase PMSG generator equipped with Rectification, Battery System, Buck-Boost converter with Maximum Power point Tracking(MPPT) of Incremental Conductance Method are designed using MATLAB/SIMULINK and the results are satisfactory.

Keywords: Photovoltaic(PV), Wind Energy, Buck-Boost Converter, Incremental conductance MPPT, Battery System, MATLAB/SIMULINK.

1. Introduction

Now a days, the most popular renewable energy sources (RES) are solar and wind for harnessing electricity. India is one of the countries with the largest production of energy from renewable energy sources. 20% of total installed capacity In India is of renewable. The Government of India has set a target of installing 20GW of solar power by 2022. Directly or indirectly all the RES are depends on sun. Photovoltaic directly depends on sun light. Wind flows due to the creation of uneven pressure in air by absorbing the heat from the earth. Earth's absorbed heat is different in every geographical region. This helps in the formation of different pressure regions. The availability of Renewable energy sources at a constant rate is a major problem. 70% for daytime solar due to passing clouds and 100% for wind due to calm days—is a major challenge to integrating renewable energy resources on the grid[6],[7]. Application of MPPT techniques for PV system is important to operate the system in maximum power operating points. Various MPPT algorithms include Perturb & observe, incremental conductance [5], incremental current, incremental power, Hill Climbing technique and other neural network based methods have been proposed by various authors. These MPPT algorithms are used to control and operate the Duty Cycle of DC-DC converter to achieve the maximum amount of power from various sources.

Photovoltaic (PV) – wind-based generation of electricity and its Grid interfacing are the important and ever green research areas. Chen etal. [5], [1] have proposed a multi-input hybrid PV–wind power generation system which has a buck/buck– boost-fused multi-input dc–dc converter and a full-bridge dc–ac inverter. Most of the authors are also proposed the AC-DC-AC conversion methods to utilise power in a better fashion. One of the major concerns related to the high-level penetration of integrated wind turbines is their impact on power system stability and is concerned with frequency regulation and voltage stability [2]. Recent advances in energy storage technologies provide an opportunity for

utilizing energy storage devices to address the intermittency of renewable energy resources (RES). Possible choices for wind energy storage system are flywheel, super capacitor, super-conducting magnetic energy storage (SMES), batteries, compressed air system and hydro pump stations [3]. Compared with other energy storage technologies, batteries are the most cost-effective option for wind farm integration. The battery storage device can store the power as well as they can control active and reactive power at the point of interconnection. The generation of fly wheel energy storage is available from 1970s which uses a rotating body on large mechanical bearings. It consists of a large rotating cylinder where rotational energy is stored in a rotor [4].

The Proposed system is shown in figure 1, consisting of Photovoltaic and Wind energy system, AC Load, AC Grid, Battery Storage and a Buck-Boost Converter. The main Goal of this work is to meet the load demand and uninterrupted power supply and injecting excess power from various sources to Grid and Control of Battery charging and discharging.

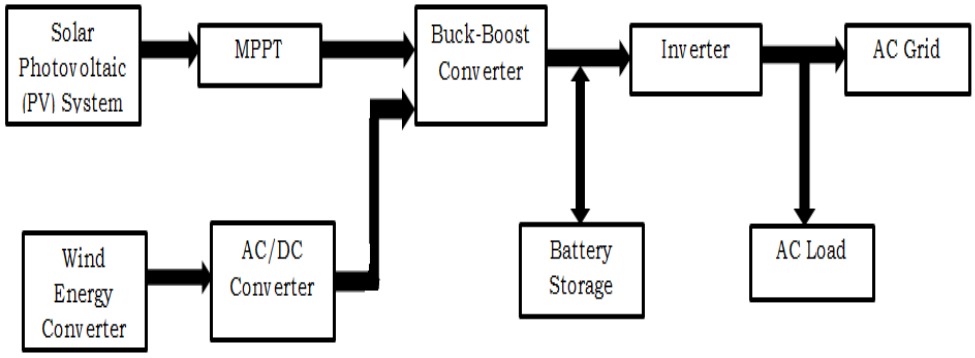

Figure 1. Block Diagram of a Proposed System

2. Modeling of Proposed system

2.1 photovoltaic Power System

The equivalent circuit of a solar cell is shown in figure.2. A solar cell is modelled by a current source in parallel with a diode, no solar cell is ideal so a shunt resistance and series resistance components are added to the model.

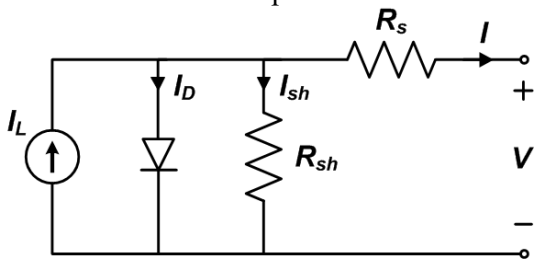

Figure 2. Solar Cell Equivalent circuit

$$I = I_L - I_D - I_{sh} \quad (1)$$

Where I = output current, I_L = Photo generated current, I_D = Current through Diode, I_{sh} = Current through shunt resistance

$$V_j = V + I\,R_s \quad (2)$$

$$I_D = I_0\{\exp[\frac{V_j}{nV_T}]\text{-}1\} \quad (3)$$

Where V_j = voltage across both diode and shunt resistor, R_s= series resistance, R_{sh}= Shunt Resistance, n= diode ideality factor

$V_T = \frac{KT}{q}$ = Thermal voltage (4)

K= Boltzmann Constant, T= Absolute temperature, q=Charge Magnitude

On Substituting Equations (2), (3), (4) in Equation (1) we get

$$I = I_L - I_0\{\exp[\frac{V_j}{nV_T}]\text{-}1\}\frac{V+IR_s}{R_{sh}} \quad (5)$$

The typical IV and PV characteristics of a solar cell mainly depend on Temperature and irradiance. As the temperature increases the voltage that is build up in a solar cell decreases shown in Figure3 due to decrease in energy gap between valence band and conduction band decreases. As the irradiance increases the current that is produced by the solar cell also increases as shown in Figure4.

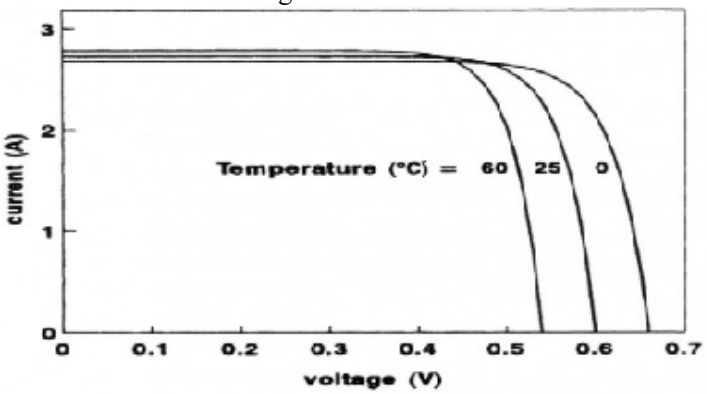

Figure 3. IV Characteristics of a solar cell

In Figure 3, IV characteristics the maximum current is called the short circuit current where the voltage is zero and the maximum voltage point is called as open circuit voltage where current is observed to be zero. The power that is produced by the solar cell varies directly with the irradiance. More irradiance means power produced by the solar cell is also more as shown in Fig4, most favorable conditions for solar panel to generate power is 25 deg C. i.e 300 deg K.

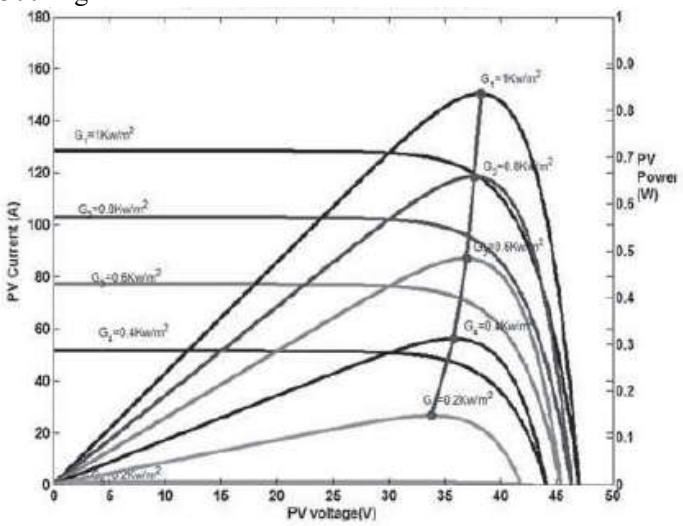

Figure 4. IV and PV Characteristics of Solar cell at variable irradiances

2.2 Wind Power System

Wind turbines are used to harnessing power from the kinetic energy present in wind. The expression for power present in kinetic energy of wind is given by

$$P_K = 0.5925 * \frac{1}{2}\rho A V^3 \quad (6)$$

A= area of duct, ρ= density of air at turbine, V= velocity of air

From the above expression we can found that maximum power extracted from the wind is in the fraction of 0.5925 of its total kinetic power. This fraction is known as Betz coefficient. This power is of theoretical however practical power of wind turbine is much less than this due to fractional losses and inefficiency of aerodynamic design.

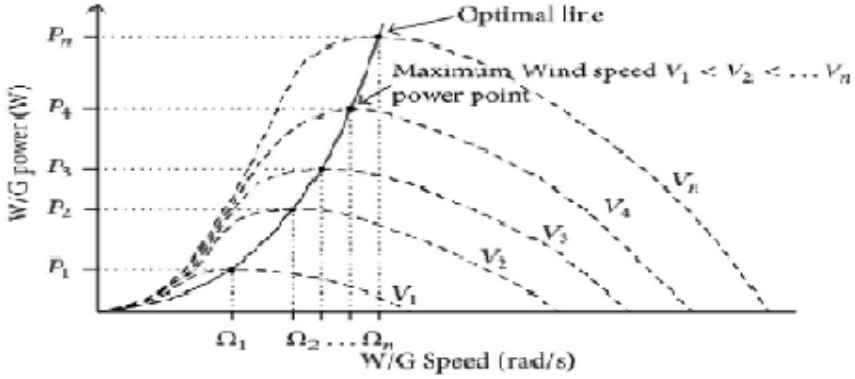

Figure 5. Output Power for Different Values of Wind speed

The mechanical power generated by the wind turbine under different wind speeds and the optimal line is also shown in Figure 5.

2.3 Battery storage system

Battery model used in the simulation of this work is presented in Figure6, assumes that the battery is composed of a controlled-voltage source and a series resistance.

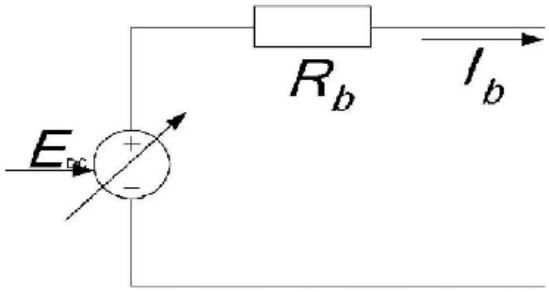

Figure 6. Battery Model for Dynamic Simulation

2.4 Buck-Boost Converter

The Topology of this buck-boost converter can perform either stepping up or stepping down the voltage levels, output voltage polarity is opposite to that of the input. The relation between input and out voltage is given by equation 7.

$$V_{in}T_{on} + V_{out}T_{off} = 0 \quad (7)$$

$$\frac{V_{out}}{V_{in}} = \frac{-T_{on}}{T_{off}} = \frac{-d}{1-d} \quad (8)$$

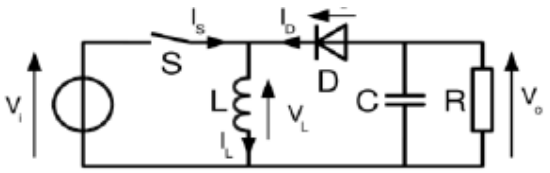

Figure 7. DC-DC Buck-Boost Converter

3. Incremental Conductance Method

This algorithm exploits the fact that the slope of the power-voltage curve of a PV array is equal to zero at the maximum power point. The slope is positive in the area to the left of the maximum power point and negative in the area to the right. Figure 8, shows the flowchart of incremental conductance technique.

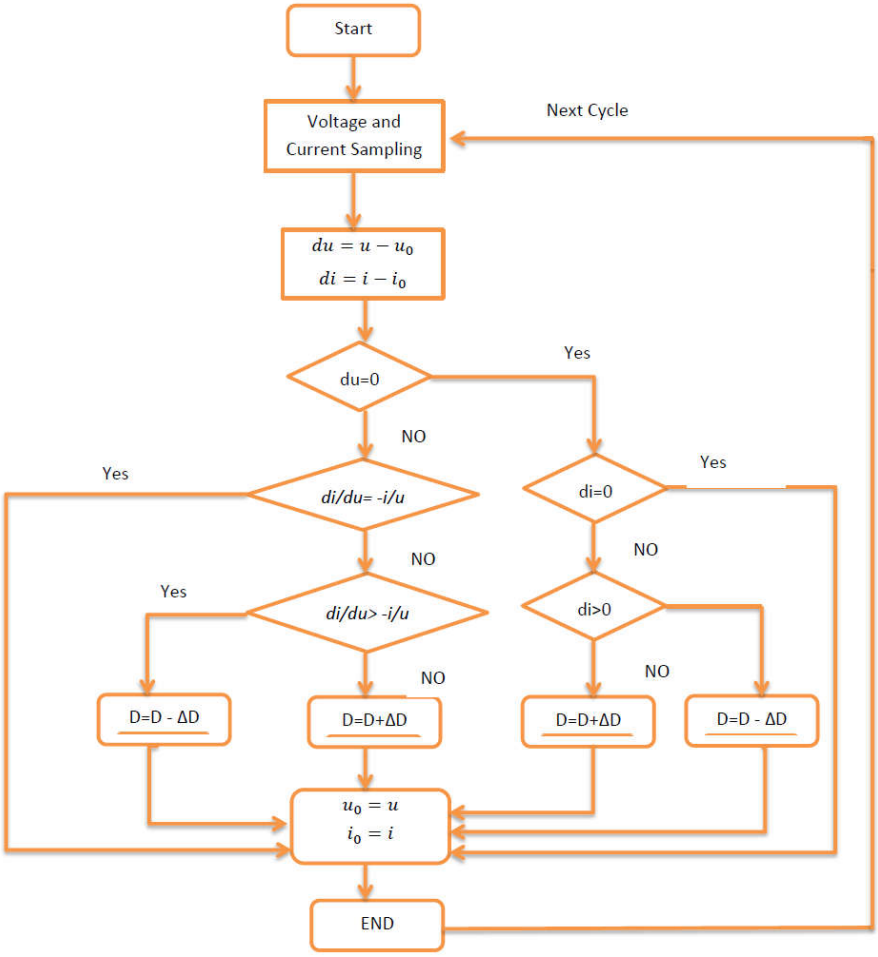

Figure 8. Incremental conductance MPPT technique Flowchart

4. Results and Discussions

The Proposed system is designed and simulated in Matlab/Simulink 2013a version. Photovoltaic system is designed at a capacity of 12Kw at a maximum irradiance of 1000w/m^2 and dynamically simulated at a step response for a time period of 5 seconds. The output power of the solar power generation with respect to time is shown in figure 9.

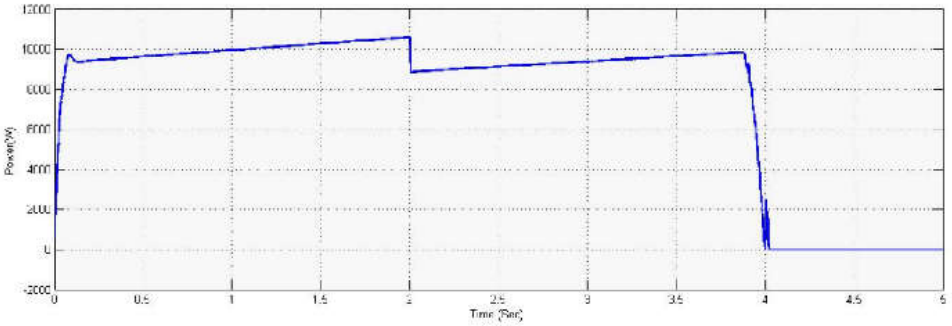

Figure 9. Output Power from Solar panel

The voltage at the maximum power point of the photovoltaic system is 710v and the current at the MPP point is 11.97A when MPPT technique is used for PV system. The output power and current wave forms of wind power system are shown in figure 10 and figure 11 respectively. Here in this proposed work 8.5Kw wind power plant is constructed using permanent magnet synchronous generator. Taking stator phase resistance of 0.425 ohms, armature inductance of 0.000835 H, Flux linkage established by magnets is 0.433.

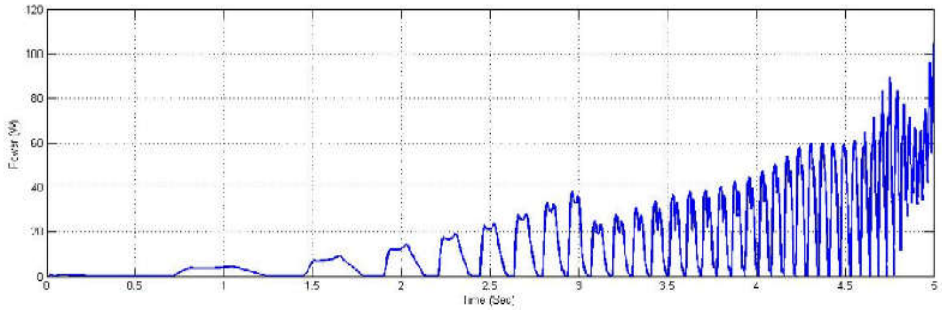

Figure 10. Power generated by wind power system

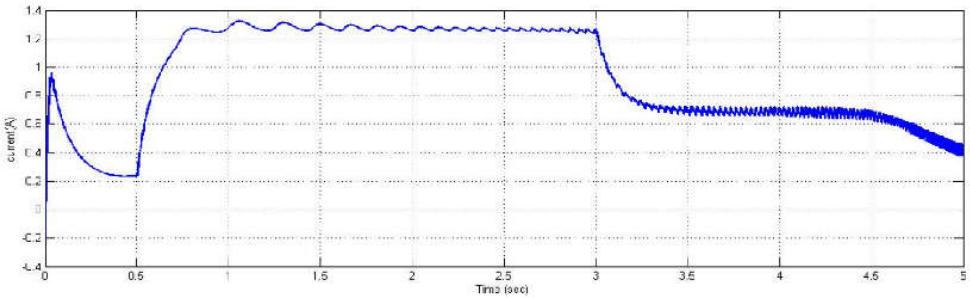

Figure 11. Current Wave form of wind power system

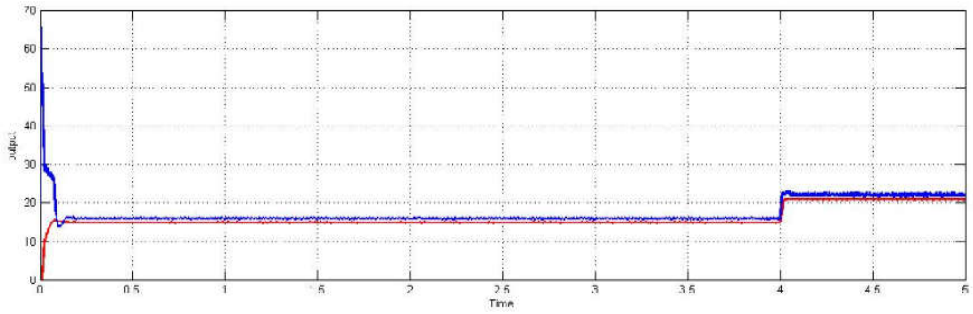

Figure 12. Output of DC-DC Buck-Boost Converter

The battery charged with the constant magnitude of current, and the remaining power is fed to the grid. Up to 4seconds the PV systems generates more power and the load is totally depend on it and after 4seconds the irradiance is decreased to zero. Coming to the wind turbine the power generation rapidly increases after 3.5 seconds, in between these time periods the battery system taking care of meeting the load demand. Meanwhile the storage system gets charged. The output of the DC-DC Buck-Boost converter controlled by the Incremental Conductance method of MPPT technique is shown in figure12.The excess power of either the sources after meeting the load demand is sent to the ac grid. A 10KW active power consumable three phase parallel RLC block is used as an AC load. The RMS voltage and current wave forms at the AC grid are shown in figure-13 and figure-14 respectively.

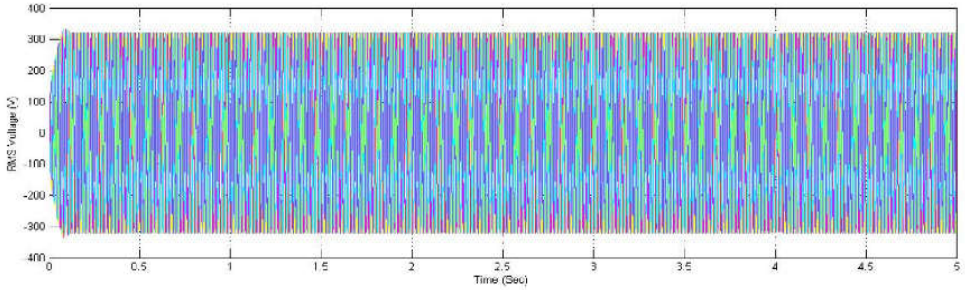

Figure 13. Voltage Wave forms at Ac Grid

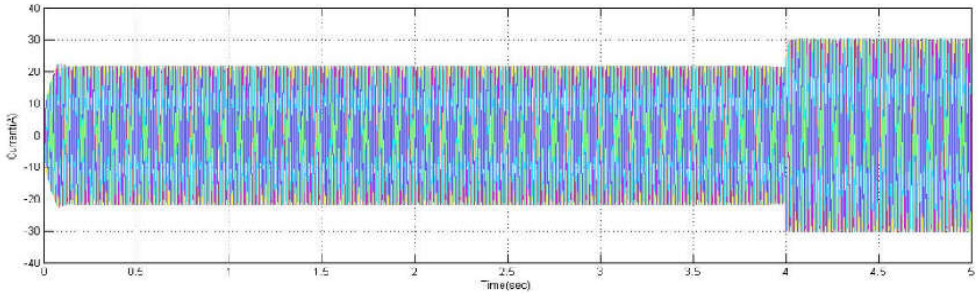

Figure 14. Current wave forms at Ac Grid

5. Conclusion

The main aim of this proposed work is to integrate the renewable power to the grid with the smart operation of battery storage and to utilize the abundantly available renewable energy sources to a great extent. The proposed system can feed the ac load demand uninterruply and injecting the excess power to the grid.

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