Scientific Journal of Impact Factor(SJIF): 3.134

e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 3, March -2015

Simulation of DC Microgrid with Integration of Renewable Energy Resources

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Abstract — *Microgrid is a part of distribution network embedding multiple distributed generation systems with local loads, which can be disconnected from the main power grid network under emergency conditions. This paper presents the simulation and control of DC microgrid in islanded mode under various loads. DC microgrid consists of wind turbine and solar-photovoltaic which establish constant DC bus voltage. To provide DC, AC supply should be rectified and regulated .This process occur more losses. I instead of this rectification process a separate independent DC microgrid can be designed to which the DC load can be connected. The DC bus voltage of DC microgrid should be regulated to avoid current with proper control strategies. Integration of renewable energy resources with the DC bus is presented in this paper. Simulation of DC microgrid is done in Matlab/ Simulink*

Keywords - *Microgrid, DC microgrid, Distributed Generator (DG), DC-DC converters,PV system, Wind turbine.*

I. INTRODUCTION

In the world, conventional power system such as fossil fuelled are facing problem gradually. It faces the problem such as depletion of fossil fuel resources, poor energy efficiency, and environmental crises. These problem leads to new treads of generating power locally at distribution generators [1]. Distribution generation is an approach in which Distribution generation such as wind turbine; photo voltaic panels, fuel cells etc. are the non-conventional renewable energy sources have led to new trends in small scale distributed generators. Distributed generators has progressively increased in social and economic aspects due to high efficiency, it reduced power networks losses and exploitation of non-conventional sources, it provide low cost electricity and higher power reliability [2].

Distributed power generation has some drawbacks when the grid is connected. Mostly the distributed generators are connected to grid directly, so there is some significance impact on the operation of power grid. However, if any fault occurs in the power grid then the distributed generators is to be isolated from the power grid [4]. In order to solve this problem microgrid came into existence.

Microgrid is a group of single controllable entity which contains micro sources, energy storage system, load components, interfacing converters and many other devices. It is a kind of structure which provides self-management, and also builds strong control schemes and makes the electricity network more appropriate and smart with the use of micro source and energy storage devices. Basically microgrid can be operated in two operating modes: grid-connected, islanded modes.

There are some challenges while integrating with the renewable energy sources because their output is variable and intermittent also requires an energy storage system [5]. If only one renewable energy source is considered then the integration is easier and it can be in standalone mode and it is also connected to the energy storage system. When the grid is connected to the integration of renewable energy sources then the power is injected directly into the power network. It creates some problem of power balancing, need to handle the transmission system operators [6].

The power connection between microgrid components such as distributed generators and energy storage system can be done through direct current (DC), and alternating current (AC). In this paper DC microgrid has been considered, which emphasis mainly on the islanded operating modes [6]. Islanded mode is also known as autonomous control.

This paper mainly focuses on modeling and operational analyses of an autonomous coordinated control scheme for DC microgrid. The proposed DC microgrid consists of Wind Turbine (WT), Solar-Photovoltaic (SPV). DC microgrid able to supply AC and DC power both to the loads simultaneously. An autonomous coordinated control stratergy is proposed in this paper by using only DC voltage of DC microgrid (DCMG) [5]. The main issue is the circulating current among the distributed generators to the DC microgrid, when the voltage difference occurs among them. This problem can be eliminated with the proposed control stratergy.

In the proposed DC microgrid, the variable speed wind turbine is connected to the permanent magnet synchronous generators (PMSG) and is integrated through the uncontrolled rectifier AC to DC and then to maintain the DC bus voltage constant, DC-DC converter is implemented [9]. Power generators by the wind turbine distributed generation are consumed by the loads connected locally to the wind turbine generators and the remaining part of the wind power generators flow through DC grid to others loads in DC microgrid [5]. The solar-photovoltaic system with the MPPT control is integrated to DC microgrid through a DC-DC boost converter. To maintain the voltage constant the closed loop buck converter is implemented. DC microgrid voltage rating is ±400V.

II. DC MICROGRID CONFIGURATION

The proposed architecture of DC microgrid for integration of renewable energy sources is shown in the following figure 1.W In proposed DC microgrid 50kW autonomous control comprises of PMSG with AC- DC uncontrolled rectifier for DC output, The DC-DC buck converter closed loop is used with PI controller. Then three loads of resistive and inductive loads are connected, therefore DC bus voltage is 400V and it remains constant in wind.

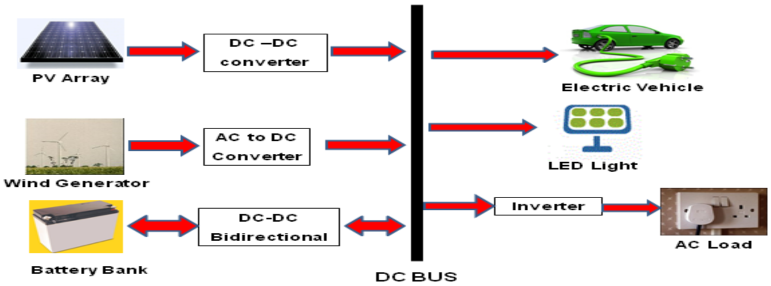

Figure 1 DC microgrid

The solar-photovoltaic is integrated with the DC Microgrid as shown in above Figure1. Solar-photovoltaic generation comprises of a MPPT controller to track the maximum power output from PV array [12]. The MPPT controller tracks the peak power of the PV system based on P-V characteristics with perturb& observe or Hill Climbing method with the boost converter. To maintain the voltage constant of DC link bus DC-DC buck converter closed loop control is used.

III. INTEGRATION OF RENEWABLE ENERGY RESOURCES

A. Wind Turbine

The Figure 2 shows the overall block diagram of the proposed microgrid with wind turbine. The main source of wind turbine is based on permanent magnet synchronous generator. It is interfaced with DC bus and feed the power to the load. Wind turbine are based on many types of generators such as doubly fed induction generator, permanent magnet synchronous generator, induction generator, squirrel cage induction generator. So, here in these paper permanent magnet synchronous generators is used because there are many advantages by using this type of generator. Advantages such as maintenance cost is less because no sliprings are used no brushes. Gear mechanism can be avoided.

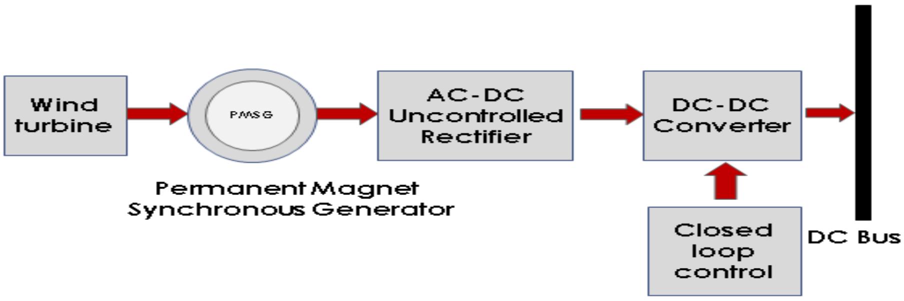

Figure 2 Wind turbine block diagram

Moreover, power electronics converters are used to interface the load and the Renewable energy sources. Uncontrolled rectifier is used to convert AC – DC. Therefore, input voltage is more than output voltage so, there is requirement of DC-DC buck closed loop converter to main the DC bus voltage constant.

B. PV System

In proposed system the figure 3 represents the PV system block diagram interfaced with the DC microgrid. In these proposed system PV array output is measured with the MPPT boost controller to track the maximum power point from PV array. According to the change in irradiation and the temperature the maximum power point track and boost the voltage and current accordingly. Then after, to maintain the DC bus voltage constant DC-DC buck closed loop converter is used.

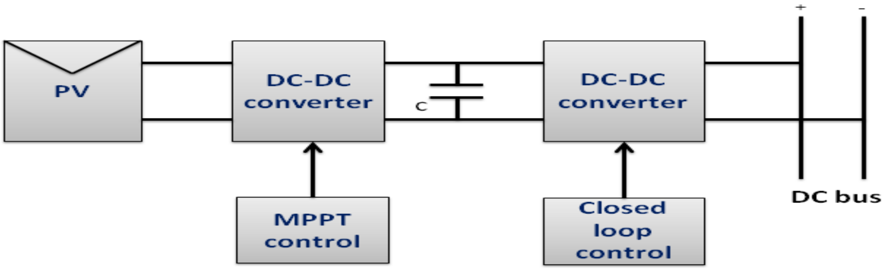

Figure 3 PV System Block diagram

For the maximum power point there are various different techniques to track the power. Subsequently, here Perturb & Observe or Hill climbing techniques is used. The main reason to use these technique is that it takes less time to track the maximum power point, and it is well known techniques efficiently used nowadays. Whereas, in different techniques it takes long time to track the MPP, and they were mostly used in ancient periods.

IV. SIMULATION & RESULTS

A. Wind Turbine Model

Parameters of PMSG are listed in Table 1.Wind turbine Model is designed for 50kw.

Table 1 Parameters of PMSG

Parameters	values
No. of phases	3
Nominal Power	50kw
Speed	600 rpm
Frequency	50 Hz
Pole pair	5

In Wind model simulation subsystem of Wind turbine and DC-DC Buck converter are presented in figure 4.

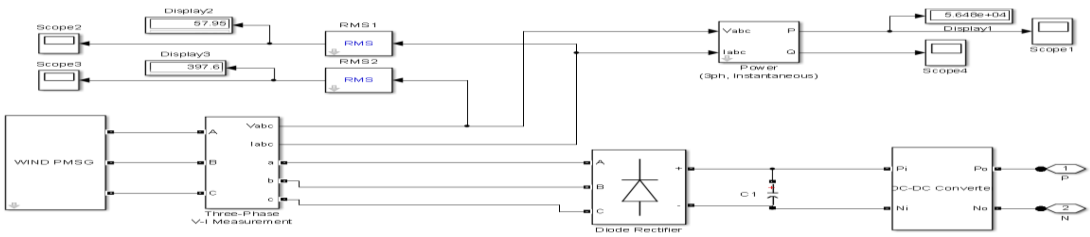

Figure 4Wind Model simulation

Wind turbine is connected to PMSG is presented in figure 5 below. Wind speed is 12m/s constant. PMSG output is then rectified AC-DC with uncontrolled rectifier.

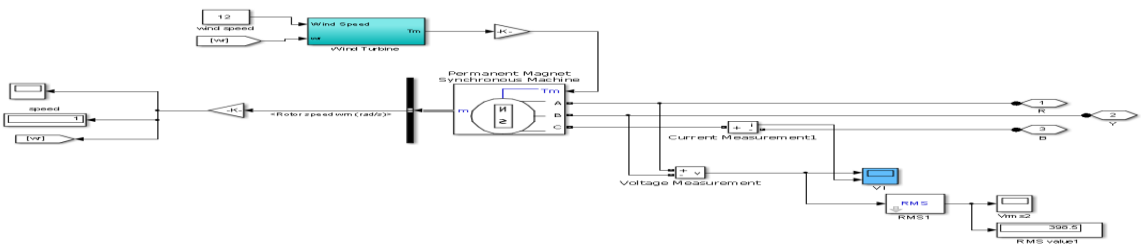

Figure 5 wind subsystem

DC-DC buck converter subsystem is presented in figure 6. Reference 400 voltage is set and the gate pulse is given to the buck converter Switch.

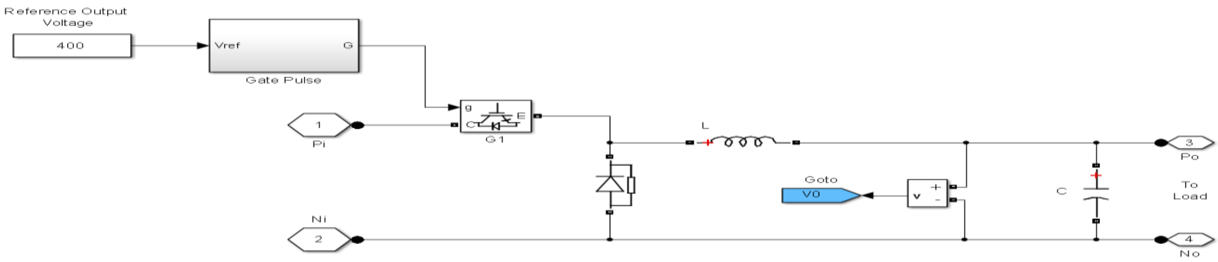

Figure 6 DC-DC buck converter

DC load is connected to the DC-DC buck converter is presented in figure 7. Three loads are connected; one is resistive load, second and third is R-L load. Therefore output of DC voltage is 400.Power and current is also measured as shown in figure 7.

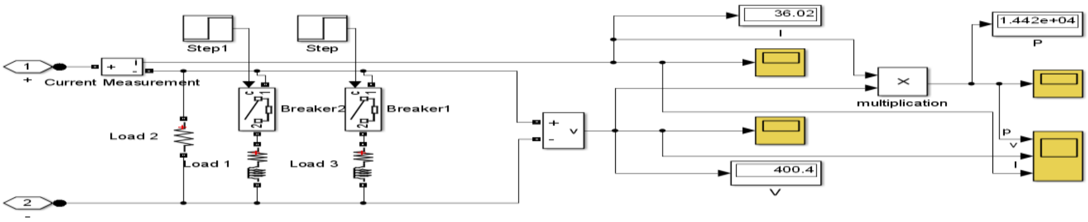

Figure 7 DC load

B. PV System Model

PV system Modeling parameters are given in table 3PV array is designed for 50kW..

Table 2 PV parameter

No.	Parameter	Value
1	No. of PV Cells	50
2	V_{oc}	64.2V
3	I_{sc}	5.96A
4	P_{max}	305.22 W
5	V_{mppt}	54.7V

In PV system subsystem of PV array and MPPT control of boost converter is used as shown in figure 8 .DC-DC buck closed loop converter is used to maintain the DC voltage constant.

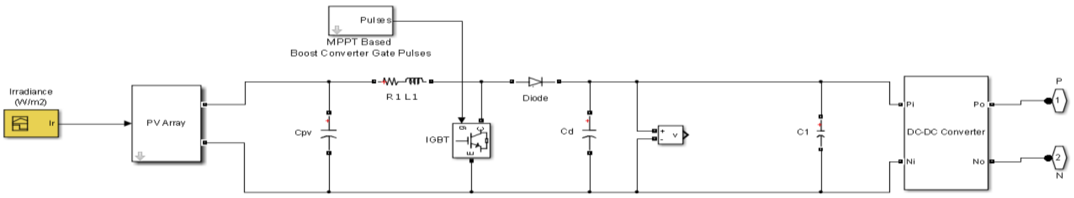

Figure 8 PV system

PV array subsystem is presented in figure 9.there are two subsystem Iph and diode system. This PV array system is based on PV cell equivalent circuit.

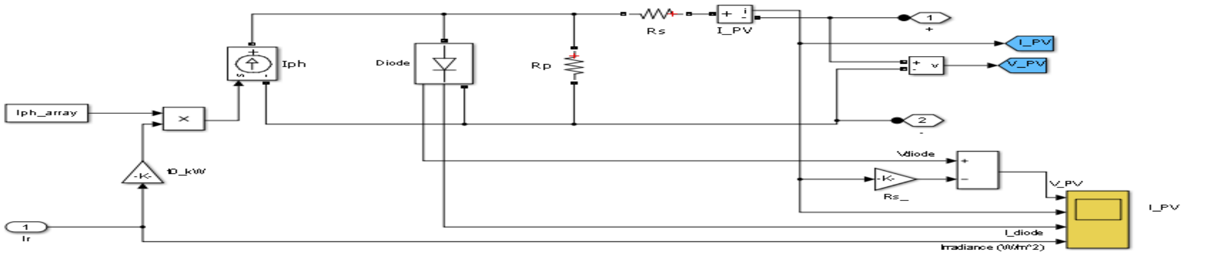

Figure 9 PV array subsystems

Diode subsystem represents in the figure 10. This subsystem is based on s Shockley's diode equation

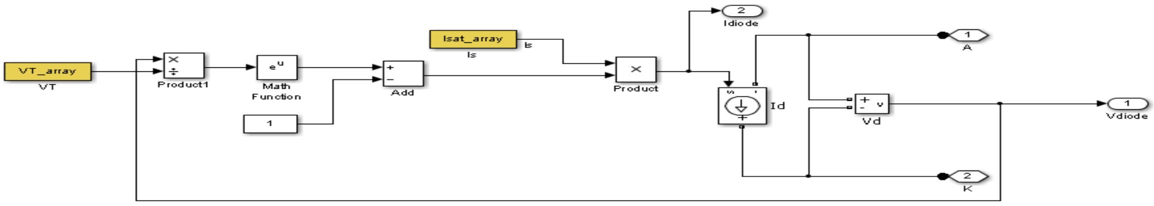

Figure 10diode subsystem

MPPT controller is presented in figure 11. Duty ratio of MPPT boost converter is 0.5. In these proposed system for MPPT Perturb & observe technique is used to track the maximum power point

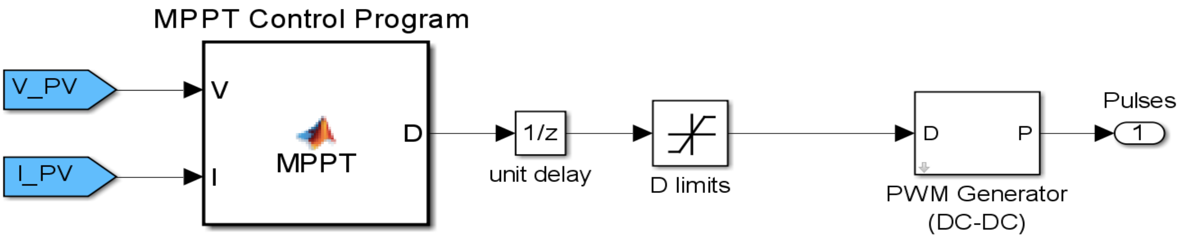

Figure 11 MPPT Control

C. Results of DC microgrid

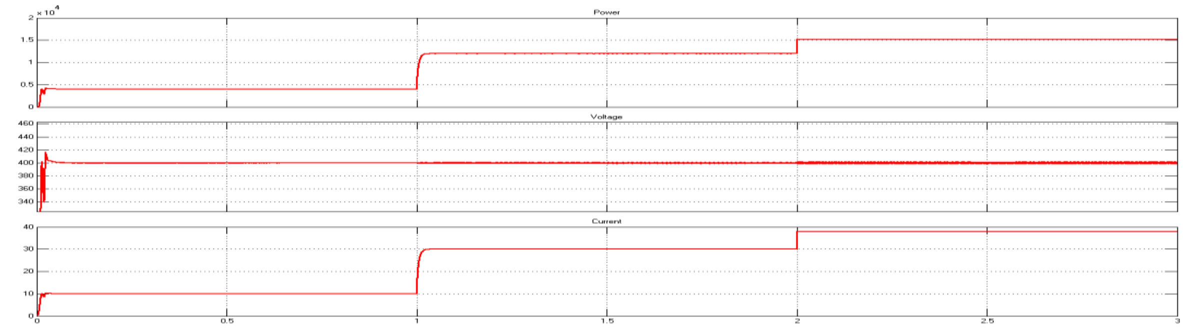

Figure 12 wind Power, voltage current waveform

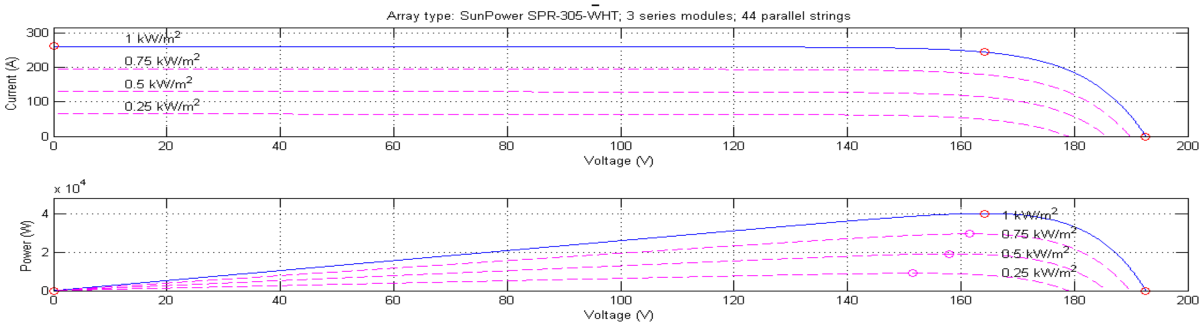

Figure 13 I-V &P-V characteristics

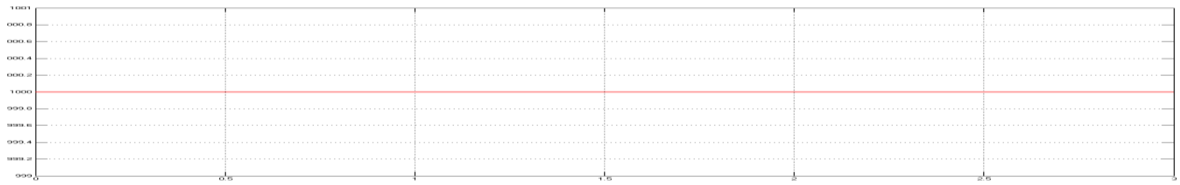

Figure 14 irradiation constant

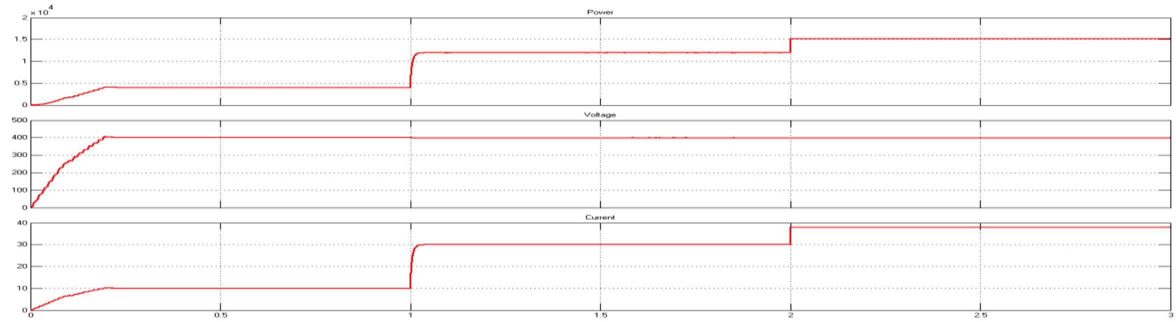

Figure 15 PV outputs

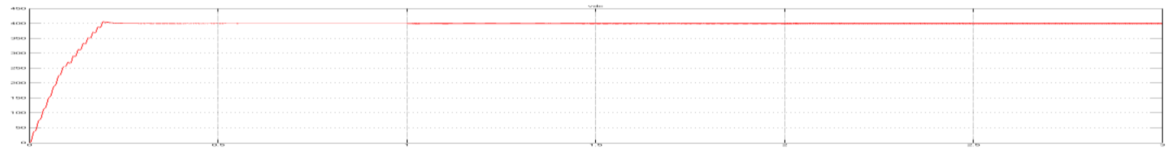

Figure 16 DC voltage of PV

V. CONCLUSION

A DC microgrid with the distributed generators can operate in grid connected and islanded mode automatically .The proposed DC microgrid is islanded mode which is found to be reliable, stable and have high quality power supply at desired constant DC voltage. It also facilitates the network of distribution Generators and different DC loads. The circulating current among the distribution generators has been suppressed. It can eliminate DC-AC and AC-DC power conversion. In future Battery Energy Storage System will be analyzed and implemented.

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