International Journal For Technological Research In Engineering
Volume 8, Issue 8, April-2021 *(Online): 2347 - 4718*

SIMULATION OF MICROGRID BASED ON SOLAR PV-DFIG-DG FOR OPTIMAL FUEL CONSUMPTION IN DISTRIBUTED GENERATION SYSTEM

[1]Ravi Bharodiya, [2]Dr. Bhavin J. Shah
[1]PG Scholar, [2]Associate Professor
Electrical Department, LDCE, Ahmedabad, Gujarat, India

Abstract: - Many remote areas still use a diesel engine based electric generator commonly known as a diesel generator (DG) for their electrical energy needs, despite the fact that DG is costly, noisy and pollutant. The remote areas usually have vast availability of renewable energy sources (RES) such as solar, wind, biomass, as well as hydro. Advancements in power electronics and electrical machines, have made it possible to decrease the cost of energy provided by these RES, and to reduce dependence on DG in remote areas by integrating various RES and to form a local electrical network called as a standalone microgrid (SMG). Moreover, RE based power sources are pollution free and abundant in nature. Among RE sources, wind and solar are considered to be more popular because of their reduced cost and technological advancements. Wind turbines are mainly categorized as fixed speed and variable speed type. Fixed speed wind turbines have been used earlier due to their simple operating features. However, they suffer with more power loss. The solar PV array is directly connected to common DC bus of back-back voltage source converters (VSCs), which are connected in the rotor side of DFIG. Moreover, battery energy storage (BES) is connected at same DC bus through a bidirectional buck/boost DC-DC converter to provide path for excess stator power of DFIG. The extraction of maximum power from both wind and solar, is achieved through rotor side VSC control and bidirectional buck/boost DC-DC converter control, respectively.

1. INTRODUCTION

Rapid depletion of fossil fuel resources on a worldwide basis has necessitated an urgent search for The Micro grid (MG) concept assumes a cluster of loads and micro sources operating as a single controllable system that provides both power and heat to its local area. This concept provides a new paradigm for defining the operation of distributed generation. The MG study architecture is shown in Figure 1.1. It consists of a group of radial feeders, which could be part of a distribution system. There is a single point of connection to the utility called point of common coupling (PCC). Feeders 1 and 2 have sensitive loads which should be supplied during the events. The feeders also have the micro sources consisting of a photovoltaic (PV), a wind turbine (WT), and a fuel cell (FC), a micro turbine (MT), a diesel generator (DG), and battery storage. The third feeder has only traditional loads. The static switch (SD) is used to island feeders 1 and 2 from the utility when events happen.

The fuel input is needed only for the DG, FC, and MT as the fuel for the WT and PV comes from nature. To serve the load demand, electrical power can be produced either directly by PV, WT, DG, MT, or FC. The diesel oil is a fuel input to a DG, whereas natural gas is a fuel input to fuel processor to produce hydrogen for the FC. The gas is also the input to the MT. The use of DG, or FC or MT with other fuel types can be modeled by changing the system parameters to reflect the change in the fuel consumption characteristics (e.g. fuel heating values, and efficiency of the engines).

Each component of the MG system is separately modelled based on its characteristics and constraints. The characteristics of some equipment like wind turbines and diesel generators are available from the appropriate manufacturers. Each of the local generation unit has a local controller (LC). This is responsible for local control that corresponds to a conventional controller (ex. automatic voltage regulator (AVR) or Governor) having a network communication function to exchange information between other LCs and the upper central controller to achieve an advanced control. The central controller also plays an important role as a load dispatch control centre in bulk power systems, which is in charge of distributed generator operations installed in MG.

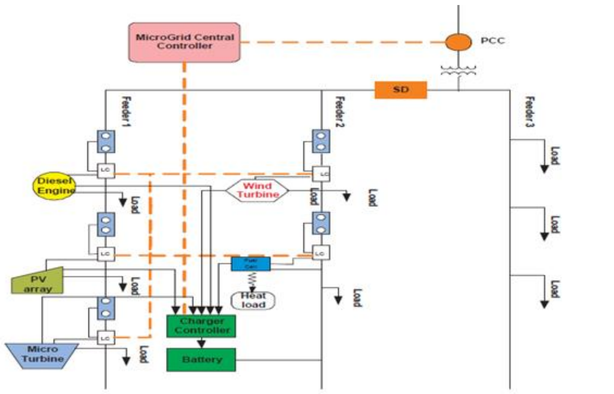

Figure 1.1: Micro Grid Architecture

Furthermore, the central controller is the main interface between the upper grid and the Micro grid. The central controller has the main responsibility for the optimization of the Micro grid operation, or alternatively, it coordinates the actions of the local controllers to produce the optimal outcome. MG technologies are playing an increasingly important role in the world's energy portfolio. They can be used to meet base load power, peaking power, backup power, remote power, power quality, and cooling and heating needs. Customers usually own small scale, on-site power generators, but they may be owned and operated by a third party.

If the distributed generator does not provide 100% of the customer's energy needs at all times, it can be used in conjunction with a distributed energy storage device or a connection with the local grid for backup power. The MG resources support and strengthen the central-station model of electricity generation, transmission, and distribution. The diagram depicted in Figure 1.1 shows how the grid looks after the addition of distributed resources. Although the central generating plant continues to provide most of the power to the grid, the distributed resources meet the peak demands of local distribution feeder lines or major customers. Computerized control systems, typically operating over telephone lines, make it possible to operate the distributed generators as dispatch able resources that generate electricity as needed.

2. CLASSIFICATION OF ENERGY RESOURCES

Energy resources are classified into non-renewable and renewable resources

Non-renewable Energy Resources
Non-renewable energy resources are the ones which are limited and become extinct with the time, such as oil, coal and coal derivatives, natural gas, wood and radioactive material (uranium, plutonium) and also produces a lot of harmful waste.

Renewable Energy Resources
Renewable energy resources are the ones that are continuously available and renewing itself with the time. Industrialization and ever increasing world population need the use of renewable energy resources. Solar energy, wind energy, biomass, tidal energy, wave energy, geothermal power are popular.
Research Objectives

- This work presents a micro grid based on wind turbine driven DFIG, DG and solar PV array with BES, in order to minimize the fuel consumption of DG.
- This paper presents a green energy solution to a micro grid for a location dependent on a diesel generator (DG) to meet its electricity requirement.
- This micro grid is powered by two renewable energy sources namely wind energy using doubly fed induction generator (DFIG) and solar photovoltaic (PV) array.
- The micro grid is modelled and simulated using Matlab-Simulink, for various scenarios such as varying wind speeds, varying insolation, effect of load variation on a bidirectional converter and unbalanced nonlinear load connected at point of common coupling (PCC).

3. DFIG SYSTEM

The doubly fed induction machine is the most widely machine in these days. The induction machine can be used as a generator or motor. Though demand in the direction of motor is less because of its mechanical wear at the slip rings but they have gained their prominence for generator application in wind and water power plant because of its obvious adoptability capacity and nature of tractability. This section describes the detail analysis of overall DFIG system along with back to back PWM voltage source converters.

Mathematical modelling of induction generator

DFIG is a wound rotor type induction machine, its stator consists of stator frame, stator core, poly phase (3-phase) distributed winding, two end covers, bearing etc. The stator core is stack of cylindrical steel laminations which are slotted along their inner periphery for housing the 3-phase winding. Its rotor consists of slots in the outer periphery to house the windings like stator. The machine works on the principle of Electromagnetic Induction and the energy transfer takes place by means of transfer action. So the machine can represent as a transformer which is rotatory in action not stationary. This section explains the basic mathematical modelling of DFIG. In this section the machine modelling is explained by taking two phase parameters into consideration.

Modelling of DFIG in synchronously rotating frame

Fig 3.1 and 3.2 demonstrates the equivalent circuit diagram of an induction machine. The machine is signified as a two phase machine in this figure.

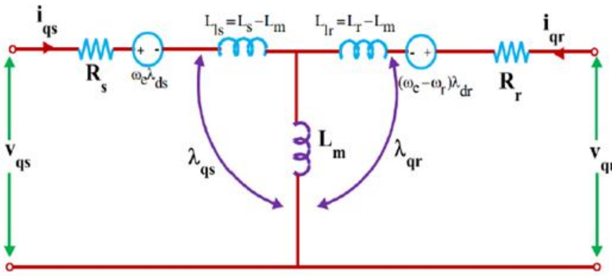

Fig 3.1. Dynamic d-q equivalent circuit of DFIG (q-axis circuit)

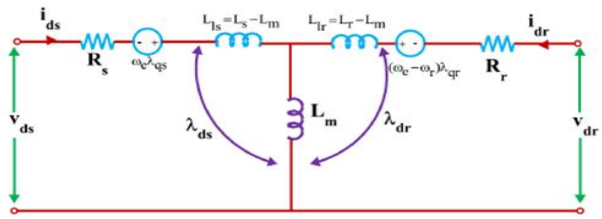

Fig 3.2. Dynamic d-q equivalent circuit of DFIG (d-axis circuit)

Equations for the stator circuit can be written as

$$v_{qs}^{s} = R_s i_{qs}^{s} + \frac{d}{dt}\lambda_{qs}^{s}$$

$$v_{ds}^{s} = R_s i_{ds}^{s} + \frac{d}{dt}\lambda_{ds}^{s}$$

In d-q frame above two Eq. can be written as

$$v_{qs} = R_s i_{qs} + \frac{d}{dt}\lambda_{qs} + (\omega_e \lambda_{ds})$$

$$v_{ds} = R_s i_{ds} + \frac{d}{dt}\lambda_{ds} - (\omega_e \lambda_{qs})$$

Where all the variables are in synchronously rotating frame. The bracketed terms indicate the back emf or speed emf or counter emf due to the rotation of axes as in the case of DC machines. When the angular speed ωe is zero, the speed e.m.f due to d and q axis is zero and the equations changes to stationary form. If the rotor is blocked or not moving, i.e. ωr = 0, the machine equations can be written as

$$v_{qr} = R_r i_{qr} + \frac{d}{dt}\lambda_{qr} + (\omega_e \lambda_{dr})$$

$$v_{dr} = R_r i_{dr} + \frac{d}{dt}\lambda_{dr} - (\omega_e \lambda_{qr})$$

4. SIMULATION & RESULTS

The schematic configuration of the micro grid is depicted in Fig. 4.1. It consists of wind turbine, DFIG, DG, solar PV array, BES, bidirectional buck/boost DC-DC converter, RSC, LSC, interfacing inductors, Δ/Y transformer, linear and nonlinear loads, circuit breakers (CB1 & CB2), DC link capacitor and ripple filters etc. This paper presents a green energy solution to a micro grid for a location dependent on a diesel generator (DG) to meet its electricity requirement. This micro grid is powered by two renewable energy sources namely wind energy using doubly fed induction generator (DFIG) and solar photovoltaic (PV) array. The solar PV array is directly connected to common DC bus of back-back voltage source converters (VSCs), which are connected in the rotor side of DFIG. Moreover, a battery energy storage (BES) is connected at same DC bus through a bidirectional buck/boost DC-DC converter to provide path for excess stator power of DFIG. The extraction of maximum power from both wind and solar, is achieved through rotor side VSC control and bidirectional buck/boost DC-DC converter control, respectively.

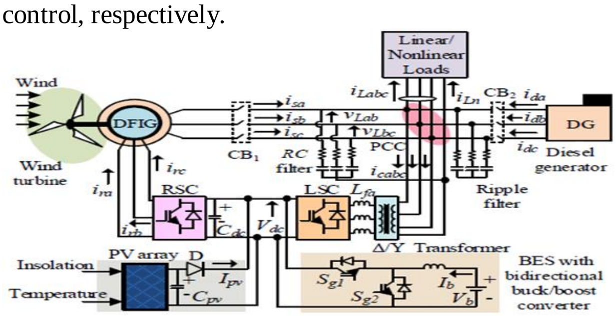

Fig. 4.1. DFIG based micro grid

This work presents a micro grid based on wind turbine driven DFIG, DG and solar PV array with BES, in order to minimize the fuel consumption of DG. In this, the DG is designed to deliver the base load requirement of a particular household locality. The main contributions of this study are on the control aspects of the scheme, which are as follows.

- A novel generalized concept is used to compute the reference DG power output for the DG to remain operating in optimal fuel consumption mode.
- The load side converter control (LSC) is designed to control DG along with the power quality issues such as load unbalance compensation, harmonics compensation and reactive power compensation.
- The RSC control is designed to extract maximum power from the wind turbine.
- The BES is connected to the common DC bus of back-back connected VSCs through a bidirectional buck/boost DC-DC converter. It aims to provide path for excess stator power of DFIG. Moreover, a solar PV array is directly connected at DC bus.
- The bidirectional buck/boost DC-DC converter control is designed in a way to extract maximum power from the solar PV array and to control the current through BES.
- A modified perturb and observe (P&O) MPPT algorithm is presented to obtain maximum power from a solar PV array.
- This micro grid configuration is implemented with minimum number of converters, thereby reducing the total system cost and switching losses.
- The DFIG stator currents and DG currents, are maintained balanced and sinusoidal, as per the IEEE 519 standard.

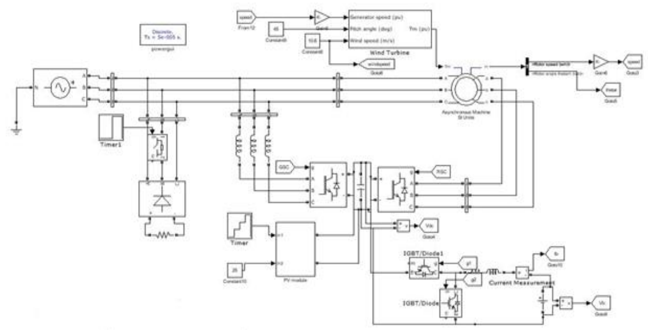

Fig.4.4. RSC control algorithm

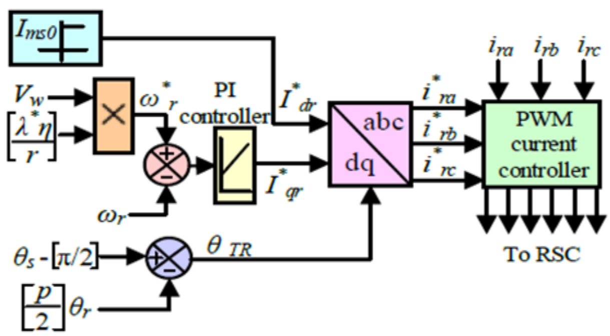

Fig. 4.5. LSC control algorithm

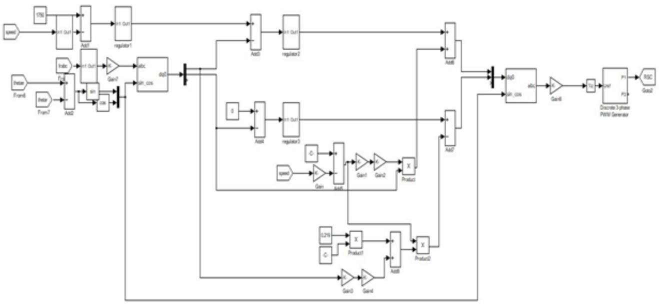

Fig. 4.6. LSC control algorithm

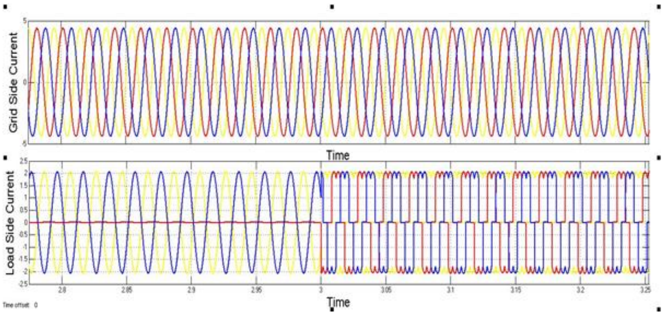

Fig.4.7- Grid Side and Load Side Current

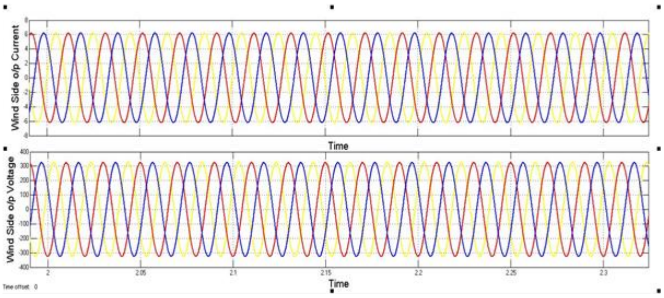

Fig.4.8- Wind Output Voltage and Current

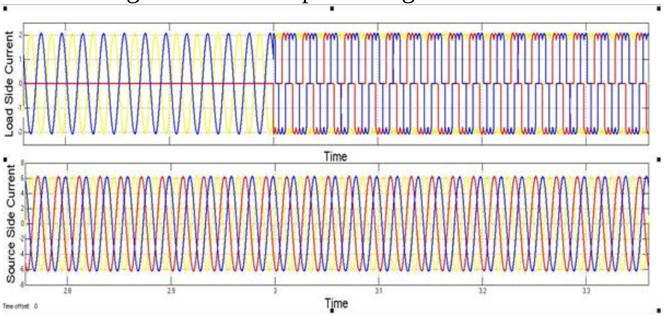

Fig.4.9- Load Side and Source side Current

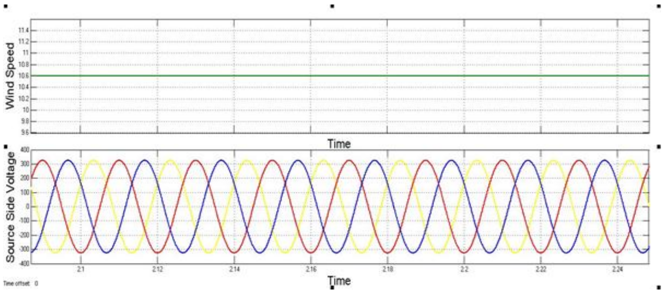

Fig.4.10- Wind Speed and Source side Voltage

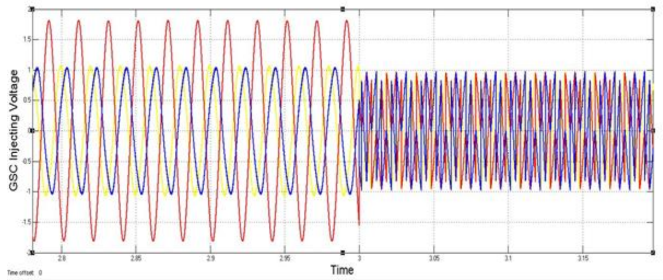

Fig.4.11- DFIG GSC injecting Voltage

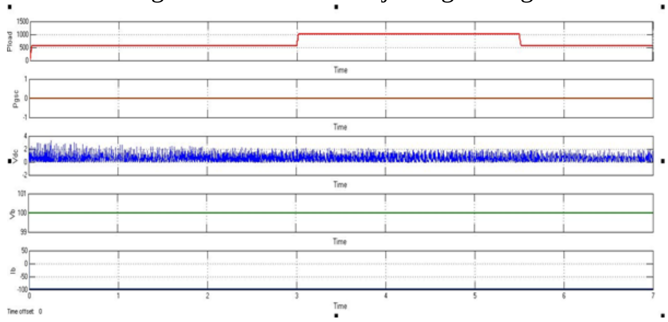

Fig.4.12- Microgrid All Parameters

5. CONCLUSION

This paper presents a hybrid wind/PV energy system for standalone system. The combined utilization of these renewable energy sources is therefore becoming increasingly attractive. In this Paper wind-PV-battery based hybrid power generation system has been proposed for standalone application. Modeling, control design, and stability analysis have been presented in detail. Simulated performance of the system has been obtained with an improved P&O method for MPPT in Solar PV. A novel generalized concept is used to compute the reference DG power output for optimal fuel consumption. The micro grid is modelled and simulated using Matlab-Simulink, for various scenarios such as varying wind speeds, varying insolation, effect of load variation on a bidirectional converter and unbalanced nonlinear load connected at point of common coupling (PCC).

REFERENCES

[1] Sambasivaiah Puchalapalli, S.K. Tiwari, Bhim Singh, and P.K. Goel, “A Microgrid Based on Wind Driven DFIG, DG and Solar PV Array for Optimal Fuel Consumption ", IEEE Transactions on Industry Applications, 0093-9994 (c) 2020 IEEE.

[2] Miloud Rezkallah, Sanjeev Singh, Ambrish Chandra, Bhim Singh, Marco Tremblay, Maarof Saad, and Hua Geng, “Comprehensive Controller Implementation for Wind-PV-Diesel Based Standalone Microgrid ", IEEE Transactions on Industry Applications, 0093-9994 (c) 2019 IEEE.

[3] Miloud Rezkallah, Sanjeev Singh, Ambrish Chandra, Bhim Singh, Marco Tremblay, Maarof Saad, and Hua Geng, “Real time Hardware Testing, Control and Performance Analysis of Hybrid Cost-

effective Wind-PV-Diesel Standalone Power Generation System", 978-1-5090-4894-6/17/© IEEE.

[4] Abir Muhtadi, and Ahmed Mortuza Saleque, "Modeling and Simulation of a Microgrid consisting Solar PV & DFIG based Wind Energy Conversion System for St.Martin's Island ", 978-1-7045-1585-6/18/© 2018 IEEE.

[5] K.V. Vidyanandan, and Nilanjan Senroy, "Improved Frequency Regulation in Wind-PV-DG Hybrid Microgrid using Wind Turbines ", 978-1-5090-0128-6/16/©2016 IEEE.

[6] Jesper Knudsen, Jan D. Bendtsen, Palle Andersen, Kjeld K. Madsen, and Claes H. Sterregaard," Supervisory Control Implementation on Diesel-Driven Generator Sets", IEEE Transactions on Industrial Electronics, 0278-0046 (c) 2018 IEEE.

[7] Waleed Obaid, Abdul-Kadir Hamid and Chaouki Ghenai," Hybrid Solar/Wind/Diesel Power System for Water Pumping Application", 978-1-7281-5152-6/19/©2019 IEEE.

[8] Mehmet Rida TUR, Nouha BOUCHIBA,"Techno-economic energy analysis of solar/wind/diesel generator hybrid system: Case study for Southeast Region of Turkey, Mardin", 978-1-5090-3407-9/16/ ©2016 IEEE.

[9] Cailing Zhu, Furong Liu, Sheng Hu and Shu Liu, "Research on capacity optimization of PV-wind-diesel-battery hybrid generation system", The 2018 International Power Electronics Conference ©2018 IEEE.

[10] M.M. Atiqur Rahman, Ali T. Al Awami, A.H.M.A. Rahim, "Hydro-PV-Wind-Battery-Diesel Based Stand-Alone Hybrid Power System", 978-1-4799-4819-2/14/ ©2014 IEEE.

