A Micro grid Based on Wind Driven DFIG and PV Array with Boost Converter

Abhinash Kumar[1], Durgesh Vishwakarma[2]

[1]M.tech Scholar, Department of Electrical & Electronics Engineering, REC Bhopal
[2]Asst. Prof., Department of Electrical & Electronics Engineering, REC Bhopal

---

Abstract - In this research work, a green energy microgrid solution for a location that relies on a diesel generator (DG) to supply electricity is presented. Two renewable energy sources—a solar photovoltaic (PV) array and wind energy from a double fed induction generator (DFIG)—power the microgrid. To maximise the power from wind and solar, rotor side VSC control and bidirectional buck/boost DC-DC converter control are employed, respectively. The microgrid is modelled and simulated for a number of scenarios using MATLAB's Sim Power Systems toolbox, such as changing wind speeds, changing insolation, the impact of load variations on a bidirectional converter, and an unbalanced nonlinear load coupled at the point of common coupling (PCC). The sinusoidal and balanced nature of the DG and DFIG stator currents is found. Another improvement to the model is a DC-DC boost converter connected to PVA for maximum power extraction controlled by the MPPT algorithm.

Key Words: Wind Turbine, DFIG, PV array, bidirectional buck/boost DC-DC converter,

1. Introduction

1.1 Microgrid-

As a result of the Micro smart-grid projects, microgrids are becoming a crucial component of the power systems of the future. When loads, distributed generators (DG), and energy storage devices are combined, a microgrid is created. Microgrids can function as autonomous power islands, in parallel with the grid, or as a transitional system between grid-connected and islanded modes. The microgrid concept effectively utilises all location-specific distributed generation (DG) and distributed energy resources (DERs) through the use of small transmission and distribution (T&D) networks. These self-sufficient power systems can function in isolated mode or connected to the main distribution grid, mostly using loads supplied by radial distribution systems.

The microgrids advantages are as follows:

i) offer a good way to supply power in the event of an emergency or power shortage during a main grid power outage;
ii) plug and play functionality allows you to switch between grid-connected and islanded modes of operation, protects voltage and frequency during islanded operation, and allows you to safely resynchronise your microgrid with the grid;
iii) you can operate independently without connecting to the main distribution grid during islanding mode, where all loads must be supplied and shared by distributed generations. Fuel cell, wind, and photovoltaic energy sources can all be integrated with a microgrid. Following implementation,

all the advantages of a microgrid may not become apparent right away because of higher cost of energy as compared to the cost of grid power.

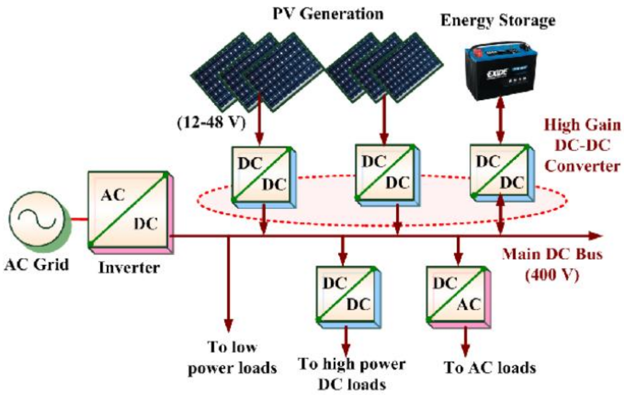

Figure 1: Block diagram of Microgrid

1.2 Maximum Power Point Tracking

A method for optimising power output from wind turbines and photovoltaic (PV) solar systems is called maximum power point tracking, or MPPT. Simply said, they transform the higher voltage DC output from solar panels (as well as some wind generators) into the lower voltage required for battery charging. Because MPPT maximises the power production of a photovoltaic system under specific conditions, it plays a crucial role in maximising array efficiency. The voltage and current at which the PV module may generate the most electricity possible is known as the maximum power point.The non-linear IPV-VPV characteristic changes in response to solar energy. Now think about the PV panel's power voltage as a feature. The maximum power point (MPP) is a distinct location on the IPV-VPV or PV curve where the complete PV system functions at peak efficiency and generates its highest output power. Although MPP's location is unknown, it can be found using search algorithms or calculating models. The most often used algorithms for implementing MPPT are the Incremental Conductance method (IC) and the Perturb and Observe method (P&O). A modified version of the incremental conductance approach is the algorithm we employ here. The incremental conductance method, which is based on the PV module's incremental and instantaneous conductance, always modifies the array terminal voltage in accordance with the MPP voltage. The most popular MPPT algorithms utilised in TEG systems are the open circuit voltage (OCV) and perturb and observe (P&O) approaches. An example of a hill climbing algorithm is the P&O algorithm. In order to obtain a desired value, hill climbing algorithms take steps over sampled data; in the instance of the P&O, this involves increasing or reducing the duty cycle in order to move closer to the MPP. A new maximum power point tracking (MPPT) method and a boost converter with variable output voltage are suggested, increasing efficiency by 10%. A modified P&O algorithm is suggested in this work. The tracking effectiveness of the suggested system is assessed through tests and simulations.

1.3 Perturb and Observe (P&O) Method

The P&O method is the most widely used MPPT algorithm. This method has few measured parameters and a straightforward feedback structure. This method involves periodically perturbing the array voltage and comparing the output power to that at the preceding perturbing cycle. By measuring ΔP and ΔV, the perturbation and observation approach determines the momentary operating region. The reference voltage is then adjusted based on the region to ensure that the systems function near the maximum power point. The approach is easy to implement because it merely modifies the reference voltage. Nevertheless, the technique is unable to easily monitor sudden and quick changes in the surrounding environment. The algorithm can be easily understood by the following flow chart:

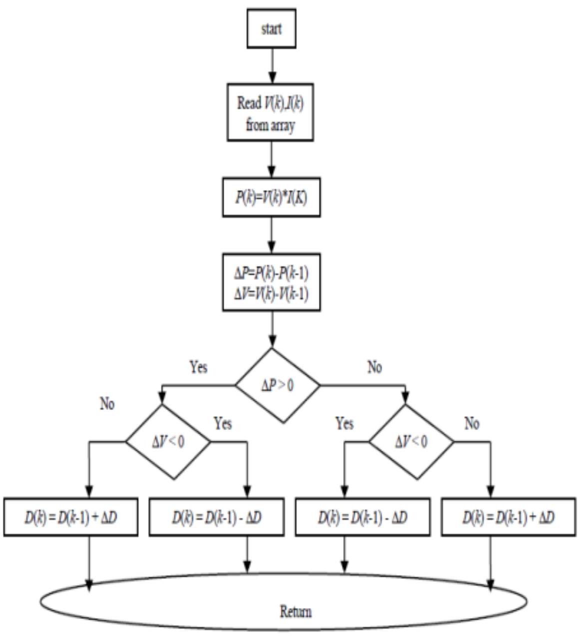

Figure 2: Flow Chart of P&O Algorithm

If raising the voltage in the P&O algorithm results in a higher output power, the system keeps raising the operating voltage until the power output reaches a maximum value (MPP) and begins to fall. The voltage is lowered to return to the MPP after the power output drops. This disturbance, which is regarded as the main flaw in the P&O algorithm, never stops and causes the power output value to fluctuate about the MPP.

1.4 DC-DC Converter

Electronic circuits that transform a dc voltage into a different voltage level are known as DC-DC converters. There are various kinds of conversion methods, including magnetic, capacitive, switched mode, electronic, and linear. This report's circuits fall under the category of switched mode DC-DC converters. When a DC electrical power transition from one voltage level to another is required, these electronic devices are utilized. When a switch or switches are used for power conversion, they can be considered SMPSs in general. We will now discuss DC-DC converters in relation to SMPS anytime we bring them up. A few applications of interest of DC-DC converters are where 5V DC on a personal computer motherboard must be stepped down to 3V, 2V or less for one of the latest CPU chips; where 1.5V from a single cell must be stepped up to 5V or more, to operate electronic circuitry. In all of these applications, we want to change the DC energy from one voltage level to another, while wasting as little as possible in the process. In other words, we want to perform the conversion with the highest possible efficiency. DC-DC Converters are needed because unlike AC, DC can't simply be stepped up or down using a transformer. In many ways, a DC-DC converter is the DC equivalent of a transformer. They essentially just change the input energy into a different impedance level. So whatever the output voltage level, the output power all comes from the input; there is no energy manufactured inside the converter. Quite the contrary, in fact some is inevitably used up by the converter circuitry and components, in doing their job.

2. Methodology

2.1 DC-DC Boost Converter

A DC-to-DC power converter that has an output voltage higher than its input voltage is called a boost converter. Such a switched-mode power supply (SMPS) has at least two semiconductor switches (a transistor and a diode) and at least one energy storage component, such as an inductor, capacitor, or both. To lessen output voltage ripple, filters consisting of capacitors—sometimes in conjunction with inductors—are typically added to the converter's output.

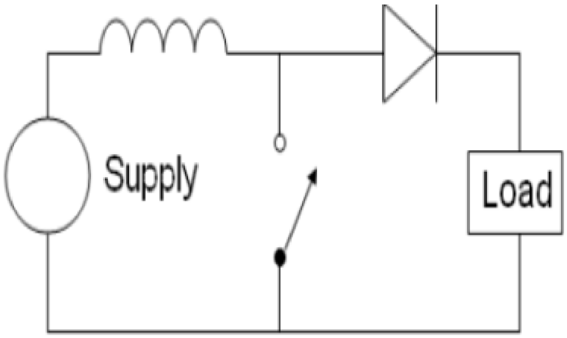

Figure 3 : The basic schematic of boost converter

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in the figure mentioned above. When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive. When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current flow towards the load. Thus, the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D. If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.

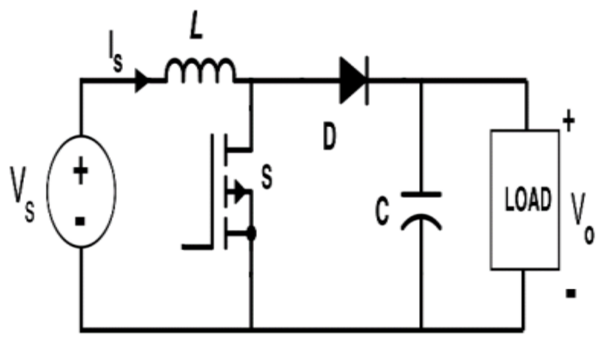

Figure 4: Boost converter Schematic

3. Simulation Results

The proposed system with DFIG connection to grid is shown in the figure given below.

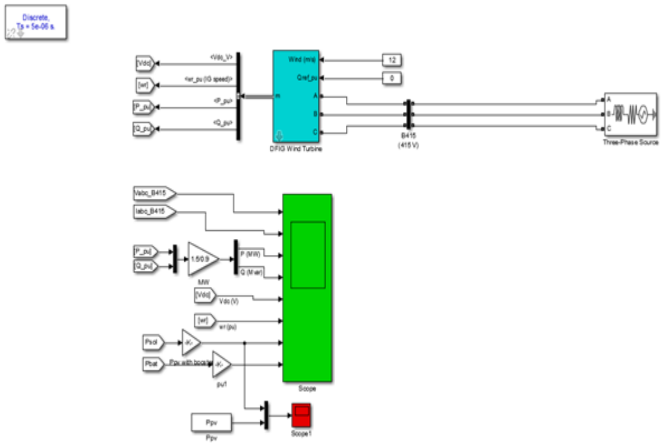

Figure 5: Proposed system with DFIG connection to grid

As seen in the above system the wound rotor induction machine is connected with back-to-back VSI converters through a DC link capacitance. The DC link is further added with PVA and battery module for power sharing along with the DFIG module. The below is the Line side VSI converter control modelling followed by rotor side converter control modelling. The below is the PVA module which is directly connected to the DC link with no converter.

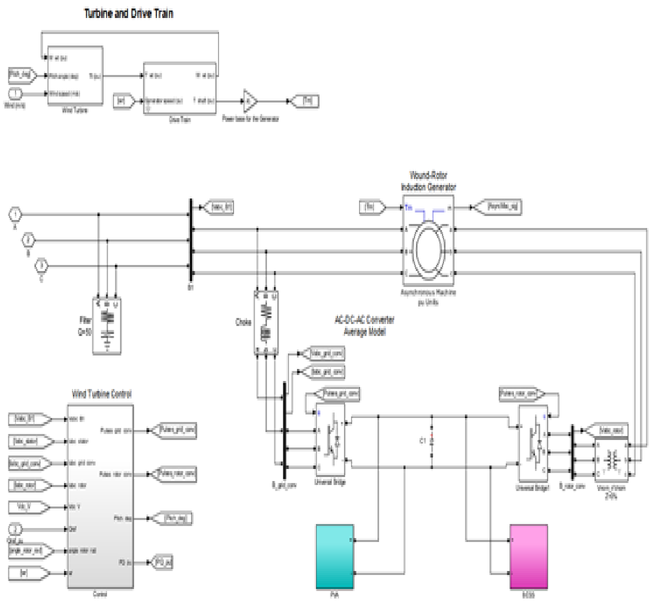

Figure 7: PV module internal modeling.

The below is the modeling of the battery storage module with DC-DC bidirectional converter controlling the charging and discharging of the battery. The charge control is done by the below control structure modelled with reference to solar power generated.

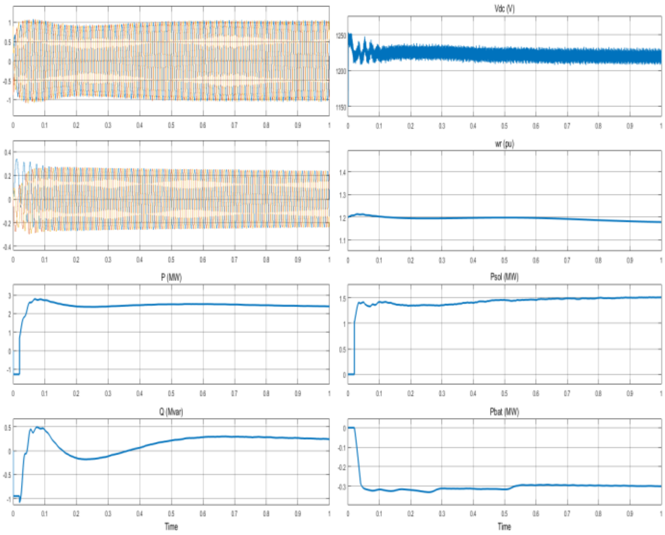

Figure 8: Generated results of the proposed system

The PCC voltage seen is maintained at 1pu and the total power injected by the DFIG module with PVA and battery storage module is 2.5MW. The reactive power is settled to 0MVAR gradually as there is no exchange of reactive power between the modules. The DC link voltage is maintained at 1200V and the speed of the machine is maintained above synchronous speed (1pu). The PVA power generated without MPPT is noted at 1.5MW and the battery is charging with 0.3MW represented in negative direction.

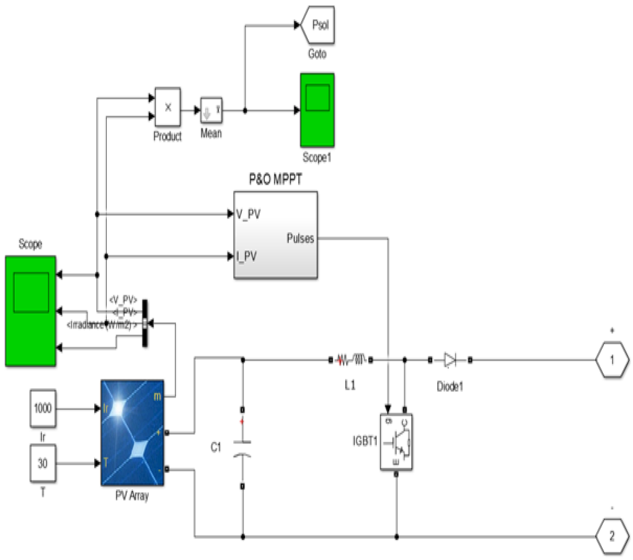

Figure 9: Modified PVA module with DC-DC booster converter

The above is the modification to the PVA module updated with DC-DC booster converter controlled by P&O MPPT for maximum power extraction. With this updated the simulation is run and the below results are recorded.

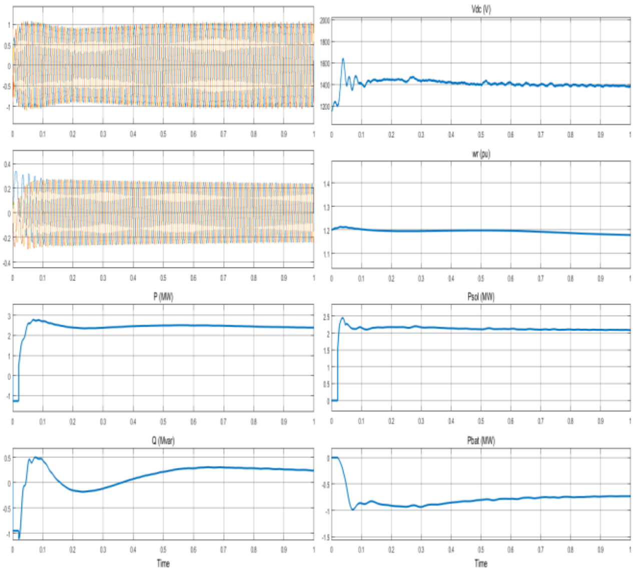

Figure 10: Generated results of the proposed system with PVA booster converter module

As seen in the above figure all the results are similar to the previous system with only change in the PVA power extraction. The power extracted by the DC-DC booster converter MPPT module is noted at 2.1MW which was previously noted at 1.5MW without DC-DC booster converter MPPT module. The comparison of the PVA extracted power is shown below with units in MW.

4. Conclusion

A microgrid with a minimal number of converters that is powered by wind turbines and consists of DFIG, DG, and solar PV arrays with BES has been introduced. While the BES is connected via a bidirectional buck/boost DC-DC converter, the solar PV array is directly connected to the DC link of back-back connected VSCs. Numerous scenarios, including variable wind speeds, variable insolation, and an unbalanced nonlinear load linked at PCC, have been studied for the system. Additionally, research has been done on the bidirectional buck/boost DC-DC converter's performance when the load changes. The system's ability to achieve optimal fuel economy has been demonstrated by simulation results.

References

[1] D. O. Johnson and A. A. Ogunseye, “GRID CONNECTED PHOTOVOLTAIC SYSTEM DESIGN FOR LOCAL GOVERNMENT OFFICES IN NIGERIA,” vol. 36, no. 2, pp. 571–581, 2017.
[2] V. R. Kolluru, R. K. Patjoshi, and R. Panigrahi, “A Comprehensive Review on Maximum Power Tracking of a Photovoltaic System Under Partial Shading Conditions,” vol. 9, no. 1, 2019.

[3] G. Sharma, "A Review on Grid-Connected PV System," no. June 2017, 2019, doi: 10.31142/ijtsrd2195.
[4] S. Alsadi, "applied sciences Status : A Review of Criteria , Constrains , Models , Techniques , and Software Tools," 2018, doi: 10.3390/app8101761.
[5] J. J. Khanam and S. Y. Foo, "Modeling of a photovoltaic array in MATLAB simulink and maximum power point tracking using neural network," vol. 2, no. 2, pp. 40–46, 2018.
[6] H. J. El Khozondar, R. J. El Khozondar, K. Matter, and T. Suntio, "A review study of photovoltaic array maximum power tracking algorithms," Renewables Wind. Water, Sol., 2016, doi: 10.1186/s40807-016-0022-8.
[7] S. Connors, "Design and Implementation of a Solar Power System in Rural Haiti by Certified by Design and Implementation of a Solar Power System in Rural Haiti," 2004.
[8] G. Shahgholian, "A brief review on microgrids: Operation, applications, modeling, and control," Int. Trans. Electr. Energy Syst., vol. 31, no. 6, pp. 1–28, 2021, doi: 10.1002/2050-7038.12885.
[9] A. Tetuko, "Analisis Kenerja Maximum Power Point Tracker (MPPT) Pada Sistem Photovoltaic Standalone Berbasis Algoritme Perturb And Observe (P & O)," vol. 8, no. 2, pp. 72–75, 2021.
[10] K. S. Patel and V. H. Makwana, "Performance Investigation of Grid-Connected DFIG using Integrated Shunt Active Filtering Capabilities," E3S Web Conf., vol. 184, no. January, 2020, doi: 10.1051/ e3sconf/ 202018401041.
[11] M. asif; D. sardar Ali, "POWER QUALITY OF A SMART GRID USING," vol. 11, no. 2, pp. 95–105, 2020. [12] I. T. MUSSA, "Design and Analysis of Dc-Dc Multilevel Boost Converter," no. February, 2019.
[13] M. Dalla Vecchia, J. Melo de Andrade, N. Colombo Dal Pont, A. Luís Kirsten, and T. Brunelli Lazzarin, "Proposal, Analysis and Experimental Verification of Nonisolated DC-DC Converters Conceived from an Active Switched-Capacitor Commutation Cell," Eletrônica de Potência, vol. 24, no. 4, pp. 403–412, 2019, doi: 10.18618/rep.2019.4.0031.
[14] A. Dida, "Adaptive P & O Control for MPPT Algorithm in DFIG System using Fuzzy Logic Controller," no. May, pp. 1–6, 2019.
[15] S. Ansari, "Assessment of Renewable Energy Sources of Iran," vol. 6, no. 12, pp. 206–211, 2019.
[16] A. Muhtadi, A. M. Saleque, and M. A. Mannan, "Solar and wind energy based microgrid: Study of architecture's potential at coastal areas in Bangladesh," AIUB J. Sci. Eng., vol. 17, no. 2, pp. 31–36, 2018, doi: 10.53799/ajse.v17i2.6.
[17] A. Muhtadi and A. M. Saleque, "Modeling and simulation of a microgrid consisting solar PV & DFIG based wind energy conversion system for St. Martin's island," 2017 IEEE 3rd Int. Conf. Eng. Technol. Soc. Sci. ICETSS 2017, vol. 2018-Janua, no. August, pp. 1–6, 2018, doi: 10.1109/ICETSS.2017.8324152.
[18] D. Dhakad and Maurya, "Integrated Renewable Energy System with the use of Battery Energy Storage," Int. J. Trend Sci. Res. Dev., vol. Volume-2, no. Issue-3, pp. 1261–1265, 2018, doi: 10.31142/ijtsrd11289.
[19] N. H. Baharudin, T. M. N. T. Mansur, F. A. Hamid, R. Ali, and M. I. Misrun, "Performance Analysis of DC-DC Buck Converter for Renewable Energy Application," J. Phys. Conf. Ser., vol. 1019, no. 1, 2018, doi: 10.1088/1742-6596/1019/1/012020.
[20] S. Priya, M. Marimuthu, S. Vijayalakshimi, and S. P. Perumal, "MODELLING AND SIMULATION OF HYBRID (WIND and SOLAR) FOR DC MICROGRID," vol. 9, no. 3, pp. 163–167, 2018
[21] T. Dobbin, "Modelling and control of a doubly-fed generator with variable speed wind turbine for electromechanical stability studies .," no. July 2014, 2018.