ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Control and Operation of DC Grid –Based Wind Power Generation in Micro-Grid



Pathapati Janardhanareddy
M.Tech Student
SSN Engineering College, Ongole.

T Mahendra Reddy, M.Tech
Assistant Professor
SSN Engineering College, Ongole.

K Sowjan Kumar, M.Tech
HoD
SSN Engineering College, Ongole.

Introduction

Poultry farming is the raising of domesticated birds such as chickens and ducks for the purpose of farming meat or eggs for food. To ensure that the poultries remain productive, the poultry farms in Singapore are required to be maintained at a comfortable temperature. Cooling fans, with power ratings of tens of kilowatts, are usually installed to regulate the temperature in the farms. Besides cooling the farms, the wind energy produced by the cooling fans can be harnessed using wind turbines (WTs) to reduce the farms' demand on the grid. The Singapore government is actively promoting this new concept of harvesting wind energy from electric ventilation fans in poultry farms which has been implemented in many countries around the world. The major difference between the situation in poultry farms and common wind farms is in the wind speed variability. The variability of wind speed in wind farms directly depends on the environmental and weather conditions while the wind speed in poultry farms is generally stable as it is generated by constant-speed ventilation fans. Thus, the generation intermittency issues that affect the reliability of electricity supply and power balance are not prevalent in poultry farm wind energy systems. In recent years, the research attention on dc grids has been resurging due to technological advancements in power electronics and energy storage devices, and increase in the variety of dc loads and the penetration of dc distributed energy resources (DERs) such as solar photovoltaic's and fuel cells. Many research works on dc microgrids have been conducted to facilitate the integration of various DERs and energy storage systems.

In a dc microgram based wind farm architecture in which each wind energy conversion unit consisting of a matrix converter, a high frequency transformer and a single-phase ac/dc converter is proposed. However, the proposed architecture increases the system complexity as three stages of conversion are required. In a dc micro grid based wind farm architecture in which the WTs are clustered into groups of four with each group connected to a converter is proposed. However, with the proposed architecture, the failure of one converter will result in all four WTs of the same group to be out of service. The research works conducted in are focused on the development of different distributed control strategies to coordinate the operation of various DERs and energy storage systems in dc micro grids. These research works aim to overcome the challenge of achieving a decentralized control operation using only local variables. However, the DERs in dc micro grids are strongly coupled to each other and there must be a minimum level of coordination between the DERs and the controllers. In a hybrid ac/dc grid architecture that consists of both ac and dc networks connected together by a bidirectional converter is proposed. Hierarchical control algorithms are incorporated to ensure smooth power transfer between the ac micro grid and the dc micro grid under various operating conditions.

However, failure of the bidirectional converter will result in the isolation of the dc micro grid from the ac micro grid.

In an investigation on the usefulness of the MPC in the control of parallel-connected inverters is conducted. The research work is, however, focused mainly on the control of inverters for uninterruptible power supplies in standalone operation. The MPC algorithm will operate the inverters close to their operating limits to achieve a more superior performance as compared to other control methods which are usually conservative in handling constraints. In this paper, the inverters are controlled to track periodic current and voltage references and the control signals have a limited operating range. Under such operating condition, the MPC algorithm is operating close to its operating limits where the constraints will be triggered repetitively. In conventional practices, the control signals are clipped to stay within the constraints, thus the system will operate at the sub-optimal point.

This results in inferior performance and increases the steady-state loss. MPC, on the contrary, tends to make the closed-loop system operate near its limits and hence produces far better performance. MPC has also been receiving increased research attention for its applications in energy management of micro grids because it is a multi-input, multi-output control method and allows for the implementation of control actions that predict future events such as variations in power generation by intermittent DERs, energy prices and load demands. In these research works, the management of energy is formulated into different multi-objective optimization problems and different MPC strategies are proposed to solve these optimization problems. The scope of this paper is however focused on the application of MPC for the control of inverters. In what follows, a comprehensive solution for the operation of a dc grid based wind power generation system in a microgrid is proposed for a poultry farm and the effectiveness of the proposed system is verified by simulation studies under different operating conditions.

DISTRIBUTED GENERATION AND MICROGRID

OVERVIEW OF DISTRIBUTION SYSTEM

A part of power system which distributes the electrical power for local use is known as “Distribution system”. It lies between the substation fed by the transmission system and the consumer meters.

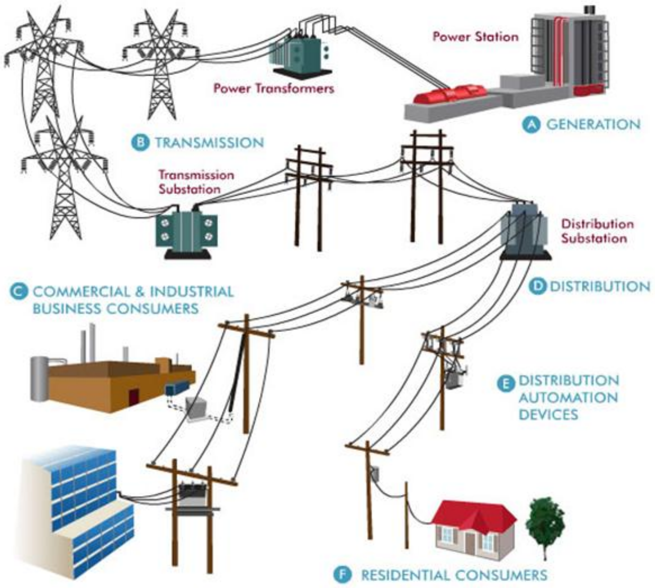


Fig.2.1 Simple model of Electrical Distribution system

Typical diagram of distribution system is shown in fig.2.1 the transmission system is distinctly different from the distribution system.

Distributed generation takes place on two-levels: the local level and the end-point level. Local level power generation plants often include renewable energy technologies that are site specific, such as solar systems (photovoltaic and combustion), fuel cells and wind turbines.

INTRODUCTION TO DISTIBUTION SYSTEM

The portion of the power network between a secondary substation and consumers is known as distribution system. The distribution system can be classified into primary and secondary system. Some large consumers are given high voltage supply from the receiving end substations or secondary substation. The area served by a secondary substation can be subdivided into a number of sub- areas. Each sub area has its primary and secondary distribution system. The primary distribution system consists of main feeders and laterals.

The main feeder runs from the low voltage bus of the secondary substation and acts as the main source of supply to sub-feeders, laterals or direct connected distribution transformers. The lateral is supplied by the main feeder and extends through the load area with connection to distribution transformers. The distribution transformers are located at convenient places in the load area. They may be located in specially constructed enclosures or may be pole mounted.

The distribution transformers for a large multi storied building may be located within the building itself. At the distribution transformer the voltage is stepped down to 400V and power is fed into the secondary distribution systems.

The secondary distribution system consists of distributors which are laid along the road sides. The service connections top consumers are tapped off from the distributors. The main feeders, laterals and distributors may consist of overhead lines or cables or both. The distributors are 3 phase, 4 wire circuits, the neutral wire being necessary to supply the single phase loads.

The following is a list of those of potential interest to electric utilities. The main part of distribution system includes.

- Receiving substation
- Sub- transmission lines
- Distribution substation located nearer to the load centre
- Secondary circuits on the LV side of the distribution transformer.
- Service mains
- Where the later draws power from the single source and transmits it to individual loads, the transmission system not only handles the largest blocks of power but also the system.

The distribution system is categorized into the sub-divisions:

- Primary distribution system
- Secondary distribution system

Primary distribution

It is that part of A.C distribution system which operates at voltages somewhat higher than general utilization and handles large blocks of electrical energy than the average low-voltage consumer uses. The voltage used for primary distribution depends upon the amount of power to be conveyed and the distance of the substation required to be fed. The most commonly used primary distribution voltages are 11 kV, 6•6 kV and 3•3 kV.

Due to economic considerations, primary distribution is carried out by 3- phase, 3-wire system. It carries loads at higher than utilization voltages from the substation to the point where the voltage is to be stepped down to the value at which the consumer utilizes the energy. It is a 3-phase, 3-wire with voltage ratings of 11KV, 33KV and 66KV.

SECONDARY DISTRIBUTION

It includes the part of the system operation at utilization voltages, up to the energy-meter at the consumer's premises. It is a 3-phase, 4-wire with voltage ratings of 11KV/400V/230V.

This independent system provides electricity to replace the normal source if it fails and thus allows the customer’s entire facility to continue to operate satisfactorily. Since these local level DG producers often take into account the local context, the usually produce less environmentally damaging or disrupting energy than the larger central model plants.

At the end-point level the individual energy consumer can apply many of these same technologies with similar effects. In the secondary distribution system their need of the consumer where the consumer supplied power through the distribution system of the power system where there is secondary uses.

The fig.2.2 shows that simple model of electrical distribution system and also it shows the primary and secondary distribution system.

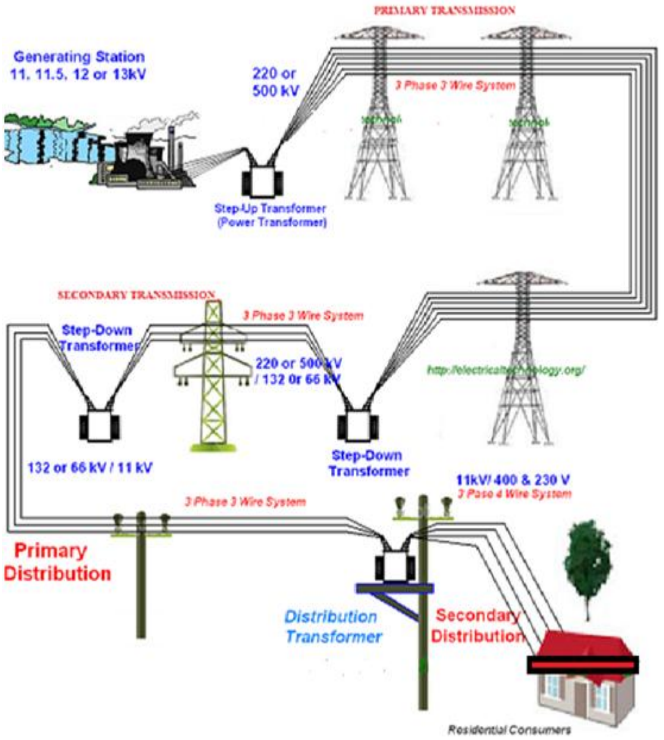


Fig.2.2 Model of electrical primary and secondary distribution system

DISTRIBUTION SYSTEM LOAD FLOW

The load flow of a power network provides the steady state solution through which various parameters of interest like currents, voltages, losses etc can be calculated. The load flow is important for the analysis of distribution system, to investigate the issues related to planning, design and the operation and control. Some applications like optimal capacitor placement in distribution system and distribution automation system, requires repeated load flow solution. Many methods such as Gauss-Seidel, Newton-Raphson are well reported to carry out the load flow of transmission system.

The use of these methods for distribution system may not be advantageous because they are mostly based on the general meshed topology of a typical transmission system where as most distribution systems have a radial or tree structure. Further distribution system posses high R/X ratio, which cause the distribution systems to be ill conditioned for conventional load flow methods. Some other inherent characteristics of electric distribution systems are

- Radial or weakly meshed structure
- unbalanced operation and unbalanced distributed loads
- large number of buses and branches
- It has wide range of resistance and reactance values
- Distribution system has multiphase operation.

DISTRIBUTED GENERATION AS A VIABLE ALTERNATIVE

Traditionally, electrical power generation and distribution are purely a state owned utility. However, in order to keep up with the growing demand, many states and provinces in North America are deregulating the electrical energy system. This trend is not without its own challenges. For example, how is an independent power producer (IPP) able to enter the market.

Recent innovations in power electronics such as fast switching, high voltage Insulated Gate Bipolar Transistors (IGBT) and developments in power generation technologies have made DG a considerable alternative to either delaying infrastructure upgrades or as additional cogeneration support. Though the cost per KW-hr is still higher than basic power grid distribution costs, (4.36rupees/Kw-hr for gas turbines and as high as 31.13rupees/KW-hr for PV). The trend to completely deregulate the North American electric power grid along with the increasing trend in the cost of fossil fuels has resulted in the consideration of DG as a viable opportunity. Currently, BC Hydro, Canada’s third largest utility has more than 50 Distributed Generator stations ranging from 0.07 MVA to 34 MVA. In the distributed system has various alternative source which always available in the nature of the system. Although the distributed system is not reliable there are renewable to system.

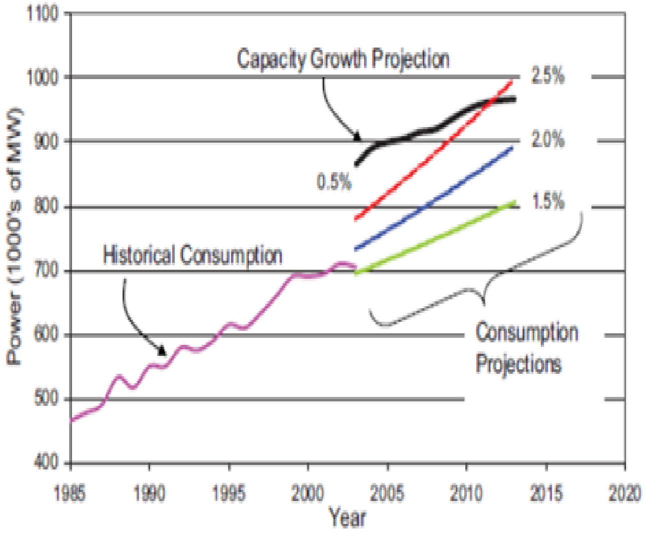


Fig.2.3 2006 United States Projected Summer Generation and Capacity

TYPES OF DISTRIBUTED GENERATION

Distributed Generators can be broken into three basic classes: induction, synchronous and asynchronous. Induction generators require external excitation (VARs) and start up much like a regular induction motor. They are less costly than synchronous machines and are typically less than 500 KVA. Induction machines are most commonly used in wind power applications.

Alternatively, synchronous generators require a DC excitation field and need to synchronize with the utility before connection. Synchronous machines are most commonly used with internal combustion machines, gas turbines, and small hydro dams. These plants tend to be smaller and less centralized than the traditional model plants. They also are frequently more energy and cost efficient and more reliable. Some of these DG technologies offer high efficiency, resulting in low fuel costs, but emit a fair amount of pollutants (CO and NO); others are environmentally clean but are not currently cost-effective. Still others are well suited for peaking applications but lack durability for continuous output. With so much to consider, it is often difficult for decision makers to determine which technology is best suited to meet their specific energy needs.

Table.2.1 Types of DG and Typical Capacities

Technology	Typical Cap	Utility Interface
Photovoltaic	10va To 5000va	Inverter
Wind	10va To 500kva	Induction And Syncronous Generators Inverters
Geothermal	100va To Several Mva	Syncronous Generator
Micro Hydro	100va To Several Mva	Induction Or Syncronous Generator
Reciprocating Engine	1000va To Several Mva	Induction Or Sycronous Generator
Comubtion Turbine	1000va To Several Mva	Syncronous Generator
Combined Cycle	1000va To Several Mva	Sycronous Generator
Micro Turbines	10 Kva To Several Mva	Inverter
Fuel Cells	10 Kva To Several Mva	Inverter

DISTRIBUTION SYSTEM WITH MULTIPLE DGS

Distributed or dispersed generation may be defined as generating resources other than central generating stations that is placed close to load being served, usually at customer site. It serves as an alternative to or enhancement of the traditional electric power system.
The commonly used distributed resources are wind power, photo voltaic, hydro power. The fig.2.4 shows the single line diagram of the distribution system with multiple DGs.

Small localized power sources, commonly known as “Distributed Generation” (DG), have become a popular alternative to bulk electric power generation. There are many reasons for the growing popularity of DG; however, on top of DG tending to be more renewable.

DG can serve as a cost effective alternative to major system upgrades for peak shaving or enhancing load capacity margins. Additionally, if the needed generation facilities could be constructed to meet the growing demand, the entire distribution and transmission system would also require upgrading to handle the additional loading.

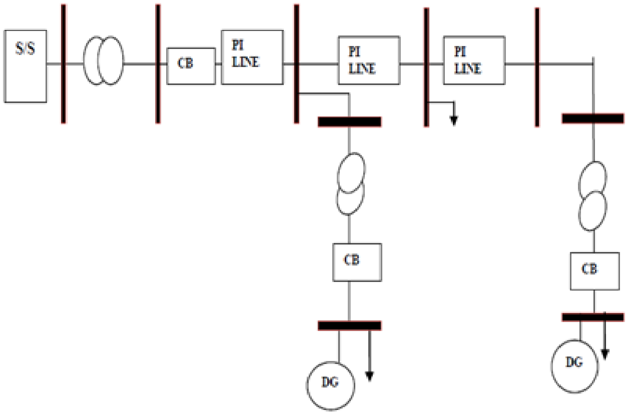


Fig.2.4 Single line diagram of Distributed system with multiple DGs

Therefore, constructing additional power sources and upgrading the transmission system will take significant cost and time, both of which may not be achievable.

Advantages of distributed generations

DG resources can be located at numerous locations within a utility's service area. This aspect of DG equipment provides a utility tremendous flexibility to match generation resources to system needs.

- Improved Reliability - DG facilities can improve grid reliability by placing additional generation capacity closer to the load, thereby minimizing impacts from transmission and distribution (T&D) system disturbances, and reducing peak-period congestion on the local grid.
- Improved Security - The utility can be served by a local delivery point. This significantly decreases the vulnerability to interrupted service from imported electricity supplies due to natural disasters, supplier deficiencies or interruptions, or acts of terrorism.
- Reduced Loading of T&D Equipment - By locating generating units on the low-voltage bus of existing distribution substations, DG will reduce loadingson substation power transformers during peak hours, thereby extending the useful life of this equipment and deferring planned substation upgrades.
- Reduces the necessity to build new transmission and distribution lines or upgrade existing ones.
- Reduce transmission and distribution line losses.
- Improve power quality and voltage profile of the system.
- In fact, many utilities around the world already have a significant penetration of DG in their system. But there are many issues to be taken into account with the DG and one of the main issues is islanding.

MICROGRID STRUCTURE AND COMPONENTS

The fig.2.5 shows the structure of a micro-grid. This structure is based on renewable energy sources. The main grid is connected to the micro-grid at the point of a common coupling. Each micro-grid has a different structure (number of the DGs and types of DGs), depending on the load demand. A micro-grid is designed to be able to supply its critical load. Therefore, DGs should insure to be enough to supply the load as if the main grid is disconnected. The micro-grid consists of micro sources, power electronic converters, distributed storage devices, local loads, and the point of common coupling (PCC).

The grid voltage is reduced by using either a transformer or an electronic converter to a medium voltage that is similar to the voltage produced from the DG

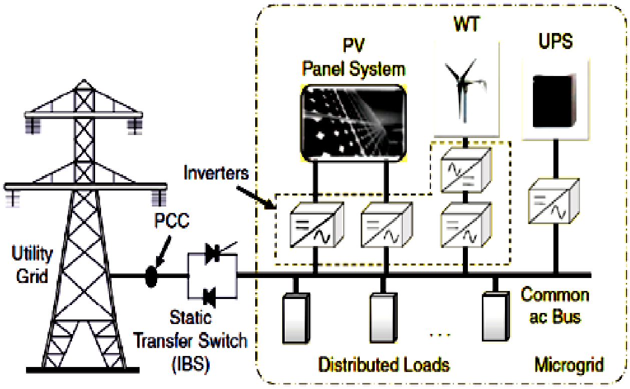


Fig.2.5 Micro-grid Structure based on renewable energy sources

The components of the micro-grid are as follows.

- Micro source
- Power electronics converters
- Various loads on micro grid
- Storage devices
- Control system

WIND ENERGY CONVERSION SYSTEMS

WIND TURBINE TECHNOLOGY

The wind turbine is the first and foremost element of wind power systems. There are two main types of wind turbines, the horizontal-axis and vertical-axis turbines.

Horizontal-axis Turbines

Horizontal-axis turbines (see Figure 3.1) are primarily composed of a tower and a nacelle mounted on top of tower. The generator and gearbox are normally located in the nacelle. It has a high wind energy conversion efficiency, self-starting capability, and access to stronger winds due to its elevation from the tower. Its disadvantages, on the other hand, include high installation cost, the need of a strong tower to support the nacelle and rotor blade, and longer cables to connect the top of the tower to the ground.

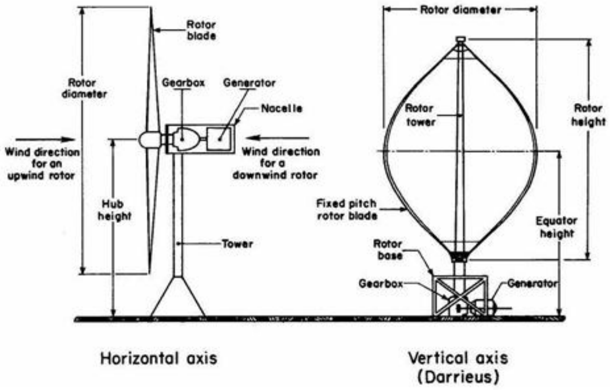


Figure 3.1: illustration of a horizontal axis and a vertical axis wind turbine.

Vertical-axis Turbines

A vertical axis turbines' spin axis is perpendicular to the ground (See Figure 3.1). The wind turbine is vertically mounted, and its generator and gearbox is located at its base. Compared to horizontal-axis turbines, it has reduced installation cost, and maintenance is easier, because of the ground level gear box and generator installation. Another advantage of the vertical axis turbine is that its operation is independent of wind direction. The blades and its attachments in vertical axis turbines are also lower in cost and more rugged during operation. However, one major drawback of the vertical wind turbine is that it has low wind energy conversion efficiency and there are limited options for speed regulation in high winds. Its efficiency is around half of the efficiency of horizontal axis wind turbines. Vertical axis turbines also have high torque fluctuations with each revolution, and are not self-starting. Mainly due to efficiency issue, horizontal wind turbines are primarily used. Consequently, the wind turbine considered in this thesis is a horizontal axis turbine.

TYPES OF HORIZONTAL-AXIS WIND TURBINES

Pitched Controlled Wind Turbines

Pitch controlled wind turbines change the orientation of the rotor blades along its longitudinal axis to control the output power. These turbines have controllers to check the output power several times per second, and when the output power reaches a maximum threshold, an order is sent to the blade hydraulic pitch mechanism of the turbine to pitch (or to turn) the rotor slightly out of wind to slow down the turbine. Conversely, when the wind slows down, then the blades are turned (or also known as pitched) back into the wind. During operation, the blades are pitched a few degrees with each change in wind to keep the rotor blades at the optimum angle to maximum power capture.

Stalled Controlled Wind Turbines

The rotor blades of a stall controlled wind turbine are bolted onto the hub at a fixed angle. The blades are aerodynamically designed to slow down the blades when winds are too strong. The stall phenomenon caused by turbulence on rotor blade prevents the lifting force to act on the rotor. The rotor blades are twisted slightly along the longitudinal axis so that the rotor blade stalls gradually rather than suddenly when the wind reaches the turbines' critical value.

Active Stall Controlled Wind Turbines

Active stall turbines are very similar to the pitch controlled turbine because they operate the same way at low wind speeds. However, once the machine has reached its rated power, active stall turbines will turn its blades in the opposite direction from what a pitch controlled machine would. By doing this, the blades induces stall on its rotor blades and consequently waste the excess energy in the wind to prevent the generator from being overloaded. This mechanism is usually either realized by hydraulic systems or electric stepper motors.

TYPES OF WIND ENERGY CONVERSION SYSTEMS (WECS)

There are two main types of WECSs, the fixed speed WECS and variable-speed WECS. The rotor speed of a fixed-speed WECS, also known as the Danish concept, is fixed to a particular speed. The other type is the variable-speed WECS where the rotor is allowed to rotate freely. The variable-speed WECS uses power maximization techniques and algorithms to extract as much power as possible from the wind.

Fixed Speed Wind Energy Conversion Systems

As the name suggests, fixed speed wind energy systems operate at a constant speed. The fixed speed WECS configuration is also known as the “Danish concept” as it is widely used and developed in Denmark. Normally, induction (or asynchronous) generators are used in fixed speed WECSs because of its inherent insensitivity to changes in torque. The rotational speed of an induction machine varies with the force applied to it, but in practice, the difference between its speed at peak power and at idle mode (at synchronous speed) is very small.

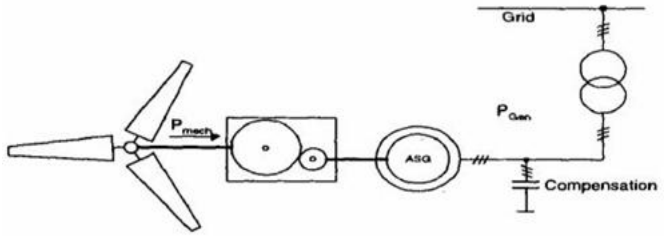


Figure 3.2: A typical fixed speed wind turbine configuration.

Variable Speed Wind Turbine Systems

In variable speed wind turbine systems, the turbine is not directly connected to the utility grid. Instead, a power electronic interface is placed between the generator and the grid to provide decoupling and control of the system. Thus, the turbine is allowed to rotate at any speed over a wide range of wind speeds. It has been discussed earlier that each wind speed has a corresponding optimal rotor speed for maximum power.

With the added control feature of variable speed systems, they are capable of achieving maximum aerodynamic efficiency. By using control algorithms and/or mechanical control schemes (i.e. pitch controlled, etc), the turbine can programmed to extract maximum power from any wind speed by adjusting its operating point to achieve the TSR for maximum power capture. The mechanical stresses on the wind turbine are reduced since gusts of wind can be absorbed (i.e. energy is stored in the mechanical inertia of the turbine and thus reduces torque pulsations). Another advantage of this system is that the power quality can be improved by the reduction of power pulsations due to its elasticity. The disadvantages of the variable speed system include the additional cost of power converters and the complexity of the control algorithms. In this thesis, an adaptive maximum power point tracking control algorithm is developed for variable speed energy systems to achieve maximum efficiency under fluctuating wind conditions.

MODELING OF A VARIABLE SPEED WIND TURBINE WITH PMSG

Full Scale Wind Turbines (FSWT) are the state-of-the-art type wind turbines that the generator is completely decoupled from the grid with two back-to-back converters and whole power is transferred through these controlled converters. One converter is used on the generator side and the other one is used on the grid side. FSWTs can employ both induction (asynchronous) and synchronous type generators, where synchronous generators can be separately excited (conventional) or permanent magnet type. Generally multi-pole permanent magnet synchronous generators are employed, which removes the need for a gearbox between wind turbine rotor and generator. Since this type of wind turbines has many advantages like mechanical reliability, better efficiency, reduced risk of possible drive-train oscillations, this thesis will deal with PMSG type FSWTs.

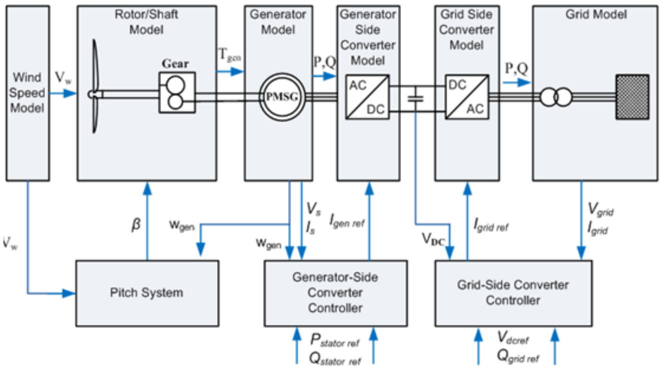


Figure 3.11 Block Diagram of PMSG Type Wind Turbine

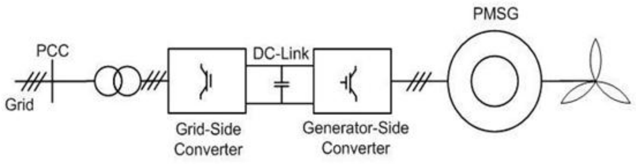
Figure 3.11 depicts the general block diagram of a VSWT with PMSG. As seen, the model of a VSWT equipped with PMSG is very similar to that of a VSWT with a DFIG. Wind speed model, rotor (aerodynamic) model and pitch model are identical to those in DFIG type wind turbine model.

Shaft Modeling

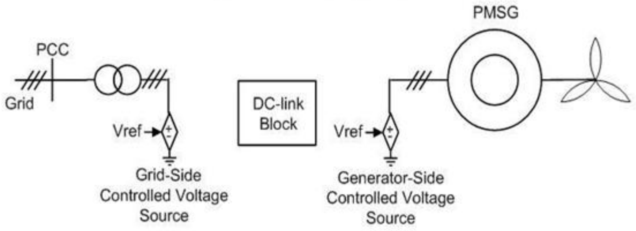
Directly connecting rotor to the generator and connecting the rotor to the generator over a gearbox are the two options for shaft system. The former method, known as direct- drive, has the advantages of being simple, mechanically reliable, efficient and having a lower risk of possible drive-train oscillations, and hence it is the state-of the- art technology for PMSG type turbines. For direct-drive systems, shaft model is not required and for the connections with gearbox, the shaft model explained in DFIG section can be used.

Converter Modeling

Although there are several options for converters to connect the generator to the grid, the converter model used in PMSG type wind turbines is very similar to the one in DFIG type turbines. The difference is, since generator is completely decoupled from the grid with two back-to-back converters, whole power is transferred through those controlled converters. Hence, the converter ratings must be equal to ratings of the generator and the converter must be able to work as a rectifier and as an inverter to allow transfer energy in both directions. Similar to DFIG converter model, the generator-side converter is responsible for controlling the generator active and reactive power. On the other hand, the grid-side converter is responsible for controlling the DC-link voltage and reactive power output of the converter. Therefore, as in DFIG, converters can be modeled as controlled voltage sources as shown in Figure 3.12.



a)PMSG with Back-to-Back VSC



b)PMSG with Controlled Voltage Sources

Figure 3.12 Converter Models of PMSG Type Wind Turbines

Generator Modeling

PMSG is a special type of synchronous machine with constant field. Since detailed explanation of synchronous machine equivalent circuit and equations are present the PMSG model is not investigated in detail. Thus a model of PMSG similar to the synchronous machine model explained in will be constructed based on the following assumptions:

- Distributions of stator windings are sinusoidal,
- Magnetic hysteresis and saturation effects are negligible,
- Stator winding is symmetrical,
- Damping windings are not considered,
- Resistances are constant.

In order to apply vector control to a PMSG, according to above assumptions, the steady state equivalent circuit will be transformed into rotor (flux) oriented d-q equivalent circuit as shown in Figure 3.13.

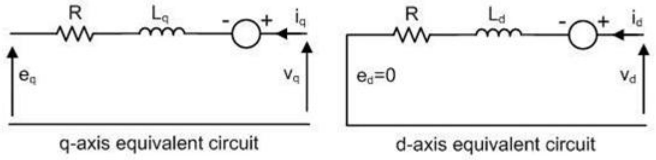


Figure 3.13 D-Q Equivalent Circuit of PMSG

GRID-SIDE CONVERTER CONTROLLER MODELING

As in DFIG, grid-side converter of PMSG is responsible for injection of reactive power to the grid and regulation of DC-link voltage. Since the converter model and the connection diagram of converter are same with DFIG, controller model of grid side converter is same as DFIG grid-side converter. Then Figure 3.14 can be used for the vector control scheme.

GENERATOR-SIDE CONVERTER CONTROLLER MODELING

Similar to DFIG rotor-side converter, the main objective of the generator-side converter of PMSG is controlling the generator active and reactive power. However, generator-side converter is directly connected to the stator of the generator as in Figure 3.15 unlike DFIG.

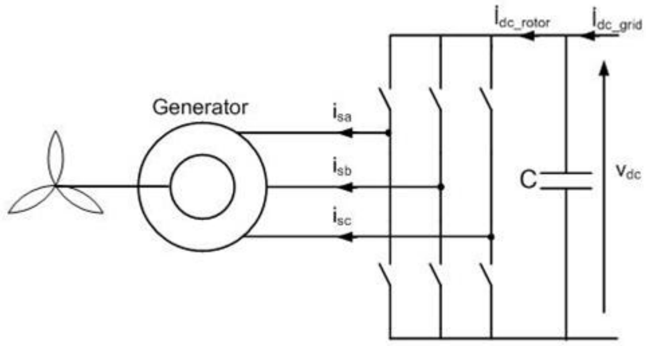


Figure 3.14 Connection Diagram of Generator Side Converter

Since the converter model is same with DFIG rotor side converter and Stator Flux Vector Orientation method is used, the control structure of the converter is similar to DFIG as given. The control diagram of the generator-side converter is shown in Figure 3.15:

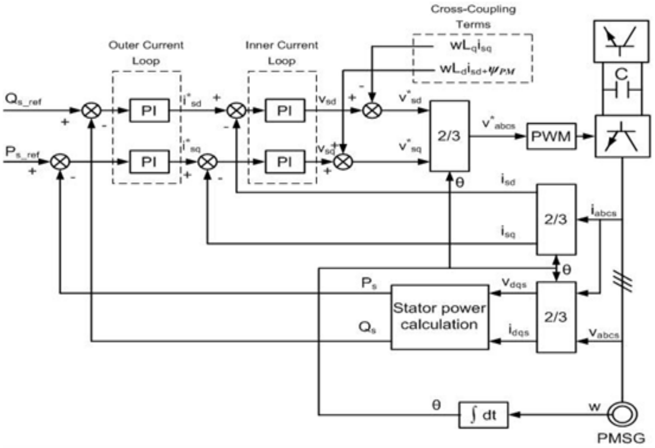


Figure 3.15 Vector Control Diagram of Generator Side Converter of the PMSG type Wind Turbines

SIMULATION RESULTS

The simulation model of the proposed dc grid based wind power generation system shown in Fig. 4.1 is implemented in MATLAB/Simulink. The effectiveness of the proposed design concept is evaluated under different operating conditions when the micro grid is operating in the grid-connected or islanded mode of operation.

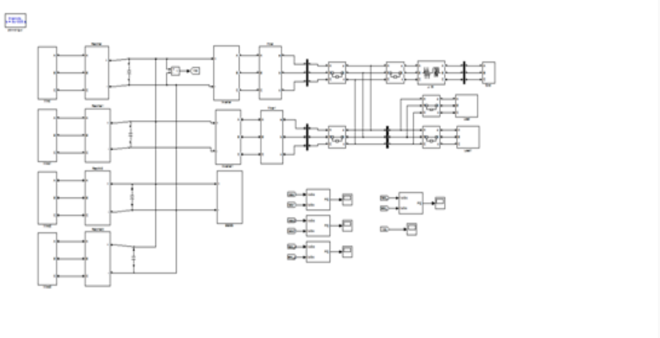


Fig:5.1- simulation diagram of a Failure of One Inverter During Grid-Connected Operationt

The system parameters are given in Table I. The impedances of the distribution line are obtained from [34].In practical implementations, the values of the converter and inverter loss resistance are not precisely known. Therefore, these values have been coarsely estimated.

A. TEST CASE 1: FAILURE OF ONE INVERTER DURING

Grid-Connected Operation When the micro grid is operating in the grid-connected mode of operation, the proposed wind power generation system will supply power to meet part of the load demand. Under normal operating condition, the total power generated by the PMSG sat the dc grid is converted by inverters 1 and 2 which will share the total power supplied to the loads.

When one of the inverters fails to operate and needs to be disconnected from the dc grid, the other inverter is required to handle all the power generated by the PMSGs. In this test case, an analysis on the micro grid operation when one of the inverters is disconnected from operation is conducted. With each PMSG generating about 5.5 kW of real power, the total power generated by the four PMSGs is about 22 kW which is converted by inverters 1 and 2 into 20 kW and 8 kVAr of real and reactive power respectively. Figs. 5.2 and 5.3 show the waveforms of the real and reactive power delivered by inverters 1 and2 for $0 \leq t < 0.4$ s respectively. For $0 \leq t < 0.2$ s, both inverters1 and 2 are in operation and each inverter delivers about 10kW of real power and 4 kVAr of reactive power to the loads.

The remaining real and reactive power that is demanded by the loads is supplied by the grid which is shown in Fig. 7. It can be seen from Fig. 7 that the grid delivers 40 kW of real power and 4 kVAr of reactive power to the loads for $0 \leq t < 0.2$ s. The total real and reactive power supplied to the loads is about 60kW and 12 kVAr as shown in the power waveforms of Fig5.5..The unsteady measurements observed in the power waveforms for $0 \leq t < 0.08$ s are because the controller requires a period of about four cycles to track the power references during the initialization period.

As compared to conventional control strategies, it can be observed that the proposed MPC algorithm is able to quickly track and settle to the power reference. This is attributed to the optimization of the inverters through the model-based MPC control.

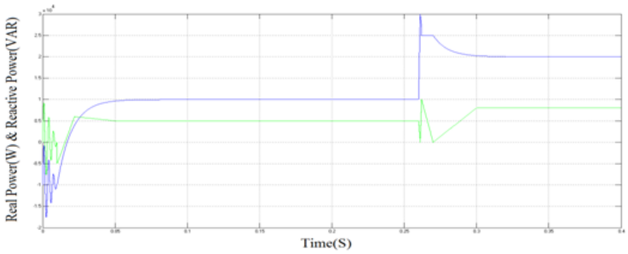


Fig:5.2- Real (top) and reactive (bottom) power delivered by inverter 1.

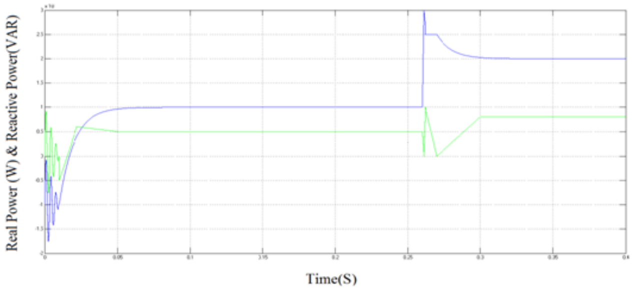


Fig:5.3 Real (top) and reactive (bottom) power delivered by inverter 2.

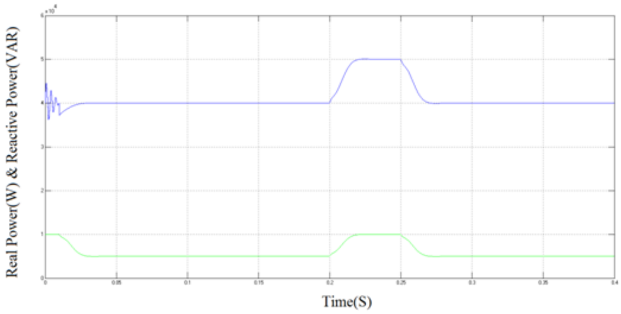


Fig:5.4- Real (top) and reactive (bottom) power delivered by the grid.

Essentially, model-based control schemes are able to take into account the system parameters such that the overall performance can be optimized. At $t = 0.2$ s, inverter 1 fails to operate and is disconnected from the micro grid, resulting in a loss of 10 kW of real power and 4 kVAr of reactive power supplied to the loads. As shown in Fig. 5.2, the real and reactive power supplied by inverter 1 is decreased to zero in about half a cycle after inverter 1 is disconnected. This undelivered power causes a sudden power surge in the dc grid which corresponds to a voltage rise at $t = 0.2$ s as shown in Fig. 5.6. To ensure that the load demand is met, the grid automatically increases its real and reactive power generation to50 kW and 8 kVAr respectively at t = 0.2 s, as shown in Fig. 7.At t = 0.26 s, the EMS of the micro grid increases the reference real and reactive power supplied by inverter 2 to 20 kW and8 kVAr respectively. A delay of three cycles is introduced to cater for the response time of the EMS to the loss of inverter1. As shown in Fig. 5.3, inverter 2 manages to increase its real and reactive power supplied to the loads to 20 kW and 8 kVAr for 0.26 ≤ t < 0.4 s. At the same time, the grid decreases its real and reactive power back to 40 kW and 4 kVAr as shown in Fig. 5.5 respectively.

The power balance in the micro grid is restored after three cycles from t = 0.26 s. It is observed from Fig. 5.6 that the voltage at the dc grid corresponds to a voltage dip at t = 0.26 s due to the increase in power drawn by inverter 2 and then returns to its nominal value of 500 V for 0.26 ≤ t < 0.4 s. As observed in Fig. 5.5, at t = 0.26 s, the changes in power delivered by inverter 2 and the grid also cause a transient in the load power.

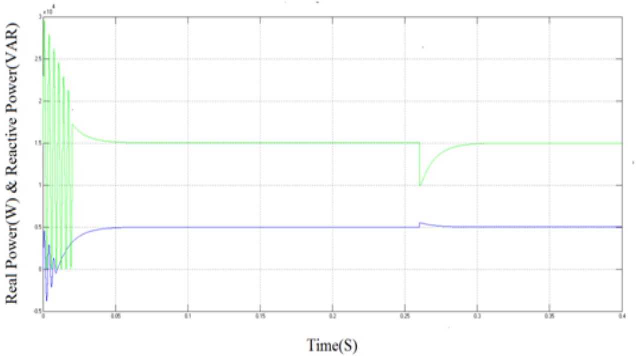


Fig:5.5- Real (top) and reactive (bottom) power consumed by the loads.

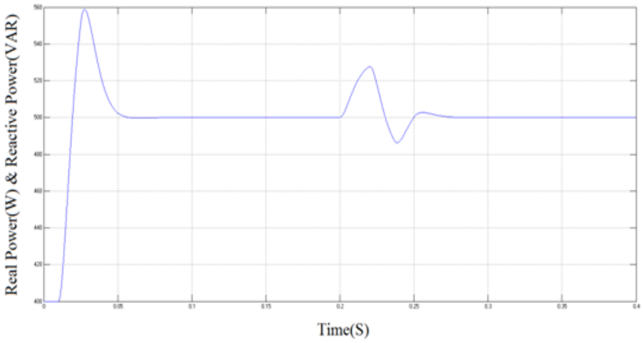


Fig:5.6- DC grid voltage.

CONCLUSION

In this project, the design of a dc grid based wind power generation system in a Micrigrid that enables parallel operation of several WGs in a poultry farm has been presented. As compared to conventional wind power generation systems, the proposed Micrigrid architecture eliminates the need for voltage and frequency synchronization, thus allowing the WGs to be switched on or off with minimal disturbances to the Micrigrid operation. The design concept has been verified through various test scenarios to demonstrate the operational capability of the proposed Micrigrid and the simulation results has shown that the proposed design concept is able to offer increased flexibility and reliability to the operation of the Micrigrid. However, the proposed control design still requires further experimental validation because measurement errors due to inaccuracies of the voltage and current sensors, and modeling errors due to variations in actual system parameters such as distribution line and transformer impedances will affect the performance of the controller in practical implementation. In addition, MPC relies on the accuracy of model establishment; hence further research on improving the controller robustness to modeling inaccuracy is required. The simulation results obtained and the analysis performed in this project serve as a basis for the design of a dc grid based wind power generation system in a micro grid.

REFERENCES

[1] M. Czarick and J.Worley, “Wind turbines and tunnel fans,” Poultry Housing Tips, vol. 22, no. 7, pp. 1–2, Jun. 2010.

[2] The poultry guide: Environmentally control poultry farm ventilation systems for broiler, layer, breeders and top suppliers. [Online]. Available: http://thepoultryguide.com/poultry-ventilation/

[3] Livestock and climate change. [Online]. Available: http://www. worldwatch.org/files/pdf/Livestock%20and%20Climate%20Change.pdf.

[4] Farm Energy: Energy efficient fans for poultry production. [Online].Available: http://farmenergy.exnet.iastate.edu.

[5] A. Mogstad, M. Molinas, P. Olsen, and R. Nilsen, “A power conversion system for offshore wind parks,” in Proc. 34th IEEE Ind. Electron., 2008, pp. 2106–2112.

[6] A. Mogstad and M. Molinas, “Power collection and integration on the electric grid from offshore wind parks,” in Proc. Nordic Workshop Power Ind. Electron., 2008, pp. 1–8.

[7] D. Jovic, “Offshore wind farm with a series multiterminal CSI HVDC,” Elect. Power Syst. Res., vol. 78, no. 4, pp. 747–755, Apr. 2008.

[8] X. Lu, J. M. Guerrero, K. Sun, and J. C Vasquez “An improved droop control method for DC microgrids based on low bandwidth communication with DC bus voltage restoration and enhanced current sharing accuracy,” IEEE Trans. Power Electron., vol. 29, no. 4, pp. 1800–1812, Apr. 2014.

[9] T. Dragicevi, J. M. Guerrero, and J. C Vasquez, “A distributed control strategy for coordination of an autonomous LVDC microgrid based on power-line signaling,” IEEE Trans. Ind. Electron., vol. 61, no. 7, pp. 3313–3326, Jul. 2014.

[10] N. L. Diaz, T. Dragicevi, J. C. Vasquez, and J. M. Guerrero, “Intelligent distributed generation and storage units for DC microgrids—A new concept on cooperative control without communications beyond droop control,” IEEE Trans. Smart Grid, vol. 5, no. 5, pp. 2476–2485, Sep. 2014.

[11] X. Liu, P. Wang, and P. C. Loh, “A hybrid AC/DC microgrid and its coordination control,” IEEE Trans. Smart Grid, vol. 2, no. 2, pp. 278–286, Jun. 2011.

[12] C. Jin, P. C. Loh, P. Wang, M. Yang, and F. Blaabjerg, “Autonomous operation of hybrid AC-DC microgrids,” in Proc. IEEE Int. Conf. Sustain. Energy Technol., 2010, pp. 1–7.

[13] J. A. P. Lopes, C. L. Moreira, and A. G.Madureira, “Defining control strategies for microgrids islanded operation,” IEEE Trans. Power Syst., vol. 21, no. 2, pp. 916–924, May 2006.