Design and Simulation of Integrated Offshore Wind Farm

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(Electrical Power Systems)

By

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CERTIFICATE

This is to certify that the Major Project Report entitled **"Design and Simulation of Integrated Offshore Wind Farm"** submitted by **Ms. Shivangi M.Gajjar (16MEEE04)**, towards the partial fulfillment of the requirements of Master of Technology (**Electrical Engineering**) in the field of **Electrical Power Systems** of Nirma University is the record of work carried out by her under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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I, **Shivangi M. Gajjar** Roll No.**(16MEEE04)**, give undertaking that the major project entitled **"Design and Simulation of Integrated Offshore Wind Farm"** submitted by me, towards the partial fulfillment of the requirement for the degree of Master of technology in **Electrical Power Systems** of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in serve disciplinary action.

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List of Figures

Abbreviations

PMSG .... Permenant Magnet Induction Generator
DBOWF .... Donghai Bridge Offshore Wind Farm
SCIG .... Squirrel Cage Induction Generator
WRIG .... Wound Rotor Induction Generator
DFIG .... Doubly Fed Induction Generator
HVDC .... High Voltage Direct Current
PCC .... Point of Common Coupling
APS .... Active Power Stabilizer
RSC .... Rotor Side Converter
GSC .... Grid Side Converter
OWF .... Offshore Wind Farm
IG .... Induction Generator
PF .... Power Factor

Contents

Chapter 1

Introduction

Generally the energy demands of the world are supplied by using fossil fuels, which is the main cause of generation of carbon emission in to environment. Nowadays consumption of energy is increasing because of utilization of more electric products which leads to higher energy consumption and hence increase of carbon emissions in the atmosphere and hence responsible for unwanted Climatic Change or Global Warming.

Some countries promote offshore wind power because it plays an major role in national energy policy to achieve national targets for the reduction of emission of carbon dioxide (CO2). However,investment costs for offshore wind power are much higher than those for onshore installations. Fortunately, in many central European waters, water depth increases only slowly with distance from the shore, which is an important economic advantage for the application of bottom-mounted offshore wind turbines.

The installation and supporting structure of offshore wind turbine is much more expensive than that of onshore turbines. Therefore, offshore wind power plants use wind turbines with a high rated capacity (less than equal to 3MW), which are particularly designed for higher wind speeds.

The develop countries usually consume large energy releasing the unwanted emissions in environment. But the growth of developing countries like India is more concern. The metropolitan regions are now over popular and they require more amount of generated energy, so the private and public companies have now started to research in the field of renewable energy sources, i.e. environmentally friendly solution of the power generation problems are more prominent now.

The interest in the utilization of offshore wind power is increasing importance in to worldwide. The reason is that the wind speed of offshore is potentially higher than onshore, which lead to higher power production. A 10% increase in wind speed results, theoretically in a 30% increase in power production. The offshore wind power potential can be considered to be important. [12]

1.1 Objective of the Work

The energy demand increasing nowadays because of increase in use of Electric products. The conventional power generation plants are not in proper manner to supply desired demand and it also affect the environment, so the power is now also generated using renewable sources. The main objective of work is to design and simulate offshore wind farm (OWF). OWF consist of sets of Induction Generator which are connected in parallel. The system will gives output nearer to actual value.

1.2 Literature Survey

M. Y. Keche and Dr.V.K.Chandrakar , "Design and simulation of integrated Offshore Wind farm," *International Conference on Computation of Power Energy Information and Communication (ICCPEIC), 2016*, pp. 823-827

- This paper comprises of design and simulation of offshore wind farm which can be connected to HVDC transmission. Here, the system has been tested under normal and abnormal condition and simulation results have been obtained.
- Here, they have simulated an offshore wind farm using MATLAB SIMULINK tool. Also, simulated the characteristics of the turbine for different pitch angle. The Real and Reactive power of the offshore wind farm has been simulated under normal and abnormal condition.
- The offshore wind farm is one in which the wind turbines are situated in water far away from the land. Offshore wind farm has more potential than onshore wind farm. Whenever strong wind blows it generates about 3-5 MW of power per hour.
- Figure 1.5 shows the block diagram of offshore wind farm, it consist of offshore wind farm of 1.5MW. The system will be simulated using MATLAB software. The standard speed of the turbine will be 9 m/s and that of offshore will be around

12m/s. this speed will vary depending on the pitch angle of the turbine. The capacitor bank helps in better voltage regulation and reactive power compensation.

- The system is observed under fault and no fault condition for time=0.01 sec between the time interval 10 to 10.1 [1]

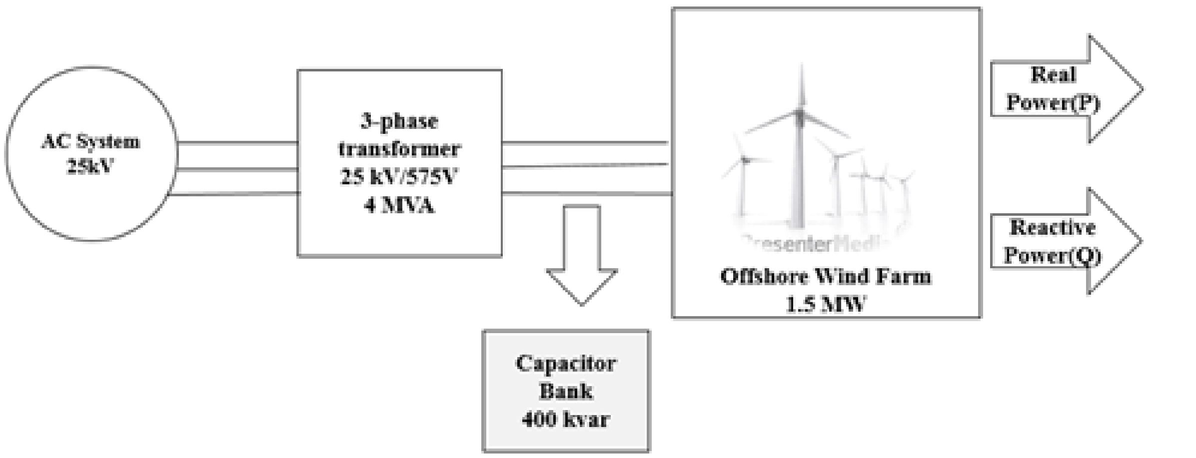

Figure 1.1: Block Diagram of Offshore Wind Farm[1]

Y. Wu, C. Lee, and G. Shu,"Taiwan' s First Large-Scale Offshore Wind Farm Connection — A Real Project Case Study With a Comparison of Wind Turbine," *IEEE Transaction on Industrial Application*, vol. 47, no. 3, pp. 1461— 1469, 2011.

- This paper comprises of four major system analyses i.e., load flow, fault current, voltage variation and transient stability. Here, there are three types of wind turbines have been adopted in this paper in order to compare their performances on the wind farm integration system.
- Here, they presents a plan of Taiwan Power Company entitled "Wind Generation Development Plan for 10 years". This plan is to install 200 onshore wind generators with more than 300-MW installed capacity within ten years according to three stages. Up to mid of April 2010, Taipower has 179.76 MW from 106 wind turbine generators in operation and 106 MW from 56 wind turbines under construction.
- This paper also presents the impact of study of connecting a 108-MW wind farm into the Taipower transmission system in central Taiwan.

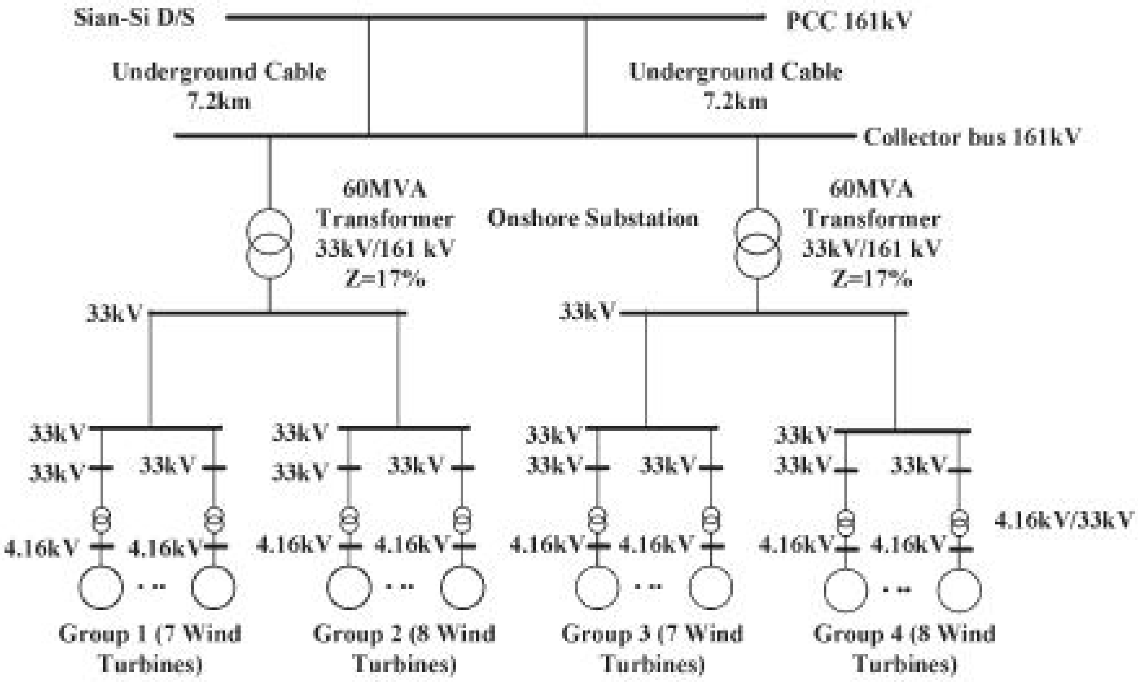

Figure 1.2: Proposed Layout of the Jhang-Bin Offshore Wind Farm

- Figure 1.6 shows the plan of the single line diagram inside the offshore wind farm. Here, they were also proposed comparisons of various wind turbines i.e; type A (Fixed speed), Type B (Limited variable speed), Type C and D (Variable speed).
- The Type A system has been used with a multi-stage gearbox and a squirrel cage induction generator(SCIG) directly connected to the grid through a transformer. SCIG cannot support grid voltage control, and its rotor speed is not controllable.
- The Type B uses a Wound Rotor Induction Generator (WRIG) with a variable rotor resistance by means of a power electronic converter and the pitch control method.
- The Type C uses a Doubly Fed Induction Generator (DFIG). The power converter system in the DFIG can perform reactive power compensation and control; However ride-through capability of the DFIG and its control strategies may be complicated.
- Type D includes Permanent Magnet Synchronous Generator (PMSG) from the viewpoint of the fault ride-through capability, the type D system may be more effective and less complicated in dealing with grid related problems compared with the DFIG systems. However, it has a higher cost and a higher power loss in the power electronics.

- The Reactive power and Voltage control capabilities of modern wind turbines are significant as most grid codes require the wind turbines to have a reactive power capability at the point of interconnect over a specified power factor (PF) range. From the system operation viewpoint, the type C and D systems have better performance on voltage control without additional capacitors.

- In this paper, the output of the reactive power for each type C turbine ranges from 1.5 to +2.08 MVAR. The output of the reactive power for each type D ranges from 0.33 to +0.4 MVAR. Based on our simulation results, the wind farm with type C wind turbines could provide a bigger total reactive power compared to other types of wind turbines so that the voltage drop at the PCC would be smaller as grid faults occur.[2]

R. Perveen, N. Kishor, and S. R. Mohanty, “Off-shore wind farm development : Present status and challenges,” *Renewable and Sustainable Energy Reviews*, vol. 29, pp. 780—792, 2014.

- This paper consists of present scenario and challenges in development of offshore wind power. The challenges and opportunities that coming out in the development stages of an offshore wind farm project, from exploration to erection and installation of wind turbines, construction of platforms and lying of sea cables, up to maintenance and Decommissioning, involving important technical aspects are addressed.

- An application of High Voltage Direct Current (HVDC) transmission for integration of large scale offshore wind farm with onshore grid is attractive as compared to High Voltage Alternating Current (HVAC) transmission system. To make the offshore wind farm feasible, reliable and secure, the different aspects in its planning, design and operation are also reviewed in this paper.

- This paper provides offshore wind farm development, installation, grid connection and power evacuation and converter etc information will be provide to develop the offshore wind farm and also the challenges which are come while designing to it.

- It also provides the various offshore wind power control and operation like voltage and frequency control, HVDC power control, Protection and security, Grid code compliance, system optimization approach, Offshore wind speed forecast and Condition or structural health monitoring.And lastly other related factors like, Planning and policy, economics and ecological condition and recent trends in designing offshore wind farm.

- This paper has reviewed extensively the development of OWF, including technology, planning, and ecological aspects. The development of engineering modeling and analysis tools will help to reduce overall offshore facility costs and to design the next generation innovative large-scale turbines optimized for installation and operation in the marine environment.

- The development of enhanced controller will facilitate wind farm dynamic performance compatible with conventional synchronous plant (i.e. to provide support to power system operation in terms of dynamic voltage and frequency control).

- Installation and Maintenance of wind farms at sea is much more complex than on the land, thus requiring special equipments and good weather conditions. Higher winds may lead to storms and big waves and sea water being salty causes corrosion to the structures.

- Cost improvements could also be envisaged through enhanced research and development efforts focusing on specific components or new materials. [3]

L. M. Fernández, C. A. García, J. R. Saenz, and F.Jurado,“Equivalent models of wind farms by using aggregated wind turbines and equivalent winds,” *Energy Conversion and Management*, vol. 50, no. 3, pp. 691—704, 2009.

- This paper presents new equivalent models of wind farms equipped with wind turbines based on squirrel cage induction generators and doubly fed induction generators are proposed to represent the collective behavior on large power system simulations, instead of using a complete model of wind farms where the all wind turbines are modeled.

- Here, Two equivalent winds are evaluated in this work:

1. The average wind from the ones incident on the aggregated wind turbines with similar winds, and

2. An equivalent incoming wind derived from the power curve and the wind incident on each wind turbine.

- Here, they were provide detailed models of SCIG wind turbines and DFIG wind turbine and that model includes Rotor model, Drive train model, Generation system and protection system.

- It also provides equivalent models for SCIG and DFIG wind turbines and equivalent internal electrical network in the wind farm. A simulation results are based on comparison of steady-state and dynamic responses of the complete and equivalent wind farm models. They have been implemented and simulated in MATLAB/Simulink environment.

- The main feature of these models is the aggregation of wind turbines into an equivalent wind turbine with re-scaled power capacity. The equivalent wind turbine with the equivalent wind obtained from the power curve supposes the best way of reducing the model order and the simulation time, enabling the aggregation of all the wind turbines of wind farm into a single equivalent wind turbine. This approach achieves an adequate approximation of the collective response of the wind farm during power system dynamic simulations, such as wind fluctuations and a grid disturbance.[4]

K. E. Okedu, S. M. Muyeen, R. Takahashi, and J. Tamura, "Stabilization of Wind Farms by DFIG-based Variable Speed Wind Generators," *International Conference on Electrical Machines and Systems 2010*, pp. 6–11.

- This paper presents a new control strategy using DFIGs (Doubly fed induction generators) for stabilizing a wind farm composed of DFIGs and IGs(Induction Generators). Simulation analysis by using PSCAD/EMTDC shows that the DFIG's can effectively stabilize the IGs and hence the entire wind farm through the proposed control scheme by providing sufficient reactive power to the system.

- The response of wind generators to grid disturbances is an important issue, because the installations of wind generators are steadily increasing. Therefore, it is important for utilities to study the effects of various voltage sags on the corresponding wind turbine responses.

- The installations of power electronic devices and reactive power compensation units like static synchronous compensator (STATCOM), superconducting magnetic energy storage (SMES), and energy capacitor system (ECS), in a wind farm composed of fixed speed wind turbines (FSWTs) as presented in , increase the system overall cost.

- This paper also comprises of wind turbine model of DFIG, the primary component of a wind turbine for modeling purposes consist of the turbine rotor or prime mover, a shaft and a gearbox unit.

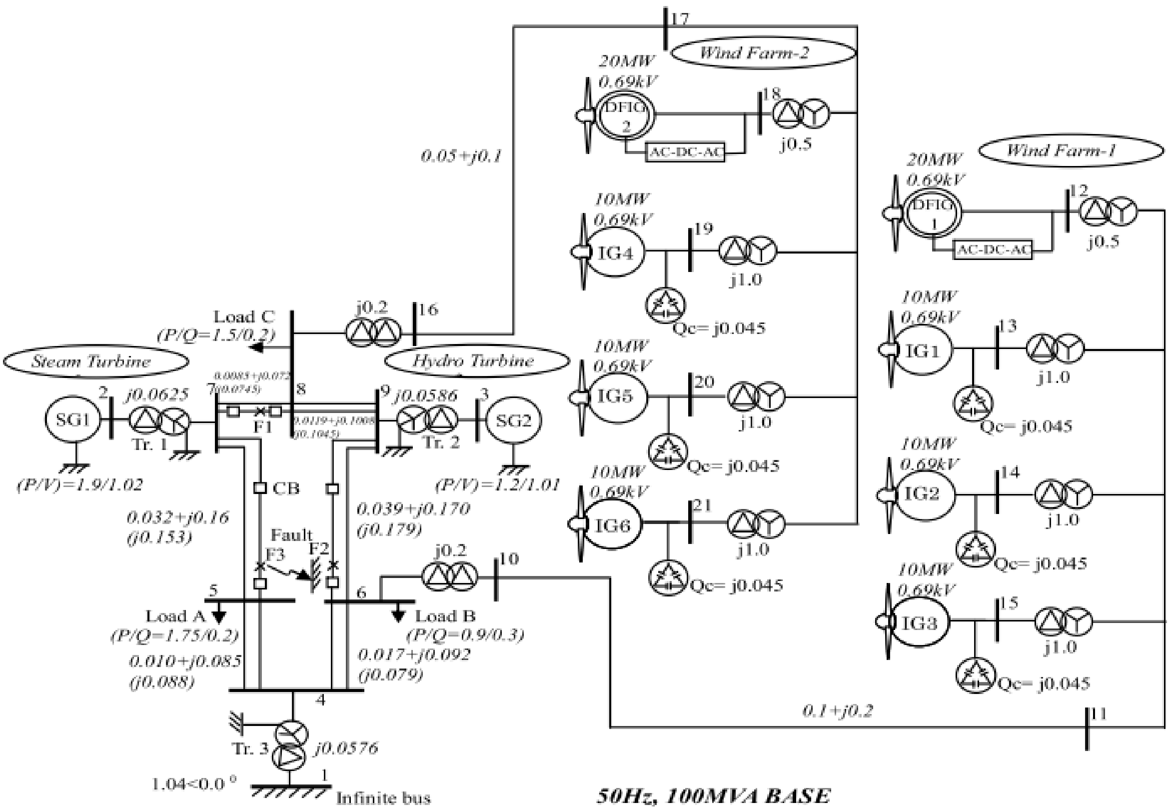

Figure 1.3: Model System

- Above model system consist of two wind farms are connected to the multi -machine power system. Aggregated wind farm model is considered in this analysis for fast computing. Each wind farm is composed of 1 DFIG and 3 IGs. Here, a protection circuit in the excitation circuit of DFIG is considered, in this study.

- The system will be simulated by PSCAD software, It has been shown that, if the DFIG control is not available, wind farm composed of induction generators becomes unstable, however, when the DFIG is incorporated in the wind farm adopted with the proposed control, IGs as well as DFIGs in the wind farms become stable.
- Therefore, it can be concluded that the proposed control method for variable speed wind turbine driving DFIG can effectively enhance the transient stability of wind farms.[5]

C. M. Singh, "Offshore Wind Energy – Potential for India," *IEEE Region 10 Conference (TENCON)—Proceedings of the International Conference,2016*, pp. 2624—-2627.

- This paper comprises of energy demand scenario especially that of almost unlimited wind energy and highlight vast potential of offshore wind energy for India in territorial water along its long coastline.
- Challenges to exploit this potential, financial viability of such offshore energy projects, social, environmental, and other related issues are discussed in Indian context to serve as a useful tool for policymakers to allocate resources for detailed studies for estimation and its ultimate utilization to add to growing pool of renewable energy.
- This paper gives the information about GDP growth and Energy Demand, the energy trilemma, fast rising electricity demand, renewable source in India, wind energy and offshore wind resources in India, levelized cost of electricity, and social impact of wind project etc.
- Wind power alone can take care of electricity requirement of India in foreseeable future centuries. As technologies evolve, hub heights increase and offshore potential get harnessed; India can be relieved off its energy worries forever.
- By this paper we can conclude that offshore wind energy has been rises its potential in India country.[6]

F. Yanhui, Q. I. U. Yingning, and Z. Junwei, "Study of China' s 1st Large Offshore Wind Project," *Renewable Power Generation Conference, China, 2015* pp. 1—4.

- This paper consist of china's first large offshore wind farm project which will name is Shanghai Donghai Bridge Offshore Wind Farm. It also the first large wind farm outside of Europe.
- The offshore wind farm, commissioned on August 2010 with a total capacity of 102 MW, is consisted of 34 offshore wind turbines made by Sinovel. The wind farm has been up and operating for over 2 years. It is shown that the power generation and Capacity Factor are 226 GWh and 25.3% in 2011, jumping to 246 GWh and 27.5% in 2012, respectively.
- This paper also consist of planning,construction and installation and operational feature of Donghai power plant.
- It also provides comparasional study between Shanghai DBOWF and European offshore wind farm,This is putting its emphasis on the features such as offshore engineering, resources, economics, Grid integration.
- This pilot project enables China wind industry to learn experiences on many engineering and management aspects, e.g. planning, installation, Grid connection, and economics.
- The economics of early China offshore wind projects are likely to remain unsatisfactory due to high capital costs and insufficient engineering experiences. However, they will improve significantly when more experiences are collected on field.
- Since the second batch of China's first round of offshore wind tender are expected to release in 2013, the lessons and experiences learned from Shanghai DBOWF could provide valuable information for future offshore wind farm development.[7]

A. Korompili, Q. Wu, and H. Zhao, "Review of VSC HVDC connection for offshore wind power integration," *Renewable Sustainable Energy Review*, vol. 59, pp. 1405–1414, 2016.

- This paper provides the information regarding VSC HVDC transmission and its application for offshore wind farm integration. Here,also presented Functionality and Development of VSC HVDC system.
- Here, they were compare various converter topology with AC and DC system.By comparing different topologies MMC (Modular Multilevel Converter) is considered as most usefull technology for VSC HVDC system.
- They were also compare two terminal VSC HVDC system with multi terminal VSC HVDC system among these two topologies multi terminal topology,the WFRT (Wind Farm Ring Topology) is found to be more efficient.
- After performing various converter topology new converter topology were proposed. The controller topology depends on the application.It has been found that instead of reactive power control, AC voltage control is preferred for the offshore wind farm integration.
- The focus is given on the control methods of the VSC HVDC connected offshore wind power plants for fulfilling the LVRT and frequency regulation support requirements. Due the decoupling between the wind farm and the AC grid how to efficiently communicate between both sides is the main challenge.[8]

T. Lei, M. Ozakturk, and M. Barnes, "Modelling and Analysis of DFIG Wind Turbine Sstem in PSCAD / EMTDC," *6th IET International Conference on Power Electronics, Machines and Drives, 2012* pp. 1–6.

- This paper comprises of modelling of Doubly Fed Induction Generator(DFIG) in PSCAD/EMTDC software. A 4.5 MW wind turbine model were simulated in this system.
- It also includes Mathematical representation of closed-loop control system are developed and verified against the model. This model varifies the control scheme, mechanical and electrical dynamics and fault ride through capability.

- With future WTs moving offshore, very large size turbines will be installed making their reliability critical. Comprehensive studies on the WT behaviours and control systems are needed in order to improve their design and operation.

- This paper consist a complete DFIG WT model and its overall control systems. The interaction of the WT control level with the DFIG control level has been presented in the paper. Two converter models, a full switched model with IGBTs and a switched-averaged model are compared.[9]

- Mathematical models of the RSC control, GSC control and pitch control systems are developed and their responses are consistent with the PSCAD/EMTDC simulations.

- These models can be used to adjust the PI gains and evaluate the control performance more accurately. This model is useful to WT manufacturers, operators as well as researchers in relevant fields.

D. Mueller, M. Rabe, and W. Kuehn, "Stabilizing Control for HVDC Connected Offshore Wind Farm," 4th IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe), 2013, pp. 1–5.

- This paper consist of controls stretching from the wind farm to the onshore AC grid to handle major load changes and weak grid conditions.

- The simulations are performed on the PSCAD/EMTDC digital simulator in conjunction with plausibility checks using PQ-diagrams. Results obtained so far prove the capability of wind farm and HVDC controls to operate under weak grid conditions.

- The system study are preliminary investigated on an AC grid containing mechanical Synchronous Generators.[10]

- The controls developed for the Wind farm and the VSC HVDC system have maximum power tracking capability and provide participation of the individual wind turbine in accordance with its capability without use of communication between the HVDC system and the turbine generators.

- The system will adopt a new steady state equilibrium at a lower power level. If mechanical synchronous machines inject power in parallel to the HVDC system, stability conditions are affected.

- The already started second part of the study focuses on the task to determine steady state conditions keeping the power system sufficiently far away from the static stability limit, so that transient stability is not endangered, and as a back-up to use the APS for ensuring transient stability if the static stability limit has been surpassed.

Chapter 2

Overview of Wind Energy Topology

2.1 Wind Farm

One primary advantage of the wind energy is that numerous wind turbines can be amassed to produce the high power. A Wind Farm or Wind Farm comprises of tens or up to some hundred of wind turbines and can find onshore and offshore. The offshore wind farm produces more steady control than inland wind farm since the wind speed is higher than typical esteem.

Figure 2.1: Onshore Wind Farm

Figure 2.1 and Figure 2.2 shows an onshore and offshore wind farm. Moreover, the wind energy can be a network associated or stand alone framework. In a farther range,

Figure 2.2: Offshore Wind Farm

a bunch of small wind turbines supply the electrical power to families or commercial buildings.

Variable speed wind turbines relieve the issues of the mechanical stresses. Since of the variable size and frequency yields of the variable speed wind turbines, there must be power electronic network interconnection to decouple the yields of the wind turbines to the network.

As the wind speed is different in each area of a wind farm, each wind turbine turns with different speed. Subsequently, it is essential that each wind turbine has individual association to the power electronic network association.

2.2 Different Types of Foundation of Offshore Wind Farm

The offshore wind turbines have different types of Foundation depending upon the depth of the water. The various foundations are:[1]

2.2.1 Monopile

It is composed of a steel pipe, The diameter of it is 6 meters and its used in waters upto 30 meters deep.

2.2.2 Gravity

It consists of a larger base which may be either made of concrete or steel resting on the seabed. The turbine of this foundation will be depend on the gravity for erection. is used in waters up to 20—80 m deep.

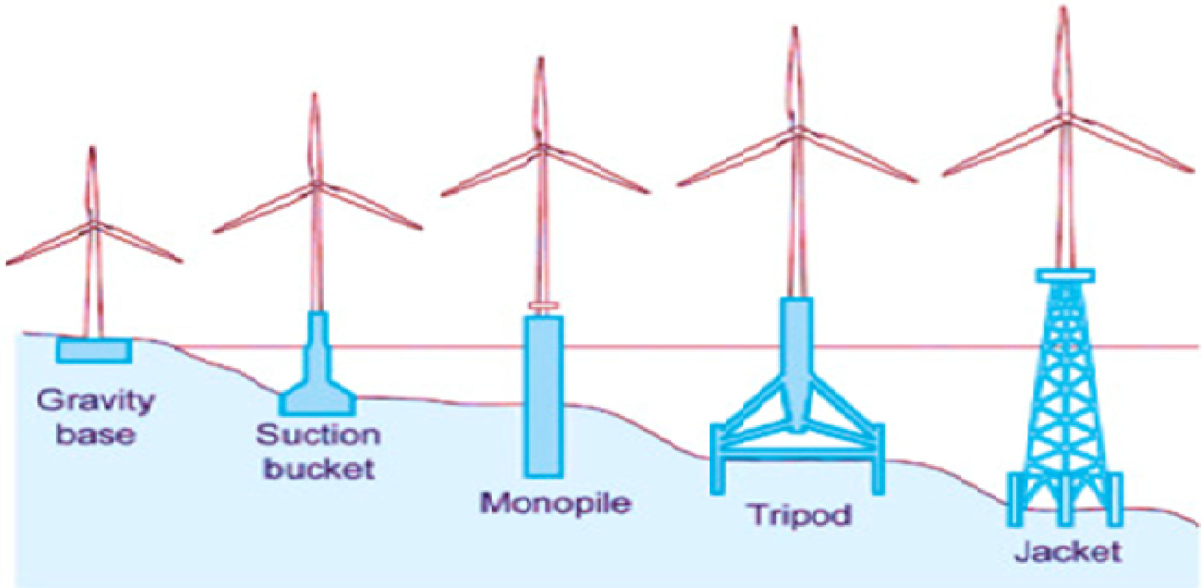

Figure 2.3: Different Types of Foundations

2.2.3 Tripod

It depends on the technology used by oil gas industries. The piles on each end are driven 34–60 ft in seabed. This foundation is used in deeper water. is used in waters up to 20–80 m deep.

2.2.4 Jacket

A three legged platform able to be towed out to sea and lowered into place. is used in waters up to 30–60 m deep.

2.2.5 Floating

It uses a tension-leg platform design which relies on a platform that floats below the surface of the water docked to the bottom with chains.

2.2.6 Suction Bucket

The suction bucket design consist of three legs welded together in a lattice jacket structure that stand atop of three giant suction bucket foundations.

2.3 Wind Turbines

Wind turbines can operate either with a Fixed Speed or a Variable Speed.[12]

2.3.1 Fixed Speed Wind Turbines

It is characteristic of Fixed-Speed wind turbines that they are prepared with an induction generator (squirrel cage or wound rotor) that's straightforwardly associated to the grid, with a soft starter and capacitor bank for decreasing receptive control compensation.

They are plan to attain most extreme efficiency at one specific wind speed. In arrange to extend power generation, the generator of a few fixed-speed wind turbines has two winding sets: one is utilized at low wind speeds and the other at medium and tall wind speeds .

The fixed-speed wind turbine has the advantage of being simple, strong and solid. Additionally, the fetched of its electrical portion is low. Its disadvantages are an wild responsive control utilization, mechanical stress and restricted control quality control.

2.3.2 Variable Speed Wind Turbines

Variable speed wind turbines are outlined to realize greatest streamlined productivity over a wide run of wind speeds. Inside a variable speed operation, it is conceivable ceaselessly to adjust the rotational speed of the wind turbine agreeing to the wind speed.

A variable speed framework keeps the generator torque reasonably consistent and the varieties in wind are ingested by changes within the generator speed. The electrical framework of a variable speed wind turbine is more complicated than that of a fixed-speed wind turbine.

It is ordinarily prepared with an acceptance or synchronous generator and associated to the lattice through a control converter. The electrical framework of a variable speed wind turbine is more complicated than that of a fixed-speed wind turbine. It is regularly prepared with an acceptance or synchronous generator and associated to the network through a power converter.

2.4 Different Types of Wind Turbines

2.4.1 Type 1: Fixed Speed (Squirrel Cage Induction Generator)

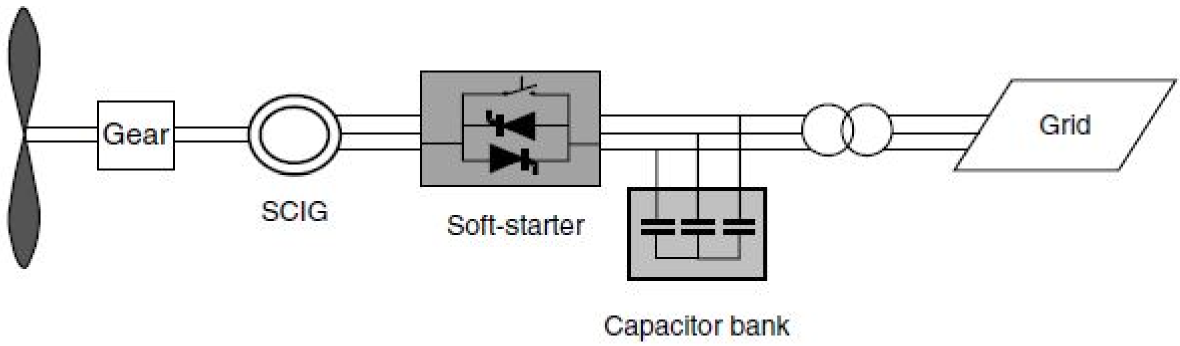

Figure 2.4: Fixed Speed Wind Turbine Squirrel Cage Induction Generator[12]

This system signifies the fixed-speed wind turbine with an Asynchronous squirrel cage Induction Generator (SCIG) specifically associated to the framework through a transformer. Since the SCIG continuously draws reactive power from the grid, this setup employments a capacitor bank for Reactive power compensation. A smoother grid connection association is accomplished by employing a soft starter.

Agreeing to the control control rule in a fixed speed wind turbine, the wind vacillations are changed over into mechanical variation and subsequently into electrical power fluctuations.

The fixed-speed wind turbine draws changing sums of reactive power from the utility network, which increments both the voltage variation and the line losses. In this way, the most downsides of this concept are that it does not back any speed control; it requires a hardened lattice and its mechanical development must be able to endure large mechanical stress.[12]

2.4.2 Type 2: Limited Variable Speed (Wound Rotor Induction Generator)

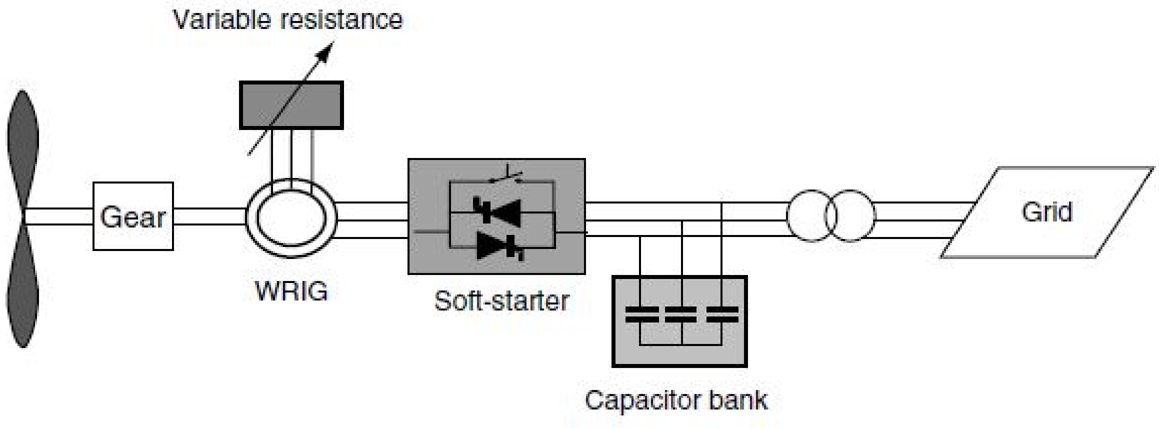

Figure 2.5: Wound Rotor Induction Generator[12]

This sort of wind turbine employments a wound rotor Induction Generator with a variable extra rotor resistance, which is controlled and changed powerfully by control gadgets. This empowers control of the slip and control yield of the generator.

This highlight permits the generator to have a variable slip (limit run) and to select the ideal slip, coming about in littler changes within the drive prepare torque and in control output. The variable slip could be a exceptionally basic, dependable and cost-effective way to realize stack decreases, compared with more complex arrangements such as full variable-speed wind turbines utilizing full-scale converters.

This arrangement still needs a soft-starter in arrange to diminish the inrush current and a Reactive power compensator in arrange to decrease the Reactive power request from the generator to the grid.

The advantages of this concept are a basic circuit topology and an moved forward operating speed extend compared with the SCIG. To a certain degree, this concept can reduce the mechanical loads and power variation caused by gusts. In any case, it still requires a Reactive power compensation framework, and ordinarily a capacitor bank is utilized. The dis-advantages are that: (1) the speed extend is restricted, because it is subordinate on the measure of the variable rotor resistance; (2) as it were poor control of Active and Reactive power is achieved;and (3) the slip power is scattered within the variable resistance as losses.[12]

2.4.3 Type 3: Variable Speed with Partial-Scale Frequency Converter (DFIG)

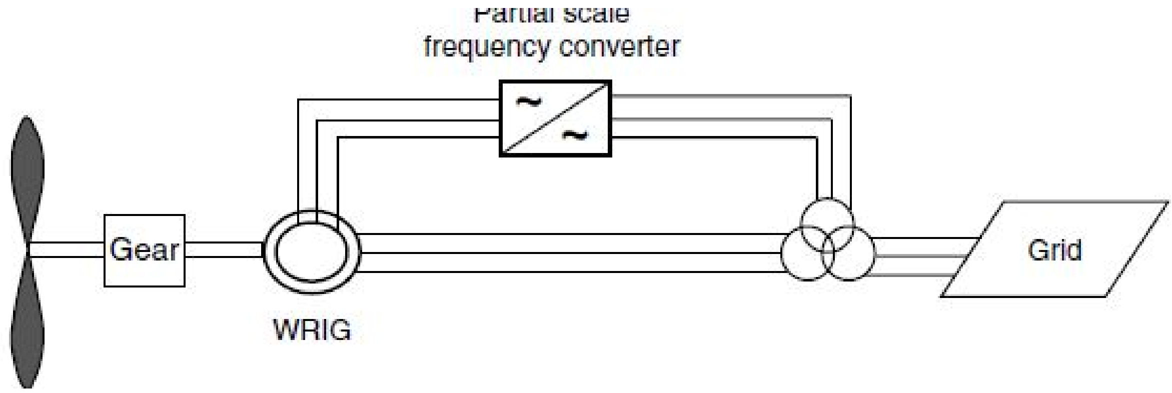

Figure 2.6: Doubly Fed Induction Generator

This configuration needs neither a soft-starter nor a reactive power compensator, as the partial-scale frequency converter is able to perform both the reactive power compensation and the smoother grid connection. The power converter consists of two converters, the rotor-side converter and grid-side converter, which are controlled independently of each other.

The main idea is that the rotor side converter controls the active and reactive power by controlling the rotor current components, while the line-side converter controls the DC-link voltage and ensures a converter operation at unity power factor.

The DFIG has several advantages. It has the ability to control reactive power and to decouple active and reactive power control by independently controlling the rotor excitation current. It is also capable of generating reactive power that can be delivered to the stator by the grid-side converter.

In normal operation, the grid-side converter operates at unity power factor without being involved in the reactive power exchange between the turbine and the grid.

In the case of a weak grid, where the voltage may fluctuate, the DFIG may be ordered to produce or absorb an amount of reactive power to or from the grid, with the purpose of voltage control. The size of the converter is not related to the total generator power but to the selected speed range and, hence, to the slip power. Thus, the cost of the converter increases when the speed range around the synchronous speed becomes wider.[12]

2.4.4 Type 4: Variable Speed with Full-Scale Frequency Converter (PMSG)

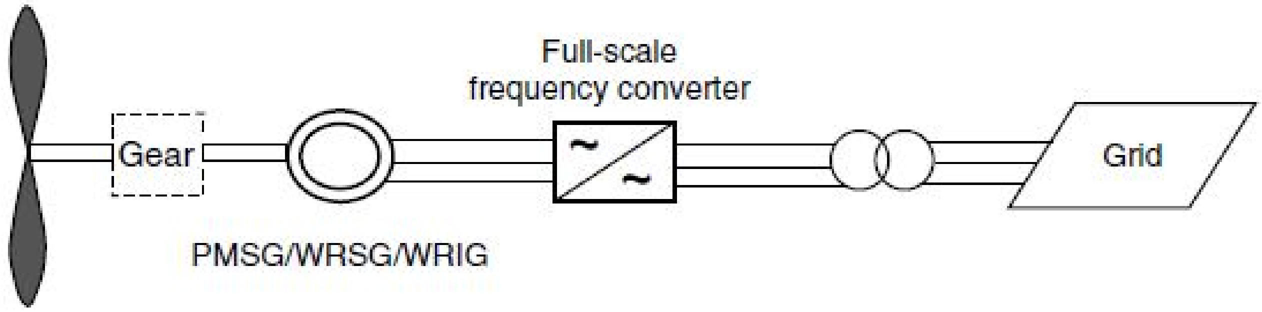

Figure 2.7: Permanent Magnet Synchronous Generator

PMSGs in wind turbines since of their property of self-excitation, which permits an operation at a tall Power factor and a high effectiveness. Within the permanent-magnet machine, the efficiency is higher than within the Induction machine, as the excitation is given without any energy supply. In any case, the materials utilized for creating permenant magnets are costly, and they are troublesome to work during manufacturing. Also, the utilize of Permanent-Magnet excitation requires the utilize of a full-scale power converter in arrange to alter the voltage and frequency of generation to the voltage and the frequency of transmission individually.

The advantage is that power can be produced at any speed. The stators of PMSGs are wound, and the rotor is given with a permanent-magnet pole system and may have salient poles or may be round and hollow. Notable posts are more common in slow-speed machines and may be the foremost valuable adaptation for an application for wind generators.

The synchronous nature of the PMSG may cause issues during startup, synchronization and voltage regulation. It does not promptly give a steady voltage. The synchronous operation moreover causes a really very execution within the case of an outside short circuit, and in case the wind speed is insecure.

Another demerit of PMSGs is that the magnetic materials are sensitive temperature; for occurrence, the magnet can lose its magnetic qualities at tall temperatures. In this manner, the rotor temperature of a PMSG must be directed and a cooling system is required.[12]

2.5 Comparison of Onshore and Offshore Wind Farm

Offshore wind farms are diverse from coastal establishments for a few reasons:
(1) The wind turbine generator have, on normal, bigger distances across and rated power.
(2) Installation and maintenance are more expensive.
(3) The submarine electrical association to shore increments the investment cost.
(4) Offshore wind vitality requires more progressed innovation, particularly within the coupling plan of wind farms.

A primary center is on to create bulk sum of vitality production.due to huge wind control producing capacity and energy generation of offshore wind farm may be bigger than onshore wind farm. for that wind turbines are utilized for offshore wind farm is bigger than onshore wind farm.

In expansion, onshore wind farm stop the daylight and create significant noise to residents, whereas offshore wind farms are more or less invisible. Most of the offshore wind farm are built almost 10 to 20 km to shore,both shadow and noise issues, and the impact upon onshore population is minor.

Cost may be a major demerit of offshore wind energy generation. The cost of an offhore wind farm is more than onshore wind farm. Offshore wind farm regularly are introduced in shallow water with most extreme water deep of up to 30 meters. This requires higher costs and more progressed innovations to construct the establishments and the submerged parts of the monopile. Since offshore sites are distant offshore,the power has got to be transmitted from the wind turbines to the power stations on land through under-sea cables, which is more costly, particularly with the higher voltage required. Another additional fetched for offshore wind farms is maintenance. As offshore wind farms are in a saltwater environment, and most of the wind turbines are planned and tried on arrive without considering saltwater corrosion, the repair and Maintenance costs are for the most part much greater.[11]

Chapter 3

Simulations And Results

3.1 Simulation of Wind Turbine Induction Generator (Phasor Type)

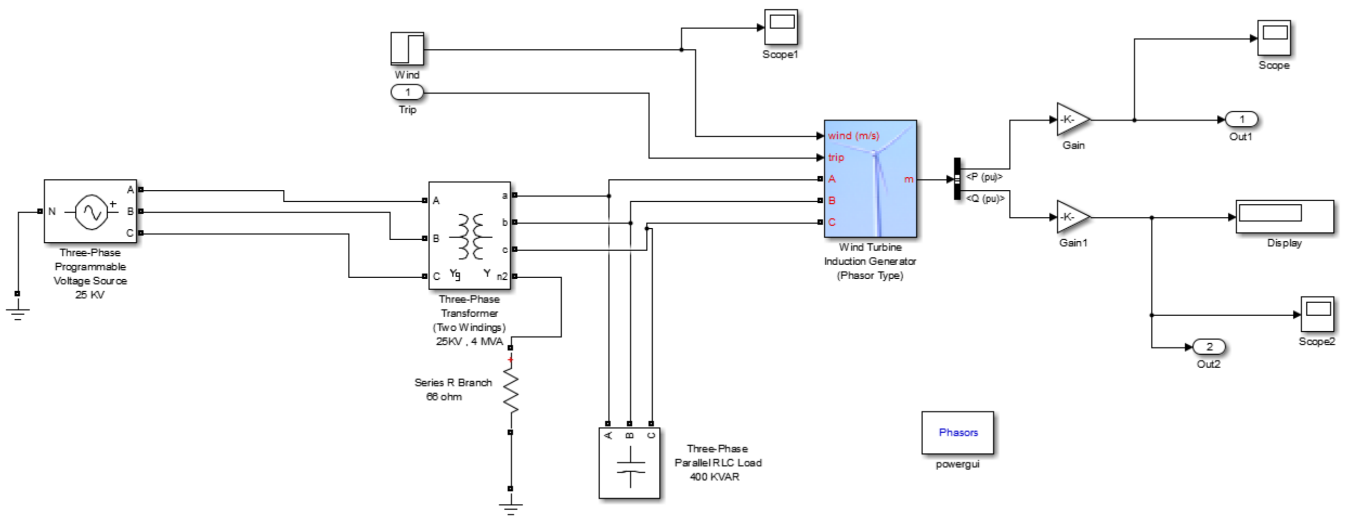

Figure 3.1: Simulation of Wind Turbine Induction Generator (Phasor Type)

- Figure 3.1 shows the simulation of while only one wind turbine is connected with the grid. it measures the Real power(P) and Reactive power(Q) .Figure 3.2 shows the results of Real power(P) which will be 4MW which is approx near to actual value simulation. And Figure 3.3 shows the result of Reactive power(Q) which will absorb the power into results which is -1.771e+05.

3.1.1 Results

- Real Power (P)

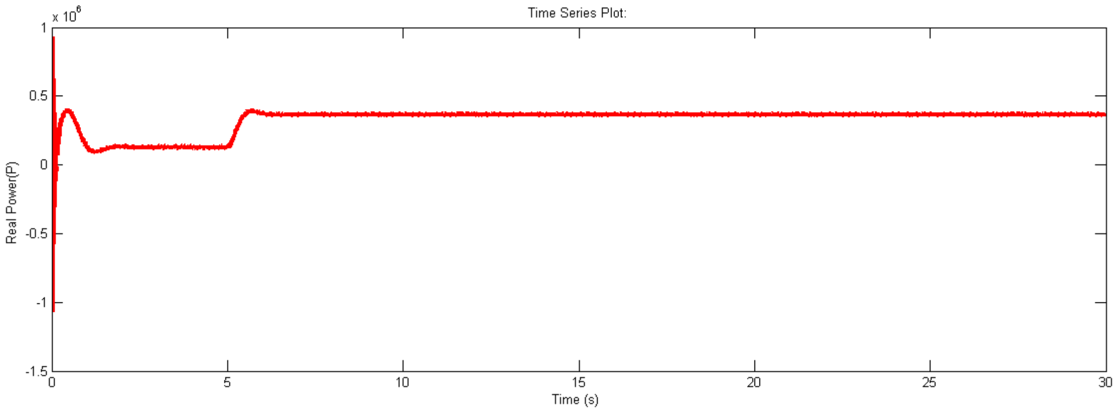

Figure 3.2: Real Power(P)

- Reactive Power (Q)

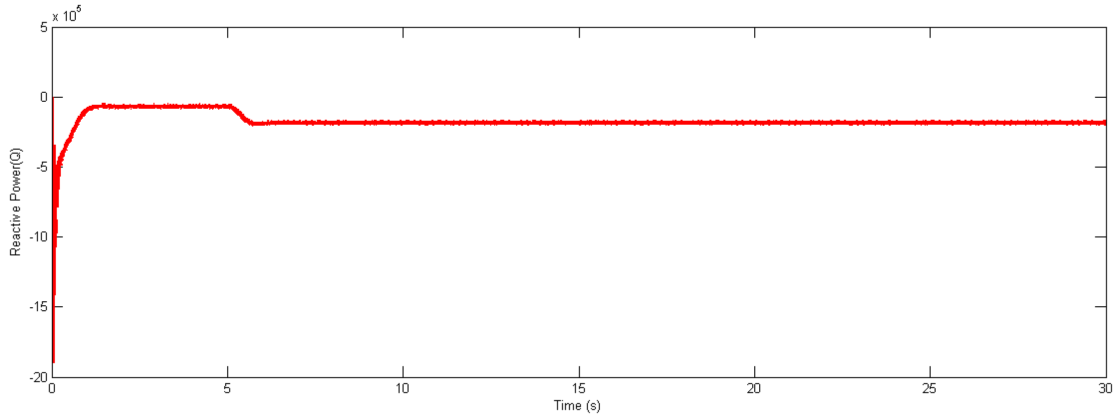

Figure 3.3: Reactive Power(Q)

3.2 Simulation of Wind Turbine Induction Generator(Phasor Type) while 3 Wind Turbines are connected.

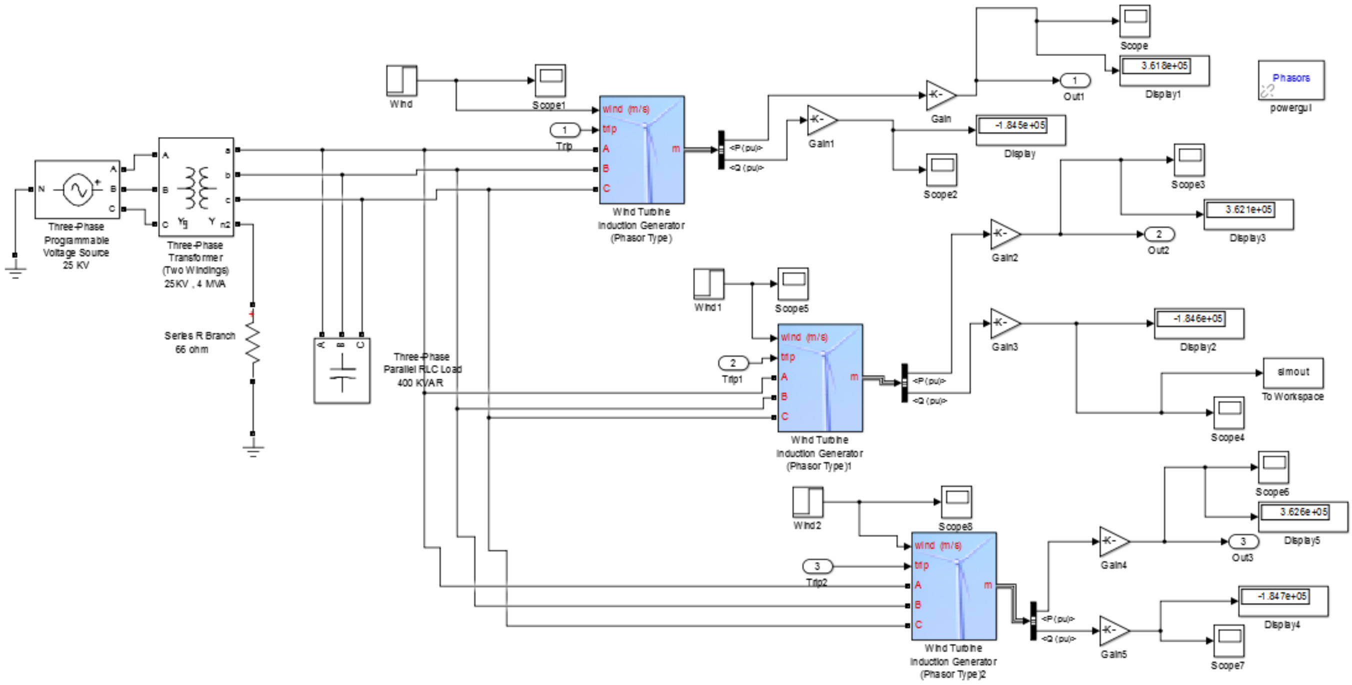

Figure 3.4: 3 Wind Turbines are connected

- Figure 2.4 shows the simulation of three wind turbines which are connected in parallel.It measures Real and Reactive power of the system. below figures i.e Figures 2.5 to 2.10 are the wave forms of real and reactive power of three wind turbines respectively.
- The Real and Reactive power for wind turbine1 is 3.6 MW and -1.845 respectively. Real and Reactive power for wind turbine 2 is 3.5 MW and -1.825 respectively. Real and Reactive power for wind turbine 3 is 3.4 MW and -1.822 respectively.

3.2.1 Results

- Real power (P1)

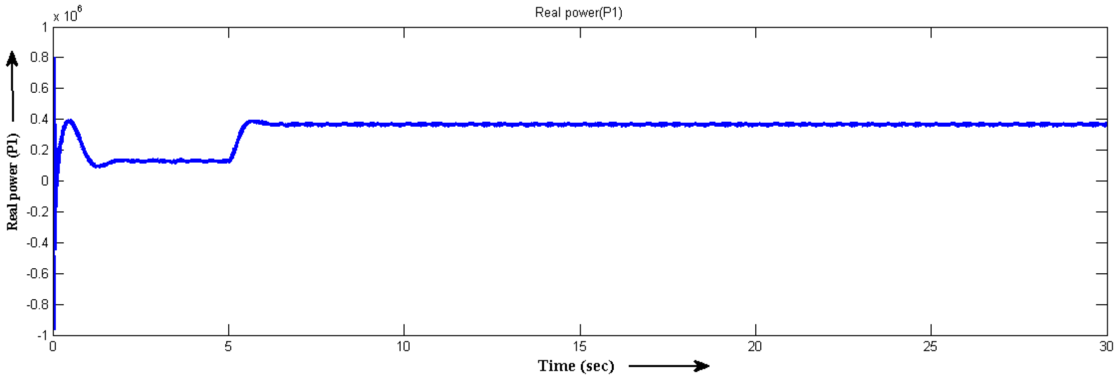

Figure 3.5: Real Power(P1)

- Reactive power (Q1)

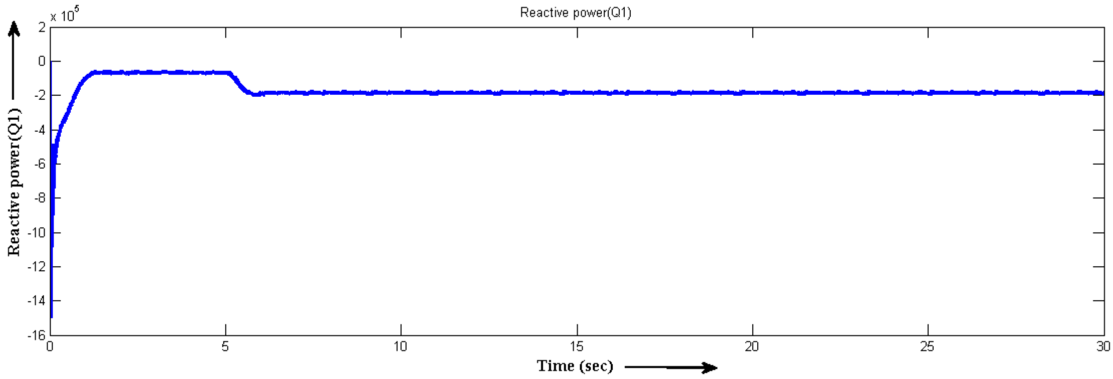

Figure 3.6: Reactive Power(Q1)

- Figure 3.5 and Figure 3.6 shows the output of Real and Reactive power of Induction Generator 1. Real power for Turbine 1 is 3.6 MW and Reactive Power for Turbine 1 is -1.845, which is nearer to the actual value of Turbine.

- Real power (P2)

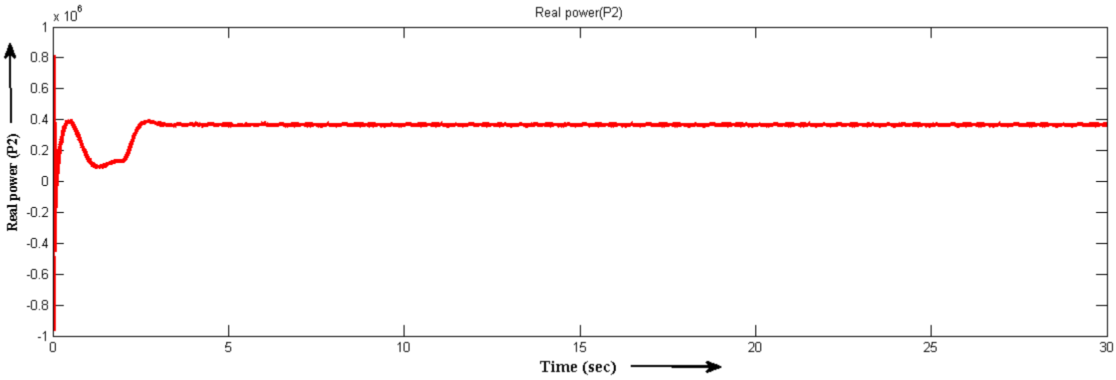

Figure 3.7: Real Power(P2)

- Reactive Power (Q2)

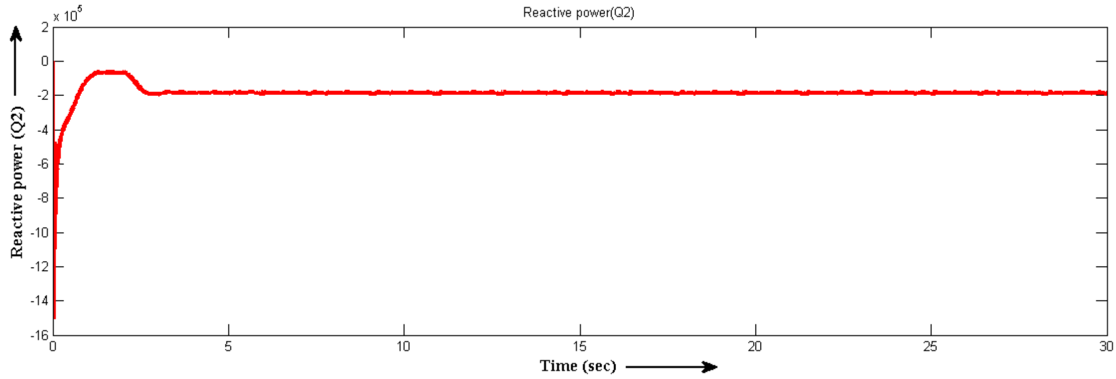

Figure 3.8: Reactive Power(Q2)

- Figure 3.7 and Figure 3.8 shows the output of Real and Reactive power of Induction Generator 2. Real power for Turbine 2 is 3.5 MW and Reactive power for Turbine 2 is -1.825 which is nearer to the actual value of turbine.

- Real Power (P3)

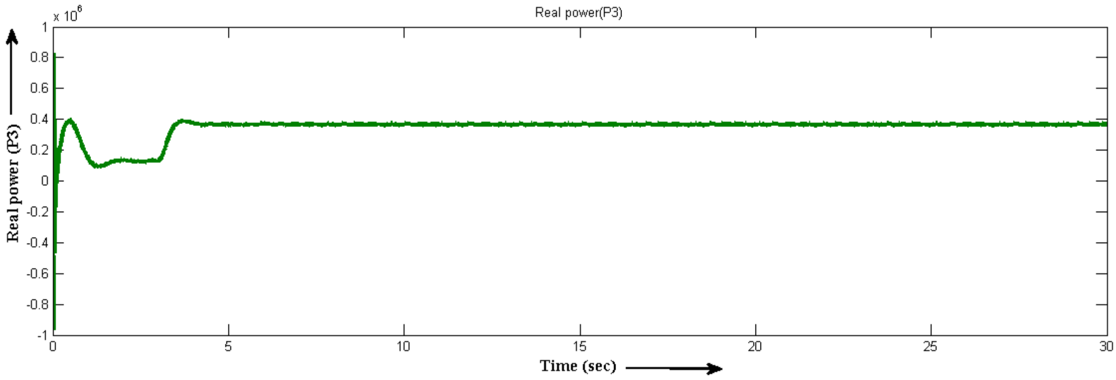

Figure 3.9: Real Power(P3)

- Reactive Power (Q3)

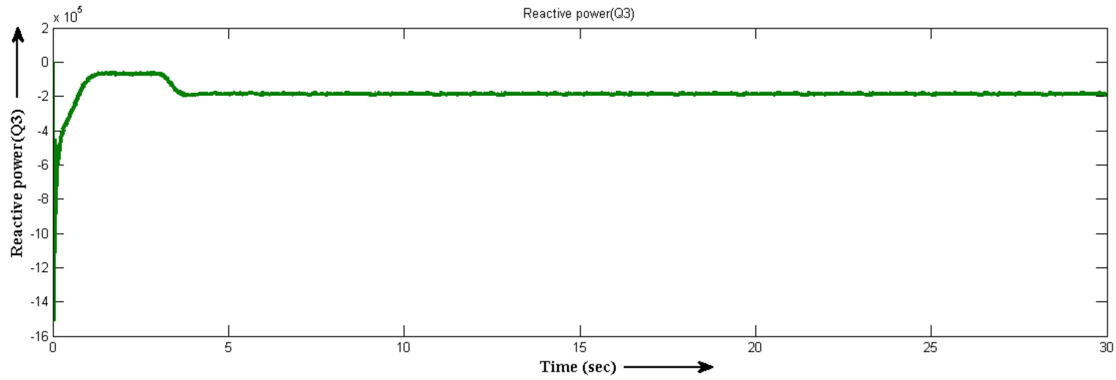

Figure 3.10: Reactive Power(Q3)

- Figure 3.9 and Figure 3.10 shows the output of Real and Reactive power of Induction Generator 3. Real power for Turbine 3 is 3.4 MW and Reactive power for Turbine is -1.822 which is nearer to the actual value of turbine.

3.3 Simulation of Wind Farm

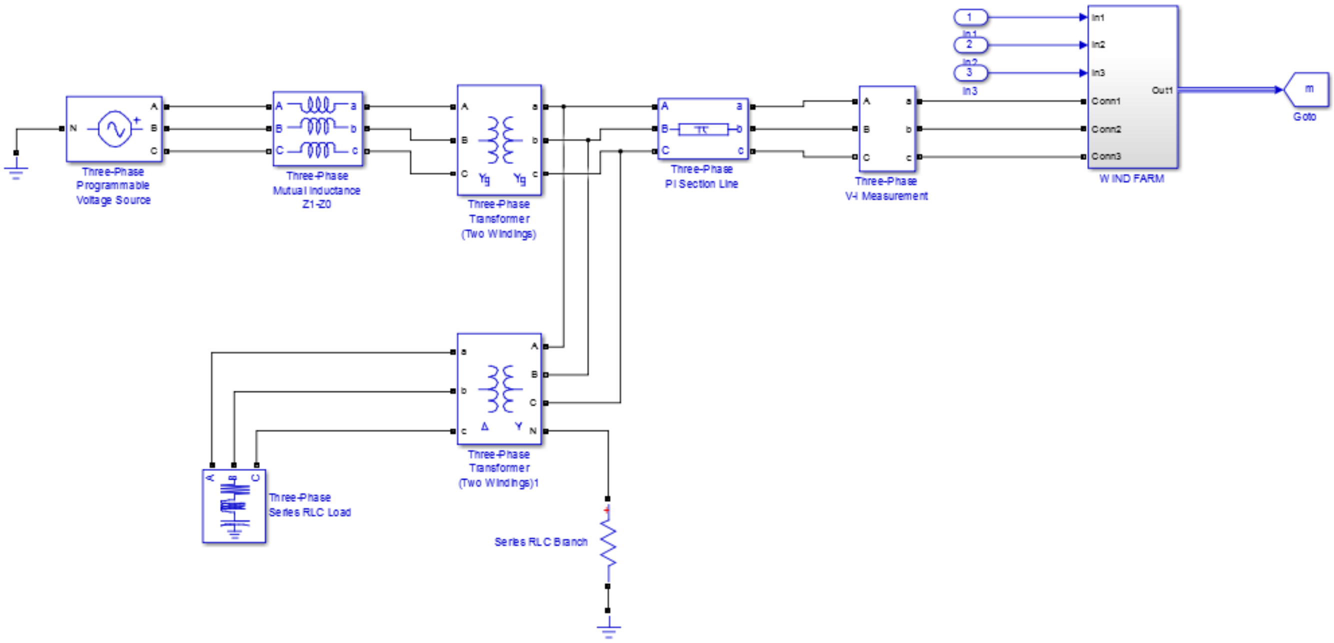

Figure 3.11: Simulation of Wind Farm

- Figure 3.11 Shows the Simulation of wind farm in which 3 Induction Generators are connected in parallel. Each Generator has rating of 2*1.5 MW. A 9 MW wind farm is connected in parallel.

Chapter 4

Conclusion and Future scope

4.1 Conclusion

- In this report Wind Farm is developed in the MATLAB SIMULINK software. The entire system is yet to developed for Wind Farm design and simulation results are carried out is satisfactory.

- In this project Induction Generator(IG) is considered and it is directly connected to the grid. So active power generated by IG is injected into the grid. So due to this three phase variable AC source is considered in this project instead of variable AC output of the Induction Generator because of active power calculation problem.

- The simulated results are verified and considered as satisfactorily.

4.2 Future Work

The work carried out during this project work can be improved further with following work:

- The further work can be extended by illustrating the steady-state and dynamic performance of the WTIG.

- Basic simulation of the proposed topology will carry with another Generator. i.e Doubly Fed Induction Generator

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