

Performance analysis of Doubly Fed Induction Generator using power electronics

DISSERTATION II

*Submitted in fulfillment of the
Requirement of the award of the
Degree of*

**MASTER OF TECHNOLOGY
IN
(Electrical Engineering)**

By

**MEHAK KAUNDAL
Registration no.: 11311314**

Under the Guidance of

Mr.R.K.SHARMA



**School of Electrical and Electronics Engineering
Lovely Professional University
Punjab**

May 2015



Discipline:

PROJECT/DISSERTATION TOPIC APPROVAL PERFORMA

Name of student:

Registration No.:

Batch:

Roll no.:

Session:

Parent section:

Details of Guide:

Name:

Qualification:

U.ID.....

Research Experience:

PROPOSED TOPICS

1.
.....
2.
.....
3.
.....

Signature of Guide

*Guide should finally encircle one topic out of three proposed topics & put up for approval before project approval committee (PAC).

*Original copy of this format after PAC approval will be retained by the student & must be attached in the project/dissertation synopsis & final report.

*One copy to be submitted to guide.

APPROVAL PAC CHAIRPERSON

Signature:

CERTIFICATE

This is to certify that the thesis titled “**Performance analysis of Doubly Fed Induction Generator using power electronics**” that is being submitted by “**MEHAK KAUNDAL**” is in partial fulfillment of the requirements for the award of **MASTER OF TECHNOLOGY DEGREE (POWER SYSTEM)**, is a record of bonafide work done under my /our guidance. The contents of this thesis, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

Mr.R.K.SHARMA

Project Supervisor

(LOVELY PROFESSIONAL UNIVERSITY)

ACKNOWLEDGEMENT

I am grateful to the individuals who contributed their valuable time towards my Dissertation. I wish to express my sincere and heart full gratitude to my guide **Mr.R.K.SHARMA**, HOD, Department Of Electrical Engineering who guided me to take up thispre dissertation in sync with global trends in scientific approach.

I am also grateful to Lovely Professional University for providing me an adequate infrastructure and facilities to carry out the investigations.

MEHAK KAUNDAL

Registration No. 11311314

CERTIFICATE

This is to certify that **Mehak Kaundal** bearing **Registration no.11311314** has completed objective formulation of thesis titled, “**Performance analysis of Doubly Fed Induction Generator using power electronics**” under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study.

No part of the thesis has even been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfillment of the conditions for the award of **MASTER OF TECHNOLOGY (POWER SYSTEM)**.

Mr.R.K.SHARMA

Lovely Professional University

Phagwara, Punjab.

Date:

DECLARATION

I, MEHAK KAUNDAL student of MASTER OF TECHNOLOGY (POWER SYSTEM) under DEPARTMENT OF ELECTRICAL ENGINEERING of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report is based on my own intensive research and is genuine.

This thesis does to the best of my knowledge; contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

Date:

MEHAK KAUNDAL

Registration No.11311314

LIST OF FIGURES

Fig.1.1.Fixed Speed Generating System

Fig.1.2.Variable Speed Doubly- Fed Induction Generator System

Fig.1.3.Doubly Fed Induction Generator

Fig.1.4.Mode 1: Sub Synchronous Motoring

Fig.1.5.Mode 2: Super Synchronous Motoring

Fig.1.6.Mode 3: Sub Synchronous regeneration

Fig.1.7.Mode 4: Super Synchronous regeneration

Fig.4.1.Basic Diagram of Doubly Fed Induction Generator with Converters

Fig.4.2.Power Flow Diagram of DFIG

Fig.4.3.Back to Back PWM Structure

Fig.4.4. Block diagram of Rotor Converter Control

Fig.4.5.Grid Side Converter Control

Fig.4.6. Pitch angle control system

Fig.5.1.Schematic of Experimental System

Fig.5.2. Matlab Circuit of DFIG using back-to-back PWM converter

Fig.5.3. Output of Grid Current

Fig.5.4. Gate Pulse

Fig.5.5. Output of Phase of Stator verses Rotor

Fig.5.6. Output of DFIG Voltage

Fig.5.7. Output of Line Current

Fig.5.8. Phase Angle of Stator and Rotor

TABLE OF CONTENTS

LIST OF FIGURES	vii
CHAPTER1. INTRODUCTION	1
1.1 Notion of wind turbine	2
1.2 Category associated with Devices	3
1.3 Advantages of Doubly Fed Induction Generator	7
CHAPTER2. SCOPE OF STUDY	12
CHAPTER3. LITERATURE REVIEW	13
CHAPTER4. PROJECT WORK	16
4.1 Operating principle of DFIG	17
4.1.1 Features of doubly fed machines	19
4.1.2 Back-to-Back AC/DC/AC Converter Modeling	20
4.2. Converter Control System	22
4.2.1. Rotor side converter Control System	22
4.2.2. Grid side converter control system	23
4.2.3. Pitch angle control system	24
CHAPTER5. MAIN WORK OF PROJECT	25
CHAPTER6. CONCLUSION	31
REFERENCES	32

CHAPTER 1

INTRODUCTION

Energy may be the major standards regarding human progress in different country. Any kind of country can be in short period of time by simply creating power inside substantial range. Energy options can be broken down in to a pair of categories such as, conventional power options as well as non-conventional power options. This is not for green means usually are minimal inside characteristics, gasoline, coal and many others. Usually are non-renewable methods to obtain power. These are referred to as non-renewable since their sourcing rate is really slower upon human occasion range. So, green power options like the wind power, gasoline cell phone as well as power from the sun and many others may be used more. Blowing wind power is usually fast developing and a lot encouraging green power source. It's low cost, immense, fresh, abundant and many others. The wind power can be become electrical energy by simply coupling this induction creator along with the wind work. The overall put in ability of the wind electric power era inside '08 is usually 8754 MW as well as it may be reached approximately 12000 MW towards the end of 2012. Blowing wind in wind turbine can be broken down in to a pair of categories. They are able to possibly run from set rate or maybe variable rate. Inside the fixed-speed windmill this creator is usually specifically associated with this electric grid. They have got minimal performance and also have simply no power to produce reactive electric power help. To get a variable rate windmill this creator is usually controlled by simply electric power electronic gear. There are several advantages of applying variable-speed procedure there're: -- possibilities to cut back pressure of mechanized composition, acoustic sounds decrease as well as probability to manage effective as well as reactive electric power. Nearly all of this windmill makes usually are acquiring brand-new substantial wind turbines in the choice of 3-6 MW as well as these substantial wind turbines derive from variable-speed procedure along with toss management applying direct-driven synchronous creator or maybe doubly-fed induction creator. Nowadays, this ease on the induction device is usually controlled by simply doubly-fed induction generation devices that happen to be most often utilized by this windmill marketplace. This major selling point of applying doubly-fed induction creator may be the electric power electronic gear simply needs to deal with fraction (20-30%) of complete method. Thus, cutbacks inside electric power electronic gear lowered compared to electric power electronic gear which will

deal with complete method electric power regarding direct-driven synchronous creator. In this segment this windmill principles will be displayed.

1.1. Notion of Wind generator:-

1. Fixed-speed turbine with the induction generator.
2. Variable-speed turbine built with a Doubly-fed induction generator.

Fixed-Speed System:-

In this process, the particular induction generator is usually directly linked to the particular electric powered grid. Your rotor rate with this process is usually tweaked with a gear-box and also the pole-pair variety of the particular generator. This system is usually built with a couple induction devices, 1 with regard to lower blowing wind rate then one with regard to large blowing wind rate.

This system can be illustrated within fig.1.1

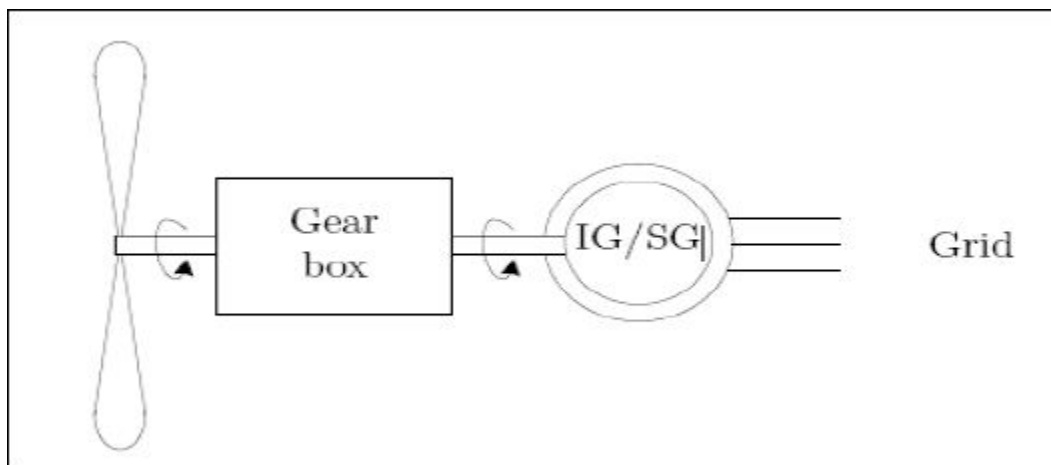


Fig.1.1. Fixed Speed Generating System

Limited Variable Speed System:-

Within this technique, see fig.1.2 a couple of that includes a wind turbine which has a variable-speed regular volume induction generator. Within this, the particular stator will be straight attached to the particular grid while the rotor rotating will be connected by way of fall happens to be to an inverter.

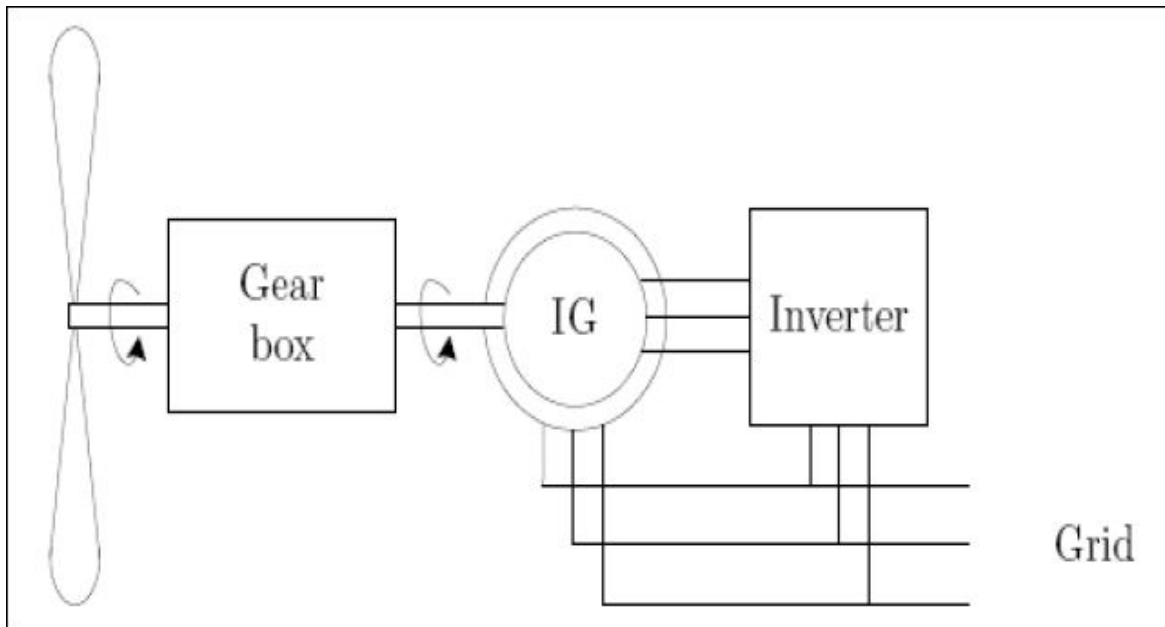


Fig.1.2. Limited Variable Speed System

The particular inverter is designed in a way how the induction turbine can operate within a restricted variable-speed range. The particular rate involving gear-box is set so the minimal pace on the induction turbine related for the middle benefit on the range rotor-speed on the windmill. It may be carried out to help limit the dimensions of this inverter that will range while using array of rotor-speed. Due to this inverter it's possible to command this reactive strength as well as pace as well as involving induction turbine.

1.2 Category associated with Devices:-

Generator turns your physical electricity straight into power.

They can be categorized straight into a couple of pieces specifically:

a) Synchronous Devices

b) Asynchronous Devices

Synchronous turbines run from synchronous velocity whilst asynchronous turbines run from velocity that's greater than synchronous velocity.

Synchronous Generators:-

They are doubly fed machines which can generate electricity by the principle when the magnetic field around a conductor changes, a current is induced in the conductor. The rotor turns within a stationary set of conductors wound in coils on an iron core, called the stator. As the mechanical input causes the rotor to turn the field cuts across the conductors and generate an electrical current. Here as the number of poles increases, it lowers the rotational speed and having low gear box ratio. But it means that the generator used here is of large dimension and more weight. AC voltage is induced in stator windings by rotating magnetic field. . The rotor magnetic field may be produced either by induction by permanent magnets, or by a rotor winding which is energized with direct current through brushes and slip rings. Due to magnetizing current, machines of permanent magnet evade the losses, but they are limited in size and due to the charge of the magnet material. Therefore, the permanent magnet field is constant and the terminal voltage varies directly with the speed of the generator.

Asynchronous Generators:-

Asynchronous generation devices are singly excited a. d. unit. Their stator winding can be straight linked for the alternating current supply and it is rotor winding get their power coming from stator from the induction. The stator in addition to rotor produced meters farreneheit in addition to meters farreneheit wave respectively, both swivel in the identical route in the air flow distance at the synchronous swiftness in addition to those two meters might subscribe to supply the particular producing air-gap flux denseness wave associated with continuous amplitude plus they are spinning at the synchronous swiftness and this also flux generate recent in the rotor in addition to the electromagnetic torque can be generate which usually swivel the particular rotor. Most of these generation devices are generally applied since wind turbines. They might be work from varying Pace.

A pair of types of asynchronous generation devices utilized specifically:

- a) Squirrel cage induction generator (SCIG)
- b) Doubly fed induction generator (DFIG).

Squirrel Cage Induction Generator (SCIG):-

It's the turning component. It contains longitudinal conductive parts. SCIG is actually specifically attached to this grid. The actual speed of SCIG is usually changed simply by several percent because turbine gets a result of modifications inside speed of wind. Therefore, that turbine can be employed for constant-speed wind turbines.

Electrical generator and also the rotor of wind mill are coupled by way of gearbox. Consequently, wind turbines are based on a SCIG which are normally furnished with a soft-starter system along with it might be installed for reactive energy pay out, while SCIGs take in reactive energy. Such a turbines have a sharp torque-speed quality along with fluctuations inside wind energy are sent right to this grid along with these kind of transients are vital through the grid network, where this in-rush existing reaches nearly 7–8 instances from the performing existing. Therefore, connections of SCIG towards the grid will be built correctly as well as slowly to help restriction this in-rush existing. With the magnetizing existing the total heat energy aspect is actually minimal that your significant problem is actually. Consequently, minimal energy aspect is usually paid simply by connecting these capacitors inside parallel towards the turbine. If the wrong doing takes place, SCIGs without having reactive energy pay out the system can certainly result in voltage lack of stability and also the rotor of wind mill is usually improve. Just for this, there's the discrepancy between your powers along with kinetic torque and once this wrong doing is actually loosened, SCIGs attract reactive energy through the grid inside plenty that leads to help lowering in voltage.

Doubly Fed Induction Generator:-

Doubly-fed power devices usually are basically power devices that happen to be fed air conditioning currents throughout both equally the rotor in addition to stator windings. Now-a-days, throughout business the vast majority of doubly-fed power devices usually are three-phase wound-rotor induction devices. These days, doubly-fed power devices usually are common.

DFIG is actually Two times Raised on Induction Generator which is generally employed in wind generators. That will depend on the induction generator using a multiphase twisted rotor in

addition to multiphase slip-rings. Wind generator might be built with any type of three-phase generator, similar to synchronous generator in addition to asynchronous generator. Twice as fed induction generator is actually asynchronous generator. Twice as fed induction generator is actually more much better to its several positive aspects. Doubly-fed induction turbines would be the most favored kind of doubly-fed power unit.

In wind generators, doubly fed induction generator usually are one of the most widespread types of generator that happen to be helpful to create electricity. Doubly-fed induction turbines include many positive aspects in contrast with other kinds involving turbines while employed in wind generators. The rule involving DFIG is actually the windings involving rotor usually are linked to the grid through slip-rings in addition to back to returning voltage resource converter. They will control both rotor and the grid currents. Therefore, rotor in addition to grid frequency varies via each other (50 as well as 58 Hz). You possibly can modify the active in addition to reactive energy fed to the grid by simply managing the rotor currents by simply convertor.

The rotor voltages is going to be better in addition to currents reduce for the reason that doubly-fed generator rotors usually are twisted with via 2-3 times how many spins on the stator. Therefore, ± 30 functional pace range throughout the synchronous pace the performing present on the converter is gloomier bringing about affordable on the converter.

Like a summary, doubly fed induction unit is usually a wound-rotor doubly-fed power unit in addition to throughout purposes involving the wind energy, it's got several positive aspects spanning a traditional induction unit.

Firstly, the rotor enterprise is actually handled by simply energy electronic devices converter and the induction generator has the ability to scan in addition to export the reactive energy. This has a vital end result intended for steadiness involving energy method and it also allows the equipment to guide the grid through extreme voltage disturbance.

Next, as you move the pace connected with turbine varies the actual control on the rotor voltages as well as currents enables the actual induction device to within synchronize with the grid. Especially through mild wind flow problems, varying pace turbine uses the actual readily available wind flow resource much more correctly than the usual fixed pace turbine. Additionally, because simply fraction on the hardware power (25-30 %) will be fed to the grid over the converter and also the relaxation connected with power fed for you to grid immediately

in the stator, the money necessary for the actual converter will be small when compared to other varying pace options. The productivity on the DFIG is very perfect for the same reason.

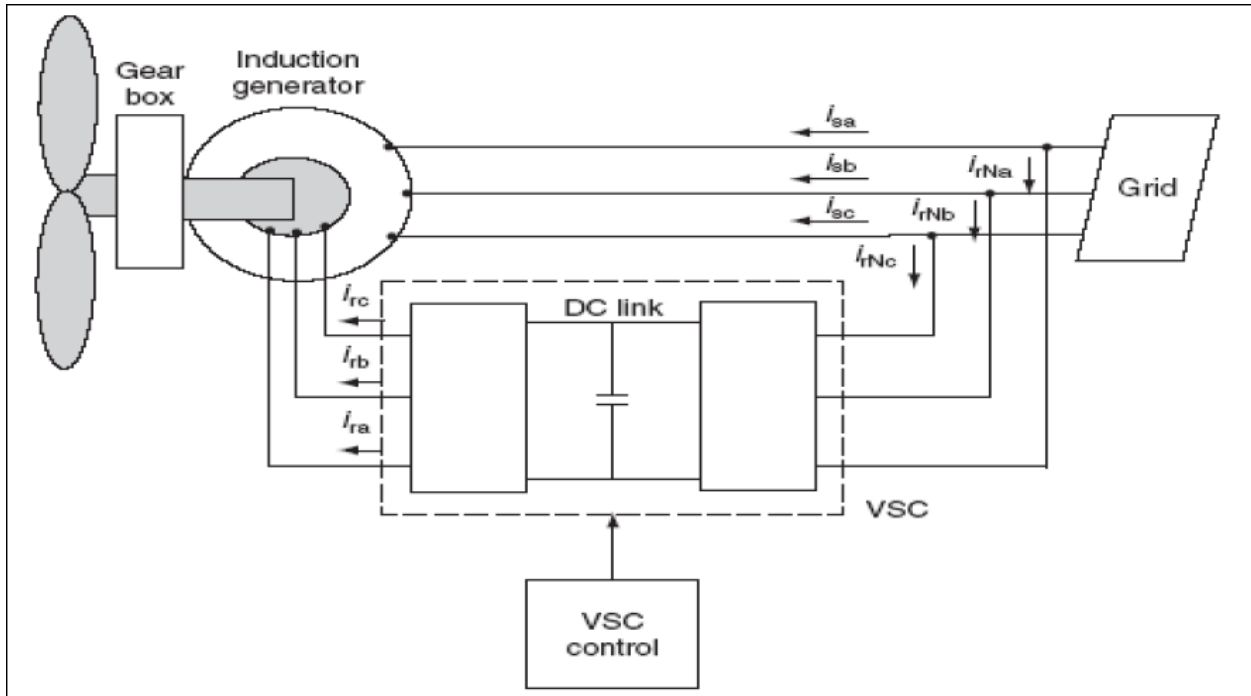
1.3. Advantages of Doubly Fed Induction Generator:-

- Doubly-fed induction machines as soon as employed in wind generators can be them to let the amplitude and also consistency of the productivity voltages to become preserved in a regular worth, simply no subject the actual velocity on the blowing wind coming within the wind generator rotor. For that reason, doubly fed induction machines can be straight connected to the actual HVACs electric power system and also continue being synchronized at all times with the HVACs electric power system.
- The chance to control the electricity factor though keeping the electricity electronic devices gadgets in the wind generator in a average dimensions.
- It can operate within electrical generator or even generator method intended for equally sub-contract and also super synchronies velocity method.
- Pace alternative all around synchronous velocity can be purchased by simply use of electric power converter.
- It's not at all important to be magnetized through grid as you possibly can magnetized through rotor circuit additionally.
- It can operate such as synchronous electrical generator and also in changing velocity, while its stator can be straight connected to grid.
- They are able to help with the actual system's stability after having a mistake arises.

When utilizing traditional squirrel crate asynchronous products, very high magnetizing currents may be utilized from the power grid when they are coping with community failing takes place in the power system. If your power system will be vulnerable and yes it is not give you a ample magnetizing present, the actual squirrel crate asynchronous equipment maintains upon quickly moving. The actual asynchronous machine pulls magnetizing current from your grid, and voltage lower takes place. If your safeguard technique disconnects this wind generator coming from grid from that fast voltage lower stop. Asynchronous electrical generator is additionally featuring a rotor linked to a VSC by using ease bands, a so-called doubly raised on induction electrical generator. Below this VSC is usually linked to handle technique which usually can determine

this voltage. Additionally it offers variable-speed ability, which usually means that we can improve electric power generation. By simply managing this rotor voltage, this VSC can be handling the actual which is attracted from your grid. The actual voltage which is impresses within the rotor is usually calculated by simply swiftness, torque and voltage. They are these controllers which this VSC handle consists.

Different parts of DFIG is shown in fig.1.5



1.3. Doubly Fed Induction Generator

Within this, a couple connections in the machine for the around multilevel provide increase the phrase 'doubly fed'. The particular VSC involves a couple converters that have a DC website link involving these. The particular VSC hooks up this rotor for the multilevel.

The particular the different parts of this DFIG are:

- 1) Wind Turbine
- 2) Gear box
- 3) Induction generator
- 4) Converters (VSC)
- 5) DC link (VSC)
- 6) Voltage control

- 7) Speed control
- 8) Torque control

The VSC determines the rotor voltage and for this purpose they can use speed, torque and voltage controllers. Here it is assumed that the wind turbine provides a constant mechanical torque i.e. T_{mech} to the generator and neglect the gearbox. We will derive the equations of the induction generator. The converters and the DC link will not be discussed in detail and the VSC is represented by its output.

There are four modes of operation of WRIM. Each and every mode is described below by assuming that system is lossless.

(1) Sub Synchronous Motoring:- In this, the operation of sub synchronous motoring is same as that of the induction machine. Out of input air gap, the stator power P_g , rotor power $P_r = sP_g$ which is returned to the supply. So that the balance power $P_m = (1-s) P_g$ appears as the mechanical output which is required to come from supply. Stator draws the reactive power continuously from the supply and produces rotating magnetic field with respect to the stator. Rotor field with respect to rotor is slip speed in the same direction of rotating magnetic field which makes the rotor field and stator field stationary with respect to each other.

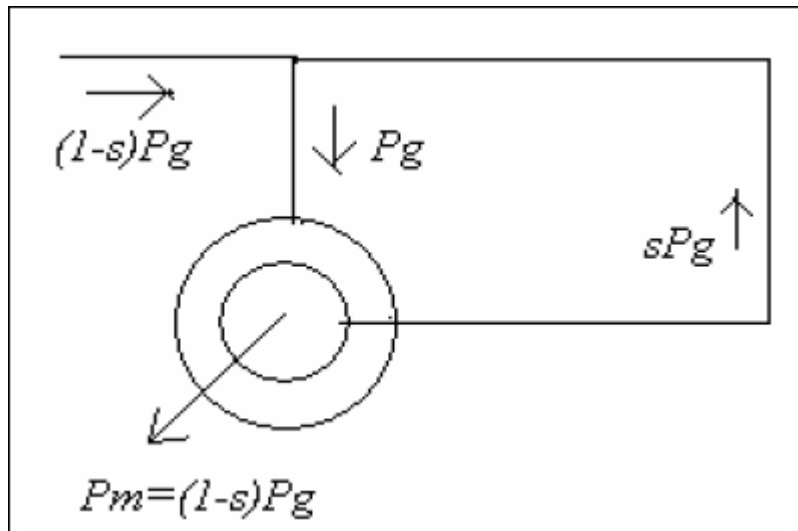


Fig.1.4. Mode 1: Sub Synchronous Motoring

(2) Super Synchronous Motoring:- With this, functioning stage series associated with rotor fall rate of recurrence can be reversed, in order that the rotor area regarding rotor can be fall swiftness in the other course associated with synchronously rotating permanent

magnetic area. To generate the rotor area stationary regarding stator area, rotor might be rotate earlier mentioned the synchronous swiftness in the course since in which associated with stator area. It's simply feasible when the rotor additionally forces the power coming from present. Given that, both stator along with rotor bring strength coming from present hence the mechanized strength P_m hours = $(1+s) P_g$ presents itself as a possible result.

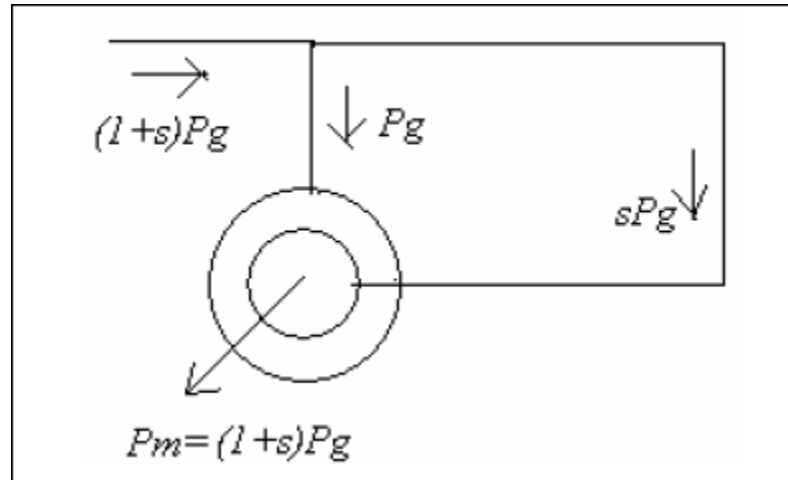


Fig.1.5. Mode 2: Super Synchronous Motoring

(3) Sub Synchronous Regeneration:- In this, insight mechanized electrical power P_m hours = $(1-s) P_g$ spun your rotor which can be a lot less than synchronous speed, so the rotor discipline regarding rotor will be ease speed from the very same course of stator discipline. The item is comparable to subscription synchronous motoring mode, though the rotor needs to attract the power $P_r = sP_g$ via present to obtain result as electricity P_g from the stator. As a result, entire electrical power feasted for the present will be $(1-s) P_g$.

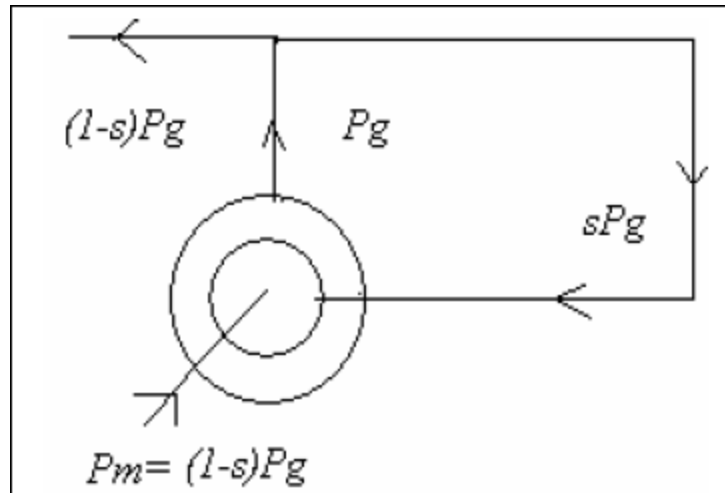


Fig.1.6. Mode 3: Sub Synchronous Regeneration

(4) **Super Synchronous Regeneration:-** In this, this insight mechanical electrical power $P_m = (1+s)P_g$ turned this rotor previously mentioned this synchronous velocity, so the rotor discipline with respect to rotor is usually slide velocity in the contrary course associated with stator discipline. This resembles tremendous synchronous car method, although below this rotor has to produce the electricity Public relations $= sP_g$ towards offer for getting electricity result P_g from your stator. Thus, full electrical power given to supply is usually $(1+s)P_g$.

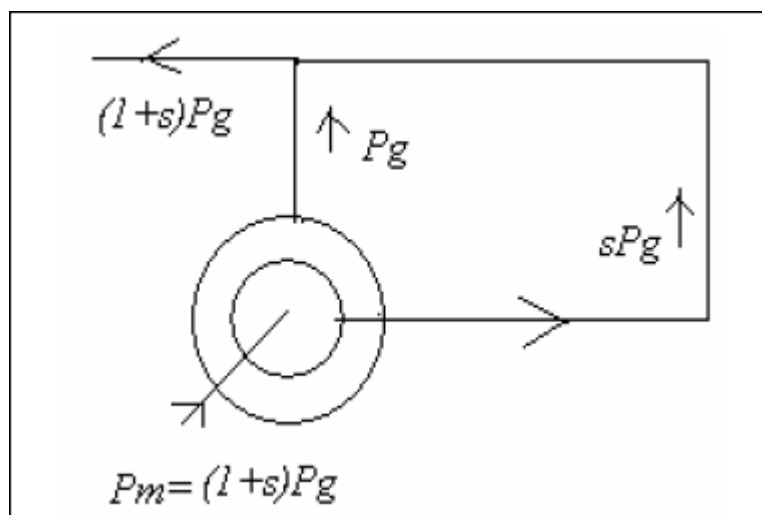


Fig.1.7. Mode 4: Super Synchronous Regeneration

CHAPTER 2

SCOPE OF STUDY

The wind can be a renewable source of vitality and it's also another solution resource to make electrical energy. It is low-cost, immense; clean up as well as numerous and many others blowing wind vitality can be become electric power by simply coupling the actual induction generator along with blowing wind work. Energy created by simply blowing wind increasing to some great magnitude. Twice as feasted induction generator provides several because they make it possible for to keep up on-line associated with amplitude as well as regularity continual of their end result. A number of completely new blowing wind jobs were put in from the U. Ersus. From the late '90s, which include any bunch associated with Zond Z-40 generators run for just a power throughout south west Arizona, any blowing wind grow associated with 46 Vestas products designed with regard to Huge Planting season, Arizona, any 10- megawatt blowing wind grow throughout Northern Colorado, quite a few plant life from the higher middle west, and also the "re-powering" associated with a few jobs throughout Colorado. Many of these include overseas products stated in the actual U. Ersus Could possibly perception which the sector is usually last but not least moving home again, along with over 2000 megawatts associated with completely new potential designed with regard to 2001 from the U. Ersus on your own. Present as well as designed U. Ersus jobs can be discovered while using the wind Undertaking Place preserved through the Us The wind Energy Connection. It truly is hard in order to accurately review the costs associated with blowing wind plant life as well as fossil energy plant life since the charge people are generally so various. Reduced installed-cost-per-kilowatt numbers with regard to blowing wind generators are generally relatively deceptive with the reduced potential factor associated with wind turbines in accordance with coal along with other fossil-fueled strength plant life. Capacity components associated with effective blowing wind village procedures cover anything from 0.20 in order to 0.35. Most of these can be weighed against components of greater than 0.50 with regard to fossil-fuel strength plant life as well as over 0.58 with regard to a number of the completely new petrol generators.

CHAPTER 3

LITERATURE REVIEW

(1) Shilpi Saini

With this document, it really is reviewed your write-up on twice as raised on induction creator. Once we are aware that, breeze is usually a environmentally friendly, non-polluting in fact it is an alternative source for your production of energy. By last few years, this method to obtain power grew to become quite popular for giving the power for syndication devices. For this purpose, they employ various kinds of generators. Presently, twice as raised on induction generators tend to be trusted for product above 1MW. Doubly rose on induction models to overpower your make it possible for effective as well as reactive power by using rotor-side converter and the stator is directly attached to your grid. For this reason a review of your suitability of Doubly Fed Induction creator and its particular qualities so that it is a lot more finer quality than standalone when compared with other generators. The particular rotor security strategies will also be incorporated for DFIG.

(2) Keith Godfrey, Feng Wu

On this document, modeling and also command of wind mill is actually mentioned. Right here this rising integration from the wind flow strength from the power process networks offers has an effect on this stability of power process. Twice as Given Induction Power generator (DFIG) turns into much more dominating wind mill sorts which might be utilized in wind flow farming because of the improvement of wind mill strategies. Because of this, throughout power process stability analysis, twice as fed induction generator might be modeled properly. Expose model of this wind mill together with twice as fed induction generator is actually mentioned below. It is controllers are generally also presented and this can be for electrical era. Style of modest indication stability springs dependant on the idea. Modest indication stability analysis ensures that this, twice as fed induction generator command which could enhance the stability of wind mill process. Applying a set of optimized controller guidelines, this stability may be additional enhanced. To be able to illustrate this command effectiveness energetic simulations are generally executed.

(3) Ling Peng, Yongdong Li

In that document, Modeling and Control regarding Doubly Feasted Induction Generator wind turbines through the use of Causal Placing your order Graph while in Voltage Dips. These days, doubly raised on induction era this widely used with regard to adjustable speed wind turbine with regard to products preceding 1MW. Because wind electric power is constantly on the climb, wind turbines are generally forced to continue to be linked with grid through the defects. The actual management program contains this greatest electric power level pursuing (MPPT), management with the reactive electric power and the standard of electric power, along with the management with the advanced beginner DC tour bus. Simulation benefits signifies that while in voltage dips, this recommended modeling and management technique offers satisfactory management regarding this DFIG wind generator program.

(4) M.B. Mohamed, M.Jemli

With this perform, twice as raised on induction electrical generator can be analyzed intended for the wind energy alteration. Right here, inside rotor reference frame the particular dq model of wound rotor can be talked about as well as exactly how it might be applied intended for rapidly simulations. PI controllers is usually for handling the ability move between stator involving twice as raised on induction electrical generator as well as grid. Result of that simulation have shown the outstanding effectiveness using stator flux angle manage (SFOC).

(5) H.Djeghloud, A.Bentounsi

In this work, simulation connected with doubly feasted induction generator applying Matlab. That document deals with the particular transformation connected with wind flow strength by utilizing doubly feasted induction generator. The objective of this really is of which in order to act in response the particular simultaneously towards element electric powered strength as well as electrical power top quality. The main purpose of wind flow strength transformation method it isn't just in order to trail the ideal electrical power stage on the wind flow strength but also in order to dampen the particular harmonic currents from the grid collection. Therefore back-to- returning heart beat width modulation (PWM) as well as voltage source converters (VSCs) are employed in order to

stimulate the particular doubly fed induction generator rotor the particular grid collection to achieve most of these uses. Intended for preventing the electricity converters, 2 legislations loops usually are following a discipline oriented manage (FOC) method. The very first never-ending loop, associated with the particular rotor converter, allows any decoupled manage connected with active as well as reactive forces moves.. The second never-ending loop, associated with the particular front-end converter (FEC) that makes convertor to modify the particular DC-bus voltage that is propagated between the 2 converters. Moreover, the particular document offers an examine on the DFIG sub-contract as well as super-synchronous managing modalities. To show the particular effectiveness connected with wind flow strength transformation method, any Matlab type seemed to be recognized as well as simulated.

(6) A.Dendouga, R.Abdessemed

In this particular paper a new decoupled handle of a twice as fed induction unit used in technology function (DFIG) is actually presented. It offers superior decoupled regulations from the primary facet effective as well as reactive power and it's suitable for both energy vitality technology as well as travel applications. The actual precise type of the machine written within an correct d-q research frame is made to look into simulations. So that you can handle the facility moving between the stator from the DFIG and also the multilevel, a new decoupled handle connected with effective as well as reactive power is actually synthesized utilizing PI controllers. Their respected tasks tend to be with regard to stator currents personal references checking.

(7) A.P. Tennakoont, A.Arulampalam

This particular report works with numerous applications involving twice as fed induction turbines regarding wind power generation. Induction devices along with the wind generators include their own purely natural attributes. This particular report explains to of which the way the injure rotor induction power generator plays its part if it's in conjunction with this wind turbine together with the manage restrict. This particular report talks about a number of features that needs to be thought to be when making along with manage involving wind power generating method utilizing DFIG.

CHAPTER 4

PROJECT WORK

Wind turbines utilize a doubly-fed induction electrical generator (DFIG) which includes a rotor induction electrical generator as well as the AC/DC/AC IGBT-based PWM converter. The particular stator rotating is right linked with this grid while rotor is raised on with varying rate of recurrence from the AC/DC/AC converter. By means of optimizing this wind turbine rate, this DFIG components at most vitality through the wind with regard to low the wind. The particular wind turbine rate yields the absolute maximum physical vitality is proportional towards the wind rate. Another advantage of DFIG is the capacity with regard to strength electronics converters to soak up or perhaps builds reactive strength. Regarding squirrel-cage induction electrical generator, there's no need associated with putting in capacitor financial institutions.

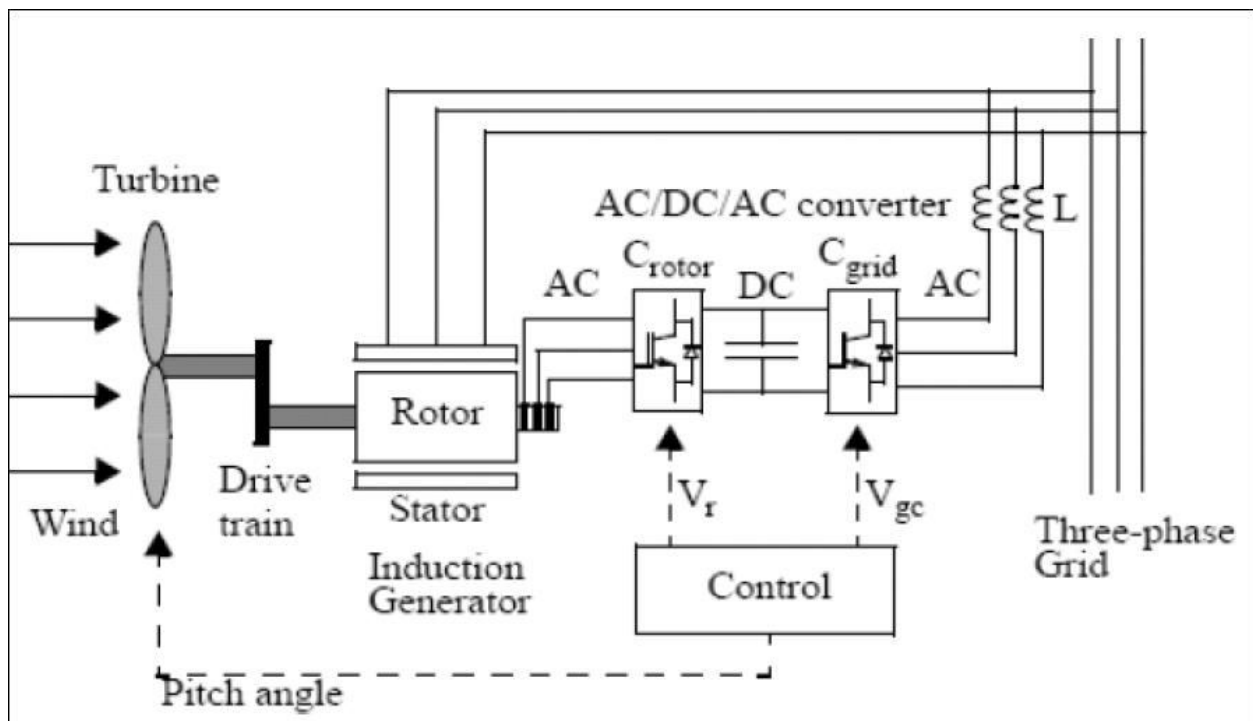


Fig.4.1. Basic Diagram of Doubly-Fed Induction Generator with Converters

Where by rotor voltage is usually V_r and grid facet voltage is usually V_{gc} . Your AC/DC/AC converter is usually PWM converter which makes use of sinusoidal PWM way to slow up the harmonics which might be specific to the particular blowing wind turbine. Right here rotor facet

converter Rotor and grid facet converter is usually Cgrid. To regulate the particular rate involving turbine gear packing containers or maybe electric handle can be used.

4.1 Operating Principle of DFIG:-

Inside DFIG, this stator is usually directly associated with this AC main and also the injury rotor is usually provided through the Electric power Gadgets Converter via fall jewelry which in turn let DFIG to operate with a different rate of speed since the velocity connected with the wind adjustments. The concept is usually that will to be able to interpose this consistency converter relating to the varying consistency induction power generator and preset consistency grid. The particular DC capacitor hyperlinks this stator-converter and rotor-side converters which in turn let the hard drive connected with energy by induction power generator intended for further generation. To attain whole management connected with grid current, this DC-link voltage has to be lifted into a degree greater than this amplitude connected with grid line-to-line voltage.

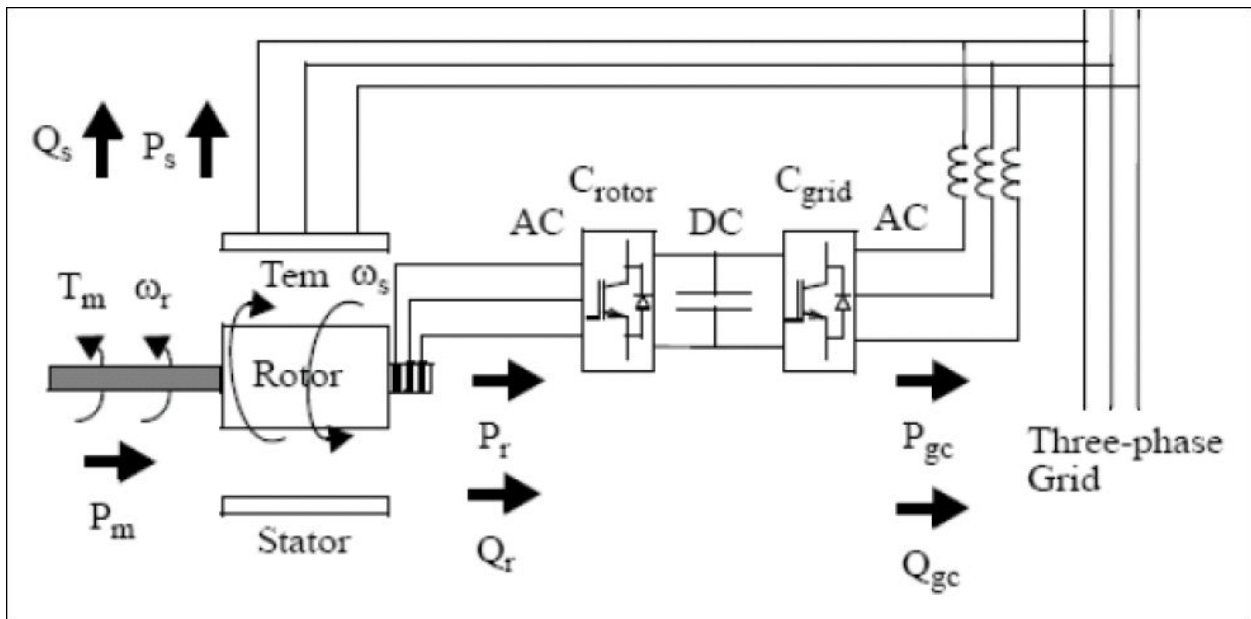


Fig.4.2.Power Flow Diagram of DFIG

From above figure it is shown that the slip power can flow in both directions, i.e. to the rotor from the supply and from supply to the rotor. Therefore, the speed of the machine can be controlled in both super and sub-synchronous ranges from either rotor- or stator-side converter.

As a result, the machine can be controlled as a generator or as a motor. Rotor-side converter operates as a rectifier and stator-side converter as an inverter when the speed is below the

synchronous speed in the motoring mode and above the synchronous speed in the generating mode. Rotor-side converter operates as an inverter and stator-side converter as a rectifier when they are below the synchronous speed in the generating mode and above the synchronous speed in the motoring mode. At the synchronous speed, slip power is taken from supply to excite the rotor windings and in this case machine behaves as a synchronous machine.

The mechanical power and the stator electric power output are computed as follows

$$P_r = T_m \cdot \omega_r \quad \text{-- (4.1)}$$

$$P_s = T_{em} \cdot \omega_s \quad \text{-- (4.2)}$$

For a lossless generator the mechanical equation is

$$J \left(\frac{d\omega_r}{dt} \right) = T_m - T_{em} \quad \text{-- (4.3)}$$

In steady-state at fixed speed for a lossless generator

$$T_m = T_{em} \quad \text{and} \quad P_m = P_s + P_r \quad \text{-- (4.4)}$$

And it follows that:

$$P_r = P_m - P_s = T_m \omega_r - T_{em} \omega_s = -S P_s$$

Where

$$S = (\omega_s - \omega_r) / \omega_s \quad \text{is defines as the slip of the generator.}$$

Usually the utter importance regarding slip is actually a lot less than 1 and Page rank will be the portion regarding P_s . Due to the fact T_m is actually optimistic regarding power era and ω_s is actually optimistic and constant regarding volume grid voltage plus the signal regarding Page rank is often a perform on the slip signal. Page rank is actually optimistic regarding bad slip (speed is actually more than synchronous speed) and it's also bad regarding optimistic slip (speed is actually a lot less than synchronous speed). Intended for super-synchronous speed procedure, Page rank is actually carried to be able to DC shuttle bus capacitor and can boost the DC voltage. Intended for sub-synchronous speed procedure, Page rank is actually taken out of DC shuttle bus capacitor and can lessen this DC voltage. Cgrid can be used to come up with or perhaps absorb the facility P_{gc} so that this DC voltage constant. Throughout steady-state to get a lossless AC/DC/AC converter P_{gc} is actually equal to Page rank plus the speed on the wind generator depends on the facility Page rank soaked up or perhaps earned simply by C_{rotor} . The phase-sequence on the AC voltage earned simply by C_{rotor} is actually optimistic regarding sub synchronous speed and bad regarding super-synchronous speed. The volume on this voltage is actually equal to the item on the grid volume plus the utter importance on the slip. C_{rotor} and

Cgrid are capable regarding bringing in or perhaps absorbing reactive power and may even supply to regulate this reactive power or perhaps this voltage with the grid terminals.

4.1.1. Features of Doubly Fed Machines:-

There may be only 1 electric powered device which in turn has the capacity to perform with all the rated torque to be able to two times the particular synchronous velocity for a granted consistency in the excitation can be injury rotor doubly-fed models. To generate torque, doubly-fed models need present since you will discover simply no long term magnets. And so, the particular generation involving magnetic flux, present (i. age. magnetizing current) should be applied. Torque and also magnetizing present are usually orthogonal vectors and perhaps they are in a roundabout way cumulative. This magnitude involving magnetizing present to be a small fraction involving torque present, the particular magnetizing will not perform within the productivity. This magnetizing flux can be manufactured by the particular rotor present, stator present or maybe by the combination of rotor and also stator currents. It's very common running your machine fully magnetized from your rotor and therefore it possess oneness electrical power element in the stator. At synchronous velocity the particular rotor present should be DC but if the velocity involving device is different from synchronous velocity then a rotor present must be AC. Throughout non-synchronous operations, if it's helpful to magnetize your machine, the particular reactive electrical power can be feasted on the rotor turning.

Throughout magnetization, rotor present is additionally necessitating to generate torque. Therefore, besides the reactive electrical power the particular lively electrical power is present within the rotor. This magnitude involving rotor voltage and also consistency are usually similar to one another while they are usually proportional on the fall. Ease would be the big difference relating to the velocity involving device and also synchronous velocity. At standstill ailment, the particular consistency would be the as the consistency within the stator. This voltage can be based on the particular percentage involving stator and also rotor windings converts. Thus, amount of converts can be similar then a rotor gets the similar voltage as the stator. It's possible to quickly of which with standstill doubly-fed device can be transformer. When it's twisting, manifesting through transients within the grid the particular transformer-like attributes can also be providing.

Depending on the velocity and also torque, the particular rotor can sometimes call for or maybe crank out the particular lively electrical power because of the voltage and also present behavior with regards to the velocity and also torque. This rotor can crank out electrical power in the event the device can be functioning to be a engine with velocity beneath the particular synchronous velocity (sub-synchronous operation). At standstill ailment, complete electrical power can be feasted within the stator that is returned throughout the rotor. When the engine has rated torque, rated electrical power can be distributed by the rotor and also stator. At reduced velocity, productivity involving device can be of low quality since to generate the particular torque present is required although reduced or maybe minimal mechanized electrical power can be created.

This mechanized electrical power can be feasted within the each on the rotor and also stator in the event the device can be functioning to be a engine with velocity above the synchronous velocity (super synchronous operation). Therefore, productivity is not delicious compared to together with singly feasted generators. One example is, with optimum velocity doubly-fed electric powered models together with similar stator and also rotor converts produce similar toque with dual velocity (and thus two times the particular power) to be a singly-fed electric powered models.

These losses are usually proportional on the torque. Just 50% or maybe a lesser amount of in the electrical power in the device can be management by the consistency converter involving doubly-fed models.

4.1.2. Back-to-Back AC/DC/AC Converting Modeling:-

Modeling associated with converter system may be dependent upon utilizing various kinds designs which can be separated in to 2 groupings such as, Numerical functional designs along with Numerical real designs. There're either equation-oriented or graphic-oriented.

Numerical functional style talks about their bond between enter along with result transmission on the system available as numerical characteristics so because of this sun and rain which can be used in the system will not be modeled individually. The advantages of this type of modeling tend to be simulation may be simple along with fast time-domain. This can be a favorite technique with regards to DFIG modeling, where by simulations associated with converters is possible on the based on expected reaction associated with controllers rather than actual modeling associated with Electrical power Technology Devices.

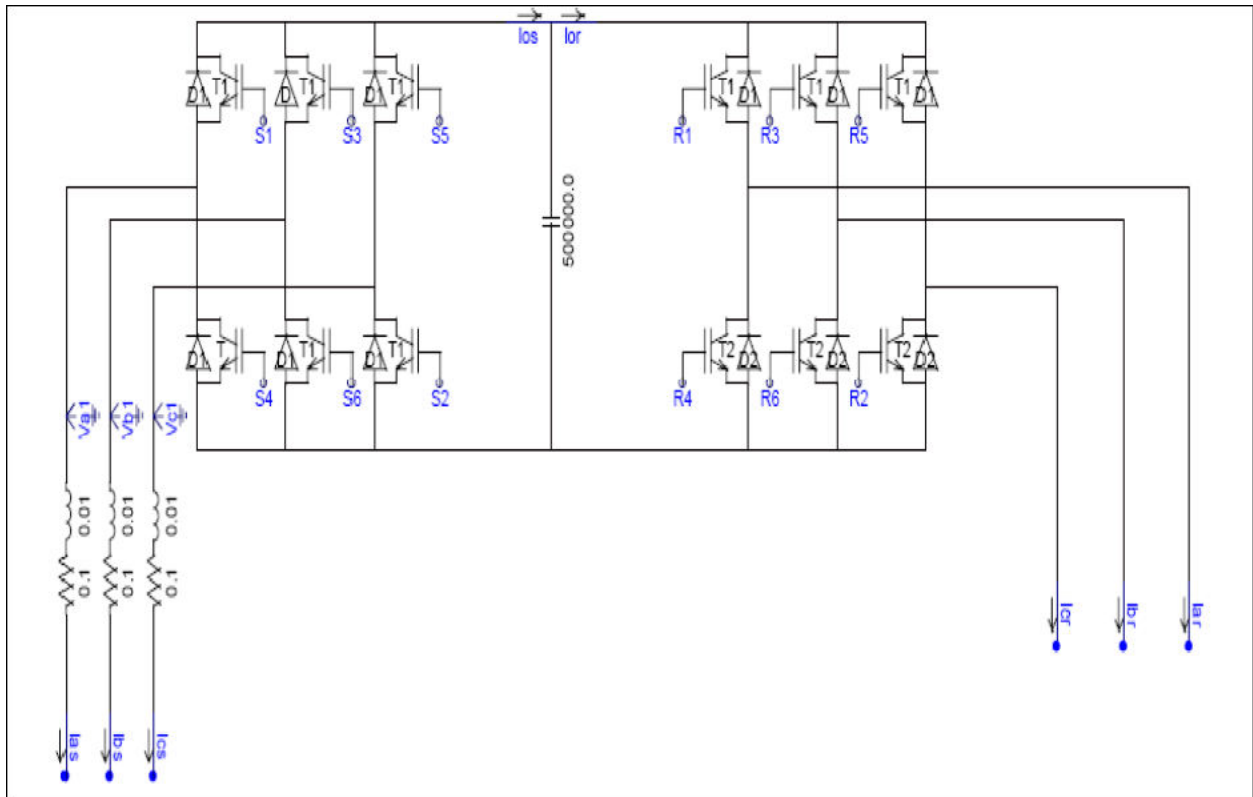


Fig. 4.3.Back-to-Back PWM Structure

In truth, it is assumed that the converters which may be utilized here I will discuss best and the DC-link voltage between all of them is actually frequent. To symbolize your function from the rotor-side from the converter, any controllable voltage or even current supplier is usually executed which can be based on the converter manage. Sun and rain which may be employed in actual model of the device usually are separately plus think about the relationship amid distinct factors inside technique. The type and the construction from the style is actually displayed because of the unique dependence on your investigation, age. h. steady-state, failing scientific studies, and so forth. Due to fact that additional reasonable actions from the DFIG, actual style is usually acquired in lieu of useful style efficiency regarding DFIG is actually additional appropriate as well as individuals any failing and then creator will vacation after having a failing. Right here, graphic-oriented switch-by-switch rendering from the back-to-back PWM converters because of their modulators is usually displayed with regard to both equally rotor-side converter as well as stator-side converter where IGBT as well as opposite diode products usually are displayed as being a two-state resistive change.

4.2. Converter Control System:-

Within this, the particular converter could be manipulated as the back-to-back PWM converter features two converters by which you are linked with rotor facet and also a different is actually linked with grid facet. Their own handling could be outlined under.

4.2.1. Rotor-Side Converter Control System:-

The actual rotor-side converter may be used to command the actual production electrical power with the windmill and the voltage can be determined with the grid terminals. The ability is actually governed to be able to stick to any pre-defined electrical power swiftness qualities, branded following qualities.

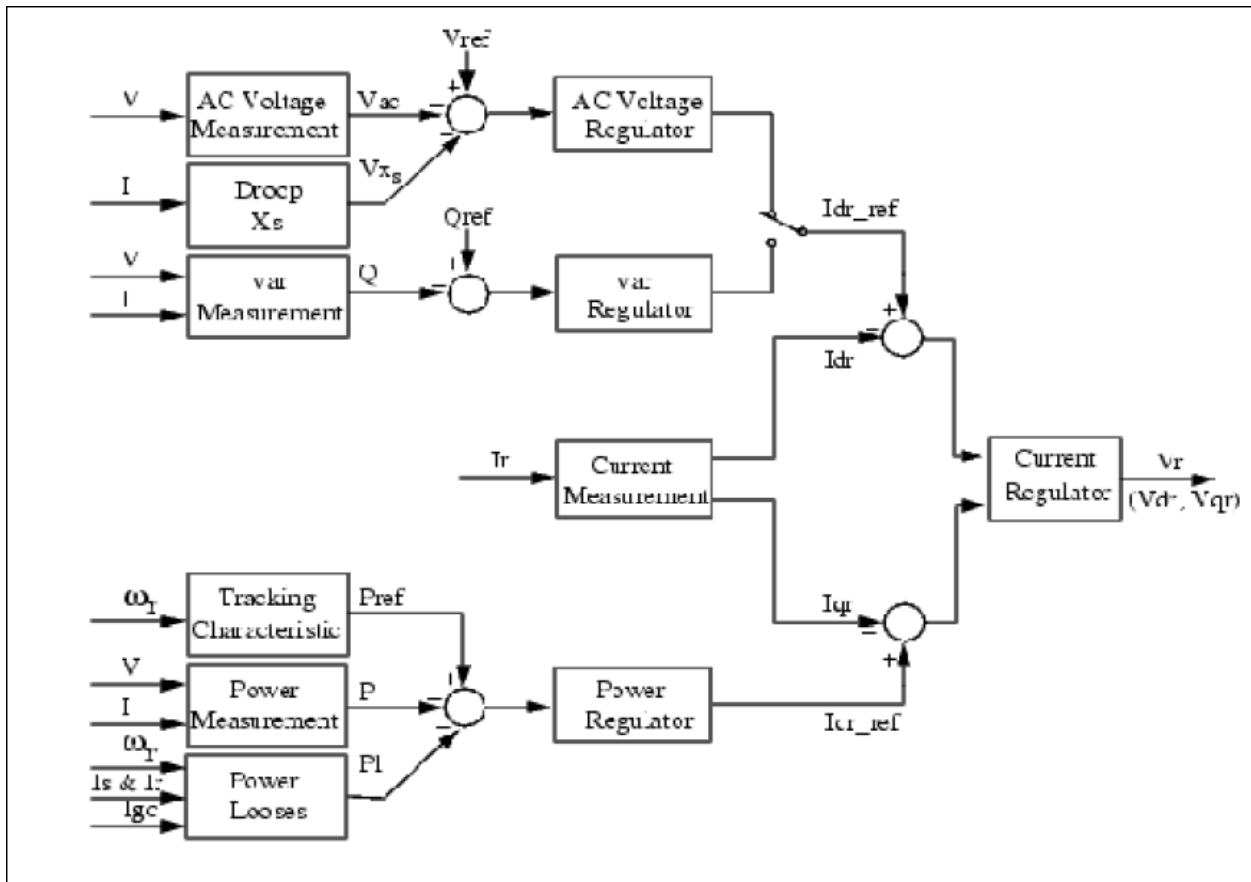


Fig.4.4. Block Diagram of Rotor Control Converter

The following Proportional-Integral (PI) regulator can be used to lessen or eliminate the strength malfunction in order to no. And so, the result of this regulator is usually consumed because

reference recent involving rotor when i. e. I_{qrref} that may be injected inside the rotor with the converter C_{rotor} . Here is the recent aspect which often can create the electromagnetic torque T_{em} . The actual rotor recent I_{qr} aspect can be balanced with the reference rotor recent I_{qrref} along with the malfunction can be reduced in order to no by means of recent regulator. The actual result which is often produced by means of rotor converter of this recent controller may be the voltage V_{qr} . The existing regulator can be served by means of supply forward phrases which often foresee V_{qr} . The actual voltage on the grid fatal can be handled with the reactive strength which is often produced or maybe soaked up with the rotor converter. The actual reactive strength is usually sold involving converter rotor along with the grid, from the power generator. Within the change process, the power generator absorbs reactive power to supply. The extra volume of reactive strength is usually shipped to the grid or rotor converter.

4.2.2. Grid Side Converter Control System:-

To regulate the voltage associated with DC tour bus capacitor the grid aspect converter may be used. With the grid-side controller the d-axis with the revolving recommendations frame useful for d-q change for better will be aimed while using the constructive collection with the grid voltage. This controller consists of:

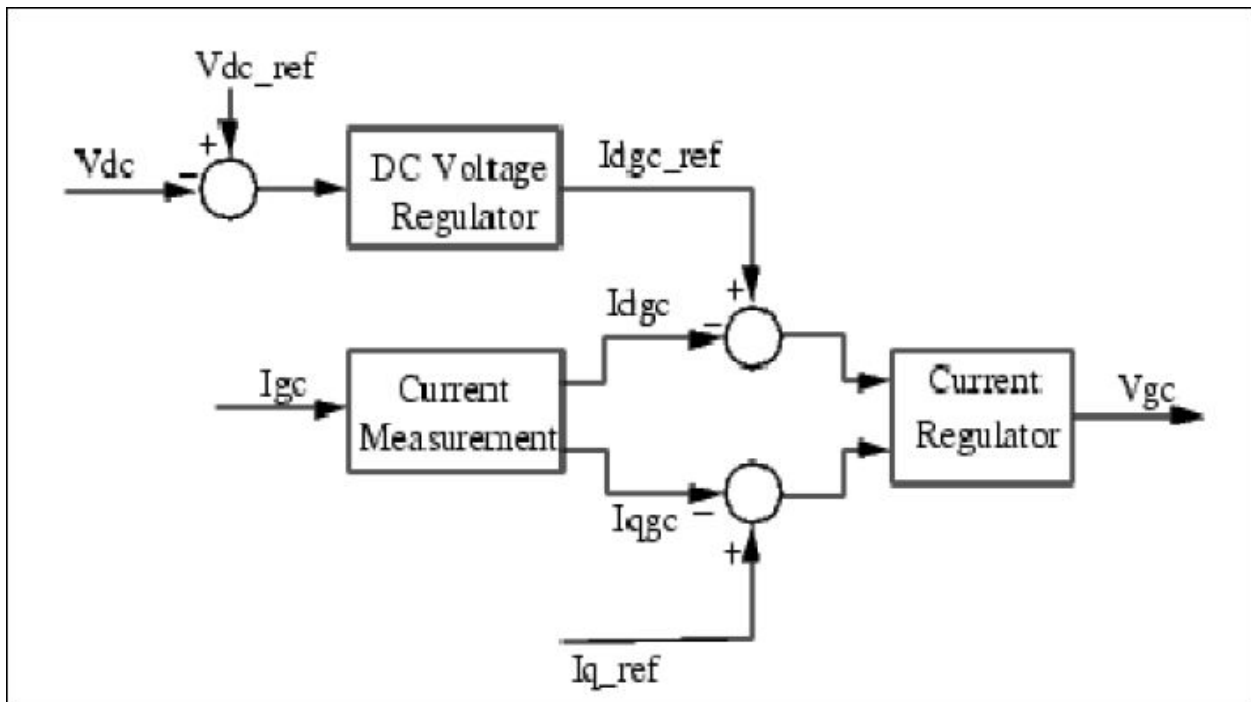


Fig.4.5.Grid Side Converter Control

1. A measurement system measuring the d and q components of the AC currents to be controlled as well as the DC voltage Vdc.
2. An outer regulation loop consisting of a DC voltage regulator.
3. An inner current regulation loop consists of a current regulator.

The latest regulator adjusts the value and step on the voltage created simply by converter Cgrid (Vgc) from the Idgc_ref made by the DC voltage regulator and particular Iq_ref. The latest regulator is made it easier for simply by give ahead conditions which usually anticipate the Cgrid output voltage.

4.2.3. Pitch Angle Control System:-

The actual try to sell viewpoint can be held continual from absolutely nothing amount before the speed reaches level N speed on the checking traits. Beyond level N your try to sell viewpoint can be proportional on the speed deviation from level N speed. With regard to electromagnetic transients within power technique your try to sell viewpoint command can be involving fewer curiosities. The actual wind flow speed needs to be selected so that your rotational speed can be lower than your speed from level D.

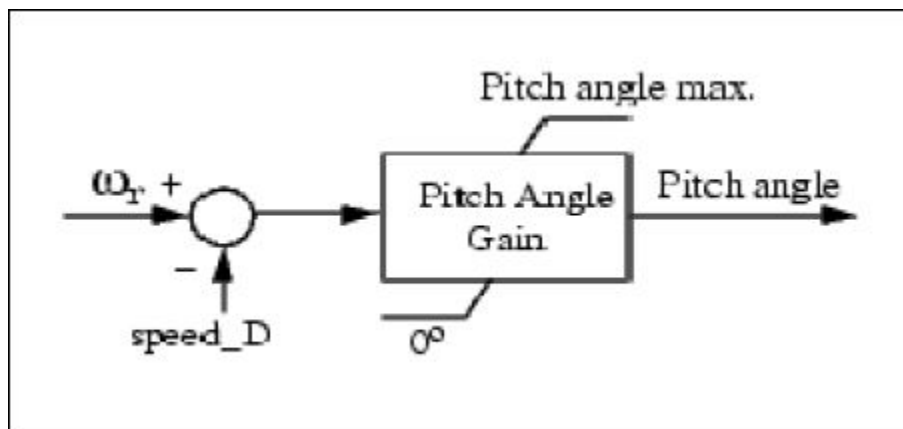


Fig.4.6.Pitch Angle Control System

CHAPTER 5

MAIN WORK OF PROJECT

Doubly fed induction power generator might be design to make use of as back-to-back PWM voltage supply converter inside the rotor part. A new vector-control with the supply-side the consequence of PWM converter is usually in addition to the management regarding active and also reactive energy and this can be sketched in the source.

Vector management to the rotor-connected converter and this can be offers the wide variety regarding speed function. In control loops, the vector system is usually embedded which enable the checking regarding optimal speed regarding utmost energy and this can be seize in the wind flow. The following the experimental processes that may symbolize any 7.5 KW wind flow energy creation process together with variable speed. The actual experimental connection between this particular are supplied the superb performance characteristics with the process. The actual doubly fed induction unit utilizing an AC-AC converter inside the rotor routine regarding high-power applications which involving a fixed selection of speed. For that independent management regarding torque and also rotor excitation latest vector-control approaches are known. Wind-energy creation might be considered to be an organic and natural request to the DFIG process when the selection of speed might be restricted. The majority of the DFIG devices are whether current-fed DC web page link converter (naturally commutated) or even cycloconverter inside the rotor. The application of any current-fed DC-link converter has quite a few negatives much like the choke regarding DC-link is quite pricey and also regarding function from synchronous speed more commutation routine is essential and possesses a result that from minimal fall rates it is performance is usually bad. Through cycloconverter we are able to triumph over the condition from synchronous speed. Generally there are quite a few negatives with the naturally commutated DC web page link and also cycloconverter. To triumph over most of these negatives we are able to employ a couple PWM voltage-fed current-regulated inverters which might be hooked up back-to-back inside the rotor routine.

This features associated with these kinds of kind of plan, in which each converters are generally vector governed, are generally as practices:

- Operations below, over in addition to via synchronous pace with all the variety of pace could be restricted simply by the evaluations associated with rotor voltage with the DFIG
- Operations on synchronous pace, operating associated with inverter with dicing function, DC existing is shot into your rotor.
- Reduced distortion associated with rotor, stator and gives currents
- Independent handles with the creator torque in addition to rotor excitation.
- Control of the displacement factor between the voltage and the current in the supply converter, and hence control over the system power factor.

A schematic diagram of the overall system is shown in Fig. 4.1. The DFIG used was a 7.5kW, 415V, 50Hz 6- pole machine. Two voltage-fed PWM converters are inserted in the rotor circuit; with the supply-side PWM converter connected to the stator is supply via three single-phase chokes.

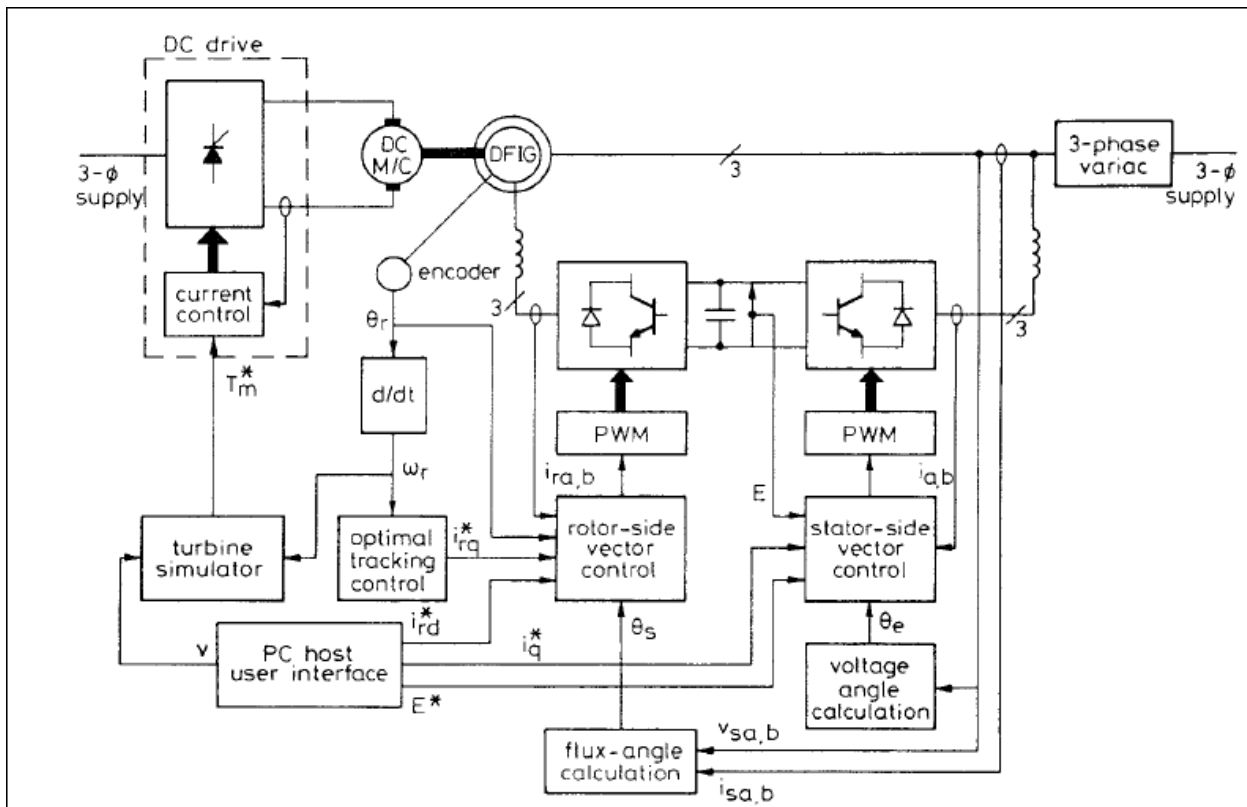


Fig.5.1.Schematic of Experimental System

The particular converters utilized are usually common 7.5 kW industrial bipolar transistor PWM inverters using a performing DC-link voltage of 580V and also a greatest changing rate of

recurrence of 1 kHz. Only at that energy level, the usage of IGBT converters would have permitted a higher changing rate of recurrence along with would certainly possess eased a lot of the control-loop design and style. Nevertheless, period of time changing rate of recurrence used in the actual prototype realizes that these strategies utilized could possibly be converted to much higher energy amounts utilizing, for example, GTO units. So that you can shield the actual inverter energy units.

This turbine is influenced by the torque-controlled 15kW DC power plant drive, which simulates any windmill. A microprocessor is provided with wind-velocity facts from the computer, in addition to computes your immediate generator torque from the offered turbine-blade quality. This particular torque types your torque need towards DC drive soon after reimbursement with regard to drive cutbacks. This pace in the turbine-generator set is dependent upon a good best pace tracking criteria that will has an effect on greatest strength capture on the blowing wind. Transmutes bears away your vector command in addition to PWM creation in the present facet PWM converter; a second is responsible for your vector command in the DFIG and also the best pace tracking algorithms, still another uses your PWM with the rotor-side converter.

The matlab circuit of DFIG by using back-to-back PWM converter

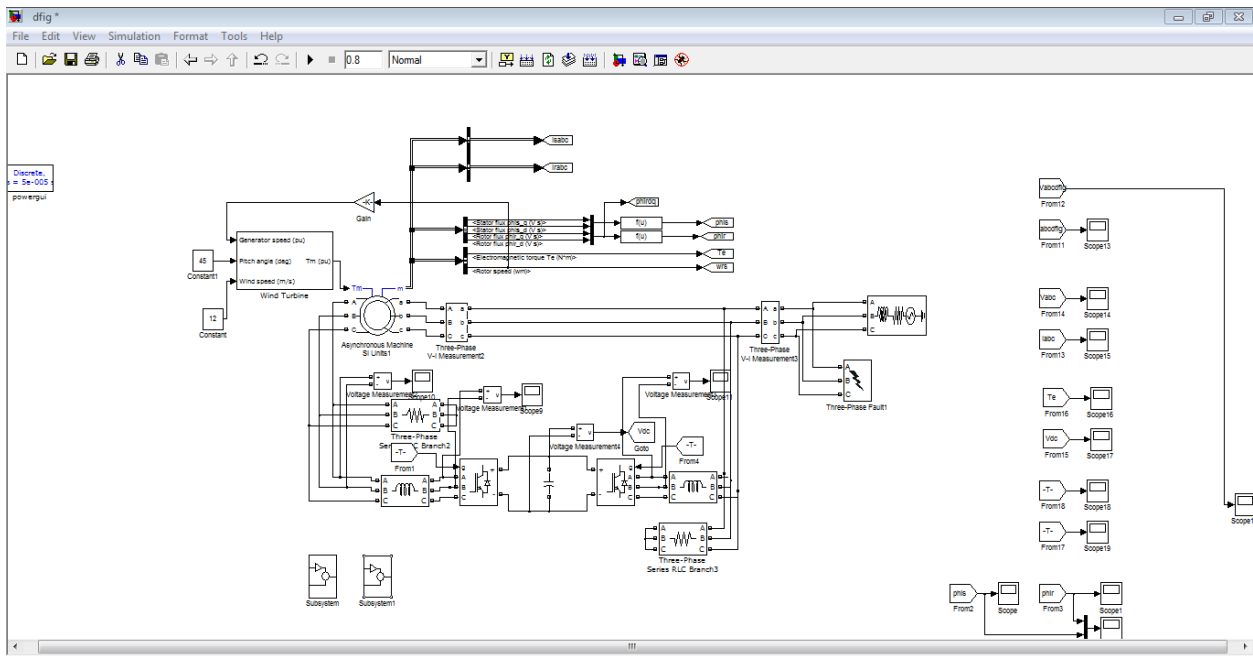


Fig.5.2 Matlab Circuit of DFIG using back-to-back PWM converter

The output of this matlab circuit is

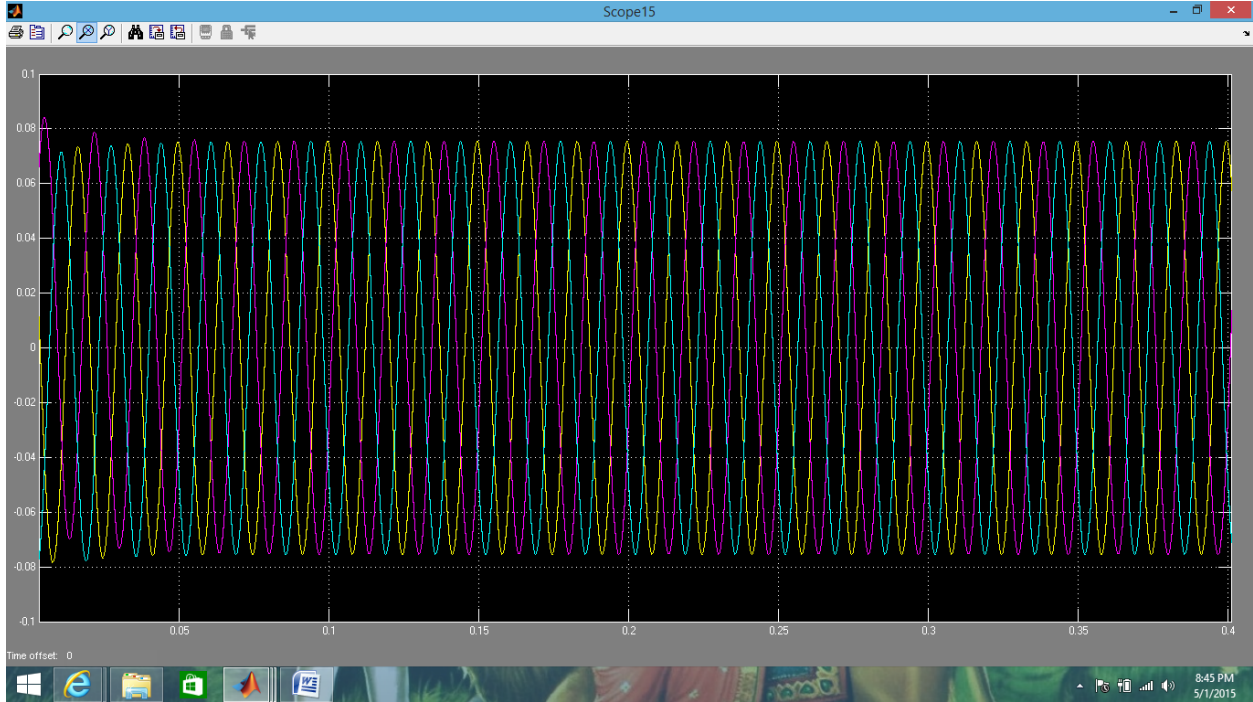


Fig.5.3 Output of Grid Current

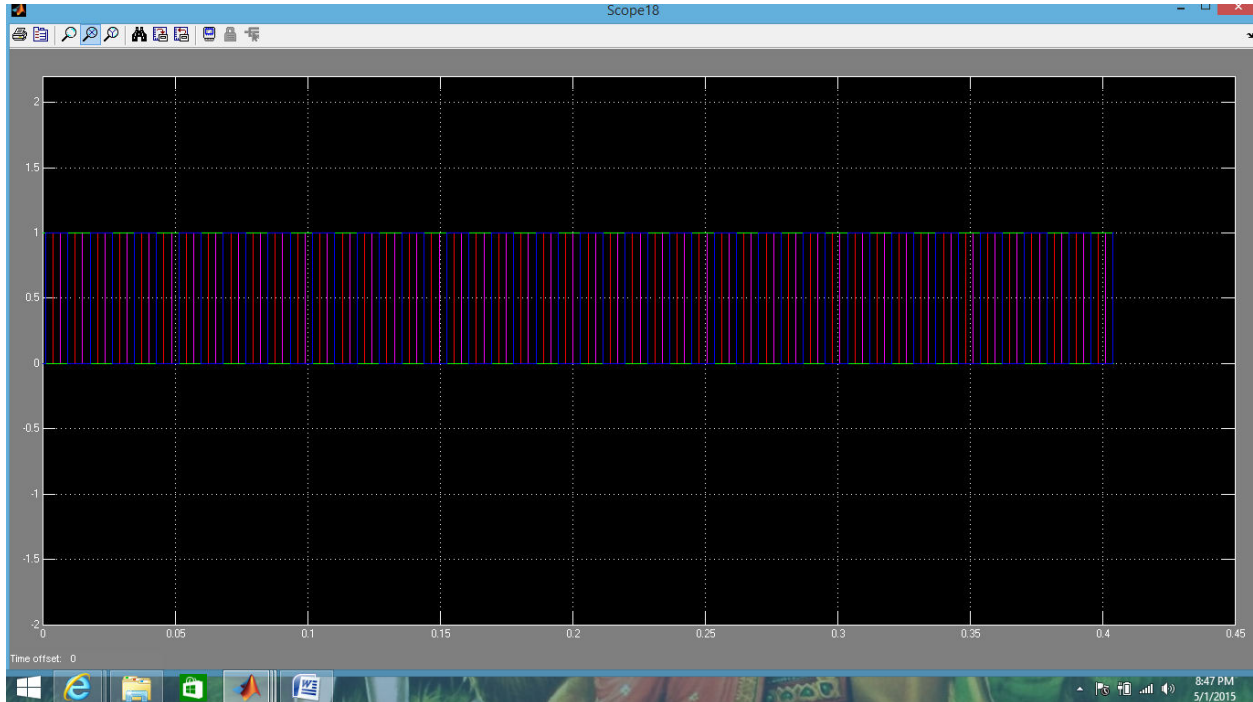


Fig.5.4 Gate Pulse

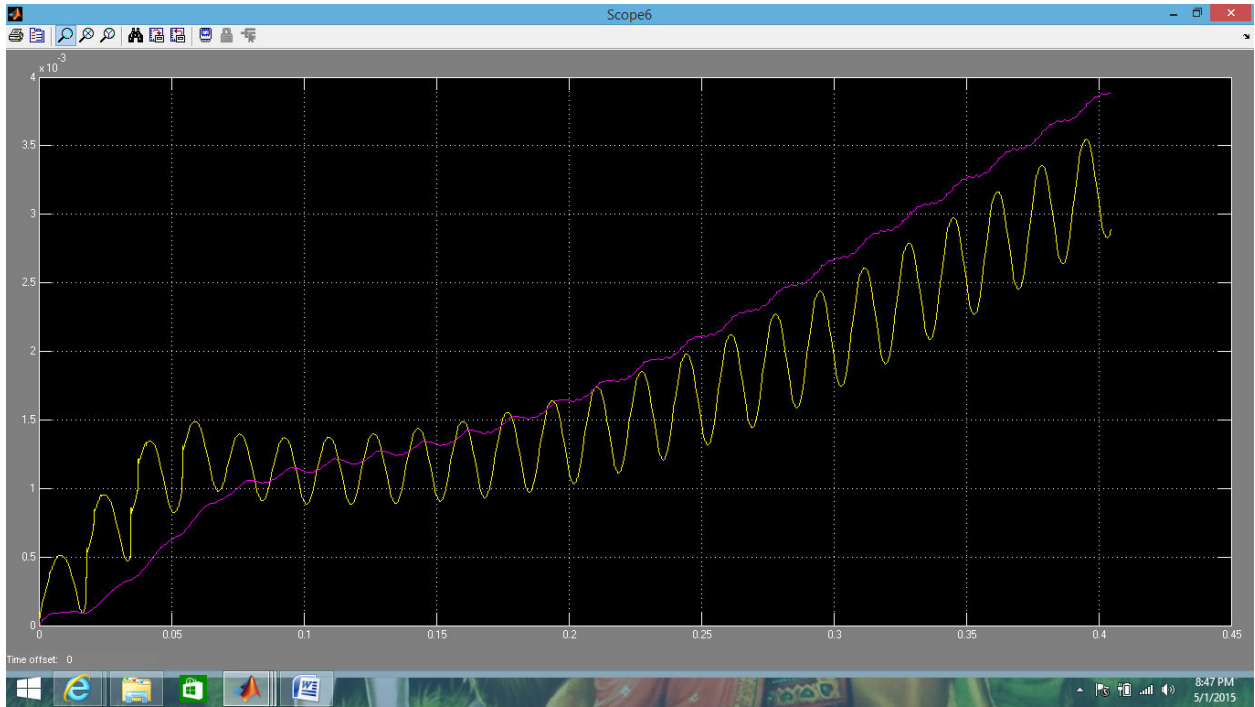


Fig.5.5 Output of Phase of Stator Verses Rotor

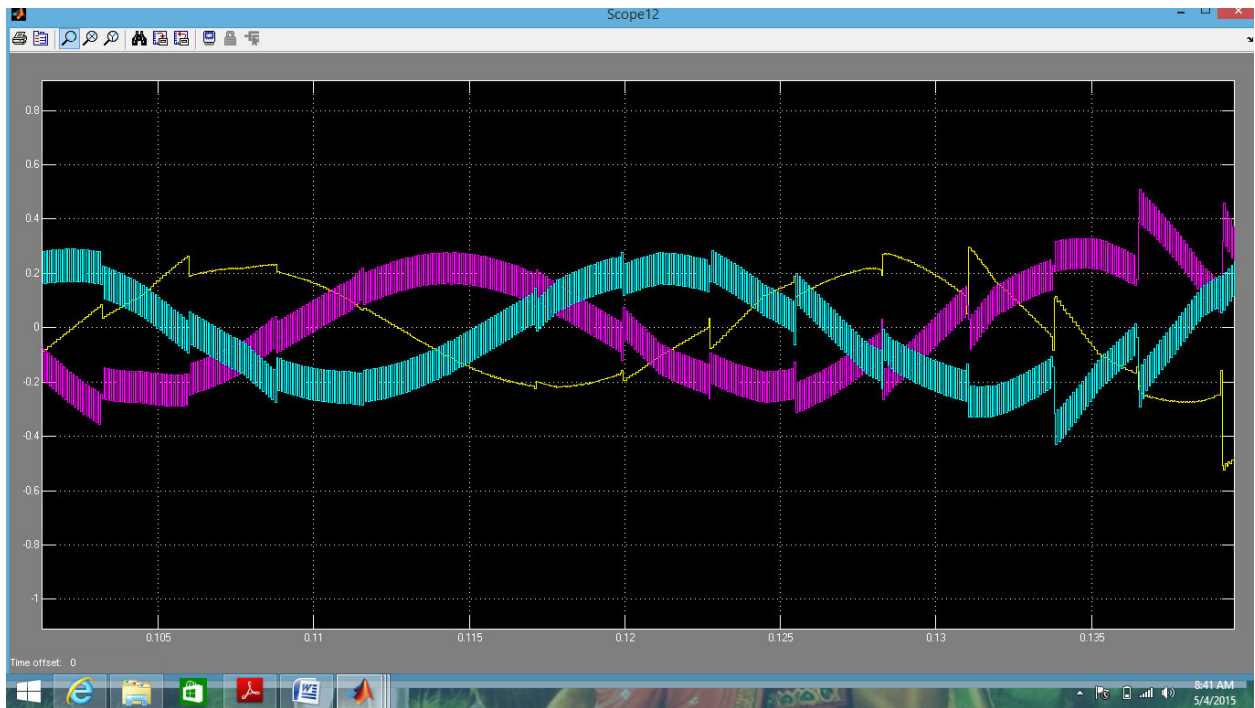


Fig.5.6 Output of DFIG Voltage

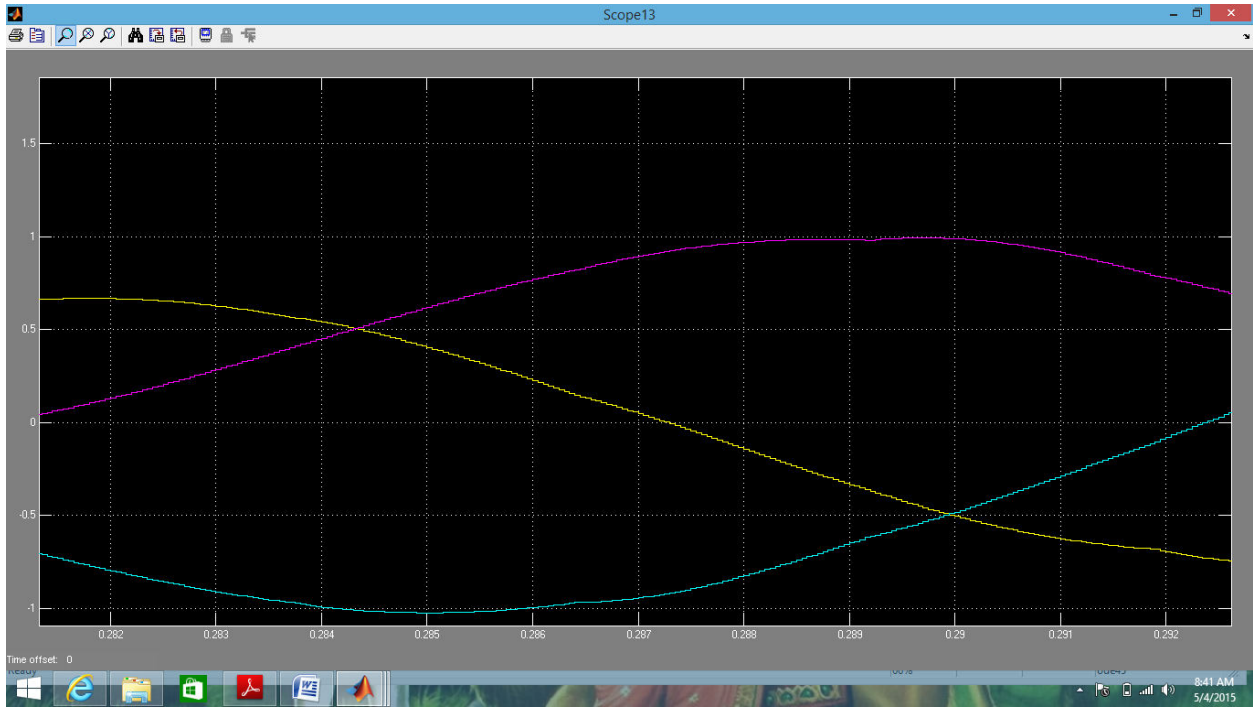


Fig.5.7 Output of Line Current

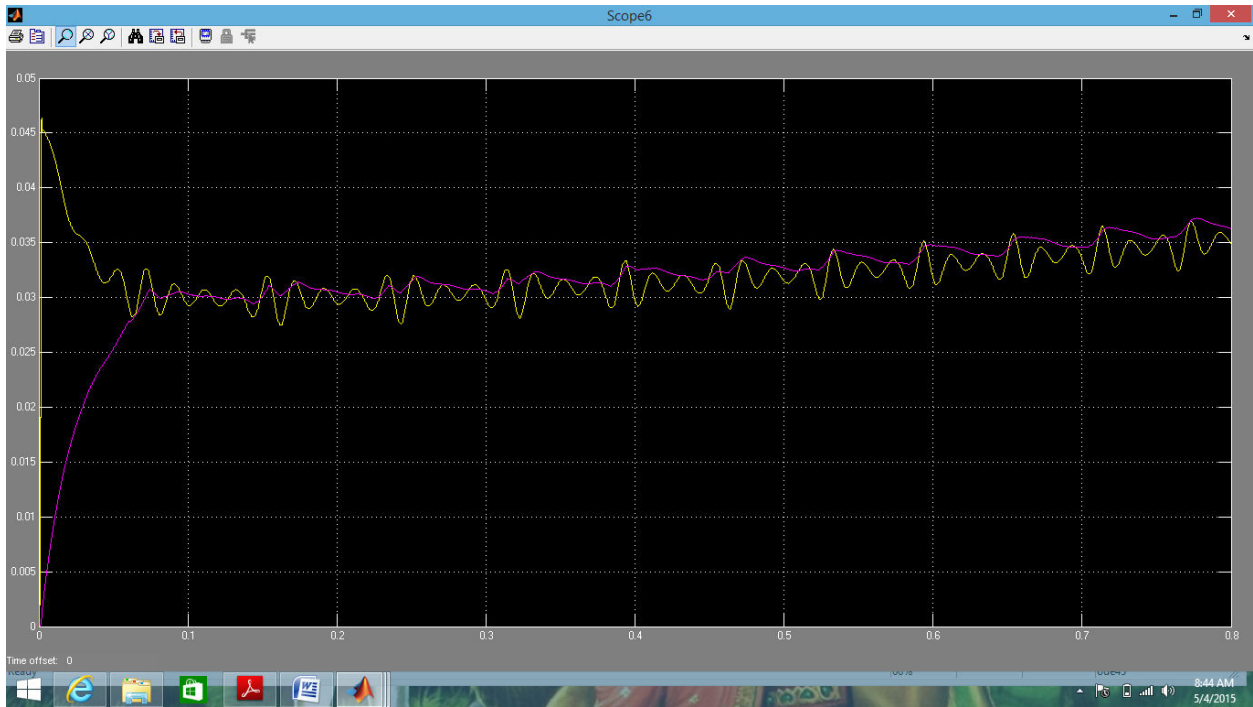


Fig.5.8 Phase Angle of Stator and Rotor

CHAPTER 6

CONCLUSION

This architectural as well as style tasks of a new DFIG utilizing a new Scherbius structure, including things like a pair of back-to-back PWM converters, are offered. A trial and error managed program has also been explained, and the basic detailed rewards are confirmed. Such as this even function by way of synchronous swiftness, low distortion currents fed towards the source as well as the chance to handle the system electrical power factor. Vector-control techniques are given to both converters. The typical objective DFIG grid-side converter handle would be to maintain your dc-link capacitor voltage continuous simply by controlling the real electrical power on DFIG machine-side as well as grid-side converter, and cover DFIG reactive electrical power whenever you can. This vector handle regarding the appliance has been inlayed within the ideal following controller regarding greatest vitality get in the breeze vitality app. A couple this kind of following schemes are explained, as well as experimentally executed, and the fineness regarding speed-mode handle regarding active swiftness overall performance has been demonstrated. This kind of structure uses a new torque observer, which in addition provides for uncomplicated execution regarding stop moving regulation to safeguard towards turbine clog. The optimal handle regarding DFIG grid-side converter must evaluate this aspects regarding reactive electrical power settlement, real-power equilibrium between the a pair of DFIG back-to-back converters, and the greatest allowable dc-link capacitor voltage. This current document has explained this back-to-back PWM DFIG structure while using program grid linked. This structure could also be used regarding providing an out of the way HVAC heap, increased which has a managed dump heap.

REFERENCES

- [1] TANG, Y., and XU, L.: 'Stator field oriented control of doubly excited induction machine in wind power generating system', 35th Mid-West Symp. on *Circuits and systems*, Washington, DC, 1992, pp. 1446-1449
- [2] T. Burton, D. Sharpe, N. Jenkins, and E. Bossanyi, *Wind Energy Handbook*. John Wiley & Sons, Ltd, 2001.
- [3] P. Kundur, *Power system stability and control*. New York: McGraw- Hill, 1994, pp. 279-306.
- [4] F. Mei, B. C. Pal, "Modelling and small-signal analysis of a grid connected doubly-fed induction generator," *Proceedings of IEEE PES General Meeting 2005*, San Francisco, USA, 2005.
- [5] A. Bouscayrol, B. Davat, B. de Fomel, B. Francois, J.P. Hautier, F. Meibody-Tabar. M. Pietrzak David, "Multi-machine Multi-converter System for drives: analysis of coupling by a global modeling", IEEE IAS' 2000, Rome, October 2000.
- [6] S. El Aimani, B. Francois, B. Robyns, F. Minne, "Modeling and simulation of doubly fed induction generators for variable speed wind turbines integrated in a distribution network", EPE 2003, Toulouse, September 2003, CD-ROM
- [7] L.H Hansen, F.Blaabjerg, H.C.Christensen, U.lindhart "Generator and Power Electronics Technology for wind Turbines." *Proced of IECON'200 1*, pp. 200-205.
- [8] SHEIER, "Grid integration of wind energy conversion system.", John Wiley & Sons Ltd, England, 1998;
- [9] A. Peterson, "Analysis, modeling and control of doubly-fed induction generators for wind turbines", *Licentiate of Engineering Thesis*, Department of Electric Power Engineering, Chalmers University of Technology, Göteborg, Sweden 2003.
- [10] J. López, P. Sanchis, X. Roboam, and L. Marroyo, "Dynamic behaviour of the doubly fed induction generator during three-phase voltage dips," *IEEE Trans. Energy Conversion.*, vol. 22, no. 3, pp. 709–717, Sept. 2007.
- [11] Roberto Cardenas, Ruben Pena, Jose Probooste, Greg Asher, John Clare, "MRAS Observer for Sensorless Control of Standalone Doubly Fed Induction Generators", *IEEE Transactions on Energy Conversion*, Vol. 20, No. 4, December 2005.