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

Implementation of Fuzzy Logic Based Pitch Control in DFIG-Based Wind Turbines on Micro Grid/Weak-Grid Stability

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Abstract:

Wind speed variation, due to the effects of wind shear and tower shadow, wind shear and tower shadow of the grid, the energy sources that produce flicker during continuous operation of wind turbines connected to the effects of fluctuations in the grid connected wind speed variation. MW-scale variable speed wind turbine provides a model for this theory flicker doubly fed induction generator, check the ventilation and mitigating factors. Reduce flickers in earlier days we have been using the pitch control system of a person who is. In this theory, a modern pitch angle control strategy based on fuzzy logic generator speed error of the proposed (FLC) is used as a variable speed wind turbine systems for the input variables for the fuzzy logic controller error control to change the speed. Fuzzy logic controller can achieve a change in the angle of the wind turbine blade and sustainable energy are implemented. Using the linear model Matlab / Simulink software to the controller in the proposed turbine pitch, propeller pitch control system design and block diagram.

INTRODUCTION

1.1 Introduction

Recently, renewable energy, especially wind energy, energy shortages, environmental concern will have to pay a lot of attention. Increasingly widespread penetration of wind energy into the electrical power grid, wind turbine systems, frequency and voltage stability becomes even more important to the outcome. Consequently, the point of view of connecting wind turbines to the power grid is getting more and more important as a method of control.

Variable speed, variable pitch wind turbine systems usually have two operating regions, according to the wind speed. Vrated wind speed, wind speed is lower than the partial load, turbine speed is controlled at the optimal value from the wind turbine [5-6] to collect the maximum amount of energy. Wind speed exceeds the value of the rate of the value of the price of a full load by controlling the pitch angle of the output power of the generator because the generator and the converter has a limited capacity. In contrast, partial load region [10-11], the pitch control of the output power can be used for smoothening.

Considering the extent of the industrialization of the most important in the last few decades, the demand for electric power has become a consequence of the world's hydrocarbon Stock consume. Therefore, the development of industrialized countries under the Kyoto Protocol and solar, biomass, geothermic launched from the use of renewable energy sources as one of the hydraulics. These energy sources, wind energy, but rather refers to the capacity of the bearing and more with the request to replace the existing powers of dumping gallops. Forward in search of the next few decades and centuries of evolution, wind energy has become a concern in many countries today. Doubly fed induction wind power using the machine, using the ax as a means to generate electricity to drive the search. DFIG is connected to an air system to work in a wide range of wind speeds, and each is likely to raise the maximum speed from the wind power. Stator circuit is connected directly to the grid. The rotor is placed at the second circuit, but the power converters of the network (Fig. 1.1) is connected through. Rotor power forward that is low, the cost of converters, power converters, variable speed wind generator Stator is reduced compared to soften. It is a strong reason for the production of energy found in this device.

Flicker "whose luminance or spectral distribution fluctuates with time, the unsteadiness of visual sensation induced by a light stimulus is defined by a seal," [2]. Flicker on the grid voltage fluctuations caused by changes in load flow, occurs. During the continuous operation of the variable-speed wind turbines connected to the grid are fluctuating power sources. Wind speed, wind shear, tower shadow, yaw errors, etc., which can cause voltage fluctuations in the electricity network fluctuations, flicker, because of the diversity, the way [3]. Wind turbines connected to the grid, such as grid [4-5], the angle of the barrier properties of a short circuit in the power system capacity and resource conditions of wind power, rather than the effect of flicker emission. Flicker is very different from the emission of different types of wind turbines. The big increase in the level of penetration of wind power in variable speed wind turbines, has the best performance in relation to the emission of more than a flicker constant speed wind turbines, variable speed wind turbines in the study, and it is imperative to flicker.

The number of solutions to reduce the emission of wind turbines connected to the grid provided flicker. The most commonly adopted technique is the reactive power compensation [6]. If the low-impedance angle of the grid, flicker mitigation technique shows the limits of distribution networks [7]. When the wind speed is high and the grid impedance angle 10◦, flicker mitigation necessary reactive power 3.26 per unit [8]. It is the amount of reactive power to generate electricity in a grid side converter (GSC) doubly fed induction generator is particularly difficult for the (DFIG) system for the converter capacity of around 0.3 per unit. STATCOM also receives a lot of attention is taken to reduce the emission flicker. However, it may not be financially viable for distributed generation applications. Back-to-back converter, DC- link voltage is provided to attenuate the emission of various active power control, flicker [8]. However, a large DC- link capacitor is required, and the lifetime of the capacitor, DC Volatility in the energy stored in the link will be shortened.

An open-loop pitch control [6] and [8] are used to investigate the emission of flicker in high wind speeds, however, the pitch actuation system (PAS) is not taken into account. PAS delay at the rate of pitch and variable speed wind turbines, making great contributions to flicker, because the results of the emission, it is necessary to take these factors.

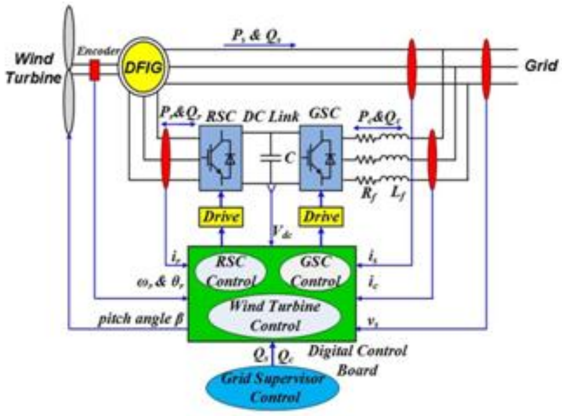

Fig. 1.1 Overall scheme of the DFIG-based wind turbine system.

1.2 Introduction to Wind Energy:

Wind power or wind turbines to produce mechanical or electrical energy is extracted from the air flow using the sail. The mechanical strength of the water pumping

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

windmills, wind pumps are used, and are sails to propel ships. Fossil fuels, plentiful, renewable, widely distributed, clean, no greenhouse gas emissions generated during the operation of an alternative wind energy, and use less land. Nonrenewable resources far less than the net effects on the environment are problematic.

Wind Many wind turbines connected to the electric power transmission network. Onshore wind power is an inexpensive source or coal or gas plants will be cheaper than most places in the competition. Steadier and stronger than on land and offshore in offshore wind farms, less visual impact, but construction and maintenance costs are high. Some small onshore wind farms to feed the electricity grid to provide electricity or isolated off-grid locations. [6]

Wind power is more stable from year to year, but there is a significant difference between a short period of time. It is used in combination with the other it is possible to provide a reliable supply of electric energy sources. To maintain traditional production of wind energy, grid and reduced capacity may need to be upgraded in terms of percentage growth. Consequently, the point of view of connecting wind turbines to the power grid is getting more and more important as a method of control.

1.3 Introduction to Doubly Fed Induction Generator:

Doubly electric machines, electric motors and power generators or shaft stationary and rotating parts in the windings of the two windings of the power system active power transfer between the two most important are soft. Stator winding is connected directly to the grid, usually three-phase and three-phase winding through the rotor is rotating or static frequency converter is fed to the grid.,, ± 30% of the machine shaft to the speed of the frequency converter, it is usually the power rating of the doubly fed machines as well, because of the limited range of synchronous speed around different applications, for example, may be reduced. Currently, the most common variable speed drives, doubly-fed wind turbine concept.

Rings doubly-fed through a set of resistors connected to the rotor winding machine, Rotor and Stator winding wound rotor induction motors, multiphase sets the roots begin to slip. However, the slip is the power resistors. Slip energy recovery have been developed to increase the efficiency of variable speed operation.

Kramer (or Kramer) machine set on the machine to be fed to the shaft of the rotor is connected to the slip ring with an AC and DC drives connected to a DC. [1] DC Inspiration flows could be controlled by machines, and converts mechanical energy to drive back to the slip. In order to cope with the extra turning power over to drive machines KRAMER drawback to dimensioned. Slip power motor generator error grid, the AC drive will be put back what Scherbius sets.

Rotating machinery, heavy and expensive to be used for the supply of the rotor. In this case, the rotor-inverter mercury arc rectifier diodes and thyristors semiconductor-based devices with a built-in unit, static Scherbius sank to connect the drive. Methods of the uncontrolled rectifier, a rectifier is only possible using the rotor out of the flow of energy. Moreover, when the motor is only a sub-synchronous operation.

DOUBLY FED INDUCTION GENERATOR

2.1 Introduction

Doubly electric machines, electric motors and power generators or shaft stationary and rotating parts of the windings of the two main energy transfer between the two windings of the electric system to be flexible. Stator winding is connected directly to the grid, usually three-phase and three-phase winding through the rotor is rotating or static frequency converter is fed to the grid. ± 30% the speed of the shaft of the machine, for example, around a limited range of applications that require synchronous speed is different because it is usually doubly fed machines, as well as frequency converter's power rating, may be reduced.

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Currently, the most common variable speed drives, doubly-fed wind turbine concept.

2.2. History:

Doubly-fed through a set of resistors connected to the rotor winding machine starts to slip rings, rotor and rotor induction motors Stator winding wound in the roots of multiphase sets.

However, the slip is the power resistors. Slip energy recovery have been developed to increase the capacity by variable speed operation. Kramer (or Kramer) on the set of the machine is connected to a DC that is fed to the rotor shaft of the machine is connected to the slip ring are equipped with an AC and DC drives. [1] of the DC Inspiration flows could be controlled by machines, and converts mechanical energy to drive slip back. Kramer, a negative feature of the drive machinery must be over dimensioned in order to cope with the extra turning power. Slip power motor generator sets, the defect is fed back into the grid, AC drive Scherbius OK.

Is used for the supply of the rotor rotating machinery, heavy and expensive work. A connection, a mercury arc rectifier-inverter unit for static Scherbius drive the rotor built after the development of diodes and thyristor semiconductor devices. The only possible due to the flow of energy out of the rotor using the methods of the uncontrolled rectifier, a rectifier.

Moreover, whenever the motor is only a sub-synchronous operation.

Another aspect of using static frequency converter is connected between the rotor and the AC grid is a cycloconverter. Cycloconverter orders and therefore can run the machine for more than two sub-synchronous speed and power, can feed two. In Europe, cycloconverter controlled doubly fed machines, running 16 2/3 Hz railway grid single phase generators [4] and pumped storage plants have been used to run turbines to eat. [5]

Today, in return for a few tens of MW connected to the frequency changer IGBT inverters are used in applications.

Many also require management techniques have been developed in order to get rid of the brushless slip rings.

2.3. Classification:

Electric energy conversion process, either singly or in sets of two winding doubly fed up with a set of active actively involved in the winding of the Fed. Doubly-fed induction slip one by one in the field of energy recovery excited synchronous electric machines to confuse the two power ports, many have fed; Other passive energy conversion process on a winding set of the port, while looking forward to the active participation of dissipative energy passes, the port is set to shut down.

Set in traditional wound-rotor doubly-fed wind power machine is active 1) doubly fed induction machine (DFIM), the only practical control over the evolution of education, now doubly-fed electric machine systems through three types of slip ring assembly descended into a multiphase rotor and Stator, respectively, and the motivation of the rotor flux vector control; 2) brushless doubly-fed induction machine (BDFIM), brushless doubly-fed induction (or reluctance) Stator winding assembly, flux vector control and flux in the machine, instead of the more active is one of the pole-pairs of force, sets cascaded, one that focuses on the rotor assembly; And real-time control system 3) brushless doubly-fed asynchronous machine (BDFSM), a rotor and a set of Stator winding is less active, but in a brushless slip ring assembly and the rotor flux vector controller traditional DFIM in place of the circuit topology.

Both are super-synchronous speed synchronous speed, bi-directional energy to be excited with the sub-synchronous operation, stopped the practice of the true, active (ports) sets and the doubly-fed electric machine to shut down.

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SYSTEM DESIGN

3.1. Wind Turbine Modeling

Converts mechanical energy by means of torque produced by the wind turbines convert the kinetic energy in the air. Through wind energy, being in the form of kinetic energy, air density and wind speed will depend on its size. Through the development of the wind power turbine is given by the equation (1) [1-10]:

$$Pm = \frac{1}{2} * Cp(\lambda, \beta)\rho A v^3 \qquad (1)$$

Where

- Pm = Mechanical power captured by the wind turbine and transmitted to the rotor
- C_p = Power Co-efficient
- β = air density in kg/m3
- A = area of the turbine blades in m2
- V = wind velocity in m/sec.

The power coefficient is defined as the power output of the wind turbine to the available power in the wind regime. This coefficient determines the "maximum power" the wind turbine can absorb from the available wind power at a given wind speed. It is a function of the tip-speed ratio ( ) and the blade pitch angle (The blade pitch angle can be controlled by using a "pitch-controller" and the tip-speed ratio (TSR) is given as

$$\lambda = \frac{wR}{v} \qquad (2)$$

Where

- λ = rotational speed of the generator
- R = radius of the rotor blades.
- V = wind velocity in m/sec.

So, TSR can be controlled by controlling the rotational speed of the generator. The wind speed at a given β, which gives the maximum value of a rotational speed of the generator is the same. The "maximum-power-point tracking" (MPPT) and the main principle behind a wind turbine has been designed keeping in mind the need for this strategy.

3.2. Doubly Fed Induction Generator

And doubly-fed induction wind turbine generator (WTDFIG) and doubly-fed induction wind turbine generator system will be shown as fig.1. The rotor-side converter (Crotor) and grid side converter (Cgrid): AC / DC / AC converter is divided into two parts. CrotorCgrid DC voltage source and the forced-commutated power electronic devices (IGBTs) used to recruit from an AC voltage converters, voltage-Sourced. DC side of a capacitor acts as a DC voltage source. Cgrid combining the inductor L is used to connect to a grid. Crotor three-phase and three-phase Stator winding rotor slip rings and brushes are connected by a winding is connected directly to the grid. Rotor Stator windings of the power to take over the induction wind turbine generator and converted into electrical energy and is transmitted through the grid. Command and the command voltage VR and VgcCrotor and Cgrid production in order to control for the pitch angle of a wind turbine control system, the DC bus voltage and reactive power or voltage signals at the end of the power grid.

3.2.1. Operating Principle of DFIG wind turbine

Power flow, power flow illustrated in Fig.2, is used to describe the operating principle. The parameters used in the followings:

Pm - mechanical power captured by the wind turbine and rotor transmitted

Ps - Stator electrical power output

PR - rotor electric power output

PGC - Cgrid electric power output

Q's - Stator reactive power output

QR - rotor reactive power output

Qgc - Cgrid reactive power output

TM - mechanical torque applied to the rotor

Tem - the electromagnetic torque applied to the generator rotor

WR - the rotational speed of the rotorW_s - Rotational speed of the magnetic flux in the air-gap of the generator, this speed is named synchronous speed. It is proportional to the frequency of the grid voltage and to the number of generator poles.

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International Journal & Magazine of Engineering, Technology, Management and Research
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J - Combined rotor and wind turbine inertia coefficient.

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

$$Pm = Tm * Wr \quad (3)$$

Where

- Pm = Mechanical power captured by the wind turbine and transmitted to the rotor
- T_m = Mechanical torque applied to rotor
- W_r = Rotational speed of rotor

$$Ps = Tem * Ws \quad (4)$$

Where

- P_s = Stator electrical power output
- T_{em} = Electromagnetic torque applied to the rotor by the generator
- W_s = Rotational speed of the magnetic flux in the air-gap of the generator, this speed is named

For a loss less generator the mechanical equation is

$$J * \frac{dWr}{dt} = Tm - Tem \quad (5)$$

Where

- J = Combined rotor and wind turbine inertia coefficient.
- dw_r= Change in Rotational speed of rotor
- T_m = Mechanical torque applied to rotor
- T_{em} = Electromagnetic torque applied to the rotor by the generator

In steady-state at fixed speed for a loss less generator

$$Tm = Tem \;\&\; Pm = Ps + Pr \quad (6)$$

Where

- T_m = Mechanical torque applied to rotor
- T_{em} = Electromagnetic torque applied to the rotor by the generator
- Pm = Mechanical power captured by the wind turbine and transmitted to the rotor
- P_s = Stator electrical power output
- P_r = Rotor electrical power output

It follows that:

$$Pr = Pm - Ps = TmWr - TemWs = Tm * \frac{Ws-Wr}{Ws} \quad (7)$$

Where

- P_r = Rotor electrical power output
- Pm - Mechanical power captured by the wind turbine and transmitted to the rotor
- P_s = Stator electrical power output
- T_m = Mechanical torque applied to rotor
- W_r = Rotational speed of rotor
- T_{em} = Electromagnetic torque applied to the rotor by the generator
- W_s = Rotational speed of the magnetic flux in the air-gap of the generator, this speed is named
- T_m = Mechanical torque applied to rotor

$$S = \frac{Ws-Wr}{Ws} \quad (8)$$

where

- S = slip of the generator
- W_s = Rotational speed of the magnetic flux in the air-gap of the generator, this speed is named
- W_r = Rotational speed of rotor

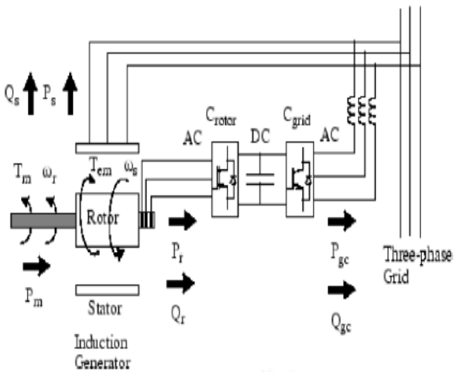

Fig. 3.1 Power Flow

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As a result, the exact value of the slip, Pr Ps is only a fraction, is less than 1. Tm power grid voltage is consistent with the presence of positive and positive and constant frequency, Pr is a function in the loose. Pr negative slip (synchronous speed greater than the speed) and it is a positive slip (speed less than the synchronous speed) is suitable to be negative. For the super-synchronous speed operation, Pr and the DC voltage on the DC bus capacitor increased transfer. Sub-synchronous speed action, Pr will reduce the DC voltage on the DC bus and removed from the capacitor. Cgrid in order to keep it consistent with the product or the DC voltage can be used to adapt to the current PGC. PGC Crotor created or determined by the perceived low speed wind turbine and AC / DC / AC converter loss is equal to the steady-state power Pr. Power control will be explained below.

Sub-synchronous speed of the AC voltage generated by the super-synchronous speed in the range of positive and negative is Crotor. Equal to the value of the grid frequency and the frequency of the voltage is certainly mistaken.

CgridCrotor or absorbing reactive power and voltage control, and the production of reactive power grid or have the ability to be used at the terminals.

3.3. Wind Turbine Control and Flicker Emission Analysis

For a DFIG-based variable speed wind turbine, the control target is different according to different wind speeds. Low wind speed, the optimum tip speed ratio to keep control of the mission, so that the maximum power absorbed from the air. Available in a high wind speed, wind turbine, which is beyond the control of the overload capacity of the power system, the value of the constant aim is to keep power prices.

3.4. Back-to-back converter control

The most common methods of vector control system for a wind turbine converter is used for back-to- back. The two vector control schemes, Fig, RSC and GSC are shown in shown. 1, VS and Stator voltage and current, etc. The rotor current, grid voltage VG IG streams GSC WG generator speed, e DC- link voltage, Ps with a ref, and the ref Q and active and reactive power reference values Stator, the grid and the reference value Ref, Eref DC- link voltage reference value, the electric torque DFIG Vector Control RSC goal by controlling the DC- link capacitor C. QR GSC reactive power flow between the implementation of tracking the maximum power from the wind. ωref a look at the table can be obtained by reference to the value of the ratio of the speed of the generator speed to enable a proper forecast. GSC sinusoidal currents to keep the link to the target voltage DC- stable, while keeping the grid. It can also adjust the grid and the grid side converter may be responsible for the control of reactive power Qg ref. General, RSC and GSC unity power factor, reactive power values and the RSC and GSC to ensure that the current operation is set to zero [1].

3.4.1 Rotor Side Converter Control

As shown in Fig. Field-oriented current control loops with a fast and slow external - - traps that produce streams of reference for the inner loops 4, RSC controller interior. RSC is designed to take into account, as mentioned in Chapter 1 of the main objectives (ie voltage and frequency control) DFIG reactive power of a voltage controller-based control method discussed to develop. In this case, the amount of reactive power output Q and Stator, DFIG given in Eq.(9) [3].

$$Qs = \frac{3}{2}\left[-\frac{Vs^2}{\omega Ls} + Vs\frac{Lm}{Ls}idr\right] \quad (9)$$

Where

- Qs = Stator Component of Reactive Power
- Vs = Stator Voltage
- W = Speed
- Lm = Magnetizing or Mutual Inductance
- Ls = Stator Inductance
- I_{dr}= Direct Axis Component of Rotor Current

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3.4.2. Grid Side Converter Control

The GSC is used to control the DC bus voltage of the back – to – back converter system and to supply any reactive power to the loads if needed. In this regard, the L – R filter model shown in Fig.3.3 is used to develop the model of the controllers for GSC.

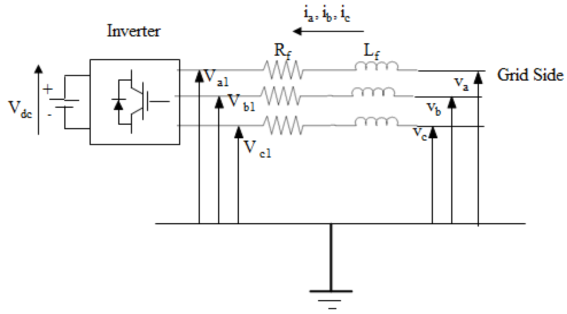

Fig. 3.3 Filter model associated with GSC

The control scheme of GSC consists of a fast inner current control loop which controls the current through the filter circuit given in Fig.3.3. The outer slower control loops are used to regulate the DC bus voltage of the back – to – back converter and control reactive power supply through GSC.

$$PGSC = \frac{3}{2}Vds * ids \quad (14)$$

$$QGSC = \frac{3}{2}Vds * iqs \quad (15)$$

Where

- Vds = Stator Voltage Direct Axis Component
- I_{ds} = Stator Current Direct Axis Component
- I_{qs}= Stator Current Quadrature Axis Component

With reference to Eq. (14) and Eq. (15), it is evident that the d and q axes components of currents through filter can be used to regulate the DC link voltage and reactive power supply to the loads respectively. There is a possibility of supplying reactive power through GSC to a static synchronous compensator (STATCOM). In the present work, the reactive power reference Qref is set at zero.

The corresponding control scheme implemented for GSC is shown in Fig.3.4.

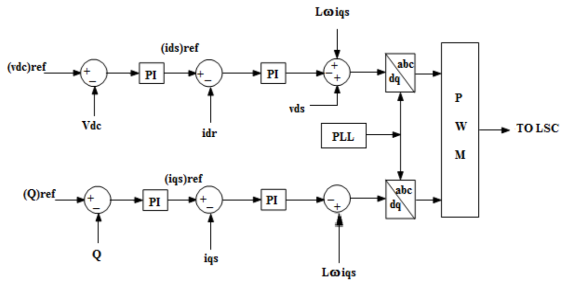

Figure 3.4: GSC control scheme

3.4.3. Pulse Width Modulation

Width modulation (PWM), or pulse-duration modulation (PDM), the data signal, a drug on the basis of pulse width modulation to control the pulse duration of the pulse. However, the modulation scheme, the internal loads of motors, electrical devices, it allows you to control the use of the power supply, can be used to encode data for transfer. In addition, PWM, solar battery chargers, two main algorithms [1] is the second one of the MPPT are used.

Voltage (and current), the average value of the weight to be fed, to be able to switch between the supply of and controlled by the load. The switch, as compared to periods of high energy is supplied to the load.

PWM load switching frequency of the load to be perceived as smooth as possible, the wave, (a device that uses the power) to say that it must be more than what is reflected in the result. Mary, who is usually an electric oven several times a minute, to 120 Hz in lamp dimmer, a few kilohertz (kHz) to a motor to drive the absolutely perfect and the tens or hundreds of kHz in audio amplifiers and computer power supplies to tens of kHz.

A simple break or the word 'long' time 'on' describes the duty cycle ratio; A low duty cycle, low power so as not to be consistent with the more energy. Being a 100% duty cycle, shown as percentage.

The main purpose of the power loss is very low PWM switching devices. The current practice of a switch, and power on it and almost across the load switch,

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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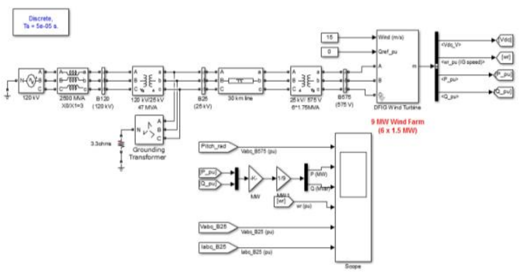
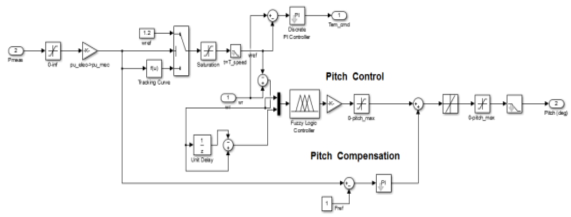
voltage drop when transferring. Power loss, voltage and power generation is to be regarded as close to zero in both cases. PWM also because of their on / off nature, the need to duty cycle, set the digital controls, and works well.

PWM duty cycle in its communication has been used in some communication systems to convey information using the name.

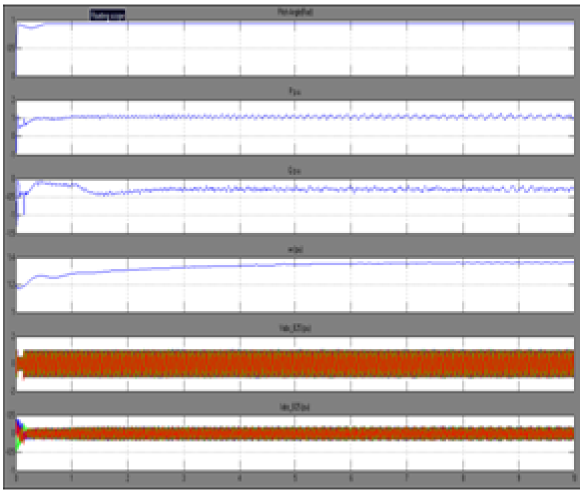
SIMULATION RESULTS



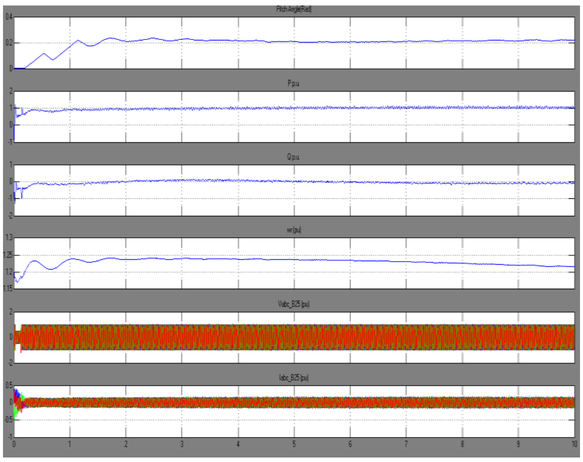
Simulation of DFIG based wind energy system



Pitch angle Control with FLC



Base Paper Results: a) Pitch angle b) Active Power c) Reactive Power d) Rotor Speed e) Grid Voltages f) Grid Currents



Extension Results: a) Pitch angle b) Active Power c) Reactive Power d) Rotor Speed e) Grid Voltages f) Grid Currents

Conclusion

Torque- and power droop, DFIG-based wind-power units, and control of the implementation of the two methods sulabhanga attainable Flex analyzed and compared in this paper. Effective torque compared to the production of flex to bend the edges of the high stability of the variance, showed why it is not permitted in the range of small-signal analysis. A study 1), the system had a positive impact on the bend in the Eigen values for frequency-stability; 2 medium frequency range) to compensate for the lack of inertia had the wind bent a microgrid and 3) wind turbine governor and inverter stoop bend a positive effect on the function. The controller also investigate the effect of the bend angle of the pitch; And found that this effect was not significant.

The pitch angle of the implementation of the proposed regulation in this paper, fuzzy logic control of DFIG-based wind energy conversion. Fuzzy logic control is effectively a good response and the power to control the angle of the pitch to get the output voltage is maintained constant value mamdani 25 design rules,

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there is. The proposed model for the Matlab / Simulink software designed for simulation and modeling. Simulation results show the fuzzy controller effectively controls the angle of the wind turbine pitch. And it also results in a more effective notice of the proposed fuzzy controller.

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