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Modelling and Analysis of DC Link Capacitor in Doubly Fed Induction Generator for Wind Turbines

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Abstract

Energy is an essential ingredient of socio-economic development and economic growth. Renewable energy sources like wind energy is indigenous and can help in reducing the dependency on fossil fuels.Wind is the indirect form of solar energy and is always being replenished by the sun. Wind is caused by differential heating of the earth's surface by the sun. It has been estimated that roughly 10 million MW of energy are incessantly accessible in the earth's wind. The stretchy speed double-feed induction generator wind turbine (DFIG) is today the most widely used concept, due to its high concert, its capability to capture the maximum wind energy. This paper reconnoitres steady-state characteristics of a typical new variable-speed and This variable of wind power generation nature makes it difficult for study, and design, the management of a wind energy conversion system (WECS) designedthe capacitor charge control regulator is based on a model reference adaptive system observer for estimating the rotational speed.Wind velocity for wind power generation system have been presented in this paper, this dynamic steady-state model of the DFIG is complete on MATLAB. Simulation analysis is performed to investigate a variability of DFIG characteristics, based on torque-speed, real and reactive-power covered speed characteristics.

Keywords: Doubly Fed Induction Machines, Field Oriented Control Schemes, Squirrel-Cage Induction Generator, Steady-Statecharacteristics, Torque-Speedwind Power System.

Introduction

With a continuous decreasing of fossil fuels and global concerns for environmental sustainability, the demand for renewable energy is increasing gradually. Wind energy conversion system is generally connected to the electric power grid and supplies electric power to enhancement the base power from other generation systems using fossil fuel or nuclear energy, Induction generator have been widely used and analysis in wind power system because of their advantages over synchronous generators induction generators are mostly on load dependent and cannot be used above for grid frequency control[1] There are basically two method of wind power generation using induction machines, One uses outdated fixed-speed induction generators and the other uses double-fed adjustable speed Induction generators. The fixed-speed wind turbine is relatively easy and healthy Even though DFIG transient simulation has been used as an important style in shaping the result of a wind power systems and in a short time period[2] For both motoring and generating modes of induction generator, the DFIG may send an additional real power through the DFIG rotor to the grid., the dynamic steady-state study is important to deeply understand the generator or WECS behaviour in a broader range, controlling the wind generator speed by veering the charge accumulation on dc bus or coupling capacitor, real and Reactive power depend on the connected different instrument on differ place or with sensor fed back which compared with reference value, in this method anemometer measure the wind velocity in order to derive the desired shaft speed for control in specific time these method is more costly, butin this paper now we can use charge controlling method[3] Aspeed valuation, taken from a MRAS (model reference adaptive system), and this output used to control the electrical torque of the induction machine here we propose the reactive power fluctuating technology maximum power tracking control of wind power generation system.The optimal rotor speed is determined using the estimated value obtained[3] The DFIG is a typical, wound rotor[4] induction machine with its stator winding connected straight to the grid and its rotor windings connected to the grid trough an ac/dc/ac PWM converter. The ac/dc/ac converter normally consists of a machine-side converter and a grid-side converter[5], both of which are controlled by decoupled d-q control methods. The detailed model of the DFIG demands high computational requirement, its increases when a wind farm is measured. The aim of this paper is, to suggest a new simplified model of the DFIG to changing the reactive power as required the regulation of voltage and appropriate for bulk power system. Also to reduce stresses of the mechanical assembly, to smooth wind power variations, acoustic noise reduction and the possibility to control active and reactive power.

Power-Driven Input

There are a number of aspects of the methods presently used for the design calculation of wind turbine performance and loading. The different types of study and methods for the design of wind turbine systems have been reviewed in this literature in a detailed manner. According to Thomas and Urquhart, at present, both the horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT) designs are very efficient, however both are being rigorously tested and improved[6] The wind turbine consists of a rotor, a gear box, and the DFIG subsystem. The DFIG is a standard, wound rotorinduction machine with its stator windings directlyconnected to the grid,[7] Choice the torque applied to the shaft or the rotor speed as a Simulink® input of the slab or to the represent the machine shaft by a simscape™rotational mechanical part select torque Tm to specify a torque input. Input, in Nm or in pu, and change category of the block input to Tn, The machine speed is determined by machine inertia J (the constant of the inertia) and by the different between the applied power-driven torque Tm and the internal electromagnetic torque Te. Te sign conversion for the Mechanical torque is when the speed is positive a positive torque signal indicated motor mode a negative signal indicates generator modeSelect speed w to specify a speed input in rad's or in pu, and change labelling of the block input to w the machine speedis imposed and the mechanical part of the model is ignored using the speed as the mechanical input allows modelling a mechanical coupling between to machine.

Wind Turbine Size

In the primary and mid-1980s, the characteristic wind turbine size was less than 100 kW. By the late 1980s and early 1990s, turbine sizes had increased from 100 to 500 kW. Further, in the mid-1990s, the typical size reached from 750 to 1000 kW. And by the late 1990s, the turbine size had gone up to 2500 kW. Now turbines are offered with dimensions up to 3500 kW.

Wind Turbine Aerodynamics

Aerodynamics is a science and study of corporal laws of the behaviour of objects in airflow and the armies that are produced by airflows. There are significant interactions with universities, industries and foreign researchers in the area of fundamental aerodynamics. Different models of aerodynamic analysis of wind turbine system have been reviewed in this paper. Miller had made aerodynamics and dynamic analysis of horizontal axis wind turbines and also highlighted the need for a complete design theory. The unsteady aerodynamic loads resulting from wind shear may be estimated from relatively simple momentum theory.[22,23] Karl et al. had inspected the modal behaviour teetered-rotor turbine using simple models, ranging from one to seven degrees-of-freedom and showedthat the central equations are periodic and that a Floquet analysis must be used to[24]

Design

Power Equation

Mechanical power and stator electric power output are computed as follows as

$$Pm = Tm\omega r,\ Ps = Tem\omega s$$

For a lossless Generator the Mechanical Equation is;

$$\frac{Jdwr}{dt} = Tm - Tem$$

In steady -state at fixed speed for a lossless generator Tm=Tem and Pm=Ps+Pr

It follows that

$$Pr = Pm - Ps = Tm\omega r - Tem\omega s = -Tm\,\omega s - \frac{\omega r}{\omega s}\omega s = -Tm\omega s = -SPs$$

Mechanical Power received by shaft

$$Pwind = \rho airArotorCp(\gamma,\beta)v3$$

Where;

S	Slip of the generator Pm
Pr	Rotor electrical power output
Ps	Stator electrical power output
Pgc	Cgrid electrical power output
Qs	Stator reactive power output
Qr	Rotor reactive power output
Qgc	Cgrid reactive power output
Tm	Mechanical torque applied to rotor
Tem	Electromagnetic torque applied to the rotor by the generator
Ωr	Rotational speed of rotor,
ωs	Rotational speed of the magnetic flux in the air-gap of the generator,
J	Combined rotor and wind turbine inertia coefficient,

Through the orthogonal d_q transformation, the DFIG's model is represented by (1-4) [15-16].

$$vds = Rsids - \Omega\psi qs + \frac{d\Psi ds}{dt}(1)$$

$$vqs = Rsiqs + \Omega\psi + \frac{d\psi qs}{dt}(2)$$

$$vdr = Rridr - (\Omega - \omega)\psi qs + \frac{d\psi dr}{dt}(3)$$

$$vqr = Rriqr + (\Omega - \omega)\Psi ds + \frac{d\Psi qr}{dt}(4)$$

Where

$V_{ds,qs}$: stator voltage in axes d and q :

$I_{ds,qs}$: stator current in Axes d and q:

$\psi drqr$: rotor current in axis d and q

Ω :generic reference speed

ω: mechanical speed

For super synchronous speed operation, P is transmitted to DC bus capacitor and tends to raise the DC voltage. For sub synchronous speed plan, Pr is taken out of the DC bus capacitor and tends to decrease the DC bus voltage. Fig. 2 shows the general configuration of a stand-alone DFIG supplying an unbalanced three-phase load. The system is collected of a rotor-side converter and a load-side converter (LSC), The grid side converter is used to generate or absorb the grid electrical power Pgcr in order to keep the DC voltage constant. In steady state for a lossless AC/DC/AC converter P is equal to Prr and the speed of the wind turbine is determined.

Power Flow in DFIG

Figure 1 present a WECS using DFIG. A wind turbine collects the wind through its rotor blades and handovers itto the rotor hub. The rotor hub is attached to a low speed shaft through a gear box. The high speed shaft drives an electric generator which changes the mechanical energy to electric energy and delivers it to the grid[8]. As the wind speed diverges, the power captured, converted andtransmitted to the grid also varies.[9] Mechanical Power collect from wind by wind turbine blade is known as cubic low of power $Pwind = \rho air Arotor Cp(\gamma,\beta) v3$ Figure2 shows the Power flow in a DFIG Commonly the absolute value of slip is much. Lower than synchronous speed. the DFIM generator [10] and con-squinty the rotor electrical power output P is only a fraction of stator real power output P, Since the electromagnetictorque T_{ms} is positive for power generation and since W is positive and constant for a constant frequency grid voltage, the sign of Psis a function of the slip sign.P_{rr} is positive for negative slip (speed greater than synchronous speed) and it is negative for positive slip (speed lower than ing style, equivalent to the negative torque valuescan extend from negative slip (super synchronous speed) till positive slip (sub-synchronous speed).generating mode for $--1<s1\leq 0$ and motoring mode for $0<s1\leq 1[2]$ Beneath any generating condition, the generation target power of a DFIG rises too,[11] showing higher DFIG stability and powergeneration capability, as V_d changesfrom negative topositive, DFIG real power changes gradually from flowing $V_d$into (motoring) to flowing out of (generating) the inductionmachine. or torque caught from the wind turbine should be always smaller than the target power or torque of an induction generator to prevent a escaped the increase of Vd can not only expend DFIG torque and real power characteristics for generating mode but also reduce the DFIG inductive reactive power need and even change it to capacitive.

Figure 1[11]
Power Flow Diagram in DFIG No Control

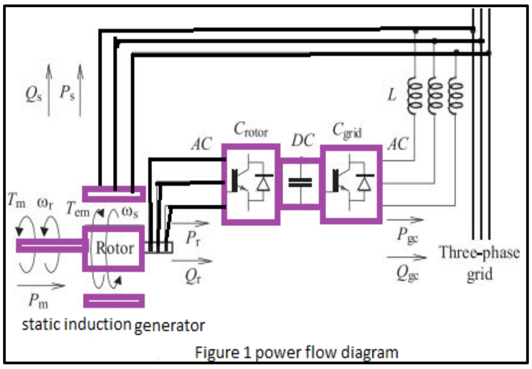


Figure 1 power flow diagram

Wind Turbine and Controls

Ezzeldin et al. had presented the modelling and controller strategy for a wind turbine induction generator unit. The mechanical power input was controlled using the vane pitch-angle. Both state and output feedback controllers are designed using MATLAB software to regulate the generator output. From the simulation grades, the response of closed loop system exhibited a good damping and fast recovery under different types of large disturbances.[12] The main goals of the DFIG control system are:

1. The power drawn from the turbine in order to track the maximum power operation point controlling.
2. Control the power in case of high wind speeds.
3. Controlling the reactive power switched between the wind turbine generator and the grid.[13]

In order to perform these jobs, the control system is separated into four sub-systems: the power, pitch, the rotor-side converter, and the grid-side converter controller[14].

Figure 2[11]
Power Flow Diagram in DFIG with Control

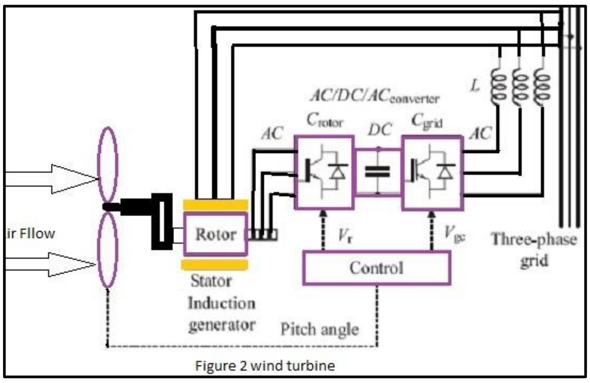


Figure 2 wind turbine

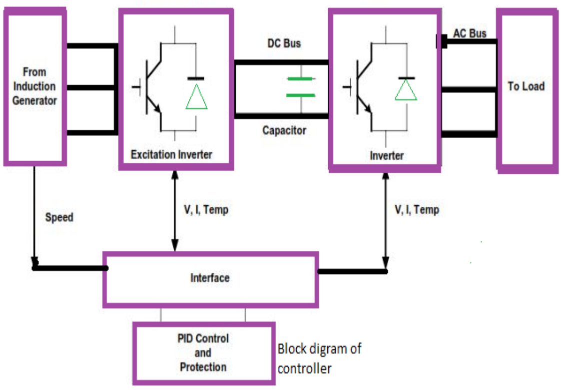
Vector Control of Doubly Fed Indication (DFIG)

Direct vector control, the equations of the machine has the reference in the synchronous frequency of voltage grid, so d axis is aligned to stator flux, i.e., Ψ=0. In steady state operation, stator flux is proportional to the voltage, this ensures that v_{dsqs}=0. Thus, power equations simplified.[15]

$$Ps = -\left(\frac{3}{2}\right) vqs \left(\frac{Lm}{Lr}\right) iqr \qquad (5)$$

$$Qs = \frac{\left(\frac{3}{2}\right) v2qs}{\varpi Ls} - \frac{\left(\frac{3}{2}\right) vqsLm}{Ls} idr \qquad (6)$$

Figure 3[2]
Induction Machine Operating Curve



The GSC control block, which is devoted to the control of the powers flow from the GSC. In case of some loads, that have unexpected behaviours, are connected to the grid, the GSC canacts according the behaviour of these loads. Some specific control[19-20]

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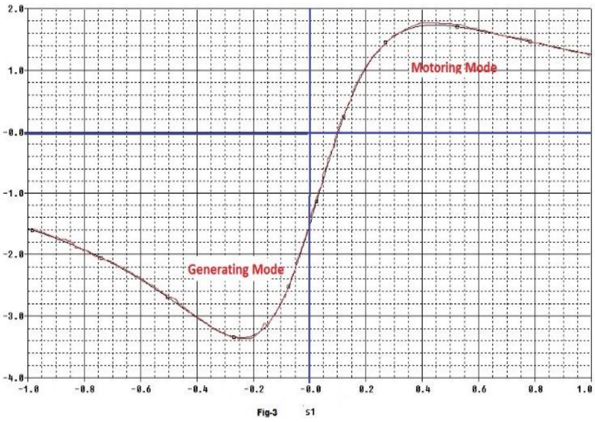
algorithm adapted to the behaviour of these loads can be used inthis case to control the GSC. As an instance, the converter can becontrolled to act as an active filter to mitigate the proliferation of the harmonics injected by non-linear loads.[15] Likewise, it can be used to equilibrium the grid currents in case of unbalancedloads are connected to the grid.

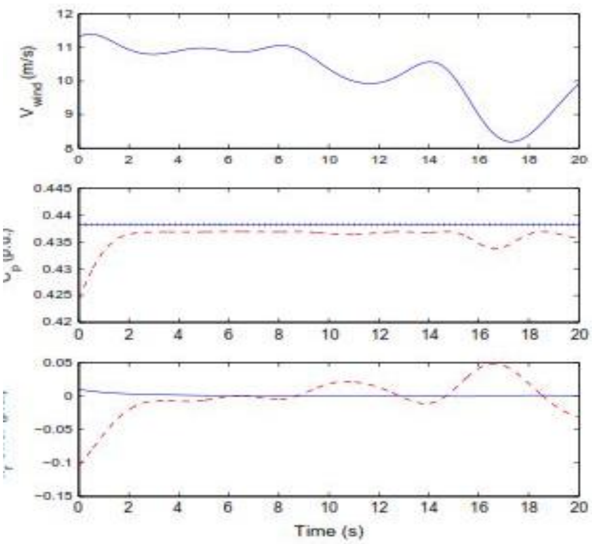
Figure 4[17]
Block Diagram of DFIG Control System



Maximum Power Point Tracing (MPPT) Performance

Simulation results for MPPT under time-varying wind speed 8–12 m/s are showed in Fig. 5. Response of power coefficient and rotor speed following error which show a higher power efficiency can be achieved by FLC than Cover the variable speed array. Wind The system model corresponding to different wind speed between v¼ 8–12 m/s with 0.5 m/s increment[16] It can be found that all system modes provided by the FLC vary slightly and almost unaffected when wind speed changes[18], which show that the consist dynamic show can be maintained; while the system mode loci provided by V_C changes with different wind speed. Besides, their scenes can be located at the left-side of all modes provided by VC and thus more damping can be delivered. In addition, the fully decoupled I wind qs and I modes result in a decoupled regulation of react power androtor speed. In fact, the large difference of mode loci of VC is official to that ds.

Figure 5[18]
Maximum Power Tracing Curve



Grid Side Converter Controller

The goal of the control of the grid-side con verter is to keep the dc-link capacitor voltage in a set value (1 pu) irrespective of the magnitude and the direction of the rotor power and to guarantee a converter operation with unity power factor (zero reactive power).[19] Its result the grid-side converter conversations with the grid only active power, the reactive power transmission from the DFIG to the grid is done only through the stator of the induction machine. The dc voltage and the reactive power are organized indirectly by controlling the grid side converter current. During the super-synchronous DFIG action,the active power flows from the rotor to the grid, and hence the capacitor voltage is increased. The reverse occurs when the induction machine works at sub-synchronous speed. In grid-side converter controller, the error between the locus andthe actual dc voltage enters to a PI controlloop in order to obtain the d-axis current situation. Then, the actual grid-side current follows its mention employing a current regulator (figure 6). Finally, the grid side voltageis obtained reproducing the actual current by the coupling impedance (L); this voltage must be synthesized by the PWM grid-side converter.[20]

Figure 6[7]
Grid Side Converter Controller

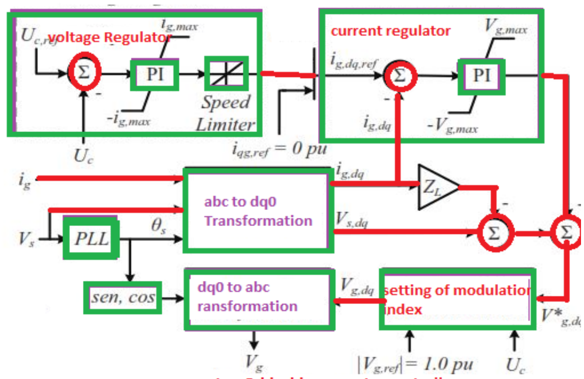


Fig 6 Grid -side converter controller

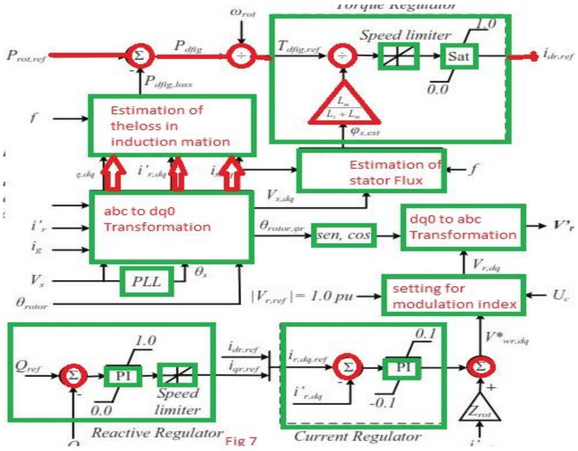
Rotor Side Converter Controller

The rotor-side converter controller usually consists ofa reactive regulator, a torque regulator, and a currentregulator as shown in figure 7. In this case, the converteroperates in stator-voltage concerned with reference frame andhence the d-axis current component affects the torque andaccordingly the active power, and the q-axis current component sets the reactive power flow of the DFIGturbine.

The rotor side controller indicates the value of*P* and discount the estimated induction machine loses$P_{rot,re\ dfig}$,lossin order to obtain the DFIG electric power *P* Thequotient between P_{dfig} is the estimated torqueT_{dfig},refrot this value is used for the calculation of the d-axisrotor current reference. In the reactive regulator, the errorbetween the reference and the ac tual reactive power entersto a PI regulator and sets the q-axis rotor current reference. In the current regulator, the actual d-q rotor current follows the reference employing a PI control loop. Then, the valueof the rotor impedance is used for the d-q voltagecalculation; this voltage must be generated bythe PWM rotor-side converter.[21]

Figure 7[7]

Rotor Side Converter Controller



Power and Pitch Controller

The power controller measures the rotor angular speed and sets the rotor power reference according to apre-defined power-speed characteristic, termed tracking characteristic. a curve superimposed to the mechanical power characteristics of the turbine obtained at different wind speeds. The pitch controller measures the rotor speed and sets the pitch angle of the rotor blades.[19] The pitch angle is kept constant at zero degree until the speed reaches a set point tracking characteristic. Beyond set point the pitch angle is proportional to the speed deviation from set point speed. The control system incorporates a proportional gain *K* a saturation block that limits the pitch angle between 0º and a speed limiter

Conclusion

The progressive wind turbine technologies have been reviewed as The factors such as selection of load, windvelocity, placeof measuring instrumentwind power would-be considered as an objective function of probabilistic models. mathematical models of wind turbine are cast-off to determine the energy output of the wind turbine system. With MATLAB simulation were found suitable to expect wind speed controlling stake charge varyingfor the system. Selection of windy site for wind power generation requires atmosphericdata for installation of wind generator. Experimental and theoretical systems are used to analyse control problems of wind turbines., The aero elastic and structural dynamic Computer-based supervisory control is used to identify operating characteristics of wind turbines. Static reactive power compensator is used to recover stability of large wind farms.

These developments and growing trends towards wind energy signal is a capable future for the wind energy industry.

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