Active and reactive power control of the doubly fed induction generator based on wind energy conversion system

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Abstract

This paper presents a dynamic modeling and control of doubly fed induction-generator (DFIG) based on the wind turbine systems. Active and reactive power control of the DFIG are based on the feedback technique by using the suitable voltage vectors on the rotor side. The rotor flux has no impact on the changes of the stator active and reactive power. The proposed controller is based on the feedback technique in order to reduce the oscillation of the generator. The control approach is estimated through the simulation result of the feedback controller assembled with DFIG wind turbines. It is applied by the feedback control based techniques in order to control the power flowing of DFIG and the power grid. Hence, an improved feedback control technique is adopted to get a better power flow transfer and to improve the dynamic system and transient stability. In stable condition, the improved performance of the controller, the proposed method is verified for the effectiveness of the control method is done in stable conditions.

Index Terms: Key word1, Key word2, Key word3, Key word4, Key word5 etc.

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1. Introduction

The renewable energy resources have emerged as a new model to meet the energy requirements of our society. In recent years, the production of electricity from hydropower, solar, the wind and geothermal energy, tides, waves and biomass energy sources have gained much attention (Yaramasu et al., 2015). Energy is considered to be the decisive input for the growth of the wind energy. Nowadays, conventional resource depletion is more concerned about environmental degradation and takes advantage of renewable energy resources to meet growing energy demands. Energy production cost is very low as compared to the conventional method. The potential sources of clean energy are considered for the future such as wind energy. For electricity production through wind energy, DFIG is commonly used for this purpose because of its numerous advantages over its counterparts (Dinesh and Rajasekaran, 2015; Ebrahimi et al., 2016)

Variable speed operation of the DFIG wind turbine based on the active and reactive power abilities, lower cost of the converter and power losses are decreased as compared to wind turbine by usingthe fixed speed generator. Variable speed wind turbines with the new standards are effective because of their improved efficiency in capturing more wind power and their ability to achieve the higher power quality Moreover, wind turbine of the variable speed with control of the speed of the turbine output power and reduces the load stress on different parts of the turbine structure, including the blades and tower. As a result, higher energy efficiency, longer life time, and improve the

quality of energy to make these wind turbines inexpensively competitive, despite the high initial costs (Zhan et al., 2014; Baloch et al., 2016; Yang et al., 2012). The dynamic model of DFIG depends upon the non-linear parameters such as electromagnetic torque, stator current; rotor current and stator flux are controlled with state feedback linearization techniques to get the better results as compared to the exit method (Baroudi et al., 2007; Hu et al., 2010). Implementation of DFIG is increasing for many reasons, such as reducing the mechanical stress, to mitigate the noise, and flexible control of the active and reactive power on the basis of back to back converter between the induction machine and the power grid (Mishra et al., 2009; Rahimi, 2016). As a result, the complexity of the system increases and it becomes difficult to analyze without a systematic point of view. In short terms, there must be the ability to support dynamic frequency of wind energy rapidly in the near future to ensure the stability of the frequency of the system. In addition, it can becontributed to the inertia of wind energy to further improve the accessibility of wind power in the grid (Zhan et al., 2014; Xiao et al., 2013; Hu et al., 2010). In order to control the generator speed is used to rotor side converter (RSC) and reactive power controlled with grid side converter (GSC) is connected to the grid through grid filter and is used to control the dc link voltage and reactive power exchange with the grid

Hence with increased penetration of the DFIG, the inertia of the effective system will be reduced. Grid integration of this variable power in increased capacity raises concerns about its impact on the power system stability (Carrasco et al., 2006; Gayen et al., 2015). Nonetheless, it is imperative for large scale transient strength studies to consider the rotor field elements of the induction generator since it assumes a critical part in deciding the inner voltage behind transient reactance. In order to reduce the efficiency of the machine due to the response of reactive power is increased. But state feedback linearization control technique is used to improve the efficiency of the machine and reduce the transient effect in the system. (Yousefi-Talouki et al., 2014; AbdelKhalik et al., 2013)

This paper proposes a new strategy for feedback control systems for wind power generation on the basis of DFIG with constant switching frequency to improve transient performance. The direct method in calculating the required voltage circuit control the transition period, based on the estimated stator flux, active and reactive power, and their errors. The transient performance of the nonlinear model of the DFIG is described by the limit of the rotor control voltage with a direct method of the active and reactive power. The aim of this paper is to provide a great idea for the dynamic behavior of the DFIG wind turbine. Control of DFIG parameters has a significant effect on the dynamic performance of wind turbines. The controller of the DFIG will play an important role in the energy system in the future with the increased penetration of the wind energy conversion system (WECS) (Bourdoulis and Alexandridis, 2014; Wang and Wang, 2011).

The proposed technique is considered by the feedback controller to regulate the rotor currents and the grid current. In order to consider the effects of the rotor and the filter of network parameters to control the dynamic performance DFIG under voltage dips. It represents the vital phenomena that are much faster than the phenomena of interest in transient stability analysis. The use of the detailed model in the study of transient stability leads to a harsh mathematical model with fast transients and long simulation times and greatly increases the computational effort. In any case, as a result of complexity of the DFIG model, extra suppositions are utilized as a part of the transient stability program for simplifying it (Naidu et al., 2014; Trilla et al., 2014). In this paper, feedback control design is developed and considered for the DFIG wind turbine system. Non-linear dynamic model of the DFIG is essentially based on stator flux as compared to conventional flux model of the wound rotor induction generator and GSC model. Non-linear dynamic model of the DFIG is improved by using the feedback control technique for alignment of the rotor and grid sides. Active and reactive power of the DFIG stator and GSC output are connected to the grid. This paper is organized as follows: in Section 2 wind turbine model is described. In Section 3 dynamic model of the DFIG wind energy System is developed. In Section 4, a controller is

designed for a DFIG Wind Turbine System. The simulation results are shown in Section 5. Final conclusion of the paper is described in Section 6

2. Wind turbine model The captured mechanical power from a wind turbine is given as follows (Yang et al., 2012): Pm = 0.5ρAV3 ω Cp(λ, β), (1) where ρ represents the air density, RT represents the wind turbine radius, Vw represents the wind speed and Cp represents the wind turbine power coefficient is given by

$$C_p(\lambda, \beta) = 22 \left(\frac{1.16}{\lambda_i} - 0.004\beta - 0.05 \right) e^{-12.5\frac{1}{\lambda_i}}, \quad (2)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}, \quad (3)$$

where β represents the blade pitch angle and λ represents the tip speed ratio as described below

$$\lambda = \frac{\omega_r R_T}{V_w}. \quad (4)$$

Owing to the presence of a gearbox with the gear ratio ng , the dynamic model wind turbine rotational speed ωr is associated to the rotor speed ωr is given as follows:

$$\omega_r = n_g \omega_r^{optimum}. \quad (5)$$

The exact dynamic model of the torque equation of the generator is given by,

where Ps and Qs represent the active and reactive power stator of the DFIG respectively, and Pg and Qg represent the active and reactive power of the grid respectively. The nonlinear dynamic model of the DFIG wind turbine is normally described by the active and reactive powers. To simplify the dynamic model is assuming an approximately constant stator voltage for DFIG. This assumption is used only under a steady state condition and grid voltages vary at the point of the common coupling typically less than ±0.005 p.u
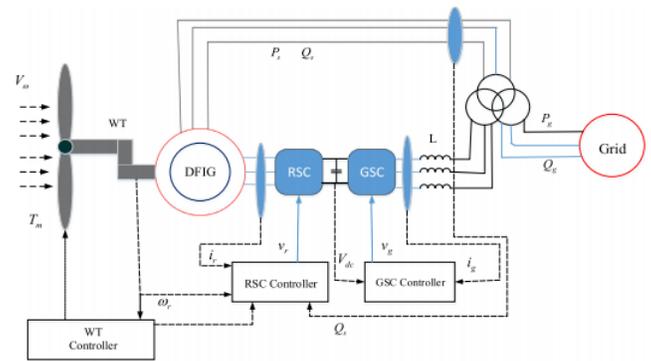

Fig. 1. Schematic diagram of wind energy based on DFIG system.

In this study, we proposed a controller through feedback algorithm for DFIG transient stability analysis of WECS in order to obtain accurate results and simulation on the basis of well-known tool Matlab. It is well known that the transient stability analysis under the typical situation which is dominated by conventional synchronous generators. In the proposed method, the most important intention is to reduce the voltage disturbance under normal operating conditions. The controller design technique is used to achieve the best outcome of the wind energy conversion system. The control method of DC voltage deals with the rotor voltage to control the suitable parameters of the DFIG, such as stator flux, stator current, active and reactive power of the machineIt is the most important intention to maintain the DC link voltage and an effect to deal with the active power transfer between the RSC and the grid. The DC link voltage is operated to the below rated value of the GSC. The proposed technique is used to eliminate the transient from the DFIG to improve the performance of the machine. The control technique is minimized by the reactive power in order to achieve the best outcomes from the dynamic system that can be used for RSC and GSC to reduce the dynamic transient from the system

Control of the real power is obtained by controlling the rotor current of the dq axis component. The rotor side converter is to improve the performance of DFIG, and the real power of the DFIG is controlled with rotor voltages to increase the efficiency of the machine. The target of the controller design procedure is to improve the performance of wind energy conversion while maintaining the stability of the system under normal operating conditions. In the conventional variable speed

of the DFIG wind turbine, it is extracting maximum rated power from the turbines unless the rated speed lower than the wind turbine speed (Asl and Yoon, 2016). The feedback linearization techniques are typically controlled to the real power of DFIG wind turbine based on wind energy conversion based. When wind speed is below the rated value, the feedback linearization technique is maximized to capture the energy from the wind turbine. To produce the maximum possible power from the wind turbine is based on its average amount of wind speed (Junyent-Ferré et al., 2010). It is noted that a new design of technique for feedback control has been established which guarantees stability, and significant simplification. The controller has been implemented for the nonlinear dynamic model of the DFIG. The RSC and GSC are required only for voltage orientation due to simpler control design for DFIG.

Table 1
1.5 MW DFIG wind turbine parameters.

Symbol	Quantity	Values	Symbol	Quantity	Values
R_s	Stator resistance	1.4 mΩ	R_f	Grid filter resistance	0.04 Ω
R_r	Rotor resistance	0.99 mΩ	l_f	Grid filter inductance	0.001 H
l_s	Stator inductance	0.08998 mH	R_L	Load resistance	4.16 Ω
l_r	Rotor inductance	0.08208 mH	l_L	Load inductance	4.093 H
l_m	Mutual inductance	1.526 mH	F	Frequency	50 Hz
P	Pole pairs	3	V_w	Wind speed	12 m/s
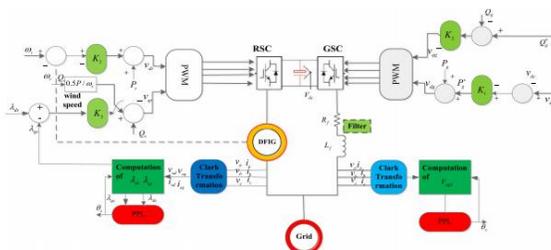
real power and reactive power. The active and reactive power are controlled independently via Vdr and Vqr, respectively. The state feedback linearization control is achieved by controlling the reactive power to keep it within the desired range. The pulse width modulation is employed to generate the control signal Vr and Vg both are derived from the RSC and GSC. Overall system oscillation is decreased by using a control signal after the disturbance elimination. It is an easy way to use the voltage single Vr and Vg as input parameters of the controller. Under all circumstances, it is easy to measure the angular velocity and fluxes and it has been implemented in the steady state condition. The analysis of the DC link voltage is equivalent to the stable system under normal operating conditions of the wind turbine. We take the following enhanced model.

The analysis of proposed scheme and performance of the controller is extensively estimated in this section and by using real-time data to obtain the results. The 1.5-MW DFIG wind turbine parameters are presented in Table 1. The state of feedback linearization controller gains are given in the Appendix. However, in the simulation environment, we have verified the effectiveness of the proposed controller of DFIG wind turbine systems considering a case 1.5 MW, at 575 Vrms and at 50 Hz frequency. Moreover, the wind always vary from time to time due to uncertain wind conditions, we are considering a ramp change around in between 10 and 12 m/s and can be easily visualized in Fig. 4. The newly generated state variables of the controller are depicted as in Figs. 5–9. Therefore, our main focus is to control and to get maximum power at the grid side. The stator flux response versus time of the DFIG is depicted in Fig. 5, where it is observed that the exactly after 2.5 a very small change in the flux occurs. Furthermore, the rotor speed response has been discussed in Section 3 in Eq.(15), can be controlled around after 0.1 up as shown
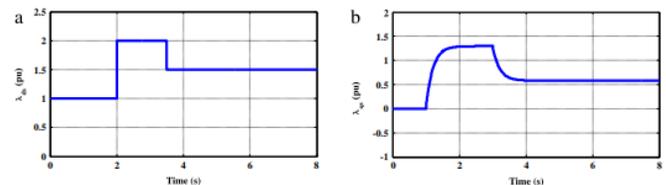
Conclusion and future work

The model has been integrated in a transient stability program which applies the simultaneous implicit method of numerical simulation to the network equations stated in the current balance form. The ability of the feedback controller in optimizing the wind production has been concentrated. The DFIG wind turbine active power control is achieved by the convenient control of the rotor voltage. It is significantly the improved performance of the wind turbine system. The proposed method of the feedback controller for the DFIG wind turbine is obtained by the maximum power. The feedback controller is designed for the

consideration of both mechanical and electrical dynamics of the DFIG wind turbine. In this paper, system reliability is increased by using a feedback technique. The observer is used to evaluate this information. The results show satisfactory system response and good performance in comparison to the other method. Finally, it is interesting to model the relatively complex energy system scenario analytically to demonstrate the applications of the feedback approach

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