

A Review of Direct Power Control Technologies of DFIG based Wind energy conversion system

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Abstract - Wind energy conversion system is becoming very popular now a days and the application of wound rotor induction machine is widely spread in wind energy generating stations because of its adaptability for variable speed wind turbines through which maximum possible extraction of wind energy is possible. DFIG's Constant Switching Frequency Direct Power Control (DPC) technologies have become a focal point due to their simple AC power converter and harmonic filter design, as well as reducing stator current harmonics and reducing power loss. This article provides a complete description of this technology. Direct power control with constant switching frequency has been shown to be achieved primarily with PWM, SVM, DSVM-DPC, and P-DPC, respectively. The principle of the scheme and the advantages or disadvantages of each approach are presented. Difficulties in the application of technology are also analyzed.

Key Words: Direct power control; constant switching frequency; DFIG.

1.INTRODUCTION

Due to increase in global warming and devastating contamination of the world's environment there is an increase in the use of non-conventional resources to fulfil the energy needs of the society which includes solar cells, wind turbines, hydro power and biomass etc. There are many engineers and several institutes working for making the optimal utilization of all these non-conventional energy sources. Wind energy is one of the alternative forms of energy that has played an important role in the history of civilization. In earlier generation, non-conventional energy resources were not used in large scale production due to lack of technology. But now wind turbine technology has emerged out with an exponential growth in the generation of power. The wind power has its own importance because of the various advancements and improved performance in several Wind Energy Conversion Systems (WECS).

According to the GWEC, despite the global financial crisis that have never seen before, in fact, the annual market grew a staggering 41.5% compared to 2008. More than 38 GW of new wind power capacity was installed around the world in 2009, bringing the total installed capacity up to 158.5 GW. This represents a year-on-year growth of 31.7%. A third of this growth was made in China, which doubled its installed capacity yet again [1].

DFIGs are also used in higher power ranges (> 3 MW). The German company Repower manufactures two models of WECSs based on DFIGs, the model 6M with a total output power of 6150 kW and the model 5M with a total output power of 5 MW [4].

The basic working of DFIG is based on the fact that stator side converter is used to control the output voltage in direct voltage control manner and the rotor side converter is current controlled where the power imbalance of the system is nullified using dc link voltage controller which modifies the quadrature axis rotor current reference value according to the changes in the wind speed as well as the load. There are various control strategies for DFIG. Although the converter used in the below works are extremely similar, great differences lie within the control strategy and complexity.

1.2 DFIG with Static Kramer Drive and SCR converter:

In this paper, the control of RSC and GSC is done in such a way so that GSC is controlled for supplying harmonics in addition to slip power transfer and RSC is used to extract maximum power and supply reactive power to grid. The proposed model uses WECS as a STATCOM for compensating harmonics during variable wind speed conditions and also during variation in the load. STATIC KRAMER DRIVE AND SCR CONVERTER METHOD are the two proposed methodology described.

1.2.1(i)STATIC KRAMER DRIVE: The static Kramer-drive is the method of controlling the speed of an induction motor by injecting the opposite-phase voltage in the rotor circuit.

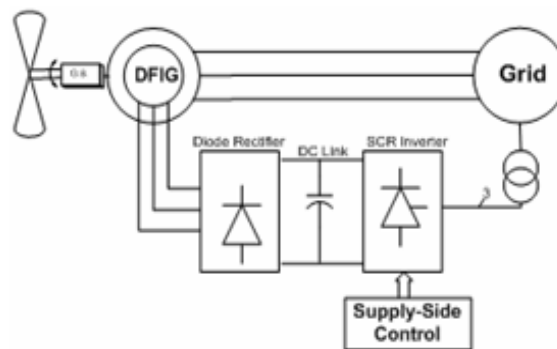


Fig1: DFIG with Static Kramer Drive.

The injected voltage increases the resistance of the rotor, thus controlled the speed of the motor. By changing the injected voltage, the resistance and speed of an induction motor are controlled. It consist of a diode rectifier on Rotor side and on Stator side , line commutated inverter is implemented .This converter combination provides a sliding mode control which converts the dynamics of nonlinear system to slide by using discontinuous control signal. Thus, providing control of stator active and reactive power at reduced switching frequency.

Disadvantage: This method is applicable only under super- synchronous speed.

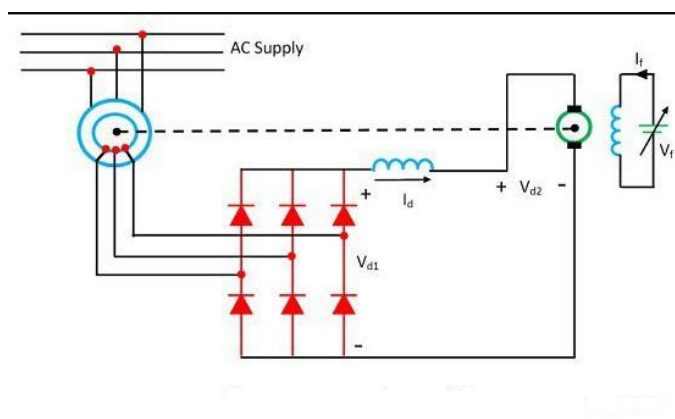


Fig2: Static Kramer Drive

1.2.2(ii) SCR CONVERTER METHODS: The limited application of Kramer drive to operate in super synchronous mode is mitigated by the use of SCR converter which provide a wide range of power control at both sub and super synchronous speed .But this approach also have some disadvantage of firing control and commutation with RSC and harmonic distortion to grid, created by supply side thyristor converter[1].

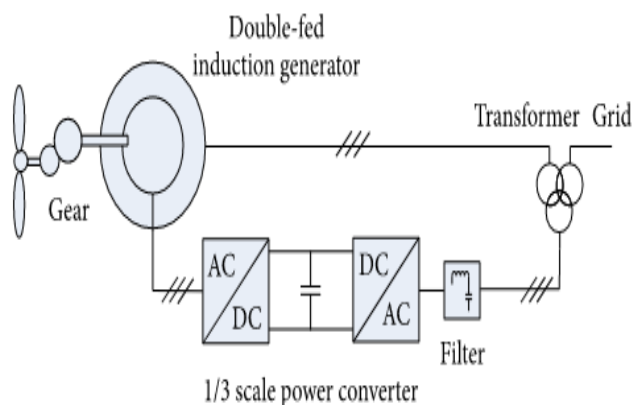


Fig3: DFIG with Back- to Back Converter

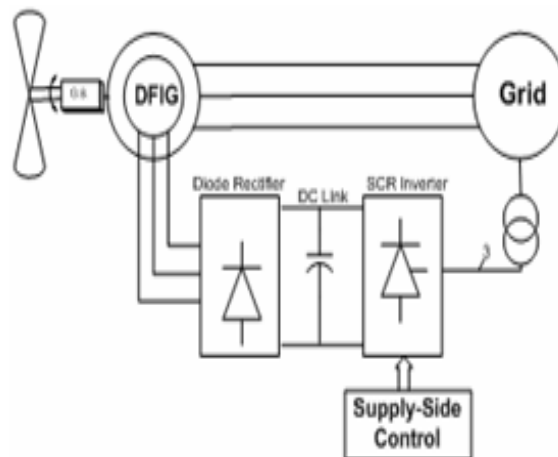


Fig2: DFIG with Back- to Back Converter

2. DFIG with Active Filter Capabilities: During power control and power transfer to the grid , the use of converters and the non-linear load connected to the grid may generate harmonics which affect the generation of power .This proposed paper presents a DFIG based WECS working as a STATCOM in which GSC is used to supply harmonics in addition to slip power transfer and RSC is used for maximum power extraction and to supply required reactive power to DFIG at different variable speed and loads. The RSC is controlled in voltage oriented reference frame and so the active and reactive powers are controlled by controlling d & q-axis rotor currents. A-DSTATCOM (Distribution Static Compensator) coupled with fly-wheel energy storage system is used at the wind farm for mitigating harmonics and frequency disturbances. The tuning of PI controllers used in both RSC and GSC is achieved by Ziegler Nicholas method. The harmonics supplied by GSC to make the grid currents sinusoidal and balanced is achieved by an indirect current control where fundamental frequency current are converted into DC and all other harmonics are converted into non -DC quantities. In this proposed DFIG, the reactive power for the induction machine has been supplied from the RSC and the load reactive power has been supplied from the GSC. The decoupled control of both active and reactive powers is achieved by RSC control. The proposed DFIG has also been verified at wind turbine installing condition for compensating harmonics and reactive power of local loads. [2]

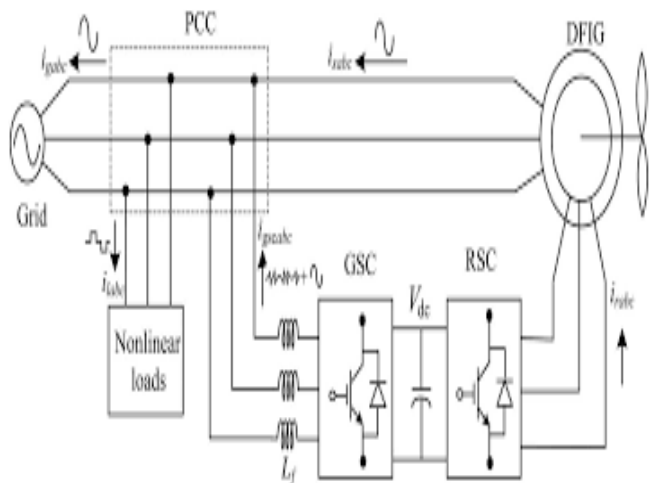


Fig3: DFIG Model for Harmonic analysis

3. DFIG Based on Power Transfer Matrix: To avoid the dependency of power on d-q reference frame for the controller operation, this proposed paper presents a power transfer matrix that uses instantaneous real/ reactive power as system state variables. The controller used here used 6 compensators for capturing the maximum wind power and supplying the required reactive power to DFIG and also providing protection against fault. Vector control scheme in a stator field oriented frame of reference is presented which directly controls the machine flux and Torque by selecting suitable voltage vectors. The multivariable control system is designed using sequential loop closing technique which capture maximum wind power and injects required reactive power to system via GSC. It consists of two loops: (a) inner loop where the control of reactive power requirement of grid and machine is done. (b) Outer control loop: where Rotor speed and dc-link voltage is regulated. Also, fault ride through algorithms like active crowbar, series dynamic restorer etc. is suggested to provide additional protection during fault condition. During transient, an extra feedback loop which will sense only the magnitude of current has been mentioned. This approach improves robustness of system and also provides simplicity to control the variables during unbalanced condition.

4. DFIG with PI Controller: In [5], the performance of PI controller for the control of active and reactive power in DFIG is simulated by keeping the wind turbine pitch control deactivated. It uses a vector control to independently control active and reactive power exchange between the stator of generator and grid with classical PI controllers. The power P_s and Q_s are independently controlled by using a PI controller. The PI controller used to control DFIG as generator is simple and quick to implement [4]. The controller forces the rotor speed to track a desired speed reference signal chosen according to

the fundamental operating modes [5]. Each converter requires active and reactive power control in order to extract the optimum power from the wind turbine while exchanging the reactive power from grid.

5. DFIG Using Fuzzy Logic Controller:

In this paper, the author displays a fuzzy logic way to deal with control variable-speed wind turbine and a Doubly Fed Induction Generator (DFIG) where the fuzzy controller is utilized for the active power and reactive power control in slow wind speed.

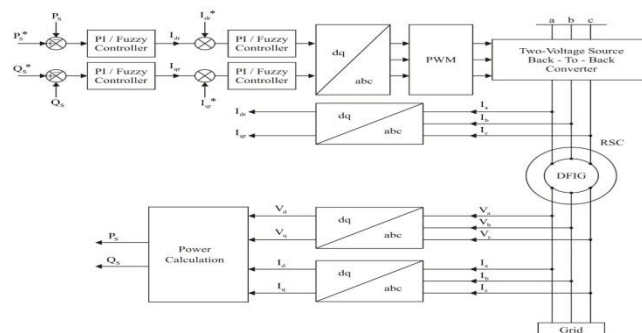


Fig4: Block Diagram showing control of active and reactive power using PI and Fuzzy Controller

This paper additionally utilizes vector control methodology that permits the independent control of the generated active and reactive power as well as the rotor speed. In this model, a rotor angular speed is controlled by pitch edge and the active and reactive power are controlled by rotor voltage, which experiences back-to-back PWM voltage source converter. The calculation of active power is done by using both the PI controller and fuzzy controller at rated wind speed = 12m/s, keeping the frequency and voltage constant. The reference active power is changed at different wind speed as $P_s^* = 2 \times 10^4 \text{ W}$ for (0s-5s) and $P_s^* = 1 \times 10^4 \text{ W}$ for (5s-9s) and $P_s^* = 2.2 \times 10^4 \text{ W}$ for (9s-12s). A notable strategy for indirect active and reactive power control depends on current vector direction as for the line voltage vector and is known as voltage-oriented control (VOC). It ensures high dynamic and static execution by means of internal current control loop [6]. In the model, are introduced the development which are later used for the improvement of the machine control. This paper shows the stator movement organized vector control and improves the PI control controller and using new Fuzzy approach to arrive at the most extreme wind energy performance coefficient with the thought of low wind speed. The block diagram of DFIG with PI Controller AND Fuzzy controller has been described in above figure.

3. CONCLUSIONS

The Literature survey of all the topologies of WECS based DFIG provide an understanding of the different control strategies ,its advantage, disadvantage ,operating speed etc. and thus providing a knowledge of calculating optimum power from the wind. As seen from the results, the static Kramer Drive can only be used for operation during super-synchronous speed and SCR converters is used for both super and sub-synchronous speed. But both of them result in harmonic distortion at the grid. The introduction of Active Power filter using STATCOM mitigates Harmonics and frequency disturbances. Also, this method can be used to operate at all the range of speed and load variation. By studying the results of different controllers, we can conclude that although the use of PI Controller is simple and easy to implement, yet it result in undesirable oscillations in Power and provide insufficient damping. Whereas, the damping characteristics of wind energy system over a wide range of operating wind speed,, the fuzzy Logic controller provides a smooth active power and better power regulation and performance.

REFERENCE

- [1] A. Baroudi, V. Dinavahi and A. M. Knight, "A review of power converter topologies for wind generators", AB, T6G 2V4, Canada., IEEE transactions,2005.
- [2] N K Swami Naidu, and Bhim Singh, "Doubly Fed Induction Generator for Wind Energy Conversion Systems with Integrated Active Filter Capabilities", IEEE Transactions on Industrial Informatics, April 7, 2015.
- [3] E.smaeil Rezaei, Ahmadreza Tabesh, and Mohammad Ebrahimi, "Dynamic Model and Control of DFIG Wind Energy Systems Based on Power Transfer Matrix",. IEEE Transactions On Power Delivery, VOL. 27, NO. 3, JULY 2012.
- [4] F.Senani, A.Rahab, F.Louar, F.bourourous "Active and Reactive power control of DFIG using PI and DPC controller", 4th international conference on Electrical Engineering (ICEE) 2015.
- [5] Azzouz TAMAARA, "Performance of PI controller for control of active and reactive power in DFIG operating in a grid-connected variable speed wind energy conversion system", Higher Education Press and Springer-Verlag Berlin Heidelberg 2014.
- [6] Hong Hee Lee Phan Quoc Dzung Le Minh Phuong, "A New Fuzzy Logic Approach For Control System Of Wind Turbine With Doubly Fed Induction Generator", IFOST 2010 Proceedings.
- [7] Abdelhak Djoudia,b, Seddik Bachac, Hossein Iman-Einid, Toufik Rekiouae ,"Sliding mode control of DFIG powers in the case of unknown flux and rotor currents with reduced switching frequency", 2017 Elsevier Ltd.
- [8] Luna, A, Lima, F. K. A, "Comparison of Power Control Strategies for DFIG Wind Turbines", Technical University of Catalonia Department of Electrical Engineering, Barcelona-SPAIN, IEEE transactions, 2008.
- [9] N. K. Swami Naidu, Member, IEEE, and Bhim Singh, Fellow, IEEE, "Grid-Interfaced DFIG-Based Variable Speed Wind Energy Conversion System with Power Smoothing", IEEE Transactions on sustainable energy, vol. 8, no. 1, January 2017.
- [10] A. Karthikeyan, Student Member, IEEE, C. Nagamani, Member, IEEE, and G. Saravana Ilango, "A Versatile Rotor Position Computation Algorithm for the Power Control of a Grid-Connected Doubly Fed Induction Generator", IEEE Transactions On Energy Conversion, Vol. 27, No. 3, September 2012.
- [11] Dr. M Kowsalya, Sumanth Srinivas Gaurav, School of Electrical Engineering, VIT University Vellore, India, Modeling of DFIG for the Variable Speed Wind Turbine", 2014 International Conference on Control, Instrumentation, Communication.