International Journal of Engineering Research in Electronic and Communication Engineering (IJERECE) Vol 3, Issue 1, January 2016

Active And Reactive Power Control Of 3 Phases DFIG By Using Vector Control

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Abstract- **This paper presents vector control of grid-connected wind turbines; also the second goal of this research is to survey the vector control for wind turbines with doubly-fed induction generators (DFIGs) when a short circuit faults in grid happens. In fact in this paper, vector control of stator-flux is applied for stator- and rotor-side converters in order to control of active and reactive powers simultaneously, and to keep the DC-link voltage constant. Also the method performances are tested in different cases.**

***Keyword*: Vector Control, WT, DFIG, Converter**

I.INTRODUCTION

With increased penetration of wind power into electrical grids, DFIG wind turbines are largely deployed due to their variable speed feature and hence influencing system dynamics. This has created an interest in developing suitable models for DFIG to be integrated into power system studies. The continuous trend of having high penetration of wind power, in recent years, has made it necessary to introduce new practices. For example, grid codes are being revised to ensure that wind turbines would contribute to the control of voltage and frequency and also to stay connected to the host network following a disturbance.

In response to the new grid code requirements, several DFIG models have been suggested recently, including the full-model which is a 5th order model. These models use quadrature and direct components of rotor voltage in an appropriate reference frame to provide fast regulation of voltage. The 3rd order model of DFIG which uses a rotor current, not a rotor voltage as control parameter can also be applied to provide very fast regulation of instantaneous currents with the penalty of losing accuracy. Apart from that, the 3rd order model can be achieved by neglecting the rate of change of stator flux linkage (transient stability model), given rotor voltage as control parameter. Additionally, in order to model back-to back PWM converters, in the simplest scenario, it is assumed that the converters are ideal and the DC-link voltage between the converters is constant. Consequently, depending on the converter control, a controllable voltage (current) source can be implemented to represent the operation of the rotor-side of the converter in the model. However, in reality DC-link voltage does not keep constant but starts increasing during fault condition. Therefore, based on the above assumption it would not be possible to determine whether or not the DFIG will actually trip following a fault.

In a more detailed approach, actual converter representation with PWM-averaged model has been proposed, where the switch network is replaced by average circuit model, on which all the switching elements are separated from the remainder of network and incorporated into a switch network, containing all the switching elements. However, the proposed model neglects high frequency effects of the PWM firing scheme and therefore it is not possible to accurately determine DC-link voltage in the event of fault. A switch-by-switch representation of the back-to-back PWM converters with their associated modulators for both rotor- and stator-side Converters has also been proposed. Tolerance-band (hysteresis) control has been deployed. However, hysteresis controller has two main disadvantages: firstly, the switching frequency does not remain constant but varies along the AC current waveform and secondly due to the roughness and randomness of the operation, protection of the converter is difficult. The latter will be of more significance when assessing performance of the system under fault condition.

II. METHODLOGY

Doubly Fed Machine Model – DFIM:
The DFIM model in synchronous reference frame is given in [16] and shows by Eq. (1) and Eq. (2)

$$\bar{v}_{1dq} = R_1\bar{i}_{1dq} + \frac{R\bar{\lambda}_{1dq}}{dt} + j\omega\bar{\lambda}_{1dq} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

$$\bar{v}_{2dq} = R_2\bar{\imath}_{2dq} + \frac{R\bar{\lambda}_{2dq}}{dt} + j(\omega_1 - PP\omega_{mec})\bar{\lambda}_{2dq} \ldots\text{(2)}$$

The relationship between fluxes and currents is given by Eq. (3) and Eq. (4).

$$\bar{\lambda}_{1dq} = L_1\bar{\imath}_{1dq} + L_M\bar{\imath}_{2dq} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

$$\bar{\lambda}_{2dq} = L_M\bar{\imath}_{1dq} + L_2\bar{\imath}_{2dq} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(4)}$$

The machine dynamics is given by Eq. (5).

$$j\frac{d\omega_{mec}}{dt} = \frac{3}{2}PPIm(\bar{\imath}_{1dq}\bar{\lambda}_{1dq}) - T_M \ldots\ldots\ldots\ldots\ldots \text{(5)}$$

The generator active and reactive power is given by Eq. (6) and Eq. (7).

$$P = \frac{3}{2}(v_{1d}i_{id} + v_{1q}i_{1q}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

$$Q = \frac{3}{2}(v_{1q}i_{id} - v_{1d}i_{1q}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7)}$$

The subscripts 1 and 2 represent the stator and rotor parameters respectively, *ω1* is the synchronous speed, *ωmec* is the machine speed, *R1* and *R2* are the stator and rotor windings per phase electrical resistance, *L1*, *L2* and *LM* are the proper and mutual inductances of the stator and rotor windings, *v* is the voltage vector, *I* is the current vector, λ is the flux vector, *PP* is the machine number of pair of poles, *J* is the load and rotor inertia moment and *TM* is the mechanical torque. The DFIG power control is achieved by rotor current control and hence independent stator active *P* and reactive *Q* power control. In this case, *P* and *Q* are computed by each individual rotor current. By using stator flux oriented, that decouples *dq* axis (3) becomes,

$$i_{1d} = \frac{\lambda_1}{L_M} - \frac{L_M}{L_1}i_{2d} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

$$i_{1q} = -\frac{L_M}{L_1}i_{2q} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(9)}$$

The active (6) and reactive (7) power can be computed by using (8) and (9).

$$P = -\frac{3}{2}v_1\frac{L_M}{L_1}i_{2q} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(10)}$$

$$Q = \frac{3}{2}v_1\left(\frac{\lambda_1}{L_1} - \frac{L_M}{L_1}i_{2d}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(11)}$$

Thus, if the rotor currents are controlled, so the stator active and reactive power control is achieved. For the power factor control, the reactive power is computed by using the active power reference and the desired power factor (*pf*) as given by,

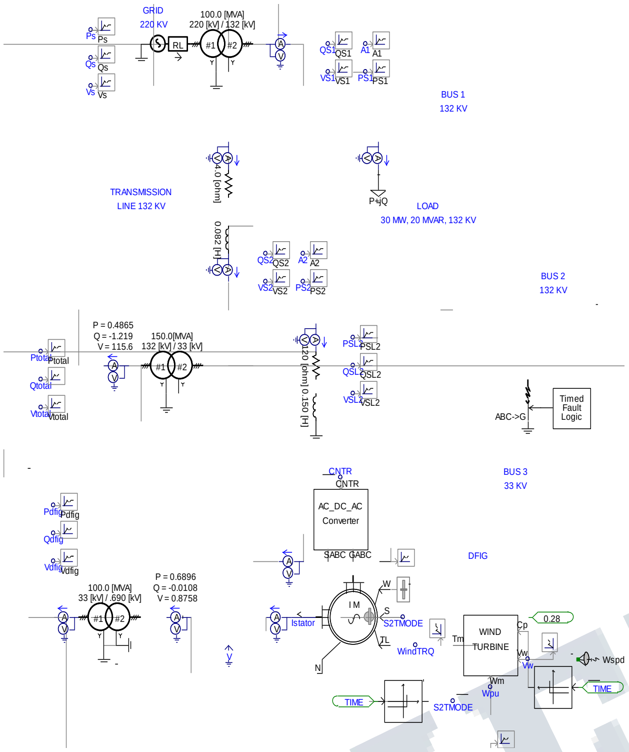
$$Q_{ref} = P_{ref}\sqrt{\frac{1-pf^2}{pf}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(12)}$$

The reactive power capability of the DFIG is limited due the maximum current of the converter . In most of cases it is 1.1 pu and the maximum power factor is 0.9.

III. SIMULATED WORK

The stator of the wound rotor induction machine is connected to the low voltage balanced three phase grid and the rotor side is fed via the back-to-back IGBT voltage source inverters with a DC bus. the power flow is controlled by the front–end converter between the DC bus and the AC side and allows the system to be operated in sub-synchronous and super synchronous speed. Fig.2shows the schematic structure of DFIG application for the wind turbine simulated in PSCAD. In fact, DFIG is basically a standard rotor-wounded induction machine in which stator is directly connected to the grid. It can be said that converter has two parts: rotor-side, and grid-side. Rotor-side converter acts as a voltage source one, while the grid-side convertor is expected to keep the capacitor voltage under wind speed changes and different conditions of grid.

IV. SYSTEM DESIGN



V.RESULT

The control scheme of the PSCAD simulated study case for a wind turbine utilizing DFIG was shown in previous section. The stator and rotor current waveforms of the induction generator are shown in Fig. 1. The case is set up to track for maximum wind power utilization. The 'power coefficient', *Cp* is a function of wind speed/machine speed. As wind speed a change, machine speed is changed to operate at maximum *Cp* , *P* and *Q* can be independently controlled irrespective of the machine slip (speed). Determining the relative difference between stator flux and rotor position is done for resolving the rotor currents. In all simulations, after 0.5 seconds, the control torque is applied. It is observed after 8th second, with a step change in speed, the flow rate have been retrieved. Also, in this paper using a filter, the stator flux dc component is removed.

In Fig.2, differences between stator and rotor flux of DFIG is shown. Also, Fig.1 shows active and reactive and reference speed of DFIG. At time 8 sec, the reference speed changed and consequently the estimated speed changes. Also, active and reactive power changes whereas vector control do well this work as soon as possible in order to get maximum torque. Turbine speed and this difference are clearly seen in this view. The capacitor of dc link can be charged to amount of the charge. These capacitors are usually a great value. Diagram and the output converter voltage obtained are as following active and reactive power output of the reference speed and DFIG rotor speed that can be seen in the Fig. 8. In this Fig, after applying vector control at time 1 sec, some various are inevitable and after that maximum torque is resulted.

In Fig.3 at time 3 sec, a fault was cleared while vector control was existed; so the variations are very little. Switching to torque control situation after 0.5 sec is done and until this time, the machine rotate at a selected speed/sec as specified at the input *W*. This value is used as the initial speed. If a turbine start up is under investigation, then the initial value will have to be changed accordingly. Although, a step changes in wind speed at the specified instant, this would cause the speed controller to react and maintain the tip speed ration for maximum power. In this regard, the optimal tip speed ration should be known and can be derived from the turbine torque equations.

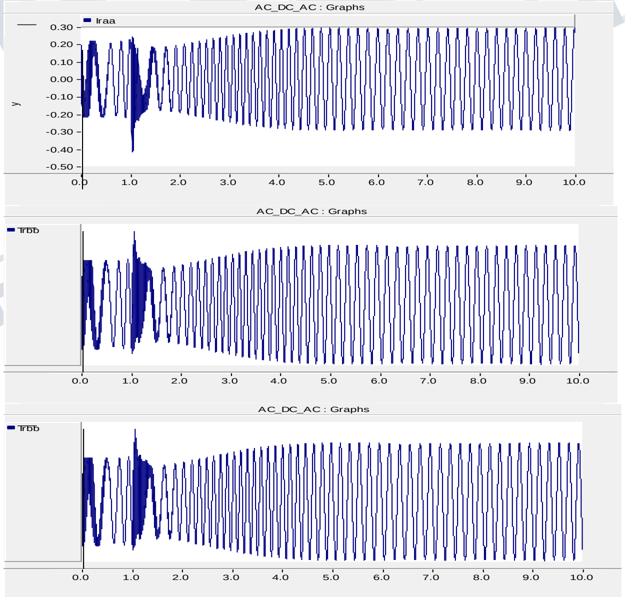


Fig 1 Turbine rotor current during speed variation

Tip speed ration will determine the value of *Cp*. (assumed constant in this example for simplicity).*Vdref1* is controlled by the capacitor voltage error. *Vqref1* is controlled by the stator side reactive power error (setting-actual). *Vdref1* and *Vqref1* are used to generate the stator side reference voltages for firing the switches (Fig.2). The diagrams of reference voltage and output two-axis wind turbine in the direction of *d* and *q* axis have shown in Fig.3. The *rms* values of voltage and rotor current supposed as following:

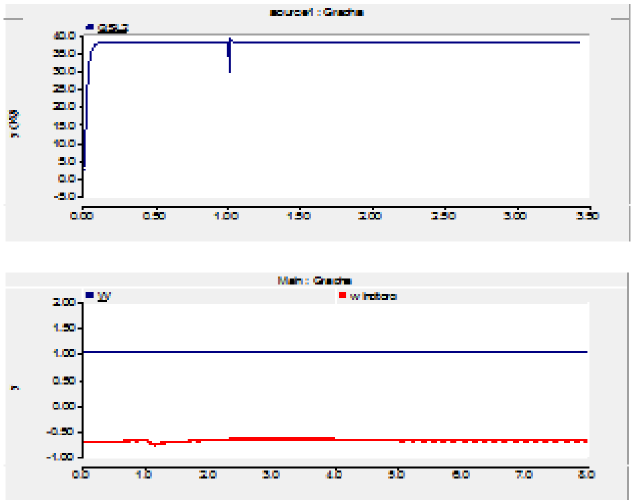


Fig. 2 Active and reactive and reference speed of DFIG

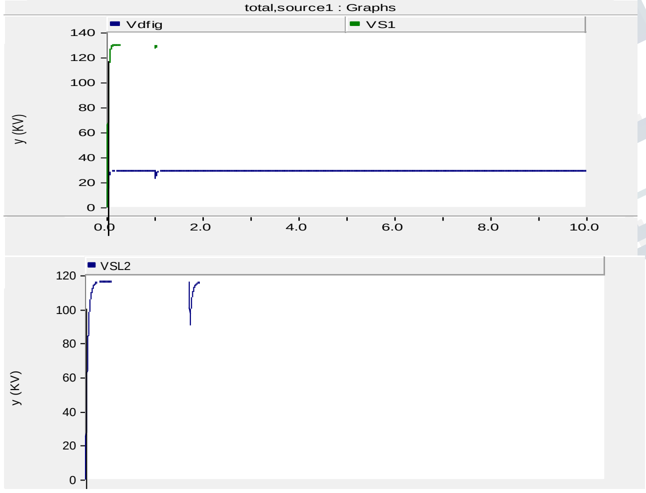
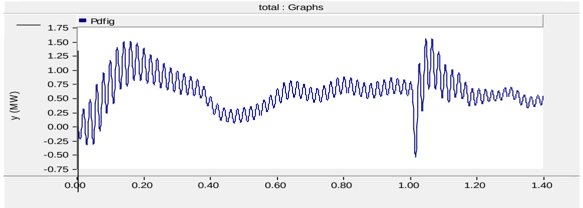


Fig. 3 Reference voltage outputs for d and q axis of DFIG



Identification of main stator flux by integrating stator voltage after removal of resistive drop. The washout filter removes any dc component from the integrated flux without significantly effecting the phase. Block the rotor side inverter during the high enough rotor current to trigger the crowbar protection circuit, in fact when S1=0, then crowbar will not be active . Finally controlled current and voltage of DFIG can be seen, In fact, the axis d, the reactive power control model and the flow axis and q, the active power and control model that we have in this section will be controlled both simultaneously. The electrical and mechanical torque. Also, *Tref* is the reference torque. In fact, Fig. 8 shows a simulation of the speed control loop with rated driving torque. At time 8 sec, reference speed is changed and consequently the torque changes as soon as possible by vector control. The produced voltages of DFIG. This figure shows the value of produced voltage for all phases and the *rms* value of produced voltage. In this paper, the dynamic performance of the DFIG generator is shown. Also, during a 3 phase fault and step changes in load, it is found that similar to previous sections initially generator operates at essentially rated condition with a load torque to base torque.

VI. CONCLUSION

In this paper, a doubly fed induction generator as the power conversion system in wind turbines is analyzed by vector controlled for better control of the grid while injecting the required active power of the system. The system model is developed in the dedicated power electronics and system simulation tool, PSCAD software. The model includes wind speed fluctuations, enabling simulation of the power quality characteristics of the wind turbine. Based on results, the proposed vector control of DFIG is capable of simultaneous capturing maximum power of wind energy with fluctuating wind speed and improving power quality, and this is achieved by cancelling the most significant and troublesome harmonics of the utility grid by vector control. Reactive and active power controls are the other two significant features of the proposed technology. Also, vector control of DFIG wind turbines is investigated after the clearance of short circuit faults in grid. This paper presented modelling of DFIG using power components as variables and the performance of the DFIG system is analysed under grid voltage fluctuations. The active and reactive power is controlled independently using the vector control strategy. It has been shown that Direct power control is a more efficient approach compared to modified Direct torque control and Vector Control .The main aim of the controlling technique is maintaining the DC link voltage constant which is achieved during voltage sag and swell conditions.

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