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A NOVEL SYNCHRONIZATION OF DFIG OUTPUT VOLTAGE TO UTILITY GRID IN WIND POWER SYSTEM WITH DIFFERENT FAULT CONDITION

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Abstract- In recent days the wind power is rapidly growing renewable energy source. The combustion of conventional fossil fuel across the globe has caused increased level of environmental pollution. In this paper DFIG application in wind power system is presented. In the DFIG topology the stator is connected direct to the grid while the rotor is connected to a back-to-back converter. This structure requires some care during grid synchronization to avoid undesired overloads. By controlling the rotor d-axis current, the magnitude of the stator EMF is adjusted to be equal to the grid voltage. A phase-locked-loop (PLL) computes the grid voltage phase displacement required for the system control orientation and synchronization procedures. By controlling the turbine pitch angle, the generator speed is determined to adjust the stator frequency to be equal to the grid. The simulation results are obtained using MATLAB/SIMULINK software.

Keywords- DFIG, Synchronization, Stator flux-oriented vector control, Grid-utility, PLL.

I.INTRODUCTION

Nowadays, doubly-fed inductionn generators (DFIG) for wind turbines are widely used. The main advantage of the DFIG compared to the other adjustable speed generators is the fact that power electronics components only handle with a fraction of the generator power. This reduces the acquisition costs and the losses in power electronics devices. Finally, the quality of the generated power is also improved in terms of harmonic and voltage fluctuations [1], [2]. It is well known that wind power generation using a variable-speed constant frequency (VSCF) scheme produces electricity over a wide range of wind speeds, thus having a high energy capture capability. One commonly used VSCF scheme employs a doubly-fed wound-rotor induction generator (DFIG) using an ac/dc/ac PWM converter in the rotor circuit [l], [2]. The DFIG can supply power at constant voltage and constant frequency while the rotor speed varies. This makes the DFIG suitable for variable speed wind power generation. The main advantages of this system are the decoupled control of active and reactive power and the reduced rating of power converter (25-30%). The DFIG using back-to-back PWM converters for the rotor circuit has been well established in wind generation applications. When used with a wind turbine, it offers several advantages compared with fixed speed generators. These advantages, including speed control and reduced flicker, are primarily achieved by controlling the voltage source converter, with its inherent four-quadrant active and reactive power

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capabilities [3], [4] As shown in Fig. 1, the stator of the DFIG is connected through SW 3 to the balanced three-phase grid and the rotor side is fed via the back-to-back IGBT voltage-source\ converters with a common dc bus. The ac-dc converter controls the power flow between the dc bus and the rotor side and allows the system to be operated in sub-synchronous or super synchronous speed. The active power is generated based on the wind speed value and wind turbine characteristics while the reactive power command is determined as a function of the desired reactive power converter compensation. The vector control strategy of the power converter is based on the stator-flux oriented control which allows a decoupled control of generator torque and rotor excitation current. The control system makes it possible to improve dynamic behavior of the wind turbine, resulting in the reduction of the drive train stress and electrical power fluctuations, and increasing energy capture [5], [6].

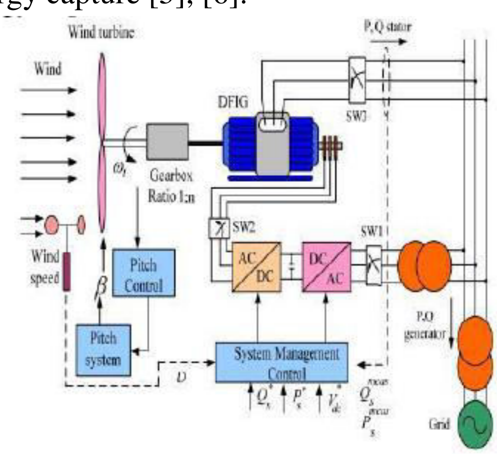

Fig. 1 Basic configuration of DFIG wind turbine system

The DFIG operation and control have been intensively investigated so far. On the other hand, only a few papers have handled the DFIG control during the synchronization process. There are two control schemes for DFIG synchronization published. One method is based on direct torque control (DTC) [7], and the other is based on the field oriented control (FOC) [8]. In this paper an induced stator voltage equal to the grid voltage is generated before the synchronization by adjusting the rotor flux. This procedure performs a null current connection with a very low impact to the grid and the machine. The paper describes soft and fast synchronization of the DFIG to the grid as well as independent control of active and reactive power of the generator using the stator fluxoriented vector control at normal operation. During the generator synchronization process, the turbine pitch angle controller adjusts the speed close to the synchronous speed to make sure that the stator frequency is the same as that of the grid. The magnitude of stator EMF is controlled by adjusting the rotor flux and the phase shift between the stator and grid voltages is compensated by PLL circuit.

II.DFIG synchronization control

A.Normal operation control:

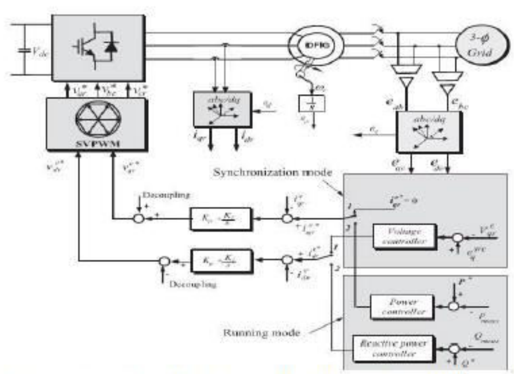

Fig. 2.Active and reactive power control for synchronization mode and running mode.

Fig. 2shows the schematic of the DFIG wind turbine configuration and its control scheme. The stator of the DFIG is connected to the

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utility grid. The back-to-back PWM converter in the rotor side provide a bi-directional powerflow control thereby enabling the DFIG to operate either in sub-synchronous (ωr < ωs) or in super synchronous modes (ωr > ωs). In both modes the stator active power is generated from the DFIG and delivered to the grid. On the other hand, the rotor active power is either supplied to the machine in the sub-synchronous mode or delivered to the grid in the super synchronous mode. The stator active power is controlled directly assuming that a maximum generator developed power is known from the optimum generator speed value. The operating curve of the studied wind turbine, which is applied to most modern wind turbines [12], is illustrated in Fig. 3.

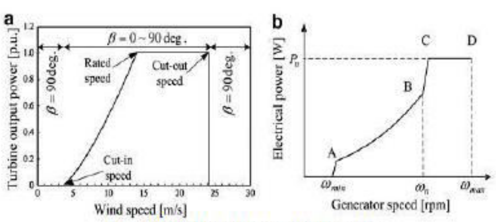

Fig. 3.Wind turbine characteristics.

This curve is characterized by four sections as follows; A ~ B for rotor speed which is less than the minimum angular speed for optimum operation, B~C for an optimal characteristic curve given by Popt = Koptv 3(where v is the wind speed) in between the cut-in speed and the rated speed, C~D for a constant speed characteristic up to the rated power, and D ~ E for a constant power characteristic beyond the speed limit followed by a blade pitch control action for high wind speed. The reference stator power P* of the DFIG is used as the reference value for the power control loop. In the inner current control loop, the stator flux vector position is used to establish a reference frame that allows q-axis components of the rotor current to be controlled. As the reference rotor current components are in stator flux-oriented coordinates, these must be transferred to the same reference frame as the DFIG rotor current vector. This is achieved by rotating the rotor reference current vector by an angular position θsl. Due to the rotor speed variation, θsl is updated at every sample interval. Once the reference frame for both the reference and measured current vectors are conformed, simple proportional plus integral (PI) regulators can be used to control the d- and q components of the rotor current. Adjustment of the q-axis component of the rotor current controls either the generator developed-torque or the stator-side active power of the DFIG.

$$P_s = \frac{3}{2}\left(v_{qs}i_{qs} + v_{ds}i_{ds}\right) = \frac{3}{2}\cdot v_{qs}i_{qs} = -\frac{3}{2}\cdot\frac{L_m}{L_s}\cdot v_{qs}i_{qr} \quad (1)$$

$$T_e = \frac{3}{2}\cdot\frac{P}{2}\cdot\frac{L_m}{L_s}\left(\lambda_{qs}i_{dr} - \lambda_{ds}i_{qr}\right) = -\frac{3}{2}\cdot\frac{P}{2}\cdot\frac{L_m}{L_s}\cdot\lambda_{ds}i_{qr} \quad (2)$$

Where Ps is the stator power, vqs, vds, iqs and vds are the dq stator voltage and current components, Ls and Lm stator and magnetizing inductances, λds is the stator flux d-axis component and iqr is the rotor q-axis component. Regulating the d-axis component controls directly the stator side reactive power flow as shown in Fig. 2.

$$Q_s = \frac{3}{2}\left(v_{qs}i_{ds} - v_{ds}i_{qs}\right) = \frac{3}{2}\cdot v_{qs}i_{ds} = \frac{3}{2}\cdot v_{qs}\left(\frac{\lambda_{ds} - L_m i_{dr}}{L_s}\right) = \frac{3}{2}\cdot\frac{L_m}{L_s}\cdot v_{qs}\left(\frac{v_{qs}}{L_m\omega_e} - i_{dr}\right) = \frac{3}{2}\cdot\frac{L_m}{L_s}\cdot v_{qs}\left(i_{ms} - i_{dr}\right) \quad (3)$$

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B. Synchronization process control:

The process of connecting the DFIG to the grid consists of two stages, that is, synchronization stage and running stage. At standstill, rotor blades are in a feathering position and the generator is disconnected from the grid. From a complete stop, the first step is to charge the dc-link voltage by closing SW1 as shown in Fig. 1. The anemometer measures the wind speed and if the wind speed is higher than the cut-in value, the switch SW2 is closed and the pitch controller changes the blade pitch angle so that the turbine begins to rotate. The controller of the generator rotor side is activated so an excitation current is sent through the rotor.

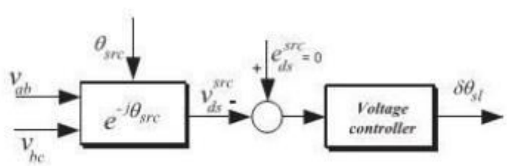

Fig. 4.Phase difference compensation for synchronization

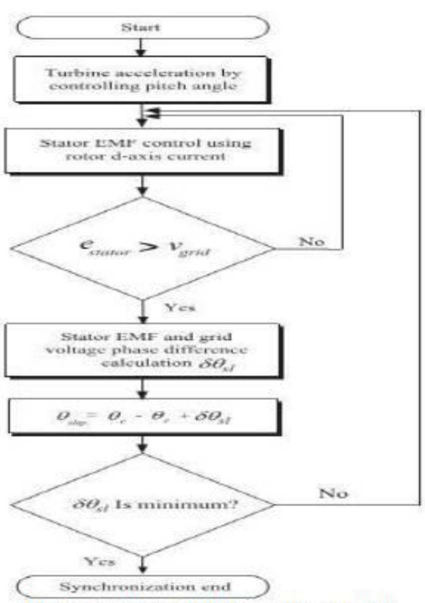

Fig. 5.Sequence of DFIG synchronization

The excitation current generates the generator flux and build-up the stator EMF. The turbine accelerates until it reaches near the rated speed. At this point the frequency of the stator EMF is about the same as that of the grid voltage. The amplitude of the stator EMF is about the same as that of the grid. Even slightly different frequencies may cause the phase difference between the two voltages. To compensate for the phase difference between the stator EMF and grid voltage, the phase difference compensation component δθsl is added to the calculated slip angle as shown in Fig. 4. The compensation component δθsl is calculated by controlling the stator d-axis voltage component to be zero, equally to the grid d-axis voltage. The synchronization process is summarized in the flow chart shown in Fig. 5. After the synchronization conditions are achieved, the stator-side contactor is closed, and the generator is connected to the grid. The pitch anglecontroller sets the blade pitch at the optimum point if the blades are not yet at this point. The generator power reference is set to the maximum value which is determined by the wind speed and the pitch angle. The overall control system for both synchronization mode and running mode is shown in Fig. 2.

C. Grid-side control:

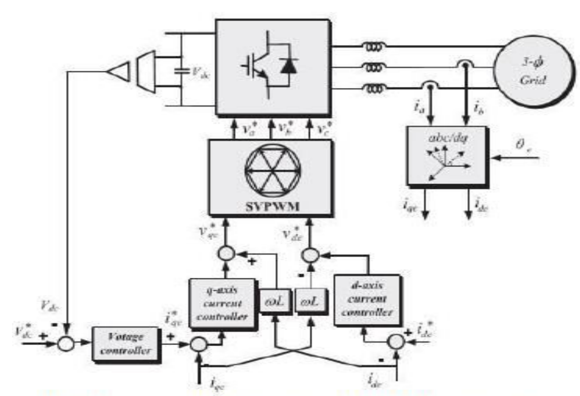

Fig. 6.Control block diagram of grid-side converter.

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The function of the grid-side converter is to keep the dc-link voltage constant regardless of the magnitude and direction of the rotor power [13]. If a vector control method is applied, with a reference frame oriented along the grid voltage vector position, an independent control of the active and reactive power for the grid-side is guaranteed. Fig. 6 shows a block diagram of the grid side converter control. The PWM converter is current-regulated, with the q-axis current used to regulate the dc-link voltage and the d-axis current component control of grid side PWM converter used to regulate the reactive power.

III.MATLAB MODELING AND SIMULATION RESULTS

Here simulation is carried out in different conditions, in that 1. Synchronization of DFIG under utility grid condition 2. DFIG under Various Fault Conditions.

Case 1: Synchronization of DFIG under utility grid condition

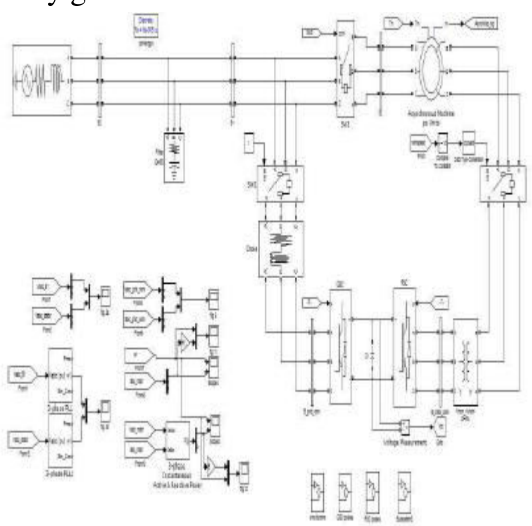
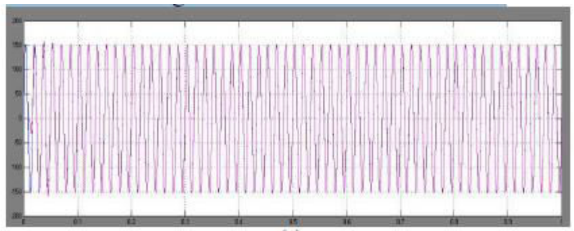
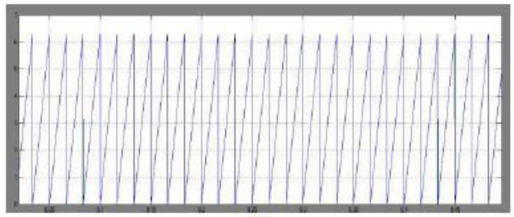


Fig.7 Matlab/Simulink Model of Synchronization of DFIG under utility grid condition

Fig.7 shows the Matlab/Simulink Model of Synchronization of DFIG under utility grid condition using Matlab/Simulink Platform.



(a)



(b)

Fig.8 Stator & Grid Voltages

Fig.8 shows the Stator & Grid Voltages of Synchronization of DFIG under utility grid condition.

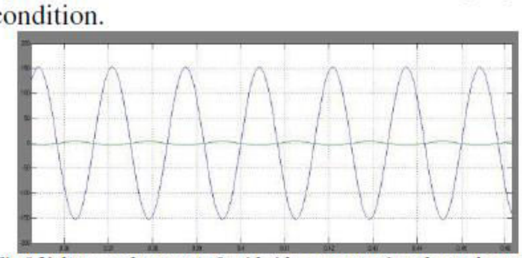


Fig.9 Voltage and current of grid-side converter in sub synchronous speed.

Fig.9 shows the Voltage and current of grid-side converter in sub synchronous speed of Synchronization of DFIG under utility grid condition.

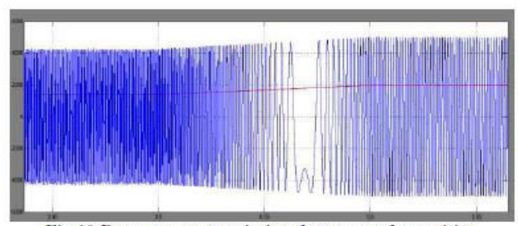


Fig.10 Rotor current variation due to speed transition

Fig.10 shows the Rotor current variation due to speed transition of Synchronization of DFIG under utility grid condition.

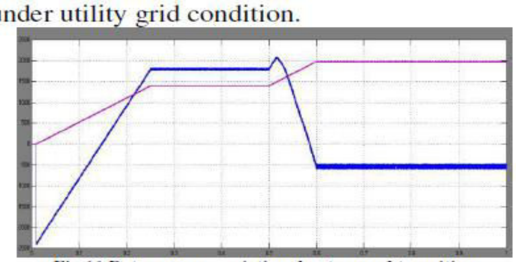


Fig.11 Rotor power variation due to speed transition

Fig.11 shows the Rotor power variation due to speed transition of Synchronization of DFIG under utility grid condition.

Case 2: DFIG under Various Fault Conditions

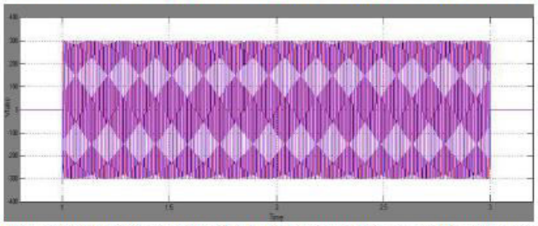


Fig.12 Grid Voltage under LLL-G Fault with Series Compensator

Fig.12 shows the grid voltage under LLL-G Fault with Series Compensator, at instant 1 sec to 3 sec fault occurs.

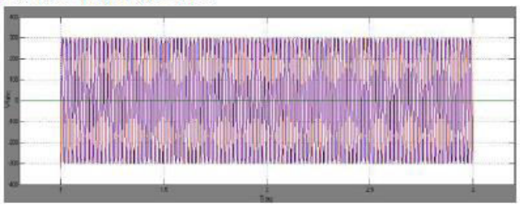


Fig.13 Grid Voltage under LL-G Fault with Series Compensator

Fig.13 shows the grid voltage under LL-G Fault with Series Compensator, at instant 1 sec to 3 sec fault occurs.

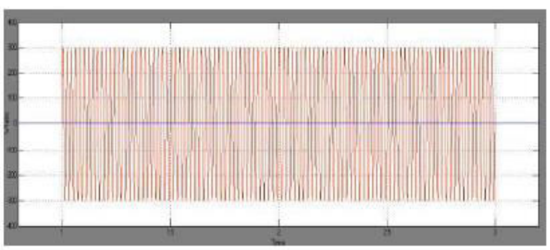


Fig.14 Grid Voltage under L-G Fault with Series Compensator

Fig.14 shows the grid voltage under L-G Fault with Series Compensator, at instant 1 sec to 3 sec fault occurs.

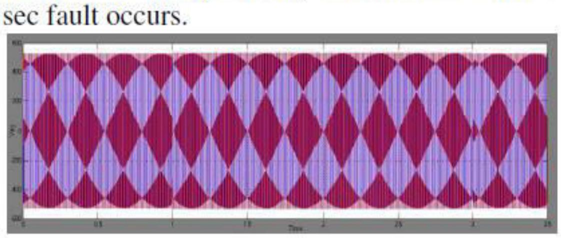


Fig.15. Grid Voltage under various fault condition with Series Compensator

Fig.15 shows the grid voltage under various fault conditions with series compensator, all the fault conditions we maintain constant voltage at our grid.

IV.CONCLUSION

In this paper, a synchronization scheme for stator flux-oriented DFIG control systems to the utility gird has been proposed. The pitch angle controller adjusts the turbine speed at the required value for equal frequency. The stator voltage is generated to be equal to the grid voltage by adjusting the rotor d-axis current. The voltage phase shift is compensated using the d-axis voltage component of both sides. The proposed synchronization algorithm gives smooth and fast synchronization, which enables the system to be reclosed quickly after grid fault clearing. With this scheme, it is possible to keep wind turbines synchronized to the grid, even in the case of faults or low grid voltages. Voltage unbalance can be completely removed by using this scheme. A new methodology is proposed to mitigate voltage sag with phase jumps with minimum real power injection in DFIG based wind generation system by using classical optimization. Objective function with constraints for mitigation of unbalanced voltage sag with phase jumps was formulated, such that real power injection by SC of DFIG is minimum. The real power injection is less compared to the existing method for voltage sag with phase jumps.

REFERENCES

[1] Zhang L, Watthansarn C, Shehered W. A matrix converter excited doubly-fed induction machine as a wind power generator. IEEE IECON Conf Proc Nov. 2004;2:906e11.

[2] Cartwright P, Holdsworth L, Ekanayake JB, Jenkins N. Co-ordinated voltage control strategy for a doubly-fed induction generator (DFIG)-based wind farm. IEE Proc Gener Transm Distrib Jul 2004;151(4):495e502.

[3] Muller S, Deicke M, De Doncker RW. Doubly fed induction generator systems for

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wind turbines. IEEE Ind Applicat Mag; May/June2002:26e33.

[4] Xu L, Wei C. Torque and reactive power control of a doubly fed induction machine by position sensorless scheme. IEEE Trans Ind Applicat May/June 1995;31(3):636e42.

[5] Sun T, Chen Z, Blaabjerg F. Transient analysis of grid-connected wind turbines with DFIG after an external short-circuit fault. Nordic Wind Power Conference, March 2004.

[6] Delmerico RW, Miller N, Price WW, Sanchez-Gasca JJ. Dynamic modelling of GE 1.5 and 3.6 MW wind turbine-generators for stability simulations. IEEE Power Engineering Society PES General Meeting, 2003.

[7] Pena R, Clare JC, Asher GM. A doubly fed induction generator using back-toback PWM converters supplying an isolated load from a variable speed wind turbine. IEE Proc Electric Power Appl 1996;143:380e7.

[8] Li H, Chen Z. Overview of generator topologies for wind turbines. IET Proc Renew Power Gener Jun.2008;2(2):123e38.

[9] Chitti Babu B, Mohanty KB. Doubly-Fed induction generator for variable speed wind energy conversion systems-modeling & simulation. Int J Comput Electrical Eng February, 2010;2(1):1793e8163.

[10] Chowary BH, Chellapilla Srinivas. Doubly-fed induction generator for variable speed wind power generation. Trans Electric Power Syst Res Jan 2006;76: 786e800.

[11] Gomez SA, Amenedo JLR. Grid synchronisation of doubly fed induction generators using direct torque control. IEEE IECON Conf Proc 2002;4: 3338e43.

[12] Yuan G, Chai J, Li Y. Vector control and synchronization of doubly fed induction wind generator system. The 4th International PEMC Conf., vol. 2, pp. 886e890, 2004.

[13] Thringer T, Linders J. Design criteria of variable speed wind turbines with doubly fed induction generator. Proc Eur Wind Energy Conf July. 2001;8(3): 1116e9.

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