Reactive Power Compensation of Doubly Fed Induction Generator using STATCOM in Grid Side

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Abstract— Wind energy generation with Doubly Fed Induction Generator is a dominant factor in wind forms. High penetration and variable fault conditions DFIG absorbs more reactive power from the grid. Applying a set of optimized control parameters, the reactive power of the systems shall be further enhanced. Due to presence of variable load with fault conditions reactive power is varied in the system. Varied reactive power is compensated by the Static Synchronous Compensator (STATCOM). In DFIG, the Real and reactive power are modified based on rotor speed and load variations. The simulation result shows the effectiveness and performance of the DFIG with Static Synchronous Compensator (STATCOM) with their control techniques.

Key words: Doubly Fed Induction Generator (DFIG), Grid Side Converter (GSC), Rotor Side Converter (RSC), Static Compensator, Real and Reactive Power

I. INTRODUCTION

The development of renewable energy for sustainable, efficient and clean electric power systems has become a critical research topic worldwide. Variable speed wind turbines employing Doubly Fed Induction Generator (DFIG) is the most popular technology in currently installed wind turbines .With the continuous increase in penetration level of DFIG wind turbines, power system stability becomes an important issue which needs to be properly investigated. Wind power generation with DFIG is optimal one and high penetration of this DFIG creates some instability in grid side based on reactive power variation. By replacing Variable Speed Wind Turbine (VSWT) generation with equivalently rated synchronous units, the small-signal stability and transient stability of the system was assessed. But efficiency of the system is reduced and it creates more stress in gear system. Power electronic converter of the DFIG acts as an interface between DFIG generator and the grid. And increased penetration of DFIG, the effective inertia of the system will be reduced. DFIGs are not synchronously coupled to the power systems, the wind turbines do not participate in electromechanical oscillations. This DFIG frequency of the stator is based on the frequency of the rotor and it is varied by the controllers. If wind speed is less than the rated speed, frequency of the rotor is increased. It is ensured in eq1.

$$f_{stator}=(n_{rotor}\times N_{poles}/120)+f_{rotor} \quad (1)$$

Wind speed is more than the rated speed, frequency of the rotor is reduced. It is ensured in eq2.

$$f_{stator}=(n_{rotor}\times N_{poles}/120)-f_{rotor} \quad (2)$$

The following equation represents the rotor frequency changes in variable wind speeds,

$$f_{rotor}= f_{network} - (n_{rotor}\times N_{poles}/120) \quad (3)$$

In order to promote the integration of wind farms into the electrical network, Flexible AC Transmission Systems, FACTS, are widely used. The FACTS STATCOM system is one of them. Numerous studies have shown that transient and steady state stability can be improved by controlling the voltage of the connection point of the wind farm to the network. The STATCOM system stimulates voltage stability by reactive power regulation. STATCOM provides or absorbs reactive power to or from the grid to compensate small voltage variations at the connection point of the wind farm with the grid. STATCOM is also used when a voltage dip occurs. Many studies show that STATCOM helps the wind farm to stabilize voltage especially after a voltage dip occurs. The function of STATCOM here is to respond quickly to maintain the voltage at a certain threshold level, preventing voltage collapse in situations of voltage disturbances. In order to compensate this voltage fluctuation the wind farm can provides reactive power. The reactive power referenced by the wind farm control is proportional to the voltage deviation at the connection point of the wind farm about a constant set point. The demand for this power can be supplied by the generators or by the STATCOM. In STATCOM is used to solve power quality problems on transmission lines. In, the benefits of installing a STATCOM in a wind farm to improve the behavior of the park when facing fault ride through situations.

II. METHODOLOGY

In this method Reactive power compensation is improved by design of STATCOM and these control technique. Grid side converter implementation is based on the reactive power modifications and it is also compensate the grid reactive power variations.

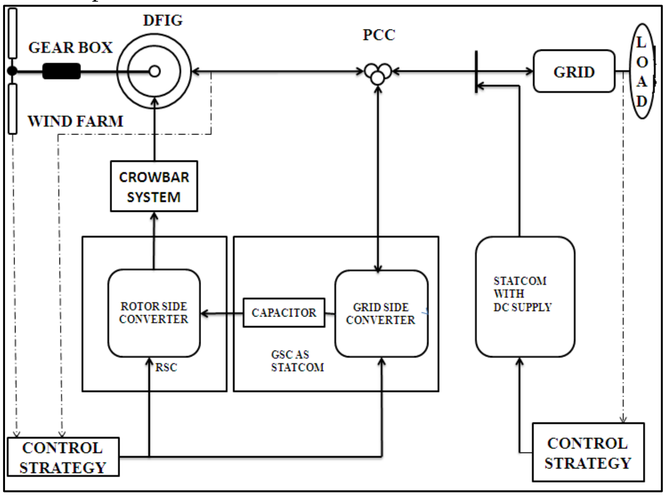

Fig. 1: DFIG with RSC-GSC control

Rotor side converter implementation is based on the frequency, real and reactive power modifications. DFIG speed variations are based on the RSC output current frequency. This two converter pulse generation is controlled by PWM technique.

III. MODELING OF DFIG

The DFIG is comprised of a wound rotor induction generator with a rotor coupled back-to-back converter system. The rotor-side converter (RSC) is connected to the GSC using a DC link capacitor. During grid disturbances, due to the magnetic coupling between the stator and the rotor, a high transient rotor current is excited. Hence, to avoid damage to the converter, the RSC is short circuited using a resistor bank, which is commonly known as the crowbar [10]. The crowbar effectively decouples the back-to-back converter unit from the wound rotor induction generator, and enables the DFIG to operate as a squirrel cage induction motor. Transition from a DFIG to SCIG absorb more reactive power from the grid so this condition GSC-DC link section act as a STATCOM and supply reactive power to the DFIG.

And the wind flow variations are creating the instability in rotor function and also create torsional vibrations by the process of electromechanical interactions. To eliminate this problem Rotor Side Converters (RSC) are used to modify the frequency, real and reactive power of DFIG rotor excitation current. These processes are obtained by the Rotor Side (RSC) and Grid Side Converter (GSC) control methods [6].

A. Modeling of Converters Control System

For controlling the voltage frequency control, we need to control the rotor side and grid side converters that in turn control the DFIG. The objective of the RSC is to regulate both the stator active and reactive powers, P_s and Q_s, independently [4],[7]. The reactive power control using the RSC can be applied to keep the stator voltage V_s within the desired range, when the DFIG feeds into a weak power system insufficient local reactive power absorbed from grid.

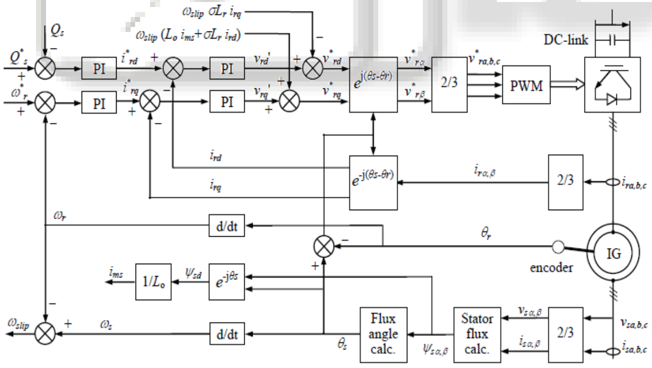

Fig. 2: Rotor Side converter control [12]

1) *Stator Voltage Equations:*

$$Vqs = p\lambda qs + w\lambda qs + rs\ iqs \qquad (4)$$

$$Vds = p\lambda ds - w\lambda qs + rs\ iqs \qquad (5)$$

2) *Stator Flux Equations:*

$$\lambda qs = (Lis + Lm)\ iqs + Lm\ Iqr \qquad (6)$$

$$\lambda ds = (Lis + Lm)\ ids + Lm\ Idr \qquad (7)$$

When the DFIG feeds into a strong power system, the command of Qs can be simply set to zero. Fig. 2 shows the overall vector control scheme of the RSC. In order to achieve independent control of the stator active power Ps and reactive power Qs by means of rotor current regulation, the instantaneous three-phase rotor currents irabc are sampled and transformed to dq components idr and iqr in the stator-flux oriented reference frame[1],[3]. The reference values for idr and iqr can be determined directly from Qs and ωr commands, respectively. The actual dq current signals (idr and iqr) are then compared with their reference signals to generate the error signals, which are passed through two proportional–integral (PI) controllers to form the voltage signals vdr and vqr .

3) ***Rotor Voltage Equations:***

$$Vqr = p\lambda qr + (\omega-\omega r)\ \lambda ds + rs\ iqr \qquad (8)$$

$$Vdr = p\lambda dr - (\omega-\omega r)\ \lambda qr + rs\ idr \qquad (9)$$

4) *Rotor Flux Equations:*

$$\lambda qr = (Lir + Lm)\ iqr + Lm\ Iq \qquad (10)$$

$$\lambda dr = (Lir + Lm)\ idr + Lm\ Ids \qquad (11)$$

The two voltage signals are compensated by the corresponding cross coupling terms to form the dq voltage signals vdr and vqr. They are then used by the PWM module to generate the IGBT gate control signals to drive the rotor-side IGBT converter. The objective of the GSC is to keep the dc-link voltage constant regardless of the magnitude and direction of the rotor power. In this paper, the GSC control scheme is also designed to regulate the reactive power Qg exchanged between the GSC and the grid. During normal operation, the GSC is considered to be reactive neutral by setting Qg = 0.

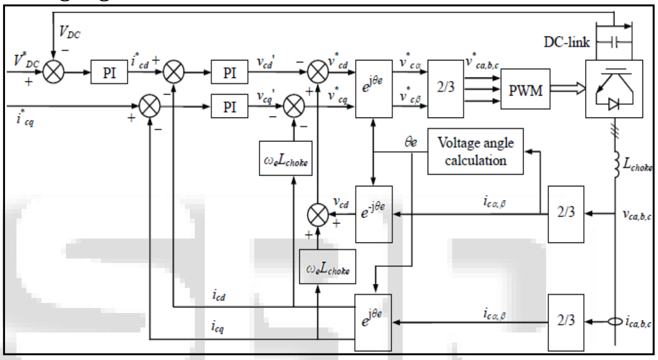

Fig. 3: Grid Side converter control[12]

This consideration is reasonable because the VFC rating is only 25%–30% of the generator rating and the VFC is primarily used to supply the active power from the rotor to the power grid. However, the reactive power controllability of the GSC can be useful during the process of voltage reestablishment, after a grid fault has been cleared and the RSC has been blocked. Fig. 3 shows the overall control scheme of the GSC. The actual signals of the dc-link voltage and the reactive power are compared with their command values to form the error signals, which are passed through the PI controllers to generate the reference signals for the d-axis and q-axis current components, respectively. The instantaneous ac-side three-phase currents of the GSC are sampled and transformed into dq current components idg and iqg by applying the synchronously rotating reference frame transformation.

The actual signals are then compared with the corresponding reference signals to form the error signals, which are passed through two PI controllers. The voltage signals are compensated by the corresponding cross coupling terms to form the *dq* voltage signals v_{dg} and v_{qg}[2],[5],[9]. They are then used by the PWM module to generate the IGBT gate-control signals to drive the grid-side IGBT converter.

B. Modeling of STATCOM

This thesis investigates the use of a Static Synchronous Compensator (STATCOM) along with wind farms for the purpose of stabilizing the grid voltage after grid-side disturbances such as a three phase short circuit fault, temporary trip of a wind turbine and sudden load changes.

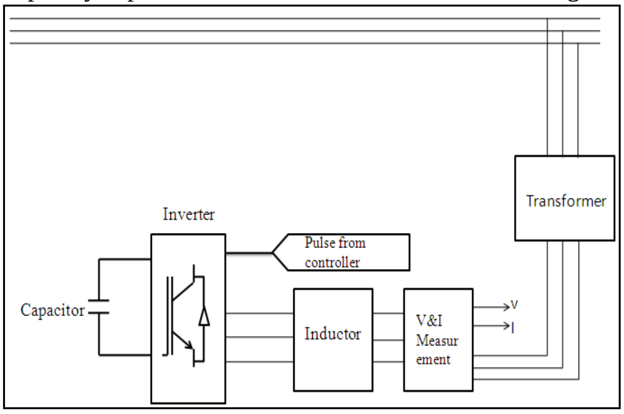

Fig. 4: STATCOM with Grid Connection

During the activation of crowbar STATCOM used to supply the reactive power to the Point of Common Coupling (PCC) and it reduces absorption of reactive power from the grid. The strategy focuses on a fundamental grid operational requirement to maintain proper voltages at the point of common coupling by regulating voltage [5],[8]. The DC voltage at individual wind turbine (WT) inverters is also stabilized to facilitate continuous operation of wind turbines during disturbances.

Under these conditions Standard devices used to supply the needed reactive recompense are mechanically switched capacitor banks. It generates a set of balanced three-phase sinusoidal voltages at the fundamental frequency, with rapidly controllable amplitude and phase angle Flexible AC transmission system (FACTS) devices can be use [2]. They are capable to provide quick active and reactive power compensations to power systems, and hence can be used to provide voltage support and enhance power oscillation damping. Properly located FACTS devices enable additionally efficient employment of existing transmission lines and the FACTS family, the shunt FACTS devices such as the static synchronous compensator (STATCOM) has been greatly used to provide flat and fast steady state and transient voltage control at points in the network.

Real and Reactive Power Equations:

$$P = VsVsisin\alpha / Xs \qquad (12)$$

$$Q = (Vs\ cos\alpha - Vsi)/Xs \qquad (13)$$

The VSC topologies are preferred in STATCOM applications. For large scale wind farm application, higher voltage rating ones are desirable. This paper adopts voltage source STATCOM as a dynamic reactive power compensator.

S.NO	PARAMETERS	VALUES
1	Generated voltage	120 KV
2	Grid voltage	565 V
3	DFIG power	1.5 MW
4	No of DFIG	6
5	Total DFIG power	9 MW
6	Pars of poles	3 p
7	Wind speed variation	10-30 m/s
8	Stator resistance	0.023 Rs(pu)
9	Stator inductance	0.18 Lls(pu)
10	Rotor resistance	0.016 Rr(pu)
11	Rotor inductance	0.16 Llr(pu)
12	Magnetizing inductance	2.9 Lm(pu)
13	Inertia constant	0.685 H(s)

Table 1: Parameters of DFIG

The voltage drop across XL and R is Vl= VS - Vsi and the current Is flown through them related to it too and this current can be leading or lagging the source voltage. Assuming that the positive direction of power transmission is from the grid to the STATCOM, if Xs >> Rs, the active power P and reactive power Q to the STATCOM can be deduced. The equation (12) and (13) clearly indicate that the active power P and reactive power Q can be controlled by adjusting the STATCOM output voltage amplitude Vsi and the phase difference α between VS and . The polarity of α determines the direction of active power, and the amplitude difference of VS and Vsi determines reactive power direction. Reactors are typically mechanically switched devices. And it is only possible to control slow variations in reactive power.

S. No	**Status**	**Real Power**	**Reactive Power**
1	Without Static Synchronous Compensator (STATCOM)	Unstable (0.7 pu)	Unstable
2	With Static Synchronous Compensator (STATCOM)	0.9(pu)	-0.5 to +0.5(pu)

Table 2: Output Parameters of DFIG

Regulated shunt reactors equipped with a tap-changer as used for voltage control with a transformer. Using such a" regulated shunt-reactor", a more smooth control of reactive power can be achieved[6],[7]. A study presented in shows the feasibility of this tool for reactive power control with large wind power plants Static synchronous compensator an STATCOM is typically a fixed shunt capacitance in parallel with reactance that is controlled using IGBT. This type of controller is made using static components that shown in figure 4.This STATCOM units may have short-time overload capabilities for 2 to 4 seconds that shown in figure 4. The VAR output is a linear function of the voltage, VARs decrease linearly with the voltage (90% voltage will provide 90% VAR capability) since they are constant current controllers.

IV. Simulation

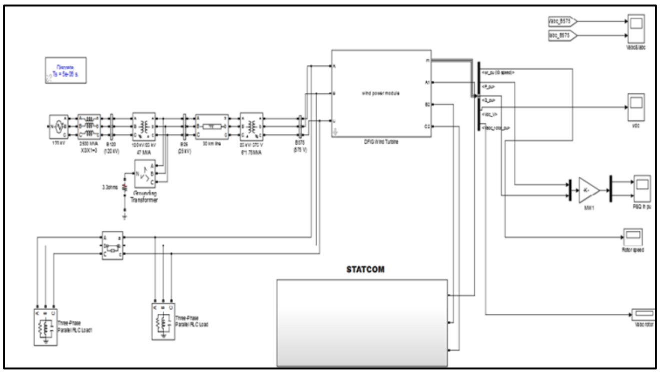

Fig. 6: Simulation of DFIG with STATCOM and control techniques

V. SIMULATION RESULTS

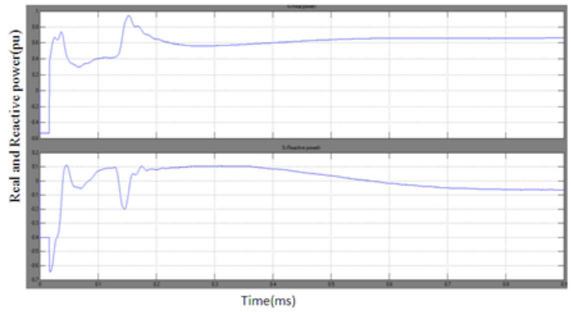

Fig. 7: Simulation result of DFIG Real and Reactive power without STATCOM.

This result represents the load variations and three faults create the instability in real and reactive power. It is shown in fig7.

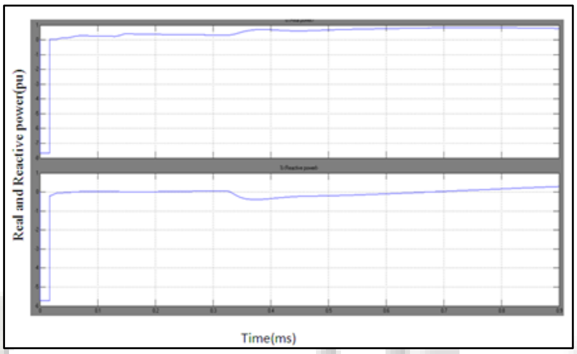

Fig. 8: simulation result of DFIG real and reactive power with STATCOM.

This result represents the real and reactive power variations are compensated by the insertion of STATCOM in grid side. It is shown in fig8.

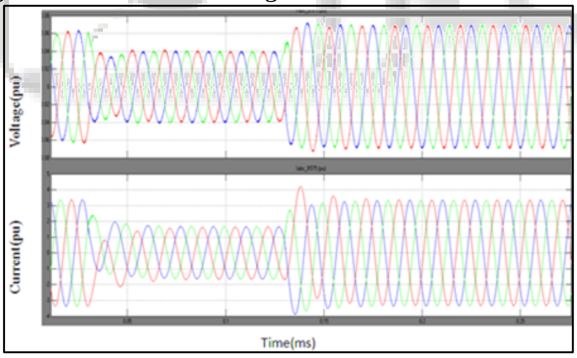

Fig. 9: simulation result of DFIG's grid input voltage.

This simulation result fig 9 represents the Output voltage and current of the DFIG in load variation time 0.01 to 0.05.After the compensation this two functions are get normal operating condition.

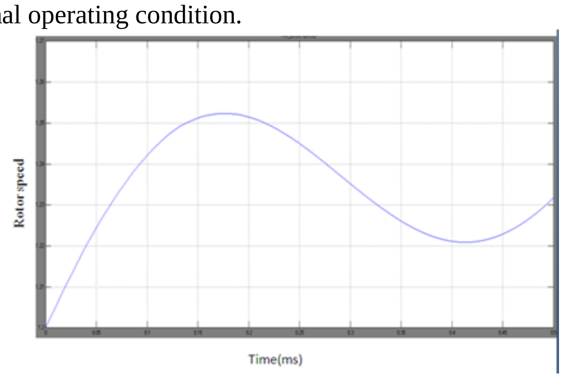

Fig. 10: simulation result of DFIG variable rotor speed.

VI. CONCLUSION

High penetration and variable fault conditions DFIG absorbs more reactive power from the grid. In this research work, we have utilized STATCOM to compensate the reactive power variation in two different operating conditions. Reactive power insertion and absorptions are based on the fault occurrence in DFIG. This reactive power is compensated by modifying the reactive power in point of common coupling using STATCOM. PI controller based control techniques are designed to control the STATCOM performances.

REFERENCES

[1] W. Feng, Z. Xiao-Ping, K. Godfrey, and J. Ping, "Modeling and control of wind turbine with doubly fed induction generator," in Proc. IEEE PES Power Syst. Conf. Expo. (PSCE '06), 2006, pp. 1404–1409..

[2] L. Qu and W. Qiao, "Constant power control of DFIG wind turbines with super capacitor energy storage," IEEE Trans. Ind. Appl., vol. 47, no. 1, pp. 359–367, Jan.-Feb. 2011.

[3] S. Muller, M. Deicke, and R. W. De Doncker, "Doubly fed induction generator systems for wind turbines," IEEE Ind. Appl. Mag., vol. 8, no. 3, pp. 26–33, May/Jun. 2002.

[4] M. Edrah, K. L. Lo, A. Elansari, and O. Anaya-Lara, "Power oscillation damping capabilities of doubly fed wind generators," in Proc. 9th Int. Univ. Power Eng. Conf. (UPEC'14), 2014, pp. 1–6.

[5] Y. Haiping, F. Lingling, and M. Zhixin, "Reactive power modulation for inter-area oscillation damping of DFIG-based wind generation," in Proc. IEEE Power Energy Soc. Gen. Meet., 2010, pp. 1–9.

[6] E. Vittal, M. O'Malley, and A. Keane, "Rotor angle stability with high penetrations of wind generation," IEEE Trans. Power Syst., vol. 27, no. 1, pp. 353–362, Feb. 2012

[7] Y. Mishra, S. Mishra, M. Tripathy, N. Senroy, and Z. Y. Dong, "Improving stability of a DFIG-based wind power system with tuned damping controller," IEEE Trans. Energy Converters., vol. 24, no. 3, pp. 650–660, Sep. 2009

[8] L. Shi, S. Dai, Y. Ni, L. Yao, "Transient stability of power systems with high penetration of DFIG based wind farms," in Proc. IEEE Power Energy Soc. Gen. Meet (PES'09), 2009, pp. 1–6.

[9] A. H. Kasem, E. F. El-Saadany, H. H. El-Tamaly, and M. A. A. Waha"An improved fault ride-through strategy for doubly fed inductiongenerator-based wind turbines," IET Renew. Power Gener., vol. 2, no. 4,pp. 201–214, Dec. 2008.

[10] Tazil, M., Kumar, V., Bansal, R. C., Kong, S., Dong, Z. Y.,Freitas,W., &Mathur, H. D.(2010). Three-phase doubly fed induction generators: an overview. IET Electric Power Applications, 4(2)

[11] Mohod.S.W and M. V. Aware, "Grid power quality with variable speed wind energy conversion," in Proc. IEEE Int[PEDES], Delhi, Dec. 2006.

[12] Mathusoothanan. T, Dr. R. Karthik, "Rotor Angle Stability Improvement of DFIG Using Grid Side and Rotor Side Converter Control," IJRESET vol 4, issue III,Page No.: 123-130