IJSRCSEIT
International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2017 IJSRCSEIT | Volume 2 | Issue 5 | ISSN : 2456-3307

Advanced Control Method of Series Voltage Compensation to Enhance Wind Turbine Ride Through

L. Senthil, Sonali Chadha, Poonam Gupta
JECRC University, Jaipur, Rajasthan, India

ABSTRACT

Due to increasing wind power penetration into utility grids, system operators have instituted rigorous standards for ride-through fulfillment of grid-connected wind turbines. Series voltage compensation can be an effectual key to meet the new-fangled standards, especially if a low-cost system can be developed. This paper first presents the uniqueness of ride-through deeds of doubly fed induction generator (DFIG) using phasor investigation. The analysis is extended to include the effects of generic series Voltage compensation. A novel control method is designated and studied, which permits possibly low energy ratings in the series compensator thereby appreciably reducing overall system cost. The reactive power requisite of the system voltage during grid fault with new grid code achieved by the novel controller empowering the DFIG with the compensator. Simulation and experimental results have conformed, the improved performances resulting from the supplication of the control method.
Keywords: DFIG, fault ride through, series compensation, wind energy.

I. INTRODUCTION

The doubly fed induction generator is an important subsystem for large variable speed wind turbines, the stator windings are directly connected to the point of common coupling via a transmission transformer. The rotor windings are controlled by a back-to-back converter which serves as a power interface between the rotor winding and the PCC.

The power rating of the back-to-back converter principally depends on the speed operation range of the DFIG, typically designed as 30% of nominal rating of the wind turbine. Thus, severe voltage sags and the ensuing stator flux place a noteworthy electrical stress on the rotor side Converter and thereby increase mechanical tension on the gearbox as well. In the literature, quite a few solutions have been proposed to improve ride-through capability of DFIG.

Using series braking resistance applied to the stator windings for the duration of voltage sag has been shown to be able to reduce torque and current spikes in the DFIG. Two improvements of the rotor circuit by introducing either silicon controlled rectifier rotor crowbar circuit or a three-phase rectifier and adjustable resistive load have demonstrated enhancement in the DFIG Ride-through capability. According to the most recent regulations wind turbines are not only required to linger connected to ride through the grid faults, but they are also required to inject reactive current to assist the grid in recovering to its rated voltage.

The braking resistor and the crowbar technology do not fulfill the latest codes, as the turbine cannot contribute reactive power for the duration of the activation of the braking resistor or the crowbar. In other words, it is not possible to control the reactive current flowing into the grid during fault periods in cases of activating braking resistor or crowbar solutions. In order to satisfy the latest codes, researchers are addressing the problem using FACT devices.

Voltage or current source inverter-based FACTs devices, such as static VAR compensator, static synchronous compensator (STATCOM), and dynamic voltage restorer, have been used for flexible power flow control, secure loading, and damping control of power system oscillation. Some of these can be tailored to wind farm stabilization. The STATCOM composed of power electronics devices has already been anticipated to augment the ride-through capability of wind farms.

However, it is still challenging to treat with cruel voltage fault since it is based on shunt compensation. Compared with a parallel reactive power compensator, a series compensator would be much more effective in restoring voltage in strong grid utility, if steps are taken to minimize the power capacity of the devices .With the aforesaid background, this paper investigates the integration of the series voltage compensator in the stator of the DFIG to reinforce the fault ride-through capability of grid connected turbine. The vital behavior of the DFIG during fault occasion is the case of grid faults.

Unlike other series compensation methods, a new ride-through control scheme based on ramp-function injection voltage has been proposed, with the view to diminish the required energy storage capacity of the compensator. Further, the doubly fed induction generator is designed to improve the fault ride through capability of wind energy generation.

Discusses the DFIG behaviour for the duration of grid faults, and the general control of the series voltage compensator is given in. Consequently, the improved control scheme of the series compensator is proposed to condense the energy capacity of the series compensator.

II. EXISTING SYSTEM

2.1 Existing System

For large variable speed wind energy conversion system, the doubly fed induction generator is having an important role. In this the stator windings are directly connected through transformer to the point of common coupling(PCC)

The rotor windings are forbidden by a back-to-back converter that serves as a power interface between the rotor windings and the PCC .The power rating of the back-to-back converter principally depends on the speed operation range of the DFIG, typically designed as 30% of nominal rating of the wind turbine. Two improvements of the rotor circuit by introducing either silicon controlled rectifier rotor crowbar circuit or a three-phase rectifier and adjustable resistive load have demonstrated enhancement in the DFIG ride-through capability.

However, as penetration of wind power into electric grid gets larger, much more stringent grid codes are being established. According to the most recent regulations, wind turbines are not only mandatory to remain connected to ride through the grid faults, but they are also required to inject reactive current to assist the grid in recovering to its rated voltage.

In the most recent 20 years, the use of doubly fed induction machines in contemporary variable-speed wind turbines has greater than before. According to grid requirements, wind turbine must be remain connected to the grid while grid disturbances. Therefore this progress has been driven by the cost decline as well as the low loss generation of IGBT’s.
Additionally, this must also contribute support to the voltage, while and the post grid faults. It is also can be get by the help of the VSC. The disconnection of the DFIG from the network while faults can be avoid by the crowbar system. It is analyzed the terminal voltage control has been achieved for the short period by inserting crowbar in to the network.

The DC link voltage level of the back to back converters plays the important role in the activation and deactivation of the crowbar system, and also the instability of the DFIG during grid fault can be analysed by monitoring and controlling the critical rotor speed.

The main focus of this work is on voltage control and Reactive power control through series compensation in a distribution network combined with WECS. In this an induction generator driven by an unregulated wind turbine is equipped, and also it is considered as fixed speed variable frequency. The problem is viewed from time domain responses of the system to different wind speed changes.

It has been concerned that variable wind speed is disturbing active and reactive power injection in distribution network, which is nearby large and small consumers because of vast voltage changes. It is being observed that the UPFC is used to overcome the problems by connecting it at the WCES end, and also it will support to voltage and reactive power flow control.

2.2 Block Diagram

Series voltage compensation Method

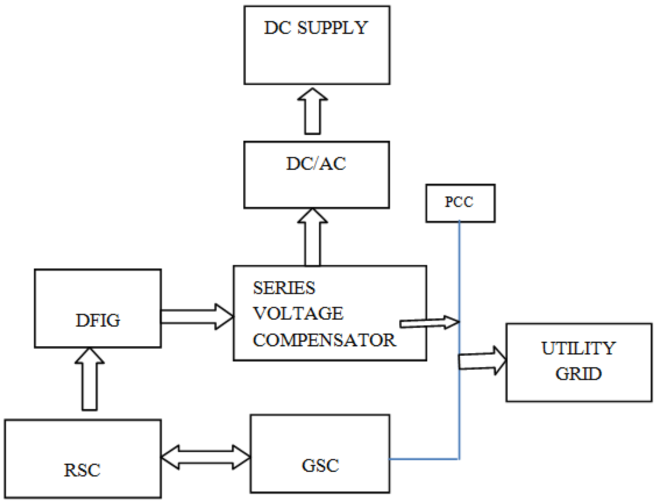


Figure 1. Series Voltage Compensation Method

The three phase power electronics controlled series resistance system is applied in crowbar system of the modern wind turbine. This system activated during over current occurred on the rotor winding and/or over voltage occurred on the DC link. Normally a typical value of the over current and over voltage appears close to the wind form during fault.

Steps followed during the activation and deactivation of the crowbar system through circuit breaker are:

- Disconnection of rotor winding from the rotor side converter.
- Insertion of the three phase resistance in series with the rotor windings.
- Disconnection of the crowbar system from the rotor windings.
- Reconnection of Rotor side converter to the rotor windings.

2.3 Disadvantages in existing system

Thus, severe voltage sags and the resulting stator flux place a significant electrical stress on the rotor side converter and thereby increase mechanical stress on the gearbox as well The braking resistor and the crowbar technology do not fulfill the latest codes, as the turbine cannot supply reactive power during the activation of the braking resistor or the crowbar.
In other words, it is not possible to control the reactive current flowing into the grid during fault periods in cases of activating braking resistor or crowbar solutions. Researchers are addressing the issue using FACT devices. Voltage source converter or current source converter based FACT's devices and STATCOM have been used for efficient power flow control, secure loading and damping of power system oscillation proposed to enhance ride through capability of DFIG using series breaking resistance applied to the stator windings during the voltage sag, it has been shown to be able to control the torque and the current spikes in the DFIG.

Some of these can be adapted to wind farm stabilization. The STATCOM composed of power electronics devices has already been proposed to enhance the ride-through capability of wind farms. However, it is still challenging to deal with severe voltage fault since it is based on shunt compensation. Compared with a parallel reactive power compensator.

III. PROPOSED SYSTEM

3.1 Proposed System

In this paper, an innovative idea has been proposed due to increasing wind power penetration into utility grids, power engineers have established stringent standards for ride through compliance on grid tied wind turbines. To meet new standards and for low cost system the series compensation method modelled and also it has been proved as an efficient as well as an effective solution.

At first in this methodology proposes the characteristics of ride through behaviours of DFIG using phase analysis. This approach is extended to add the key effects of series voltage compensation. A novel control method is then modelled and analysed, which gives comparatively low energy ratings in the series compensator, in that way meaningfully lowering the overall system cost.

In compliance with the new grid code, the reactive power required to the system during the grid fault can be achieved by the novel controller, which allows the doubly fed induction generator with compensator to provide. Experimental results using MATLAB Simulink have demonstrated the improved performances of the system by using novel control method.

3.2 Single line diagram representation DFIG.

The doubly fed induction generator is an important subsystem for large variable speed wind turbines, the stator windings are directly connected to the point of common coupling via a transmission transformer. The rotor windings are controlled by a back-to-back converter which serves as a power interface between the rotor winding and the PCC.

The power rating of the back-to-back converter principally depends on the speed operation range of the DFIG, typically designed as 30% of nominal rating of the wind turbine. Thus, severe voltage sags and the ensuing stator flux place a noteworthy electrical stress on the rotor side Converter and thereby increase mechanical tension on the gearbox as well.

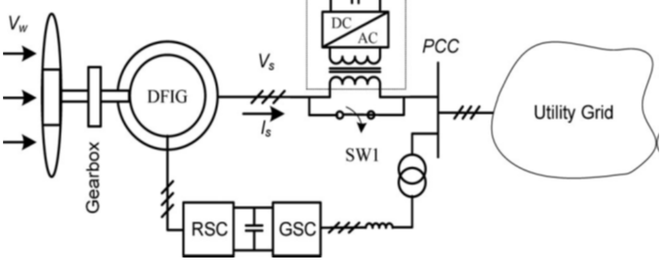


Figure 2. Single-line in DFIG

3.3 Series compensate

The requirements of fault ride through may vary for different countries, but the “E.ON” regulation is the one commonly referenced in the literatures. In the “E.ON” grid code, three-phase balanced faults should not lead to the disconnection of the wind turbines from the grid up to a certain limit.

3.4 Phase Diagram during Normal Operation

In a wind turbine connected to a strong grid utility, the stator is directly connected to the grid, and thereby the stator voltage is imposed by the grid. Hence, in normal operation, the stator voltage phasor is a rotating vector of the constant magnitude *Vs*that rotates at the synchronous speed ws.

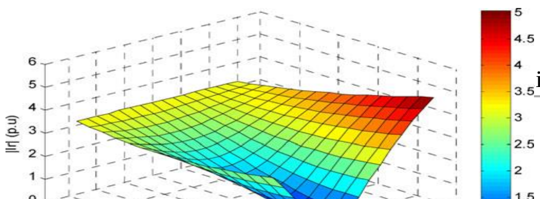


Figure 3. Phasor Diagram

3.5 Voltage Sag Detection

Fault ride-through requirements have been specified in a number of grid codes. For example, E.ON grid code specifies that wind generators are not allowed to disconnect from the grid when the network connection voltage is within a certain range.

And duration when a fault occurs. In the context of this paper, the PCC voltage as shown in Fig. 1.3 is measured for voltage sag detection and the measured voltage shall be used during the fault ride-through analysis. The accuracy of the voltage sag detection can significantly impact the performance of the series compensator. The voltage on the PCC can be measured using voltage transformer (VT).

3.6 Advantages

- A series compensator would be much more effective in restoring voltage in strong grid utility, if steps are taken to minimize the power capacity of the devices.
- With the aforesaid background, this paper investigates the integration of the series voltage compensator in the stator of the DFIG to reinforce the fault ride-through capability of grid connected turbine.
- The essential behaviour of the DFIG during Fault occasion is analysed using system phase diagram.
- The general control scheme of the series compensation is presented in the case of grid faults.
- Unlike other series compensation methods, a new ride-through control scheme based on ramp-function injection voltage has been proposed, with the view to reduce the required energy storage capacity of the compensator.
- The requirements of fault ride through may vary for different countries, but the “E.ON” regulation is the one commonly referenced in the literatures. In the “E.ON” grid code, three-phase balanced faults

should not lead to the disconnection of the wind turbines from the grid up to a certain limit.

- Moreover, the additional Reactive current has to be supplied by the generating plant during a voltage dip to support the grid voltage. However, the conventional grid-connected DFIG system is sensitive to the grid variants such as voltage sags and swells.

IV. SIMULATION RESULTS

- A detailed computer simulation model of the proto type system was developed. A list of DFIG parameters used in the simulations and subsequent experiments is presented in table.
- **Fig 5** shows the simulated stator and rotor –side three phase voltage/current in DFIG system without compensation.
- At t=3-3.2s, the DFIG experienced a grid fault, which result in 85% voltage drop.
- From fig 5, the transient over currents of the stator and rotor windings are significant at the moment of voltage dip. For instance, at t=3s, the rotor over current is up to three times of the nominal value. Hence, the rotor side converter will be damaged if the stator windings' suffer this severe fault.
- To verify the effectiveness of the ride-through enhancement of the series compensator, the proposed control scheme of the series compensator is implemented in the simulation.fig. 4 shows the operating performance of the DFIG with the proposed series compensation method. Herein, the compensation duration is chosen as 20 smother PCC voltage is faulted at time 3s and recovered at time 3.2s as shown in fig. 4 (a).fig 4 (b) shows using the proposed control scheme. The stator voltage of DFIG has a gradual transition as shown in fig.1.4(c).there is no step change in terms of the over current in the rotor.
- From fig.1.5(d) and(e),the currents of the stator and rotor currents are much smaller than that in fig.11.hence,the proposer method is effective to ride through the serve grid faults without any crowbar circuit.
- **Fig 5** (f) shows the dc –link voltage of the series compensator. At the start point of the voltage dip, the power is absorbed by compensator and thereby stored in the dc capacitor, resulting in dc link voltage dip, the power is absorbed by the compensator and thereby strode in the dc capacitor, resulting in dc-link voltage increase.
- At the end of the voltage dip, the compensator supplies the power and causes the dc-link voltage to drop back to the Perrault value within one cycle. There is no transfer of power from the turbine to the compensator. The capture power is instead stored in the mechanical rotating energy of the wind turbine rotor. Therefore; the rotor speed is increased as shown in **fig 5** (g).
- In fig.1.5, the compensation duration is chosen as 20 ms.**fig 5** shows the relationship of the rotor peak current/dc-link capacitance of the series compensator versus the compensation duration .by increasing the value of, the peak value of the rotor current can be reduced. However, the capacitance of the compensator will need to be large. Herein, the maximum allowed voltage variation is chosen 600V and the prefault voltage is 1000V.

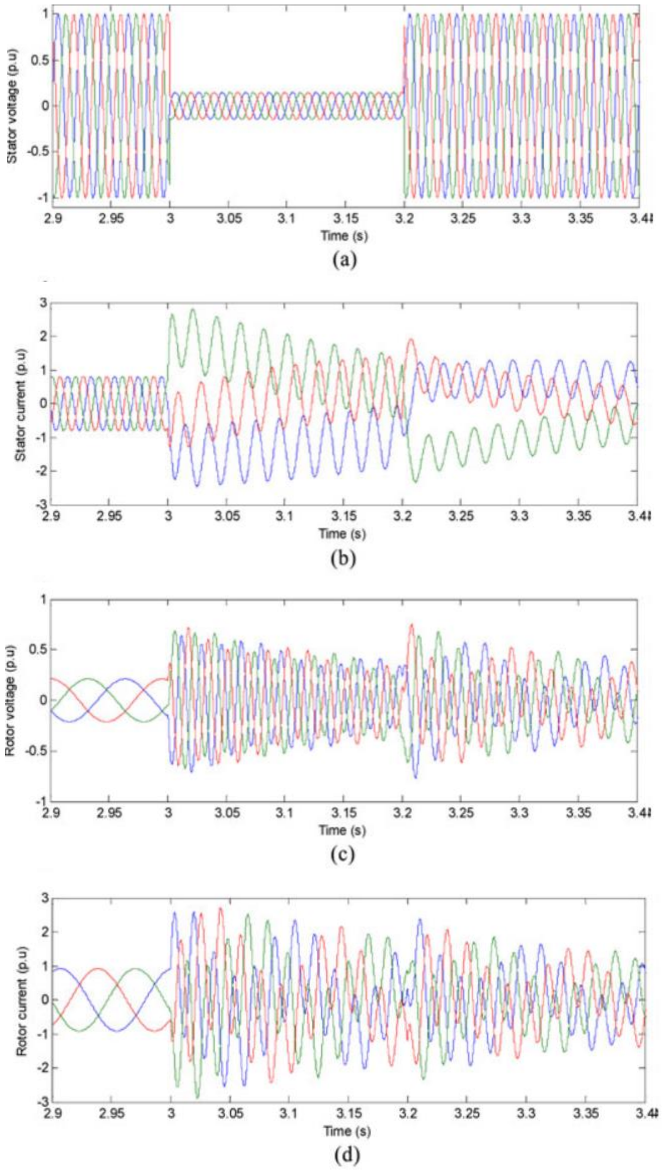
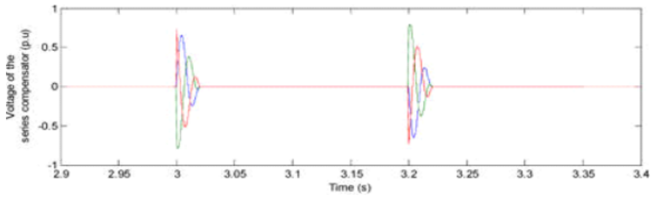


Figure 4. Simulation Result

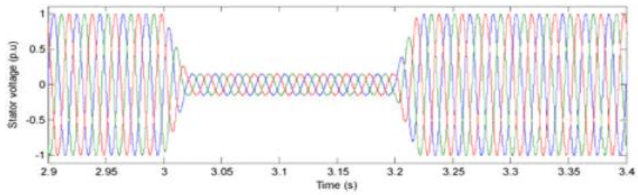
Table 1. DFIG Parameter

Parameters	Simulation	Experiment
Rated power	*1.5 MW*	*1.5 kW*
Rated frequency	*50 Hz*	*50 Hz*
Stator voltage (Phase RMS)	*332 V*	*220 V*
Stator resistance	*0.007 p.u*	*0.023 p.u*
Rotor resistance	*0.005 p.u*	*0.023 p.u*
Mutual inductance	*2.9 p.u*	*1.16 p.u*
Stator leakage inductance	*0.17 p.u*	*0.049 p.u*
Rotor leakage inductance	*0.16 p.u*	*0.049 p.u*
Number of pole pairs	*2*	*2*

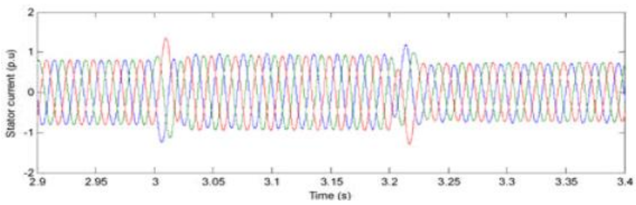
(a)



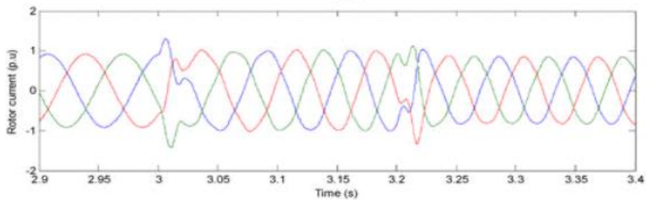
(b)



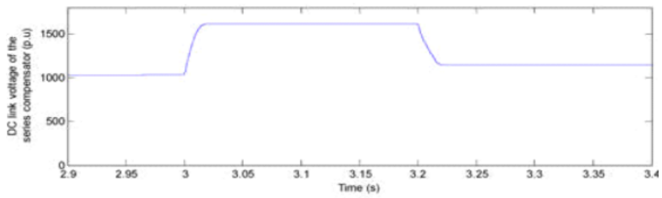
(c)

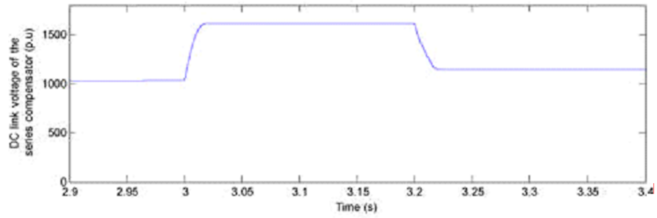


(d)

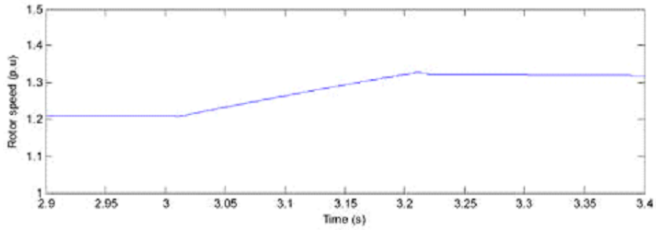


(e)





(f)



(g)

Figure 5. Using Series Voltage Compensation Result

V. CONCLUSION

Enhancing the ride-through capability under grid fault events has been recognized as a challenging problem for DFIG-based wind generation systems. This paper introduced a ride-through solution based on series compensation. The essential behaviour of DFIG under grid faults was analysed, and an improved ride-through control scheme of the series compensation was developed to significantly reduce the energy storage capacity of the series compensator, which in turn, reduces the capital cost. The performance of the proposed scheme was verified both in simulations and experiments.

VI. REFERENCES

[1]. R. Pena, J. C. Clare, and G. M. Asher, "Doubly fed induction generator using back-to-back PWM converters and its application to variable-speed Wind-energy generation," vol. 143, no. 3, pp. 231-241.May 1996.

[2]. O. Anaya-Lara, X. Wu, P. Cartwright, J. B. Ekanayake, and N. Jenkins "Performance of doubly fed induction generator (DFIG) during network faults," Wind Eng., vol. 29, no. 1, pp. 49-66, 2005.

[3]. H. Polinder, F. F. A. van der Pijl, G. J. de Vilder, and P. J. A. T. P. J. Tavner, "Comparison of direct-drive and geared generator concepts for wind turbines," IEEE Trans. Energy Convers., vol. 21, no. 3, pp. 725-733,Sep. 2006.

[4]. A. Causebrook, D. J. Atkinson, and A. G. Jack, "Fault ride-through of large wind farms using

series dynamic braking resistors (March 2007)," vol. 22, no. 3, pp. 966-975, Aug. 2007.
[5]. D. Santos-Martin, J. L. Rodriguez-Amenedo, and S. Arnaltes, "Providing ride-through capability to a doubly fed induction generator under unbalanced voltage dips," IEEE Trans. Power Electron., vol. 24, no. 7 pp. 1747-1757, Jul. 2009.
[6]. J. Morren and S. W. H. de Haan, "Ride through of wind turbines with doubly-fed induction generator during a voltage dip," IEEE Trans. EnergyConvers., vol. 20, no. 2, pp. 435-441, Jun. 2005.
[7]. O. Gomis-Bellmunt, A. Junyent-Ferre, A. Sumper, and J. Bergas-Jan, "Ride-through control of a doubly fed induction generator under unbalanced voltage sags," IEEE Trans. Energy Convers., vol. 23, no. 4, pp. 1036-1045, Dec. 2008.
[8]. L. Peng, B. Francois, and Y. Li, "Improved crowbar control strategy of DFIG based wind turbines for grid fault ride-through," in Proc. IEEE 24thAnnu. Appl. Power Electron. Conf. Expo., Feb. 2009, pp. 1932-1938.
[9]. P. Zhou and Y.He, "Control strategy of an active crowbar for DFIG base wind turbine under grid voltage dips," in Proc. Int. Conf. Elect Mach Syst., Oct. 2007, pp. 259-264.