IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 4, April 2015.
www.ijiset.com
ISSN 2348 – 7968

REVIEW OF CONTROL STRATEGIES FOR DFIG WIND TURBINE TO ENHANCE LVRT CAPABILITY

Divya S[1], Krishnakumari T

[1] M.Tech scholar, *EEE Department*
ASIET Kalady,Mahatma Gandhi University Kottayam
Kerala,India

[2] Asst.professor, *EEE Department*
ASIET Kalady,Mahatma Gandhi University Kottayam
Kerala,India

Abstract

Wind energy is the fastest growing renewable energy source. Double Fed Induction Generator, which is predominantly used nowadays in wind turbines, is very sensitive to grid disturbances and can damage the power electronic converters due to over voltage and over current. Therefore, protection elements which disconnect the machine during fault are very essential. But, in such cases, the reliability of the system gets affected which is not acceptable due to the high penetration of wind energy into the grid. Low voltage ride through (LVRT) is a mechanism by which the wind turbine can be connected to the system during the voltage dip. This is achieved by either hardware or software implementation on the converter of rotor side and grid side which will prevent the converter from tripping and thereby provide uninterruptible operation to the DFIG during severe grid voltage faults. An analysis of different LVRT control strategies has been carried out in this paper.

Keywords: Doubly Fed Induction Generator (DFIG), Low Voltage Ride Through (LVRT), Super capacitor (SC), Dynamic voltage restorer (DVR), Static compensator (STATCOM), Unified power flow controller (UPFC), Crowbar, Wind turbine (WT), Active crowbar, Series Dynamic Resistor

.

1. INTRODUCTION

Out of all the available renewable energy sources, wind power contributes significantly to electrical power generation. Earlier, simple squirrel-cage-induction generator-based wind turbines were used, which is impractical because of its fixed speed. Nowadays, the fixed speed system is replaced by variable speed system which makes use of the DFIG wind turbines. Even though DFIG can extract more power, has less mechanical stress, and has independent control of active and reactive power, it has the disadvantage of being a less stable and reliable system . DFIG machines give steady output voltage and can be directly connected to the grid. Since they are directly connected to the grid, DFIG is very sensitive to grid disturbance like voltage sag, swell ,flicker and can create technical issues such as voltage stability ,reactive power and fault ride through. In order to reduce the adverse effect on the power system, network operators alternate the grid code requirements. The typical DFIG wind turbine with rotor side converter and grid side converter is shown in fig 1[1]

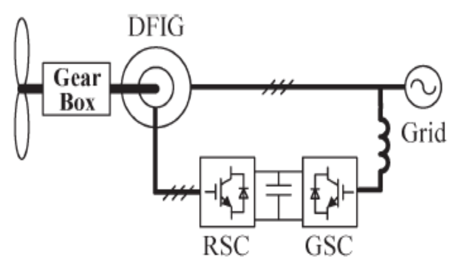


Fig. 1. Configuration of DFIG-based WECS.

Here, the stator is directly connected to the grid, while rotor is connected through a back to back converter. Low voltage ride through, is the capability of the wind system to remain connected to the grid, even with, a serious voltage problem. It may cause certain undesired characteristics on machines, like uncontrolled active and reactive power and falling grid code requirements. When a grid fault occurs, large EMF will be induced in to the rotor circuit, and the demagnetizing effect of the machine, will cause a large inrush current, in both stator and rotor [1]. So, the continuous operation of DFIG wind system is essential for the reliable operation of the power system. Various control and protection techniques have been analyzed in this paper.

II GRID CODE REQUIREMENT

Due to the significant increase of wind power penetration in the power system, many countries have revised their grid code, by defining specific technical requirements for the wind farms. Grid code requirements typically refer to large wind farms, which is connected to the transmission system. Grid codes specify that wind farms must contribute to power system control, as much as conventional power generation stations and withstanding of wind system during abnormal condition. The Grid Codes address Fault tolerance, Reactive power/voltage control requirements, Ramp rate control and Frequency response capability.

IWGC structure includes (1)Role of various organization and their linkages (2)Planning code for transmission system evacuating wind power (3)Connection code for wind farm (4)Operating code (5)FRT is an important feature. For the wind turbines to remain connected to the grid during the faults, various technologies have been developed to withstand the voltage dips [2]. This withstanding capability of DFIG against voltage sags is called Low Voltage Ride-Through (LVRT) or Fault Ride-Through (FRT) capability. The typical LVRT curve as per IWGC is shown in figure 2.

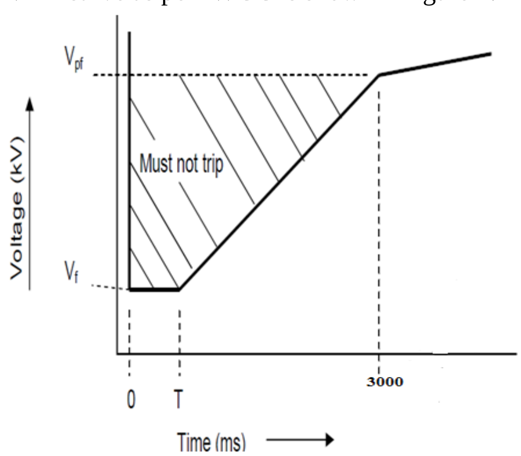


Fig . 2 LVRT curve in IWGC

III. ISSUES IN DFIG CONNECTED TO GRID

1. Voltage control and power quality

Large variations of voltage in the power systems, is one of the most common problems. Large fluctuations create voltage dips in the wind energy power generation system. Voltage control and reactive power quality can arise when there are large numbers of generators in the network for starting or stopping the generation. In the absence of proper control, a single line to ground fault, may create serious voltage fluctuation problem to other users connected to the grid and there is a chance of flickering and harmonics [3].

2. Stability of the system and frequency

Now a days most of the wind generation is integrated to grid and small disturbance can produce imbalance in the system. The instability occurs during the fault condition and light load condition. During the summer season the new generator would meet a significantly higher percentage than usual demand under windy conditions. This can be resolved by proper control. Current wind generation technology does not offer flexibility for balancing requirements [3]. Generators can be adjusted automatically with the variations in power, and thereby we can adjust the frequency of the system.

3. Continuity and protection

Continuity of the supply is a challenge even in case of renewable sources due to the high penetration of energy into the distribution network [3]. Wind energy is not the only source to be depended on. It must be balanced with sufficient spinning and non spinning reserve to ensure the supply continuously. Protection would interfere with operation of other sources and equipment's connected in point of common coupling(PCC).

4. Fault ride through and grid code

As the penetration of wind energy increases, the need to address the fault ride-through capability issues will also increases. The wind turbines were allowed to trip when a voltage dip occurs .During the fault ride through wind turbines are expected to remain connected to the grid both during and after a fault. Also upon voltage recovery, the wind turbines are not expected to absorb the excessive reactive power and it should match with the grid code requirements also[3,2].

IV. LITERATURE REVIEW

1.Crowbar Method

Crowbar method is the conventional method to enhance the LVRT capability of the wind turbines. During voltage dip, the rotor circuit is disconnected and the DFIG run as squirrel cage induction motor. The crowbar consists of the resistors and switches shown in fig3. The user can control the switching by adjusting the triggering. By adjusting the value of crowbar resistance, operation of crowbar may differ. The main aim is to reduce the rotor voltage by means of providing an additional path to the rotor current and DFIG stay connected to grid. It is the most simplest method and have the advantage of low cost. The main problem is its high short circuit current at the time of RSC thereby drawing more reactive power from the network[4].There are different methods to improve the stability and continuity namely passive crowbar ,active crowbar and stator crowbar.

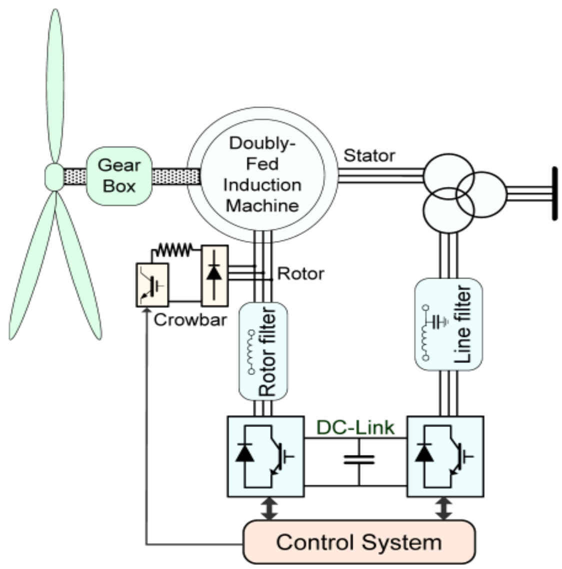
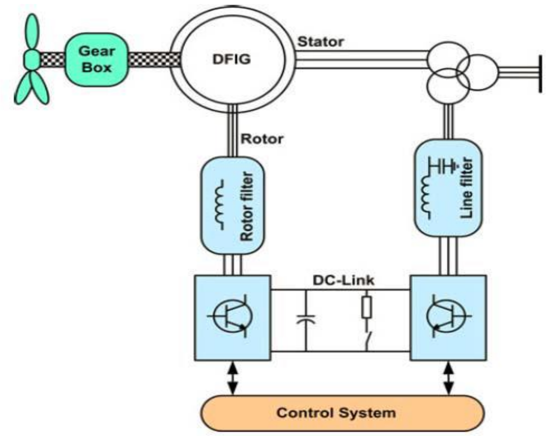


Fig .3 crowbar circuit

2. Dc chopper

DC chopper is also known as braking resistance which is connected in parallel with the dc link capacitor to limit the over voltage and current during abnormal condition. Schematic of this method is shown in figure 4.[5] The dc-link brake chopper shorts the dc-link through a power resistor when the dc-link voltage exceeds a fixed threshold level. The brake is used to maintain the dc-link voltage when transient rotor over current occurs. There are six anti parallel diodes in the rotor-side converter that are highly rated to withstand short-circuit currents. The brake chopper works on a hysteresis band, i.e., the turn-OFF voltage is set below the turn-ON threshold value.



.

Fig .4 dc chopper circuit

3.Non Linear Control

Non linear control schemes which are used to improve the LVRT characteristics may not effectively mitigate the serious voltage variations .Nature of instability can be identified by the DFIG model analysis and eigen value tracking .Lyapunov based control is widely used for removing the effects of stator dynamics and rotor current dynamics through rotor control voltage. This helps to improve rotor dynamics and LVRT capability.[11]

.

4.Series Dynamic Braking Resistor

The dc-link chopper has no effect on rotor over current. To limit this over current a dynamic resistor is connected in series with the rotor. It is controlled by a power electronic switch. The series dynamic braking resistor (SDBR) boosts the generator voltage and dissipates the active power [7].

At normal operation, the switch is ON and the resistor is bypassed. During the fault condition, the switch is OFF and the braking resistor is connected in series with the circuit[6]. The DFIG rotor equivalent circuit with all protection schemes is shown in figure 5.

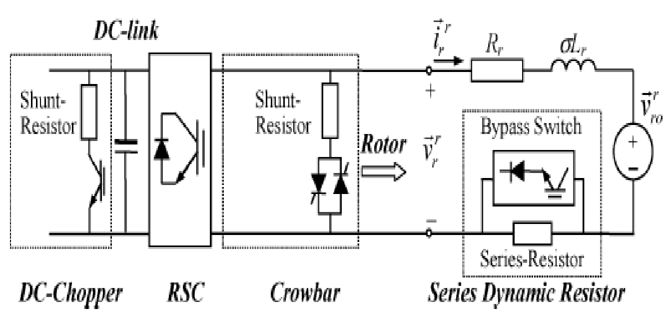


Fig .5 series dynamic resistor circuit

5.Current Feed Back Technique

A) Reverse Current Tracking

During the fault time an EMF is induced which exceeds the maximum output voltage of rotor side converter .Over current will flow through rotor side and DFIG will cause serious issues. The rotor current is controlled to track the stator current in the reverse direction. There by limiting the rotor current in a certain range with restricted RSC output voltage. No need of flux linkage or sequence component separation. This method reduces the fault current with little torque oscillation [8].

B)Stator Current Feed Back

The proposed technique aims to reduce the rotor currents by changing the RSC control instead of installing additional hardware protection like a crowbar in the wind turbine system. The solution has been presented in [9] . When a fault affects the generator the measured and transformed stator currents are fed back as reference for the rotor current controller (stator currents in stator flux orientation).The objective is to reduce stator current oscillations and thus reduce the rotor currents as well.

6.Tuned Damping Controller

By using bacterial foraging technique with coordinated tuning of the damping controller the stability of DFIG system is improved.. Damping controller using auxiliary signal for speed deviation is used in the angle control which results in damping out of low frequency variations.[10]

7.Two Degrees of Freedom Internal model control

Internal model control take the power limit characteristics of the DFIG back to back converter. The design of IMC consider power, voltage and speed of response limitation of power electronic converter. IMC improves the system stability.[12]

8.With different storage system

A)ups

The fly wheel based energy storage system to get uninterruptable supply is used in stand alone operation of DFIG. When main supply is cut off, a fixed frequency and amplitude of the output voltage is obtained. The Output voltage can be controlled by the synchronisation of actual voltage vector with reference vector in the synchronous rotating polar frame of reference . By using ups the voltage control is improved.[13]

B) super capacitor storage

In this paper the advantage of storing energy for improving LVRT is discussed. The life cycle of nickel chromium battery which is used d for small wind power generation is improved by SC.DC link voltage of DFIG is controlled and over current is inhibited.[14]

c)SMES

SMES Stores energy in the form of DC that creates a dc magnetic field. At cryogenic temperature the conductor carrying current behaves like a super conductor with zero resistive drop. During grid fault SMES provide the stored energy. The advantage of using SMES is that The transient stability of the system can be improved by using PI and Fuzzy based systems. limitation due to overvoltage that stress the SMES coil. The disadvantage is that the stress in the SMES coil increases during over voltage.[15]

9.FLEXIBLE AC DEVICES(FACTS)

Facts device play a major role in the distribution network which has higher controllability. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice relate with wind generation .The main advantages of FACTS device over the others are the better adaptation and incorporation to the existing system. So this is widely used in the up gradation of power system.

A)STATCOM

STATCOM derived from SVC is the most widely used FACTS device. . The main attraction of STATCOM is the independent voltage control. The STATCOM configuration consists of a VSC, a dc energy storage device; and a coupling transformer connected in shunt with the ac system. The Voltage Source Converter (VSC) converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with an ac system through the reactance of the coupling transformer. Suitable adjustment of the Phase and magnitude of the STATCOM output voltages allows effective control of active and reactive power exchanges between the STATCOM and the ac system.[16].

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 4, April 2015.
www.ijiset.com
ISSN 2348 – 7968

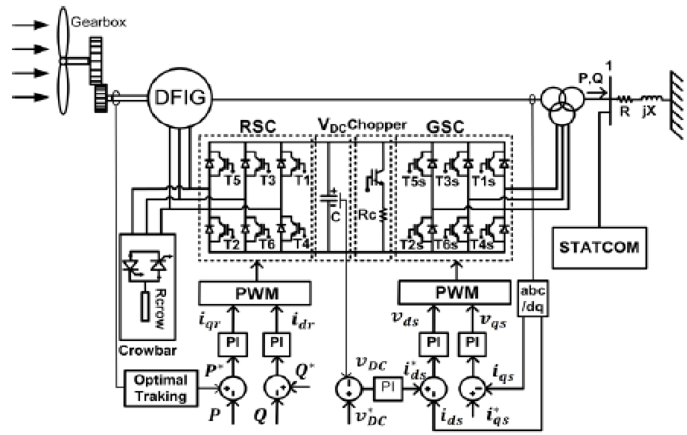


Fig .6 STATCOM protection

B)Dynamic voltage restorer (DVR)

DVR is mainly used for the voltage sag mitigation in the point of connection. This is a series device having the same configuration of D STATCOM with a coupling transformer connected to ac mains. The main disadvantage is its cost and complexity. The VSC generates a three phase voltage which is controllable in phase and magnitude. These voltages are injected into the ac distribution system in order to maintain the load voltage at the desired volt. The DVR device is used to compensate the faulty grid voltage [17]. The advantage of such an external protection device is the reduced complexity in the DFIG system.

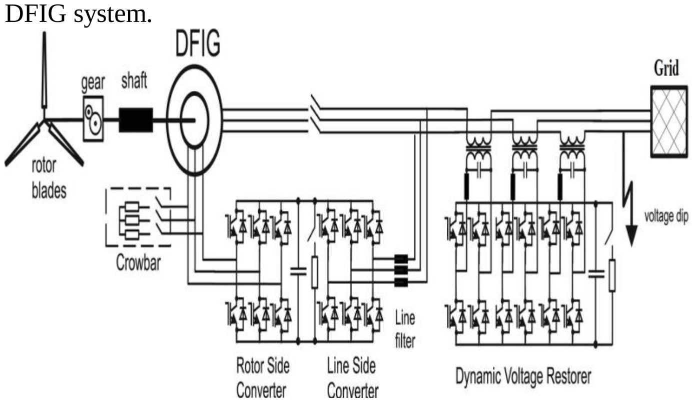


Fig .7 DVR protection

C)unified power flow controller (UPFC)

The UPFC is a combination of a static shunt compensator and static series compensation. It acts as a shunt compensating and a phase shifting device simultaneously. The UPFC consists of a shunt and a series transformer, which are connected via two voltage source converters with a common DC capacitor. The DC circuit allows the active power exchange between shunt and series transformer to control the phase shift of the series voltage. The series converter needs to be protected with a Thyristor bridge. UPFC is expensive which limits the practical applications.[18]

10 .Flux Linkage Tracking

LVRT control strategy based on flux linkage tracking is designed for RSC to suppress the rotor current during grid faults. The basic principle of the control strategy is that, when a grid fault is detected, the rotor flux linkage is controlled to track a reduced fraction of the changing stator flux linkage by altering the output rotor voltage of the RSC. As long as the difference between ψs and ψr is kept small enough, the rotor current will be restricted within the maximum current allowed. This method suppress rotor current with smaller torque oscillations, suitable for industrial applications.[1]

V.CONCLUSION

Low Voltage Ride Through is an important feature for wind turbine systems to full fill the grid code requirements. Different methods for LVRT has been studied in this paper. Crowbar method is a conventional method with low cost but draws more reactive power.From the above analysis Low Voltage Ride Through is an important feature for wind turbine systems to full fill grid code requirements. DFIG is sensitive to grid voltage variations. To overcome this, suitable control must be implemented to protect the converter from tripping during grid voltage faults. High current transients cause voltage fluctuations , rotor current ,torque variations and dc link voltage fluctuation. DFIG with energy storage system and FACTS devices are common now a days. But this increase cost and complexity of the system.Various types of modifications are done in flux tracking and current feed back technique gives good performance characteristics. Further research should be focused on the control strategy which improves the LVRT with reduced cost and complexity with good reactive power support during fault.

References

[1]Shuai Xiao, Geng Yang, Honglin Zhou, and HuaGeng, "An LVRT Control Strategy Based on Flux Linkage Tracking for DFIG-Based WECS", *IEEE Transactions on Industrial Electronics,* Vol. 60, No. 7, July 2013
[2]IWGC report
[3]Jadhav HT Ror R, "A critical review on the grid integration issues of DFIG based wind farms"*10 th International conference on EEEIC,*May 2011
[4] Pannell, G. ,Atkinson, D.J. , Zahawi, B." Minimum-Threshold Crowbar for a Fault-Ride Through Grid-Code-

Compliant DFIG Wind Turbine *", IEEE Transactions on Energy Conservation*, Vol. 23, No. 3, sep 2010

[5] Pannell. G., Zahawi. B., Atkinson. D.J., Missailidis .P.,"Evaluation of the Performance of a DC Link Brake Chopper as a DFIG Low-Voltage Fault-Ride-Through Device", *IEEE Transactions On Energy Conversion*, Vol. 28, No. 3, September 2013

[6] Andrew Causebrook, David J. Atkinson, and Alan G. Jack**,**"Fault Ride-Through of Large Wind Farms Using Series Dynamic Braking Resistors", *IEEE Transactions on Power Systems*, Vol. 22, No. 3, August 2007.

[7] K. Lima, A. Luna, P. Rodriguez, E. Watanabe, R. Teodorescu, and F. Blaabjerg,"Doubly-fed inductiongenerator control under voltage sags*," Energy 2030 Conference*, 2008]

[8]Huang Qingjun,sunmucun,zouxudong"A reverse current tracking based LVRT strategy for DFIG"Industrial electronics society ,*IECON 2013 -39th annual conference of the IEEE* November 2013.

[9]Wesselsc,Fuchs F.W. "Fault ride through of DFIG wind turbine during symmetrical voltage dip with crowbar or stator current feedback solution"*Energy conversion congress and Exposition*,sep 2010

[10]Mishra Y,Mishra s ,Tripathy"Improving stability of the DFIG based wind power system with tuned damping controller"*IEEE transactions on energy conservation* vol 24,sep 2009.

[11]Boulaam k, Boukhelifa "A non linear control of power wind turbine based on DFIG"*Applications of IT-DREPS* ,May 2013.

[12]YuanshenZhou,"The variable frequency speed control system based on the modified two degree freedom internal model control and its robustness analysis"*Control and Decision conference ,2010 chinese*,May 2010.

[13] F. Díaz-González, A. Sumper, O. Gomis-Bellmunt and R. Villafáfila-Robles, "A review of energy storage technologies for wind power applications," *Renewable and Sustainable Energy Reviews*, vol. 16, n°4, pp. 2154-2171, May 2012.

[14] A.H.M.A. Rahim and E.P. Nowicki, "Supercapacitor energy storagesystem for fault ride-through of a DFIG wind generation system,"*Energy Conversion and Management*, vol. 59, pp. 96-102, July 2012

[15] *Khamaira, M.Y. ; Shiddiq Yunus, A.M. ; Abu-Siada, A*" *Improvement of DFIG-based WECS performance usingSMES unit*"**,** *Power Engineering Conference (AUPEC), 201*3 Australasian Universities pp.1-5Sept. 2013

.[16] R. Mineski, R. Pawelek, I. Wasiak, "Shunt compensation for power quality improvement using a STATCOM controller: modeling and simulation", *IEE Proc. on Generation,Transmission and Distribution*, Vol. 151, No. 2, March 2004

[17]Christian wesels,Friedrich Fuchs"Fault Ride Through of a DFIG WT Using a Dynamic Voltage Restorer Duringf Symmetrical and Asymmetrical Grid faults"*IEEE Trans power electronics* VOL.26 March 2011

[18] Alharbi, Y.M. ; Electr. &Comput. Eng. Dept., Curtin Univ., Perth, WA, Australia
; Yunus, A.M.S. ; Abu Siada, A. "Application of UPFC to improve the LVRT capability of wind turbine generator" *IEEE ,Conference Publications*, date 26-29 Sept. 2012,in Universities Power Engineering Conference (AUPEC), 2012 22nd Australasian.

Divya S received B.Tech degree in Electrical and Electronics engineering from Calicut university in 2013.currently doing the M.Tech in Mahathma Gandhi University Kottayam**.**

Krishnakumari T Recived B.Tech degree in Electrical and Electronics engineering from MG university Kottayam.Also received M.Tech degree in Power system engineering from MG University Kottayam.Her research interests is wind energy.