IJO-SCIENCE ISSN NO: 2455-0108 VOL. III, ISSUE 8, AUGUST 2017

DOI: https://doi.org/10.24113/ijoscience.v3i8.23

Analysis of Doubly Fed Induction Generator using Fault Current Limiters for Transient Stability Improvement

Roshan Brahmwanshi
M.Tech. Scholar
Department of Electrical and Electronics Engineering
Scope College
Bhopal, M.P., India

N.K.Singh
Professor
Department of Electrical and Electronics Engineering
Scope College
Bhopal, M.P., India

***Abstract-* Currently, the doubly fed induction generator (DFIG) is getting wider popularity due to its ability to adapt with variable wind speed and to capture more wind energy. According to the grid code, transient stability enhancement of the DFIG system is very important. Though DFIG has a salient feature of the fault ride through capability, this is not sufficient to preserve the necessity of the grid code when the DFIG system is connected with the grid. The paper provides cumulative study of wind turbine technology followed by discussion of different control schemes mainly of doubly fed induction generator (DFIG) wind turbine. This paper gives proper understanding of conceptual experiments conducted with DFIG and control schemes along with their characteristics and limitations. This paper also presents a comparative study of resistive and inductive superconducting fault current limiter (SFCL) for power systems transient stability improvement.**

***Keywords*— Doubly fed induction generator; Fixed speed wind turbine; Variable speed wind turbine; Inductive SFCL; Resistive SFCL; Superconducting faults current limiter; Transient stability;**

I. INTRODUCTION

In general, the world energy comes from two different alternative sources such as non-renewable or conventional sources (coal, natural gas, fossil fuels, etc.) and renewable energy sources (wind, hydro, solar, biomass, etc.). After the industrial revolution, the worldwide demand for energy is gradually growing and the conventional energy is used as a primary energy source to meet the energy demand. Conventional energy is dependent on the fossil fuels: coal, oil, and gas, which are very limited. Also, air is being polluted by the use of conventional energy sources. This is motivating major world powers to install renewable energy sources all over the world. According to the International Energy Agency (IEA), 25% of the world's electricity will be supplied by renewable energy sources by 2035, and a quarter of this will come from the wind [1]. Wind is a renewable resource that can be used forever, free of cost. It is also pollution free, environment friendly, and minimizes our dependence on the traditional fuels such as oil, gas and coal. It is expected that a total of 760 GW of wind power will be generated through worldwide by the year of 2020 (Ngamroo, 2017).

With the modern technology incorporated in the wind turbines, wind power generation limits have been uplifted to considerable level in the grid. Therefore, a vast amount of researches on WECS have been and is being undertaken intensively WECS consists of three major aspects; aeronautical, mechanical and electrical as shown in Figure 1

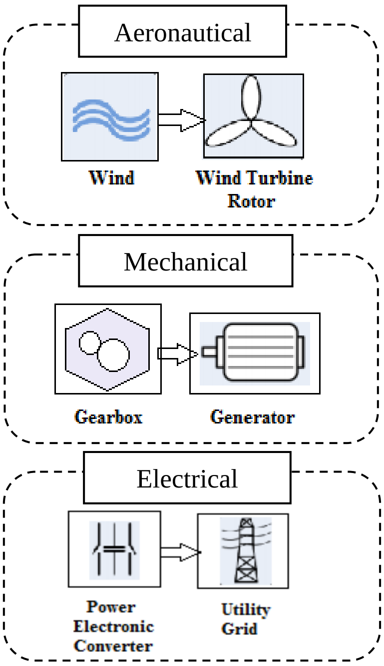

Figure 1: Wind Energy Conversion System (WECS)

The electrical aspect of WECS can further be divided into three main components, which are wind turbine generators (WTGs), power electronic converters (PECs) and the utility grid. There are many research on those electrical aspects available; however, there seem small amount of investigation and discussion on the newer concepts of WTGs.

II. WIND TURBINE GENERATOR

Wind power as a source of green and abundant energy is proposed as one of the main new world power sources and has acquired a great momentum across the world. In the last few decades, wind turbines with different generators have been developed to increase the maximum power capture, minimize the cost, and expand the use of the wind turbines in both onshore and offshore applications. A wind turbine converts the captured kinetic energy in the wind to electrical energy by means of a generator. Generators with more reliable, efficient, and compact designs should be used in wind turbines to maximize the wind power capture and produce a higher quality output power. To determine the appropriate generator designs for onshore and offshore wind turbines there are different types of wind turbine generators based on the speed range, cost, weight, size, and power quality at the grid connection.

WTGs can be classified into three types according to its operation speed and the size of the associated converters as below:
FSWT (Fixed Speed Wind Turbine)
VSWT (Variable Speed Wind Turbine
FSWT including SCIG (Squirrel-Cage Induction Generator), led the market until 2003 when DFIG (Doubly Fed Induction Generator), which is the main concept of VSWT with PSFC, overtook and has been the leading WTG concept with 85% of the market share reported in 2008 [5]. The application of doubly fed induction generator (DFIG)–based wind farms are getting more popular due to abundant advantages, including partial converter ratings (25%–30%) of the total rated power system, variable speed operation, capability to decoupled control of active and reactive power, low cost, and smaller size.

For VSWT with FSFC, WRSG (Wound Rotor Synchronous Generator) has been the main concept; however PMSG (Permanent Magnet Synchronous Generator) has been drawing more attention and increasing its market share in the past recent years due to benefits of PMSG and drawbacks of WRSG [6]. Since there is much literature available on these WTG concepts in the market such as [3, 6-12], the following section will only address the two newer concepts of WTGs, which are BDFIG (Brushless Doubly Fed Induction Generator) and BDFRG (Brushless Doubly Fed Reluctance Generator), followed by the discussion with the comparison of them to the existing concepts.

BDFIG is one of the most popular VSWT with PSFC types in the current research area due to its inherited characteristics of DFIG, the most popular WTG type at the current market. BDFIG consists of two cascaded induction machines; one is for the generation and the other is for the control in order to eliminate the use of sliprings and brushes, which are the main drawback of DFIG. This brushless aspect increases its reliability, which is especially desirable in offshore application [13-14]. Other advantages are reported in [3, 15-16] including its capability with low operation speed. On the other hand, DFIG has relatively complex aspects in its design, assembly and control, which are some of the main disadvantages of BDFIG [7].

There is also another brushless and two-cascaded-stator concept of VSWT with PSFC type in the research area, which is BDFRG. One distinct design compared with BDFIG is its reluctance rotor, which is usually an iron rotor without copper windings and has lower cost than wound rotor or PM (permanent magnet) rotor.

This design offers some advantages on top of the advantages of BDFIG including higher efficiency, easier construction and control including power factor control capability as well as the cost reduction and higher reliability including its “fail-safe” operating mode due to its reluctance rotor [17]. Some of the drawbacks for BDFRG exist, however, such as complexity of rotor deign, its larger machine size due to a lower torque-volume ratio and so forth [18].

Table 1 represents a comparison of those six concepts with respect to the five criteria; energy yield, cost, reliability, grid support ability and technical maturity.

Table I: The comparison of the six different WTG concepts

Generator Concept	Energy Yield	Cost	Reliability	Grid Support Ability
SCIG	Low	Low	High	Low
PMSG	High	Medium/ High	High	High
WRSG	Medium/ High	High	High	High
DFIG	Medium/ High	Medium	Medium	Medium
BDFIG	Medium/ High	Medium	Medium/High	Medium /High
BDFRG	Medium/ High	Low/Medium	High	Medium /High

Using DFIG is an attractive solution over the PMSG, as it requires lower rated power electronic converters than the PMSG. Besides, the DFIG provides better speed control with reduced flicker [3]. It is also reported that the electronics face more faulty events in the systems using synchronous generators compared with the system using induction generators [4]. Therefore, the DFIG system is currently a very popular technology to harness electricity from wind energy. Given that the increasing demand for electric power, power systems should be exploited near stability limits. Power system operations are becoming more and more complex. In these conditions, therefore, transient stability problems become more important.

III. DFIG MODELLING

Standard doubly-fed electric machines are basically three-phase wound-rotor induction machines, where ac currents are fed into both the stator and the rotor windings. The basic configuration of a DFIG based wind turbine with the crowbar system is shown in Figure 2, where the stator of the machine is directly connected with the grid through a transformer, and the wound rotor is also connected to the grid with the help of AC–DC and DC–AC converters. Two three-phase pulse width modulated (PWM) voltage source converters, that is, the rotor side converter (RSC) and grid side converter (GSC) are coupled to a common DC link. In this research, the vector control method has been used to control the RSC and GSC controllers of the DFIG.

One of the main reasons for the acceptance of DFIG in wind energy applications is that it offers better performance for the variable speed wind generation system. Moreover, relatively small power converters are required to control the generator. As shown in Figure 2, the power converter used by the DFIG is usually 25 to 30% of the rated power system. As a result, power loss in the electronic converter is reduced, compared with a system where the converter has to exchange the entire power. Moreover, the system cost becomes lower due to using the partially rated power converters.

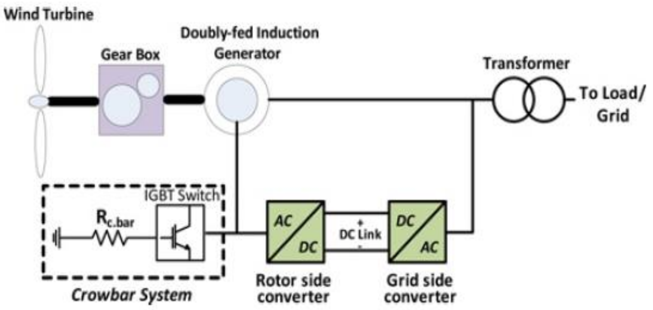

Figure 2: Doubly-fed induction generator

IV. SFCL MODELLING

SFCL is a device that limits the fault current by generating impedance when a fault occurs. SFCL installed in series with transmission lines can be just operated during the period from the fault occurrence to the fault clearing, they cannot control the generator disturbances after the clearing of fault.

The equivalent circuit in π of the transmission line with SFCL is illustrated in Figure 3. The following admittance matrix of the line can be formed:

$$Y_{ik} \frac{1}{(r_{ik} + R_{SFCL}) + jx_{ik})}$$

$$Ysh_{ik} = jb_{ik}$$

Where r_{ik}, x_{ik} , and b_{ik} are resistance, reactance line, and capacitance line, respectively. RSFCL is resistance of SFCL. The equivalent circuit of generator equipped by SFCL is given by the Figure 4.

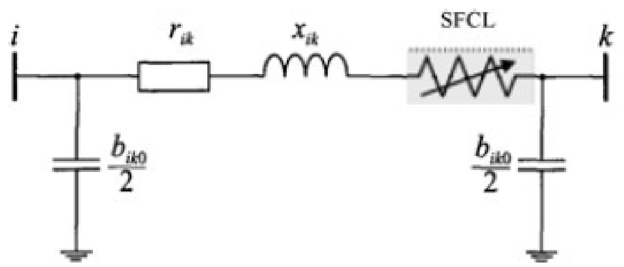

Figure 3: Model of SFCL inserted in the transmission line

Figure 4: Model of SFCL inserted in series with generator

When the inductive SFCL is placed in series with generator, the element of the admittance matrix is given by

$$Y_{ik} = \frac{1}{R_G + j(\acute{X}_d + X_{SFCL})}$$

When the resistive SFCL is placed in series with generator, the element of the admittance matrix is given by

$$Y_{ik} = \frac{1}{(R_G + R_{SFCL} + j\grave{x}_d)}$$

where x'_d is the d-axis generators transient reactance of generator, R_G is resistance of generator. X_{SFCL} and R_{SFCL} are resistance and reactance of resistive and inductive SFCL, respectively.

V. CONCLUSION

As the doubly fed induction generator (DFIG) is getting wider popularity due to its ability to adapt with variable wind speed and to capture more wind energy. In this paper, the study of various components of power systems and improving of the power system's transient stability using resistive and inductive superconducting fault current limiter SFCL placed in series with transmission line and generator have been presented. The SFCL appears to be a device of great interest to efficiently build the electrical grid of tomorrow.

REFERENCES

[1] R. Rechsteiner, "Wind Power in Context – A clean Revolution in the Energy Sector," 2008.

[2] Muller, S., Deicke, M., De Doncker, R.W.: 'Doubly fed induction generator systems for wind turbines', IEEE Ind. Appl. Mag., 2002, 8, (3), pp. 26–33.

[3] Cardenas, R., Pena, R., Alepuz, S., et al.: 'Overview of control systems for the operation of DFIGs in wind energy applications', IEEE Trans. Ind. Electron., 2013, 60, (7), pp. 2776–2798.

[4] Sabir Messalti, Saad Belkhiat, "Comparative Study of Resistive and Inductive Superconducting Fault Current Limiters SFCL for Power System Transient Stability Improvement", Springer, 2013.

[5] Md Maruf Hossain, Mohd. Hasan Ali, "Transient stability improvement of doubly fed induction generator based variable speed wind generator using DC resistive fault current limiter", IET Renewable Power Generation, 2016, pp. 1–8.

[6] H. Polinder, et al., "Comparison of direct-drive and geared generator concepts for wind turbines," Energy Conversion, IEEE Transactions on, vol. 21, pp. 725-733, 2006.

[7] H. Li and Z. Chen, "Overview of different wind generator systems and their comparisons," Renewable Power Generation, IET, vol. 2, pp. 123- 138, 2008.

[8] G. Shrestha, et al., "Review of Energy Conversion System for Large Wind Turbines," 2007.

[9] A. D. Hansen and L. H. Hansen, "Wind turbine concept market penetration over 10 years (1995-2004)," Wind Energy, vol. 10, pp. 81-97, 2007.

[10] H. Polinder, et al., "Basic operation principles and electrical conversion systems of wind turbines," EPE JOURNAL, vol. 15, p. 43, 2005.

[11] T. Ackermann, Wind Power in Power Systems. Chichester: Wiley & Sons, Ltd, 2005.

[12] L. Hansen, et al., "Conceptual survey of Generators and Power Electronics for Wind Turbines," 2001.

[13] J. Weinzettel, et al., "Life cycle assessment of a floating offshore wind turbine," Renewable Energy, vol. 34, pp. 742-747, 2009.

[14] P. Bauer, et al., "Evaluation of electrical systems for offshore windfarms," in Industry Applications Conference, 2000. Conference Record of the 2000 IEEE, 2000, pp. 1416-1423 vol.3.

[15] S. Shiyi, et al., "Dynamic analysis of the Brushless Doubly-Fed Induction Generator during symmetrical three-phase voltage dips," in Power Electronics and Drive Systems, 2009. PEDS 2009. International Conference on, 2009, pp. 464-469.

[16] P. Camocardi, et al., "Autonomous BDFIG-wind generator with torque and pitch control for maximum efficiency in a water pumping system," International Journal of Hydrogen Energy, vol. 35, pp. 5778-5785, 2010.

[17] M. Jovanovic, "Sensored and sensorless speed control methods for brushless doubly fed reluctance motors," Electric Power Applications, IET, vol. 3, pp. 503-513, 2009.

[18] R. E. Betz and M. G. Jovanovic, "Theoretical analysis of control properties for the brushless doubly fed reluctance machine," Energy Conversion, IEEE Transactions on, vol. 17, pp. 332-339, 2002.