LVRT Enhancement Capability of DFIG based WECS by Implementing STFCL-SMES

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Abstract—Wind Energy is one of the main rapid growing forms of non-conventional Electrical power source. Contrary to the non renewable and vulnerable counterparts, wind energy has proven to be momentous in the long journey for the purpose of power generation. The usage of wind turbines along the grid produces a large number of problems and one of them is Low Voltage Ride Through (LVRT). The purpose of this paper is to enhance the LVRT capability of Doubly Fed Induction Generator (DFIG) by using Super Conducting Magnetic Energy Storage system (SMES) and Switch Type Fault Current Limiter (STFCL) along with several changes along the grid side. It is required that the voltage should ride through even at a value less than 10-15% of the correct value during voltage sags.

Keywords: Wind turbines, LVRT, DFIG, STFCL, SMES, Grid code and Power converters.

I. INTRODUCTION

Wind energy has been globally perceived as one of the most profitable form of sustainable energy source owing to its origin [1]. Keeping this in mind, wind turbines have been coupled with Double Fed Induction Generator (DFIG). The reason for using DFIG, contrary to FSIG (Fixed Speed Induction Generator) and PMSG (Permanent Magnetic Synchronous Generator) is quite obvious. The DFIG can easily adapt itself to the grid side voltage dips and the short- term faults. The major advantage of Doubly Fed Induction Generator lies in its basic principle itself. In DFIG, the rotating exciter and Stationary windings of generator are separately connected to the equipment. Upon feeding variable AC power to field windings, rotating exciter can be made to rotate allowing alterations in generator speed. Hence, they can be used at a speed slightly higher or lower compared to the synchronous speed [2]. When a sudden gust of wind hits the wind turbine, the conventional generators owing to its coupling on the grid side cannot vary the speed. This leads to the wear and tear of the mechanical parts in the gearbox. However, in case of DFIG the turbine can speed up accordingly relieving the gears of excessive stress and augmenting the useful electricity output. With the advent of such systems according to the grid codes, it is essential that the wind electrical turbine should supply power to grid and remains connected to short term faults and voltage dips. This results in Low Voltage Ride Through with only 10%-15% of remaining voltage. In this paper, LVRT concept is dealt with in detail followed by classic models and proposed models for the enhancement of LVRT capability of DFIG in a WECS (Wind Energy Conversion System).

II. LVRT

LVRT is mainly the ability of a wind turbine system generator preferably a DFIG to remain connected to the power grid even during low voltage transients (or dips) and short time occurring faults. It is necessary mainly at distribution region of wind power to prevent fault occurring due to short circuit at high voltage and extra high voltage. The basic cause of voltage dips is the differences between the active and reactive power delivered to the grid and chain reaction. The chain reaction leads to a large scale cascading failure. The LVRT demands that the wind turbine is associated to the grid during voltage sag and reactive power is delivered to the grid to maintain grid voltage [3]. To sustain the grid side voltage STATCOM devices are used for maintaining the reactive power. The distinctive LVRT Capability curve as shown in figure.1.

![Fig 1: LVRT Capability Curve](image-url)
III. GRID PROTOCOLS

- Grid codes are mainly applicable for large scale power plants generating several MW and GW of power.
- Grid Protocol requirements include:
  a) **Active power**: Wind power plants must regulate their active power so as to maintain their frequency in a range.
  b) **Reactive power**: Wind turbines should regulate the reactive power in such a way that power factor is maintained in the range of 0.9 lag to 0.98 lead
  c) **Frequency**: Frequency is operated in the range of 49.5Hz - 50.5Hz.

IV. CLASSIC MODELS

![Fig 2 Classic Model of DFIG Wind Turbine](image)

The conventional model for the wind turbine system employing a DFIG is as shown in figure 2. The stator is directly associated to the DFIG and the rotor is associated to the grid through a frequency converter involving Rotor Side Converter, DC Link, Grid Side Converter and a transformer to the grid [4]. The purpose of RSC is to maintain active and reactive power whereas the reason of GSC is to sustain DC Link capacitor voltage. Besides, it can also maintain the direction of rotor power to enable converter working with unity power factor [5]. In the old model switchgears were used for isolation purpose. The DFIG Model is shown in figure 3.

![Fig 3 Schematic figure of DFIG model wind turbine](image)

V. PROPOSED MODELS

In the proposed model the RSC and the GSC have been controlled using Energy Storage Methods (SMES) and STFCL [6]. The proposed DFIG WECS consists of a wind turbine, Drive train, Bi-directional converter, SEPIC converter and frequency converters associated to the grid by using transformers. The control methods and the working of the proposed system are discussed.

VI. WIND TURBINE AND DRIVE TRAIN

A wind electrical turbine converts kinetic energy of wind into electrical energy. When the wind incident on turbine rotor of 3.5m/s - 12m/s causes the blades to rotate which is connected to a shaft which is connected to the gear box used to generate mechanical energy.

The gearbox transfers this energy to the generator which converts it and produces electrical energy. The output power delivered by wind turbine is given by [7-16]

\[ P_m = \frac{C_P(\lambda,\beta)\rho A V^3}{2} \]

Where  
- \( C_P \rightarrow \) Coefficient of power
- \( \lambda \rightarrow \) Tip-speed ratio
- \( \beta \rightarrow \) Blade pitch angle
- \( \rho \rightarrow \) Density of air in kg/m\(^3\)
- \( A \rightarrow \) Turbine blade in m\(^2\)
- \( V \rightarrow \) Velocity of wind in m/sec

The torque and \( C_P \) are calculated for modeling reasons. The drive train consists of gearbox with high speed and low speed shaft. The impact of torque is applied to generator and turbine. The gear teeth of drive train relatively uses small portion. So that transformation ratio of the gear drive is incorporated and the gear inertia is ignored. The model uses two mass modeling, since the gear model ratio is kept as unity[17]. Wind drive train based on two mass models as shown in figure 4.

![Fig 4 Wind drive train based on two mass model](image)
VII. SUPERCONDUCTING MAGNETIC
ENERGY STORAGE

SMES store the energy in the form of magnetic field by the flow of DC current through STFCL [18]. It is used for improving the power quality and stability. It is connected to the switch of STFCL to the stator of DFIG as shown in figure 5. The simulation diagram of the SMES coil is given below.

VIII. SWITCHED TYPE FAULT CURRENT LIMITER

The anticipated system uses STFCL to control and to achieve system stability even during fault conditions. During normal conditions the static switch is turned ON and current is bypassed. But the solid state switch is turned OFF during fault conditions to limit the fault currents [19].

IX. SEPIC CONVERTER

In the proposed model a SEPIC converter is used between Rectifier and Voltage source inverter. It works as buck/boost converter. The rectifier input is connected to stator of DFIG and output of VSI fed to grid through transformer as shown in figure 6.

X. ANALYSIS OF SIMULATION

To analyze the DFIG of the following system under the fault condition: Rating of the DFIG is 1.5MW whereas the stationary part of it is associated to 575V bus. Fault occurrence is at 20 kilometer of transmission line and is created between 0.2 to 0.3 seconds and wind speed during the time is 7m/sec. The above condition is simulated in MatLab and the figure 5 is the SIMULINK model of proposed system.

Figure 8 & figure. 9 show the output power, voltage and current waveforms and figure. 7 show the output voltage and current waveform of DFIG wind turbine under asymmetrical and symmetrical fault condition. The various constraints are represented in pu value.

Figure. 10 & Figure. 11 represents the waveforms of DFIG wind turbine in the SMES-STFCL method with control under LLG fault at 0.2-0.3.
Figure 12 & Figure 13 represents the waveforms of DFIG wind turbine in the SMES-STFCL method with control under 3 Phase fault at 0.2-0.3.

**XII. CONCLUSION**

Wind Turbines, being a sustainable power plant should be developed and improvised from time to time to cater to needs. The enhancement of LVRT of a DFIG has been dealt with both theoretically and via MATLAB simulations. The implementation of STFCL-SMES to enhance the performance of LVRT of DFIG is being discussed in this paper. The grid voltage, current, real power and reactive power are controlled using STFCL and SMES model. The performance of DFIG is more effective using the above system and LVRT performance is enhanced during in symmetrical and asymmetrical fault circumstances.

**REFERENCES**


