Volume 3, Issue 4, April 2013 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Voltage Sag Ride through of wind driven DFIG during Grid Interconnection/Faults

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Abstract— Energy is one of the most prominent factors in shaping the civilization of today. Under consideration for non- conventional energy source wind energy has turned out to be a leading source of energy. In recent years there has been a significant global commitment to develop a clean and economical alternative sustainable power source especially from wind. In this field of development wound rotor induction generator has seen considerable success. One scheme of wound rotor induction generator is realised when a converter cascade is used between the slip rings terminals and the utility grid to control the rotor power. This configuration is called Doubly Fed Induction Generator (DFIG). In this paper analyses the voltage sag in a grid connected to a DFIG. The paper implements a control technique to mitigate the voltage sag generated due to a fault. Finally the paper concludes with an inference of the voltage profile generated by a DFIG and a vivid study of various parameters at varied conditions.

Keywords— Doubly-fed induction generator (DFIG), protection, Wind power generation, voltage sag, fault.

I. INTRODUCTION

The installed capacity of wind power in Europe reached approximately 33,600 MW until the end of 2004. The demand for connecting large-scale wind parks to the power grid is still on the rise. The increasing size of wind turbine and Wind Park resulted in new interconnection rules or grid codes.

Today, there is a need to control wind power, both in active and reactive power, and to be able to stay connected with the grid when grid faults happen. The doubly fed induction generator (DFIG) has the largest world market share of wind turbine concepts since the year 2002 [1], because of its ability to provide variable speed operation and independent active and reactive power control in a cost-effective way. As DFIG's stator is directly connected with ac grid, it has poor low-voltage ride through (LVRT) capability due to the poorly damped flux oscillations during grid voltage dip. Many studies have been conducted on the LVRT capability of DFIG [3]–[6], [9], with most of them focused on the behavior and protection of DFIG under symmetrical fault. During the symmetrical fault, transient over current in the rotor is identified as the most severe LVRT problem of the DFIG, because the rotor-side voltage source converter (VSC) is very sensitive to thermal overload. Thus, the active crowbar protection is designed to short-circuit the rotor under symmetrical grid voltage dip, both to protect the rotor-side VSC and to damp out the oscillations faster. In reality, however, unsymmetrical fault happens much more frequently than symmetrical fault.

Furthermore, it is identified that the unbalanced voltages can occur in a weak power grid even during normal operation [7], [8], [15]. Under the unbalanced grid voltage, the most severe operation problem of DFIG may not be the transient over current, but the large electric torque pulsation that causes wear and tear of the gearbox, and large voltage ripple in the dc link of back to- back VSC that may decrease the lifetime of the dc capacitance. Literatures [10], [11] define the instantaneous active and reactive power that can be used to design and operate the grid connected VSC under unbalanced grid situations [12]–[13]. Literatures [14], [15] on the control system of DFIG under unbalanced grid voltage condition.

In [15], the grid VSC was controlled as a STATCOM and supplied reactive power to compensate the unbalanced grid voltage. A detailed model of DFIG is made in MATLAB/Simulink. Simulation results prove the effectiveness of the proposed control system.

II. DOUBLY FED INDUCTION GENERATOR

The working of DFIG is based on the principle of induction generator. It has multiphase wound rotor and a multiphase slip ring assembly with brushes for accessing rotor winding. The rotor windings are connected to the grid via slip rings and a back to back voltage source converter that controls both the rotor and grid currents (hence acting as a control system).

By adjusting the converter's parameters it is possible to control the active and reactive power fed to the grid independently of the generators turning speed, giving it a distinct advantage over other conventional power generators. Fig.1 shows a schematic representation of a DFIG setup:

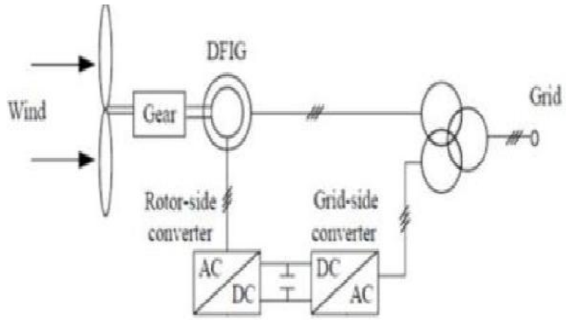

Fig1. DFIG model

III. VOLTAGE SAG

A voltage sag as defined by IEEE Standards 1159-1995,is a decrease in the RMS voltage at the power frequency for duration from .5 cycles to 1 minute. The measurement of the voltage sag is defined as the percentage of the nominal voltage. Example: Voltage sag to 60% is equal to 60% of nominal voltage i.e. 288 volt for a 480 volt system.

IV. WIND TURBINE CONCEPTS

The three most important currently applied wind turbine concepts are: [4]

1. A constant speed wind turbine, which consists of a directly grid coupled squirrel cage induction generator. The wind turbine rotor is coupled to the generator through a gearbox. The power extracted from the wind is limited using the stall effect. This means that the rotor is designed in such a way that its efficiency decreases in high wind speeds, thus preventing the mechanical power extracted from the wind to become too large. In most cases, no active control systems are used to this end.
2. A variable speed wind turbine with doubly fed (wound rotor) induction generator. The rotor winding is fed using a back-to-back voltage source converter. Like in the first concept, the wind turbine rotor is coupled to the generator through a gearbox. In high wind speeds, the power extracted from the wind can be limited by pitching the rotor blades.
3. A variable speed wind turbine with a direct drive synchronous generator. The synchronous generator can have a wound rotor or be excited using permanent magnets. It is grid coupled through a back- to-back voltage source converter or a diode rectifier and voltage source converter. The synchronous generator is a low speed multi pole generator, therefore no gearbox is needed. Like in the second concept, the power extracted from the wind is limited by pitching the rotor blades in high wind speeds. The concepts are depicted in figure 2.

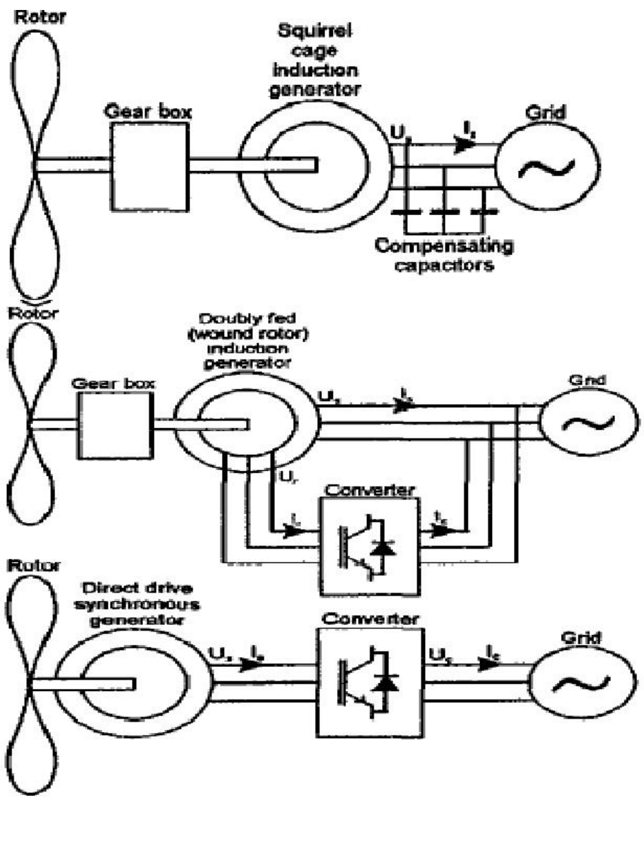

Fig2. Widely used contemporary wind turbine concepts

V. DFIG BEHAVIOUR DURING FAULT CONDITION

Voltage sag (also the word voltage dip is used) is a sudden reduction of the voltage at a point in the electrical system, which lasts for half a cycle to 1 min. Depending on the type of fault, the magnitudes of the voltage dips of each phase might be equal or unequal. The magnitude of voltage sag at a certain point in the system depends mainly on the type of the fault and the distance of the fault. [2]

The voltage dip can cause high induced voltages or currents in the rotor circuit. The high current might destroy the converter, if nothing is done to protect it. [5] Fig 3 shows the behaviour of DFIG during fault condition.

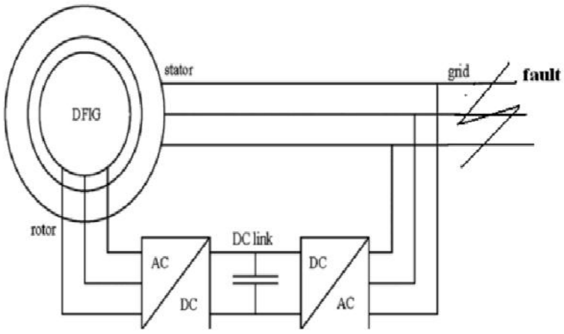

Fig 3 Block diagram of DFIG with fault at grid side

VI. Dfig Behaviour During Fault Clear Condition

The detailed model **(**discrete**)** such as the presented in this paper. The detailed model includes detailed representation of power electronic IGBT converters. In order to achieve an acceptable accuracy with the 1620 Hz and 2700 Hz switching frequencies used in this demo, the model must be discretized at a relatively small time step (5 microseconds). This model is well suited for observing harmonics and control system dynamic performance over relatively short periods of times (typically hundreds of milliseconds to one second).

VII. Simulation Model

A 9 MW wind farm consisting of six 1.5 MW wind turbine connected to a 25 kV distribution system exports power to a 120 kV grid through a 30 km, 25 kV feeder. Wind turbines using a doubly-fed induction generator (DFIG) consist of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter. The stator winding is connected directly to the 60 Hz grid while the rotor is fed at variable frequency through the AC/DC/AC converter. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. In this demo the wind speed is maintained constant at 15 m/s. The control system uses a torque controller in order to maintain the speed at 1.2 pu. The reactive power produced by the wind turbine is regulated at 0 Mvar.

The key of protection technique is to limit the high current and to bypass for it in the rotor circuit via an ideal switch and resistance are connected to rotor circuit (Fig.4).This should be done without disconnecting the converter from the rotor or from the grid. In this simulation model a relational operator is used and one comparator is used. The comparator that used to compare the actual voltage and the voltage that obtained due to voltage sag or fault will occur.

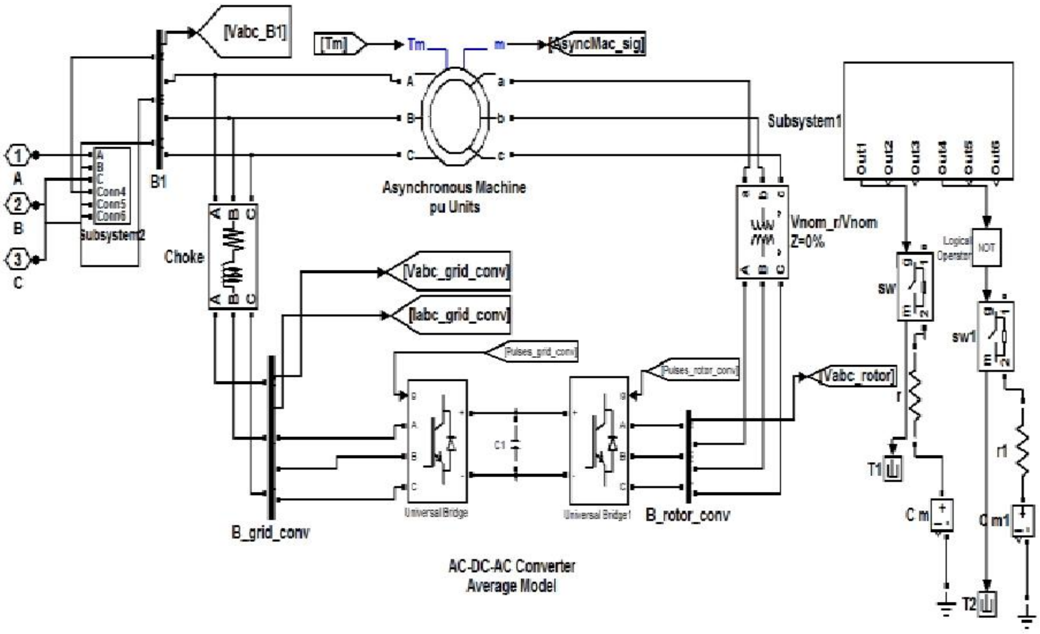

Fig 4.Detailed simulink model of DFIG

In this system, occur single line to ground fault and the fault period is set to 0.6 s to 0.7 sec. After the fault cleared the system resume their original position.

VIII. Results And Analysis

A DFIG grid system was simulated in Matlab/Simulink with the DFIG being fed by a constant wind speed. The model was simulated for 2 second with different fault scenarios from .6 seconds to .7 seconds.

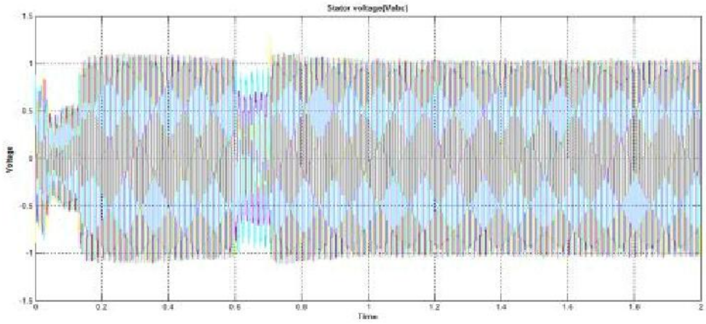

Fig.5 (a) Stator voltage for dip .6 s to .7 s

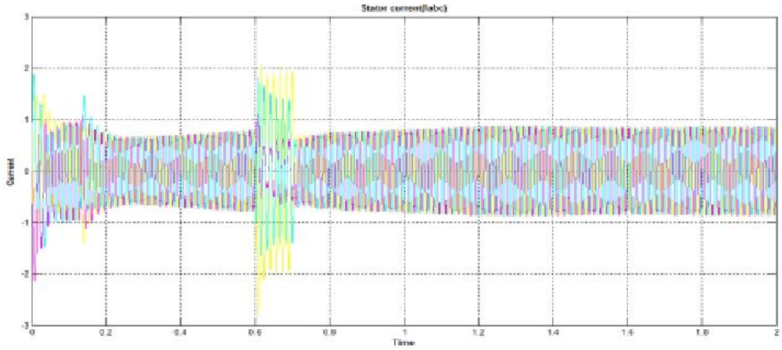

Fig.5 (b) Stator current for dip .6s to .7s

Here fig.5 (a) and fig.5 (b) analyzed the behavior of fault or dip on the stator voltage and current. During the fault period (.6s to.7s).The stator current rises and the voltage goes down during fault period.

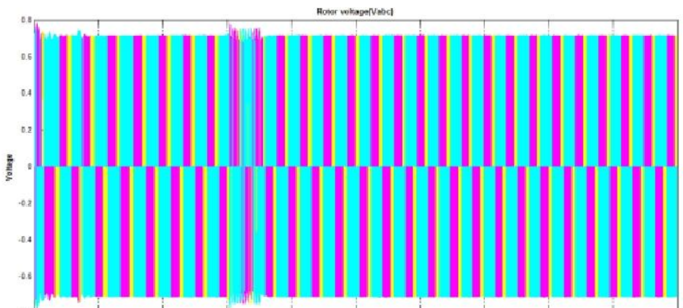

Fig.6 (a) Rotor voltage during voltage sag (.6s to .7s)

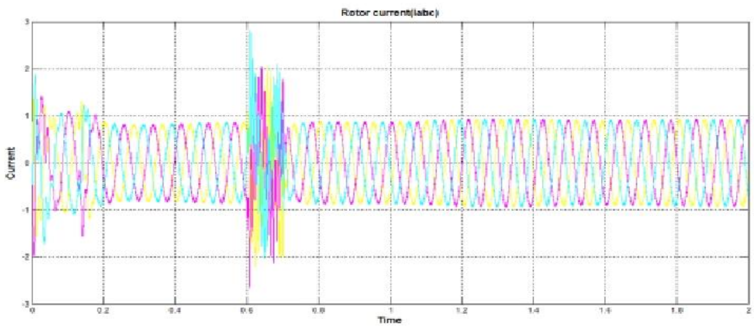

Fig.6 (b) Rotor current during voltage sag (.6s to.7s)

Here the fig.6 (a) and fig.6 (b) analysed the rotor voltage and rotor current during the fault period. In this paper we discussed the protection of rotor during fault conditions. So with the help of proper protection mitigate the problem of voltage sag during fault conditions.

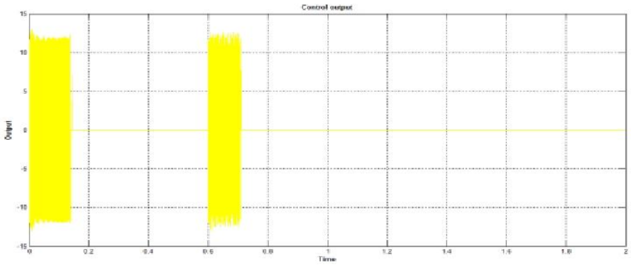

Fig.7 Control output

Fig.7 shows the control output, that control scheme are connected across rotor circuit, so during the fault period the protection scheme will be activated and when system restore their original position the protection scheme will be deactivated.

IX. Discussion

The results that have been obtained are based on simulations. Two types of errors are introduced by simulation; first, the simulation models are approximations of reality and, second, the models are evaluated with numerical methods, which introduce calculation errors. [6]

X. Conclusion

In this paper, a technique is described which the objective to keep the generator has connected to the grid in case of a grid failure so that it can resume power generation after clearance of the fault in the grid. The key of the technique is to limit the high currents and to provide a bypass for it in the rotor circuit via a set of resistors that are connected to the rotor windings without disconnecting the converter from the rotor or from the grid. The wind turbine can resume normal operation within a few hundred milliseconds after the fault has been cleared. For longer voltage dips, the generator can even supply reactive power to the grid. Simulation results show the effectiveness of the proposed technique

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