Harmonic Analysis of Grid Connected Wind Farm under Different Fault Condition

Pragnya Jita Satpathy
M.Tech Student
Department of EEE
Centurion University of Technology and Management
Ramachandrapur, Jatni,

Asima Sabat
Asst. Professor, Dept. of EEE
Centurion University of Technology and Management,
Ramachandrapur, Jatni

ABSTRACT
Wind energy is an important source of renewable energy which has a potentiality of generating energy on large scale. This emerging new technology becomes more demanding as variable speed wind turbines are highly efficient than the fixed ones. The study of variable speed wind generation system is done which is based on Doubly Fed Induction Generator (DFIG). The connection of the stator of the doubly fed Induction generator is done directly with the grid. But the connection of the rotor is done with a help of back-to-back converter which uses sinusoidal PWM technique for reducing harmonics that arise in the system. The connection of the wind energy conversion systems to the grid are done by Voltage Source Converters (VSC) so as to make variable speed operation possible. The protections of the system are also taken into consideration where the detection and isolation of the fault becomes a primary task. The paper deals with the application of DFIG, back-to-back converter control harmonic analysis under various fault conditions and finally the SIMULINK/MATLAB simulation of a model for a grid connected wind farm using Doubly Fed Induction Generator and their corresponding results and waveforms are obtained.

General Terms
Simulation has been carried out in MATLAB/SIMULINK of 2010a(i.e. MATLAB r2010a). The results show the harmonic analysis for both no fault and response under faulty conditions.

Keywords
Wind farm, DFIG, Line-to-ground fault, Harmonics.

1. INTRODUCTION
With advance of technology in wind power into electrical grids, DFIG wind turbines are in great demand due to their variable speed operation and maintaining stability in power system. It also helps in supporting the grid during voltage disturbances. Due to its numerous advantages, it has been of great interest for developing models for DFIG that can be implemented in power system. The DFIG has become a best solution in generation of power due to the development of digital controllers and power electronics devices.

A full model or a 5th order model of DFIG is important machines used in high power application which provide proper voltage regulation. The principle of DFIG is that rotor windings are connected to the grid with the help of slip rings and back-to-back voltage source converter whose function is to control both the rotor and grid currents. Such models use quadrature and direct components of rotor voltage. A rotor current is used as control parameters in 3rd order model of DFIG so as to provide very fast regulation of instantaneous currents. Apart from that, by neglecting the rate of change of stator flux linkage (transient stability model) the 3rd order model can be achieved by rotor voltage as control parameter. As compared with other variable speed machines, the cost of converter is low in DFIG. The reason is that only 25-30% of the mechanical power is fed through the converter to the grid while rest is fed from the stator to the grid directly. Therefore the DFIG is considered to be more efficient. Additionally, in order to model back-to-back PWM converters, in the simplest scenario, it is assumed that the converters are ideal and the DC-link voltage between the converters is constant. Consequently, depending on the converter control, a controllable voltage (current) source can be implemented to represent the operation of the rotor-side of the converter in the model. However, in reality DC-link voltage does not keep constant but starts increasing during fault condition. Therefore, based on the above assumption it would not be possible to determine whether or not the DFIG will actually trip following a fault.

In a more detailed approach, actual converter representation with PWM-averaged model has been proposed, where the switch network is replaced by average circuit model, on which all the switching elements are separated from the remainder of network and incorporated into a switch network, containing all the switching elements. However, the proposed model neglects high frequency effects of the PWM firing scheme and therefore it is not possible to accurately determine DC-link voltage in the event of fault. A switch-by-switch representation of the back- to-back

PWM converters with their associated modulators for both rotor- and stator-side Converters has also been proposed. Tolerance-band (hysteresis) control has been deployed. However, hysteresis controller has two main disadvantages: firstly, the switching frequency does not remain constant but varies along the AC current waveform and secondly due to the roughness and randomness of the operation, protection of the converter is difficult. The latter will be of more significance when assessing performance of the system fault condition.

Power quality is actually an important aspect in integrating wind power plants to grids. This is even more relevant since grids are now dealing with a continuous increase of non-linear loads such as switching power supplies and large AC drives directly connected to the network. By now only very few researchers have addressed the issue of making use of the built-in converters to compensate harmonics from non-linear loads and enhance grid power quality. In, the current of a non-linear load connected to the network is measured, and the rotor-side converter is used to cancel the harmonics injected in the grid. Compensating harmonic currents are injected in the generator by the rotor-side converter as well as extra reactive power to support the grid. Some researchers believe that the DFIG should be used only for the purpose for which it has been installed, i.e., supplying active power only.

2. BACKGROUND

R. Pena, J.C. Clare, G.M. Asher authors presented their work on Doubly-fed induction generator using back-to-back PWM converters and also its applications to a variable-speed wind-energy generation, May 1996[7]. The authors described the engineering and design of a doubly fed induction generator(DFIG), using back-to-back PWM voltage-source converters in the rotor circuit. Richard Gagnon, described about the Modeling and Real-Time Simulation of a Doubly-Fed Induction Generator Driven by a Wind turbine[9]. They have simulated the grid side and wind turbine side parameters and found the best efficiency by using DFIG. Dynamic modeling of Doubly Fed Induction generator wind turbines is described by J.B .Ekanayak in 2003[5].DFIG is able to provide contribution to grid voltage support during short circuit periods. Mohammed k.edan has presented a technique to analyse the propagation of harmonic current and voltage in power system networks.

This paper is to analyse the Harmonics for different faults in a grid connected wind farm through the help of DFIG. This paper deals with the application of DFIG, AC/DC/AC converter control, harmonic analysis under different fault conditions and finally the SIMULINK/MATLAB simulation for a grid connected wind farm using Doubly Fed Induction Generator and corresponding results and waveforms are displayed.

2.1 Doubly fed Induction Generator

Wind turbines use a doubly-fed induction generator (DFIG) consisting of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter. The stator winding is connected directly to the 50 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. The optimum turbine speed producing maximum mechanical energy for a given wind speed is proportional to the wind speed. Another advantage of the DFIG technology is the ability for power electronic converters to generate or absorb reactive power, thus eliminating the need for installing capacitor banks as in the case of squirrel-cage induction generator.

2.2 Faults in transmission system

The types of faults possible on the system are as follows.

1. Single line to ground fault
2. Double line to ground fault
3. Triple line to ground fault

2.3. Harmonic analysis

The harmonic distortion in the power system is increasing with wide use of nonlinear loads such as wave rectifiers, static VAR compensator, and solid-state controlled devices. Thus, it is important to analyze and evaluate the various harmonic problems in the power system prior to their occurrence. This paper presents a technique to analyze harmonic current and voltage in a grid connected wind farm.

Recently, the problem of harmonics is becoming again a current concern with the widespread use of solid state power electronics devices. The most common devices being introduced into industrial plants include variable speed ac motor drive, variable speed dc motor drive. There are a number of advantages when using these new devices. The advantages are normally a reduced cost of operation in the form of lower Energy costs, better efficiency, less maintenance and dependable operation .Each of these devices inject a non-sinusoidal current waveform into the plant distribution system and transmission network depending upon the size of the device and the system parameters.

Effects of harmonics in the electrical network:

- A rise in losses in the electrical network and equipment.
- Shorter lifespan of equipment
- Loss in quality and reliability in electrical system

Harmonics are steady-state distortions to current and voltage waves and repeat every 50 hertz or 60 hertz cycle Total harmonic distortion or **THD** is a common measurement of the level of harmonic distortion present in power systems. THD is defined as the ratio of total harmonics to the value at fundamental frequency.

3. SIMULATION RESULTS

Simulation model:

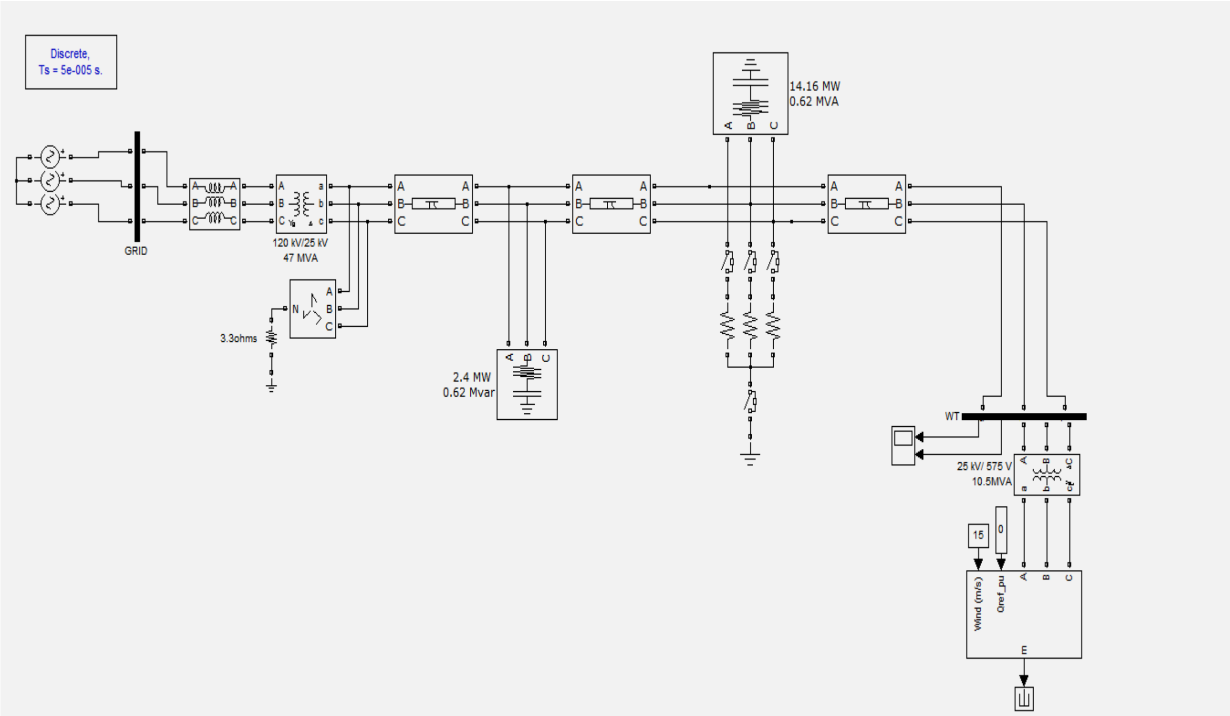

Figure 1. Simulation model

RESULTS NO FAULT CONDITION:

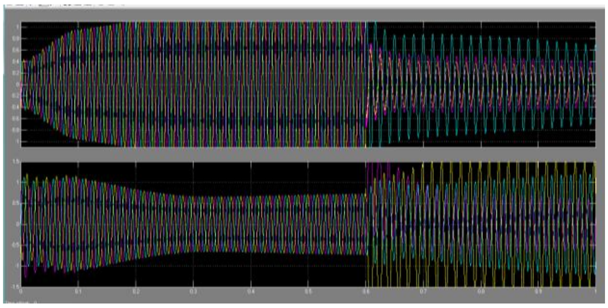

Figure 2. Current output at Wind farm for no fault condition

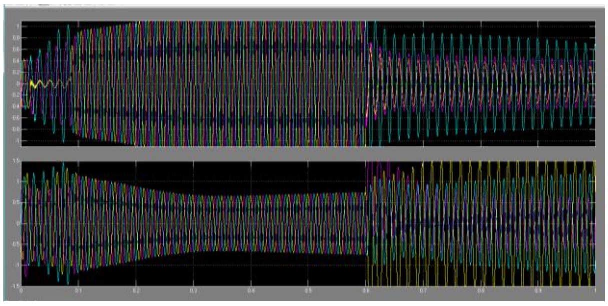

Figure 3. Current output at Wind farm for line to ground fault condition

Figure 1. is the model of Wind Farm system which consists of model elements discussed above, with ac and dc Transmission lines The list of elements are given below.

- Voltage source
- source filters
- Transformer
- AC transmission line
- Loads
- Voltage source converter
- Faults

Under fault conditions the reactive power requirement increases as can be inferred from the graph. As the reactive power is utilized in the circuit hence the reactive power at the receiving end side is lowered to a negative value.

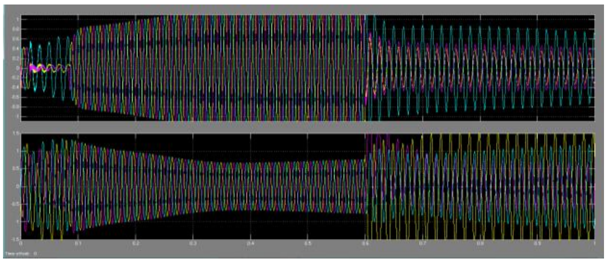

Figure 4. Current output at Wind farm for double line to ground fault condition

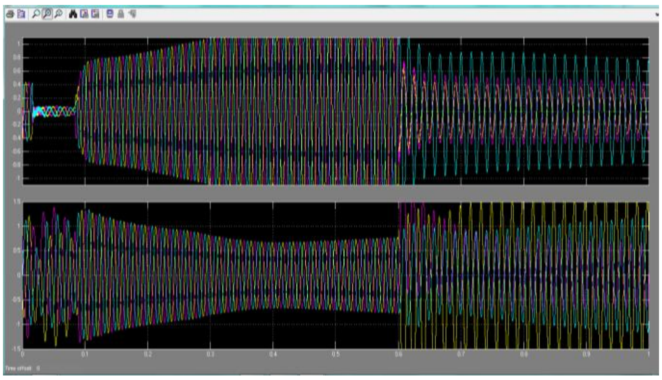

Figure 5. Current output at Wind farm for triple line to ground fault

4. CONCLUSION

The Voltage drops where as the currents increases to a very large value during the fault condition. From the observations of the waveforms of ac or dc side voltage and currents during the fault condition, we can only conclude that a fault has been occurred in the system, but this is not enough when we are concerned for the protection of the system. In Protection systems, fast and accurate detection of faults is of utmost importance. Therefore a methodology of Harmonic Analysis is presented in this paper.

Detecting fault on Wind Farm Connected to Grid is a very challenging task. Also detecting and classifying the faults is of utmost importance as far as protection of the system is concerned. The work done under this thesis is limited only to fault detection when fault is applied for a limited period of time.

5. ACKNOWLEDGMENT

My sincere thanks to Asima Sabat (Asst. Prof) for her encouragement and guidance throughout my work. I express my deep sense of gratitude to Prof. Jagannath Padhi (HOD of Electrical and Electronics Engineering) and Dr Satyasis Mishra for my research work and publication of the thesis paper.

6. REFERENCES

[1] S. K Salman and Babak Badrzadeh School of Engineering, The Robert Gordon University, IEEE paper on New Approach for modelling Doubly-Fed Induction Generator (DFIG) for grid-connection studies

[2] Slootweg JG, Polinder H, Kling WL. Dynamic modeling of a wind turbine with doubly fed induction generator. IEEE Power Engineering summer meeting, 2001; Vancouver, Canada

[3] Ekanayake, J.B, Holdsworth, L, Wu, X., Jenkins, N. Dynamic modeling of Doubly Fed Induction generator wind turbines. IEEE Transaction on Power Systems, 2003, 2:803-809

[4] J. Morren, J.T.G. Pierik, S.W.H. de Haan, J. Bozelie, “Grid interaction of offshore wind farms. Part 1. Models for dynamic simulation”, Wind Energy, 8 (3): JUL-SEP 2005.

[5] R. Pena, J.C. Clare, G.M. Asher, "Doubly-fed induction generator using back-to-back PWM converters and its applications to variable-speed wind-energy generation,"IEEE Proceedings on Electrical Power Applications, Vol. 143, No. 3, May 1996, pp. 231-341.

[6] The MathWorks, "SimPowerSystems For Use with Simulink", User’s Guide Version 4.

[7] Richard Gagnon, Gilbert Sybille, Serge Bernard, Daniel Paré, Silvano Casoria, Christian Larose “Modeling and Real-Time Simulation of a Doubly-Fed Induction Generator

[8] Kadam D. P and Dr Kushare B. E “ Overview of different wind generation systems and their comparisons”, International Journal of Engineering Science and Technology, volume 2, Issue-4

[9] Mohammed k.edan “Harmonic Analysis and calculation in Power System network” volume No-2008