Available online at www.elixirpublishers.com (Elixir International Journal)

Electrical Engineering

Elixir Elec. Engg. 82 (2015) 32406-32410

ISSN: 2229-712X

# Performance Comparison of DFIG under Various Fault Conditions

Rekha Parashar and Shashikant
Department of Electrical, BBD University, Indira nagar, Lucknow, India.

**ARTICLE INFO**

**Article history:**
Received: 20 March 2015;
Received in revised form:
30 April 2015;
Accepted: 6 May 2015;

**Keywords**
Wind Energy Conversion System (WECS),
DFIG,
PI controller,
DC-link voltage,
Symmetrical fault,
RSC,
GSC.

**ABSTRACT**

For a DFIG based wind energy system, the Rotor side converter (RSC) controls the torque and active/ reactive power of the generator while Grid side converter (GSC) controls the DC-link voltage and its AC-side reactive power. The stability of DC link capacitor voltage ensures that a nearly sinusoidal voltage is delivered by the GSC which is used as inverter. The present paper explores the important issues of maintaining the DC link capacitor Voltage value as close as possible to the nominal value of 1150 V and its Reactive Power value as close as possible to 0 Mvar under certain common types of faults.



## Introduction

In the modern era, renewable energy sources have been attracting greater attention due to increased cost, and harsh environmental impact of fossil fuels. The main advantages of generating electricity from renewable energy sources are absence of harmful emissions and infinite availability of the prime mover that is converted into electricity.

In recent years, wind energy has become one of the most important and promising sources of renewable energy, which demands more transmission capacity and better means of maintaining system reliability. Wind energy is advantageous because wind power systems are non-polluting, it avoids fuel provision and transport, and on a small scale up to a few kilowatt system is less costly.

With increased penetration of wind power into electrical grids, doubly fed induction generator wind turbines are largely deployed due to their variable speed features and hence influencing system dynamics. The DFIG system is currently used for multi-MW Wind turbines. DFIG is a popular wind turbine system due to advantages like it can operate in generator and motor mode for both sub and super synchronous speed mode, also speed variation of ±30% around synchronous speed can be obtained, and the size of the converter is related to the selected speed range.

## DFIG Based Variable Speed WECS

Variable speed wind turbines are currently the most used wind energy conversion system (WECS). The doubly fed induction generator (DFIG) based WECS "fig.1", also known as improved variable speed WECS, is presently most used by the wind turbine industry.

DFIG based WECS are highly controllable, allows maximum power extraction over a large range of wind speeds. DFIG is a wound rotor induction generator (WRIG) with the stator windings connected directly through three phase, constant-frequency grid and the rotor windings connected to a back-to-back (AC-AC) voltage source converters (VSC).

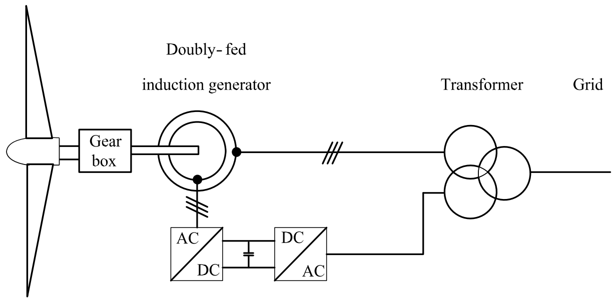


**Figure 1. General Structure of an improved variable speed WECS**

Thus, the term *"doubly-fed" means* that the stator voltage is applied from the grid and the rotor voltage is impressed by the power converter. This system provides variable-speed operation over a large, but restricted range, with the generator behaviour being governed by the power electronics converter and its controllers. The power electronics converter consists of two IGBT converters namely the rotor side converter (RSC) and grid side converter (GSC), connected to a direct current (DC) link. In normal operation, the RSC controls the real and reactive power outputs of the machine. The generator rotor speed increases during a grid voltage dip through control of rotor side converter and the Grid side converter has to transmit the active power from the dc-link to the grid, so that the dc-link voltage is kept within the limits. The Grid side control scheme provides a compensation item, during the faulty conditions to smooth the fluctuations in the grid.

The stator outputs power into the grid at all the time. The rotor, depending on the operation point, feeds power into the grid when slip is negative (over synchronous operation) and it absorbs power from the grid when slip is positive (sub-

**Tele:**
**E-mail addresses: rekhaprasharg@gmail.com**

synchronous operation). In both the cases, the power flow in the rotor is approximately proportional to the slip. The DFIG system therefore operates in both sub and super-synchronous modes with a speed range around the synchronous speed.

**Operating Principle of DFIG**

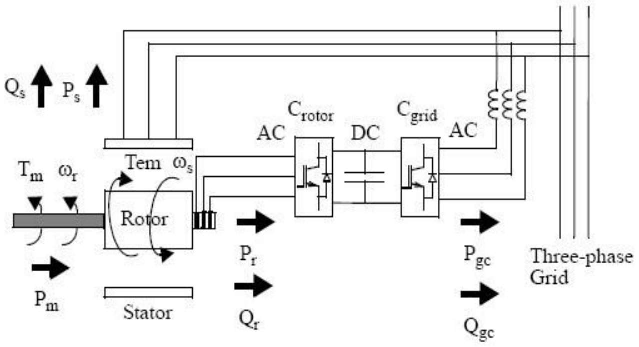


**Figure 2. Power flow diagram of DFIG**

The stator is directly connected to the AC mains while the rotor is fed from the power electronics converter via slip rings to allow DFIG to operate at changing wind speeds. The active and reactive power control is fully decoupled by independently controlling the rotor currents. Finally, DFIG based WECS can either inject or absorb power from the grid, hence it actively participates at voltage control. The slip power can flow in both the directions, i.e. to the rotor from the supply and from supply to the rotor and hence the speed of the machine can be controlled from either rotor or stator side converter in both super and sub-synchronous speed ranges. In the “Fig.2” Crotor and Cgrid have the capability for the reactive power or the voltage at the grid terminals.

**DC Link Voltage Control By PI Controller**

The DC capacitor linking the stator and rotor side converters allows the storage of power from induction generator for more distant generation. To attain full control of grid current, the dc-link voltage must be increased to a level higher than the amplitude of grid line to line voltage.

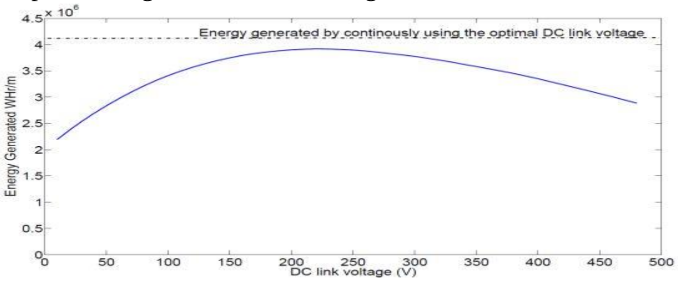


**Figure 3. Energy generated by continuously using the optimal DC link voltage**

**Conventional DC-link Voltage Controller**

Any change in load affects the DC-link voltage directly. The unexpected ejection of load would result in the DC link voltage above the reference value. On the other hand a sudden increase in the load would reduce the DC-link voltage below its reference value. Conventionally, a proportional – integral (PI) controller is used to maintain the dc-link voltage to the reference value. The conventional controller which is used for maintaining the DC-link voltage is shown in “Fig 4.” To maintain the DC link voltage the DC-link capacitor needs a certain amount of Active power, which is proportional to the difference between actual and reference voltages.

$$P_{dc} = K_p(V_{dcref} - v_{dc}) + \frac{K_i}{(V_{dcref} - v_{dc})} dt \qquad (1)$$

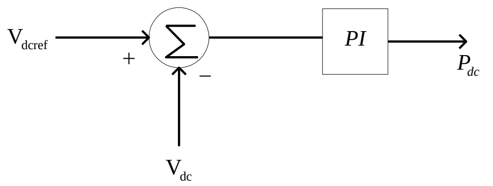


**Figure 4. Schematic diagram of conventional dc-link voltage control**

**MATLAB Simulink Model of DFIG Based Wind Turbine System**

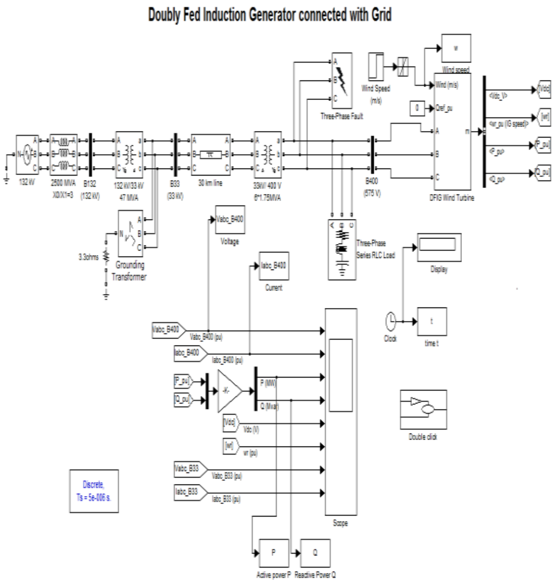


**Figure 5. Matlab Simulink model of DFIG based wind turbine system**

**DFIG With And Without PI Controller Under Faulty And Load Controller**

**DFIG With No Fault, No Load (without PI Controller)**

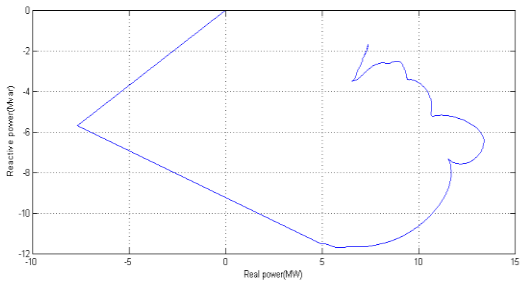


**Figure 6(i). Real power Vs Reactive power**

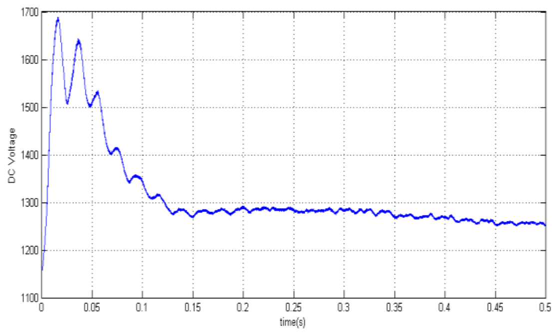


**Figure 6 (ii.) DC Voltage**

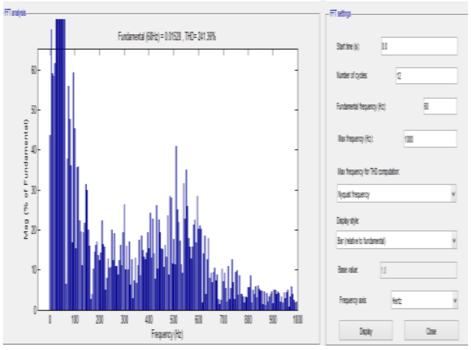


**Figure6 (iii). THD without PI [no fault] 241.36%**

**DFIG with No Load, No Fault (With PI Controller)**

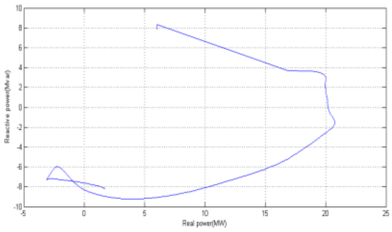


**Figure7 (i). Active power Vs Reactive power**

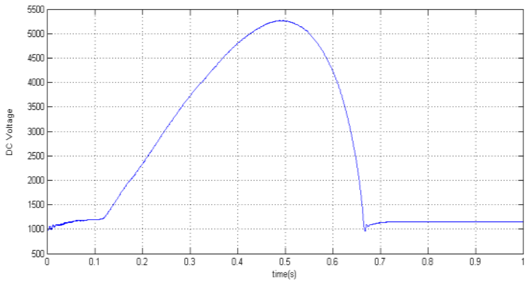


**Figure 7(ii) DC Voltage**

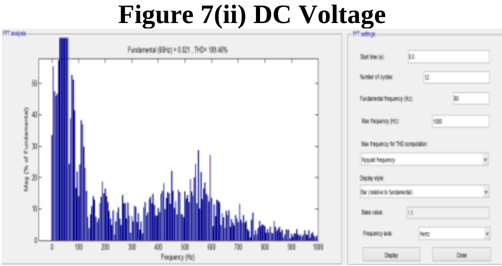


**Figure 7(iii). THD with PI [no fault] 189.46%**

In the Absence of Load and Fault, by these results we can see that with the help of PI controller variations in the active power are reduced and range of reactive power is also less. PI Controller is also useful in reducing the DC Voltage fluctuations and in maintaining its value as close as 1150V. And the Total Harmonic Distortions are also reduced when PI Controller is used.

**DFIG with Load and No Fault (without PI Controller)**

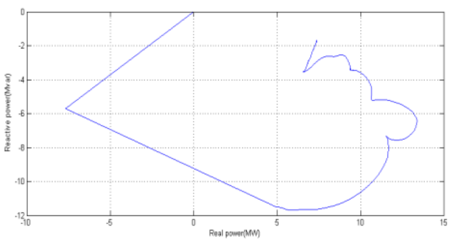


**Figure 8 (i). Real power Vs Reactive power**

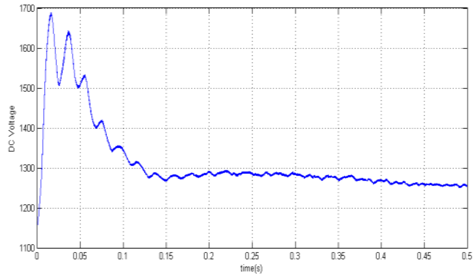


**Figure8 (ii). DC Voltage**

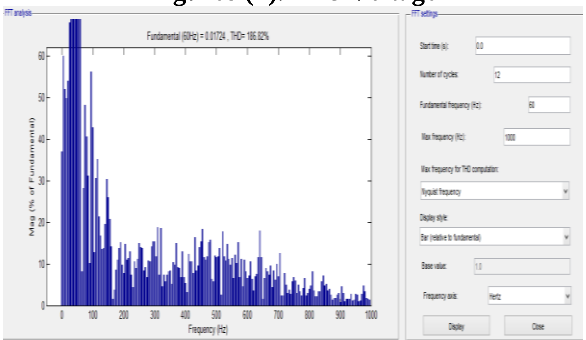


**Figure8 (iii). THD without PI [no fault] 186.82%**

**DFIG With load and no fault (with PI Controller)**

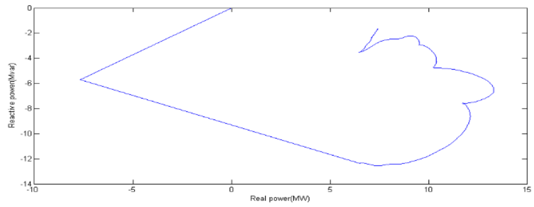


**Figure9 (i). Real power Vs Reactive power**

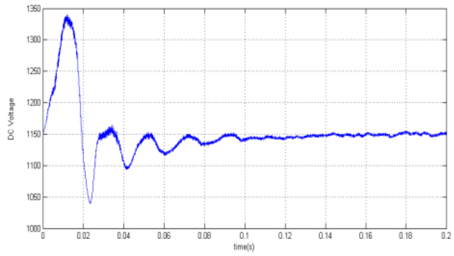


**Figure9 (ii). DC Voltage**

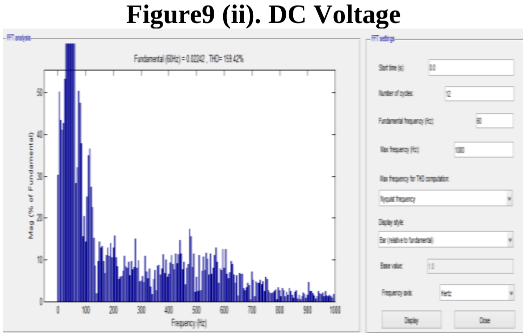


**Figure9 (iii). THD with PI [no fault] 159.42%**

In the Presence of Load and absence of Fault, by these results we can see that with the help of PI Controller Range of Reactive power is less and variations in real power are reduced. PI Controller is also useful in reducing the DC Voltage fluctuations and in maintaining its value as close as possible as 1150V. And the Total Harmonic Distortions are also reduced when PI controller is used.

**Table 1. Fixed Voltage Source**

| | VOLTAGE THD | | |
|---|---|---|---|
| $V_{DC}$ REGULATOR PI IN GSC [NO LOAD] | THD Without PI [no fault] | THD With PI [no fault] | PI Controller is useful in reducing the DC Voltage fluctuations, variations in real power and in reducing the Total Harmonic Distortions. |
| | 241.36% | 189.46% | |
| | | | |
| $V_{DC}$ REGULATOR PI IN GSC [ON LOAD] | THD Without PI [no fault] | THD With PI [no fault] | PI Controller is useful in reducing the variations in real power, DC Voltage fluctuations and in reducing the Total Harmonic Distortions. |
| | 186.82% | 159.42% | |
| | | | |
| $V_{DC}$ REGULATOR PI IN GSC [ON LOAD] | THD Without PI [with 3PH fault] | THD With PI [with 3PH fault] | PI Controller is useful in reducing the DC Voltage fluctuations, variations in real power and in reducing the Total Harmonic Distortions. |
| | 81.71% | 75.26% | |
| | | | |

**DFIG with Load and with 3 Phase Fault (without PI Controller)**

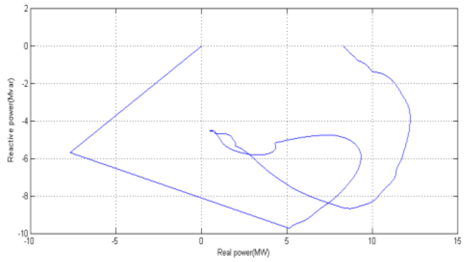


**Figure10 (i). Active power Vs Reactive power**

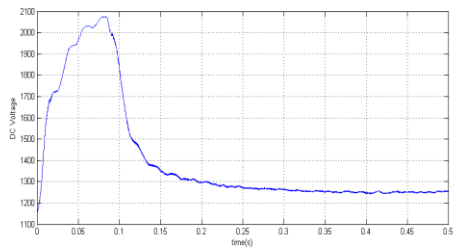


**Figure10 (ii). DC Voltage**

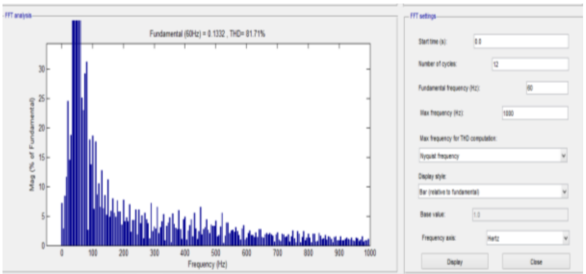

**Figure10 (iii). THD without PI [with 3PH fault] 81.71%**

**DFIG with Load and With 3 Phase Fault (with PI Controller)**

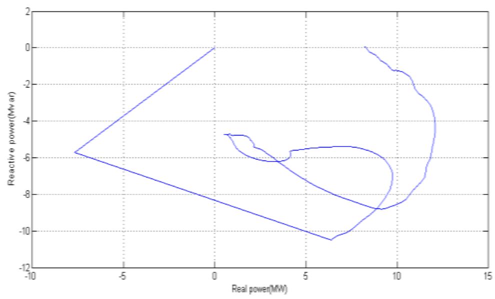


**Figure 11(i). Real power Vs Reactive power**

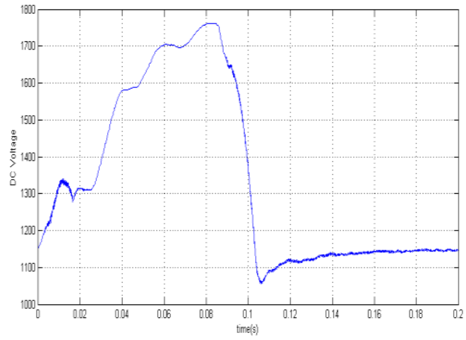


**Figure 11(ii). DC Voltage**

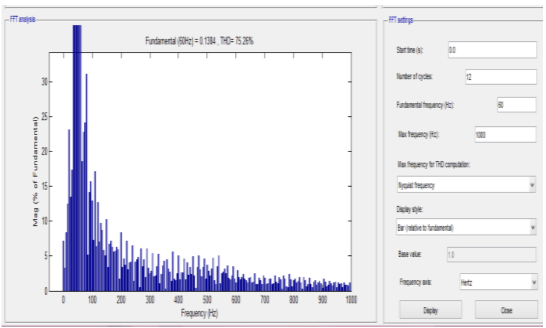

**Figure 11(iii). THD with PI [with 3PH fault] 75.26%**

In the Presence of Both Load and Fault, by these results we can see that PI Controller is useful in reducing the DC Voltage fluctuations and in maintaining its value as close as 1150V and the total harmonic distortions are also reduced. PI Controller is also useful in reducing the variations in real power and range of reactive power is also less.

The comparison of the results is shown in the form of a table.

**Conclusion**

The fluctuations in the DC-link voltage cut down the lifetime and reliability of capacitors in voltage source converters. The present paper explores one of the extremely important issues regarding the WECS i.e. wind energy conversion system and its reactive power management under Faulty and Load conditions. With continuously increasing penetration of the wind energy in the overall energy market, this issue is gaining significant prominence. The paper compares the capability of WECS using a DFIG to maintain its DC Voltage value as close as possible to the value of 1150 V. By comparing the results it was found that PI Controller is useful in reducing the THD i.e. Total harmonic distortions and in also reducing the

DC Voltage fluctuations and maintains its value as close as possible to value of 1150V. With the help of PI Controller real power variations were also reduced and range of reactive power variation was found also less. The simulation was performed for normal, symmetric fault, and load conditions on DFIG integrated with grid under MATLAB/ SIMULINK.

**References**

[1] Lihui Yang, Zhao Xu, Jacob Ostergaard, Zhao Yang Dong, kit Po Wong, “Advanced Control Strategy of DFIG Wind Turbines for Power System Fault Ride Through,”IEEE Transactions On Power System, Vol.27, No.2, May 2012.

[2] D. Burnham, S. Santoso, and E. Muljadi, Variable-Rotor Resistance Control of Wind Turbine Generators, in IEEE Power and Energy Society General Meeting (PES), 2009.

[3] D. Elhert, and H. Wrede, Wind Turbines With Doubly-Fed Induction Generator Systems With Improved Performance Due To Grid Requirements, in IEEE Power Engineering Society General Meeting , pp. 1-7 , 2007.

[4] W. Sadra and B. Neammanee, Implementation of a Three Phase Grid Synchronization for Doubly Fed Induction Generators In Wind Energy System, In 2010 International Conference On Electrical Engineering / Electronics Computer Telecommunications And Information Technology (ECTI-CON), pp. 1016-1020, 2010.

[5] Y. Lang, X. Zhang, D. Xu, S.R. Hadianamrei, and Ma Hongfei, Stagewise Control of Connecting DFIG to the Grid, in Proceeding of 2006 IEEE International Symposium on Industrial Electronics (ISIE) , pp. 11129-11133, 2006.