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Simulation of Wind Turbine Driven DFIG Using AC-DC-AC Converter

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ABSTRACT: To harness the alternative energy with efficiency the foremost reliable system within the gift era is grid Connected doubly-fed induction generator (DFIG). The DFIG brings the advantage of utilizing the turns ratio of the machine, that the converter doesn't have to be compelled to be rated for the machine's full rated power. The rotor side converter (RSC) typically provides active and reactive power management of the machine whereas the grid-side converter (GSC) keeps the voltage of the DC-link constant. The extra freedom of reactive power generation by the GSC is typically me times not used because of the actual fact that it's additional desirable to try and do so victimization the RSC. However, inside the obtainable current capability, the GSC is controlled to participate in reactive power generation in steady-state likewise as throughout low voltage periods. The GSC will offer the specified reactive current terribly quickly whereas the RSC passes the present through the machine leading to a delay. This report deals with the introduction of DFIG, AC-DC-AC converter control, and eventually, the SIMULINK/MATLAB simulation for grid-connected Doubly Fed Induction Generator and corresponding results and waveforms are shown.

KEYWORDS: DFIG, IGBT WG, AC-DC-AC Converter.

I. INTRODUCTION

The finite nature of fossil fuels and the dangers faced regarding climate-changing are two more factors contributing to the development of renewable energy sources. This paper focuses on wind energy since it is considered to be one of the most promising alternative energy sources with great potential. The wind is created when air masses are heated by the sun and as a consequence of the fact that air pressure changes from place to place. The constant movement of these air masses, which struggle to achieve thermal balance, is caused by sun radiation as long as by the earth rotation and topography. Wind energy is the transformation of the wind kinetic force into mechanical power using a turbine. The mechanical power is converted into electricity by the generator which is fed into the common grid.

In a more detailed approach, actual converter representation with the PWM-averaged model has been proposed, where the switch network is replaced by an average circuit model, on which all the switching elements are separated from the remainder of the 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 a 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. To maintain the switching frequency constant, a switch-by-switch model of voltage-fed, current-controlled PWM converters, where triangular carrier-based Sinusoidal PWM (SPWM) is applied. In order to achieve constant switching frequency, the calculation of the required rotor voltage that must be supplied to the generator is adopted. Various methods such as the hysteresis controller, stationary PI controller, and synchronous PI controller have been adopted in order to control the current-regulated induction machine. Among these, the synchronous PI controller has been acknowledged as a superior one. The harmonics injected in the grid are canceled by the RSC and the current of a non-linear load connected to the network is measured. Reactive power required to support the grid and compensating harmonic currents are injected in the generator by the rotor-side converter. It is not clear about the long-term consequences of using the DFIG for harmonic and reactive power compensation.

Types of Wind Turbines

Wind turbines are classified into two main types: horizontal axis and vertical axis. A horizontal axis wind turbine has its blades rotating

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on an axis parallel to the ground while a vertical axis machine has its blades on an axis perpendicular to the ground. Each type has certain advantages and disadvantages. Horizontal axis configuration with two or three blades is used in the modern wind turbines.

The horizontal axis wind turbine design incorporates multi-blade propellers that rotate around a horizontal axis parallel to the ground. The axis of blade rotation is parallel to the wind flow and ground. Some machines are designed with the blades upwind of the tower to operate in an upwind mode. In this case, a tail vane is normally used to keep the blades facing into the wind. Other designs operate in a downwind mode so that the wind passes the tower before striking the blades. Some very large wind turbines use a motor-driven mechanism that rotates the machine in response to a wind direction sensor mounted on the tower.

The vertical axis wind turbines are not as common as the horizontal axis ones. The main reason for this is that they do not take advantage of the higher wind speeds at higher heights above the ground as well as horizontal axis turbines do. Since the shaft is vertical, the transmission and generator can be mounted at ground level allowing easier servicing and lighter weight, lower-cost tower. Although vertical axis wind turbines have these advantages, their designs are not as energy efficient as are the horizontal machine designs.

An advantage of the DFIG is the generator can control the reactive power by controlling independently the rotor current. There is no need for a full-scale converter because the stator is directly linked to the grid. Thus, the converter is rated approximately 30% of the nominal power of the generator, minimizing both assembly losses and cost. In this point, a small reference on each one of them is being made, but a thorough analysis is avoided because this would exceed the limits of this paper, the topology selected for this paper is Variable speed with partial scale frequency converter.

II. BASIC OF DOUBLY FED INDUCTION GENERATOR

An AC-DC-AC IGBT-based PWM converter and a wound rotor induction generator are present in a doubly-fed induction generator (DFIG) in the wind turbines as shown in fig.1. The rotor of the induction generator is fed at variable frequency through the AC-DC-AC converter while the stator winding is connected directly to the 60 Hz grid. The turbine speed which produces maximum mechanical energy for a given wind speed depends on the wind speed. During gusts of wind, the DFIG technology minimizes the mechanical stresses and also extracts the maximum energy from the wind.

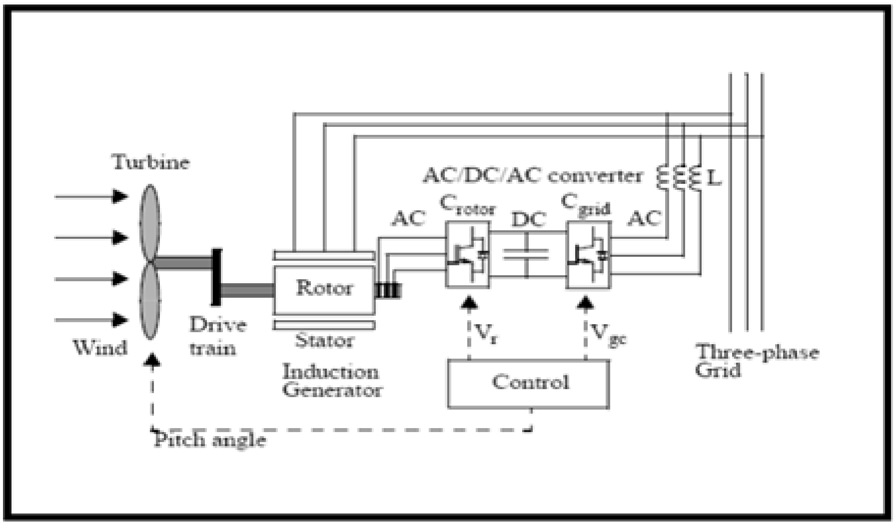

Figure-1: **Basic Diagram of DFIG with convertors.**

The major advantage of the DFIG technology is to generate or absorb reactive power by power electronic converters, thus eliminating the need for installing capacitor banks as in the case of squirrel-cage induction generator. To reduce the harmonics, present in the wind turbine which is driven DFIG system, the AC-DC-AC converter which uses a sinusoidal PWM technique is used. Gearboxes or electronic control can be used to control the speed of the wind turbine.

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Modelling of Power Electronic Converters in Wind Generators

Power electronic converters with PWM switching frequencies in the range 1 to 5 kHz use modern WGs (type-III and IV). The simulation of PWM switching is very demanding for electromagnetic transient's(EMT) simulation since each switching implies matrix manipulation that is very costly in computation time. Two different approaches were implemented, instead of a detailed switch model, The average model and the switching-function model are identified.

In the average model, the converter is represented by a 3-phase controlled voltage source. These sources are driven by the control voltages of the PWM converters. The AC power flowing in or out the converter must be kept equal to the DC power so that the capacitor voltage variation is considered. There is no change in circuit topology and switching in the average converter model as such the simulation speed is fast. Time step as large as 20-50 µs can be used to conduct various power system studies as harmonics are not represented.

III. DYNAMIC SIMULATION OF DFIG IN TERMS OF DQ-WINDING

The following equations represent modeling of induction generators.

1. Voltage equations:

Stator Voltage Equations:

$v_{qs} = p\,\lambda_{qs} + w\lambda_{qs} + T_s i_{qs}$

$v_{ds} = p\,\lambda_{ds} + w\lambda_{ds} + T_s i_{ds}$

Rotor Voltage Equations:

$v_{qr} = p\,\lambda_{qr} + (w-w_r)\lambda_{dr} + T_r i_{qr}$

$v_{dr} = p\,\lambda_{dr} - (w-w_r)\lambda_{qr} + T_r i_{dr}$

2. Power Equations:

$P_s = 3/2 * (v_{ds} i_{ds} + v_{qs} i_{qs})$

$Q_s = 3/2 * (v_{qs} i_{ds} - v_{ds} i_{ds}$

3. Torque Equation:

$T_s = -3p/4 * (\lambda_{ds} i_{qs} - \lambda_{qs} i_{ds})$

4. Flux Linkage Equations:

Stator Flux Equations:

$\lambda_{qs} = (L_{ls} + L_m) i_{qs} + L_m i_{qr}$

$\lambda_{ds} = (L_{ls} + L_m) i_{ds} + L_m i_{dr}$

Rotor Flux Equations:

$\lambda_{qr} = (L_{lr} + L_m) i_{qr} + L_m i_{qs}$

$\lambda_{dr} = (L_{lr} + L_m) i_{dr} + L_m i_{ds}$

IV. WIND GENERATOR MODEL AND SIMULATION OF DFIG WIND TURBINE

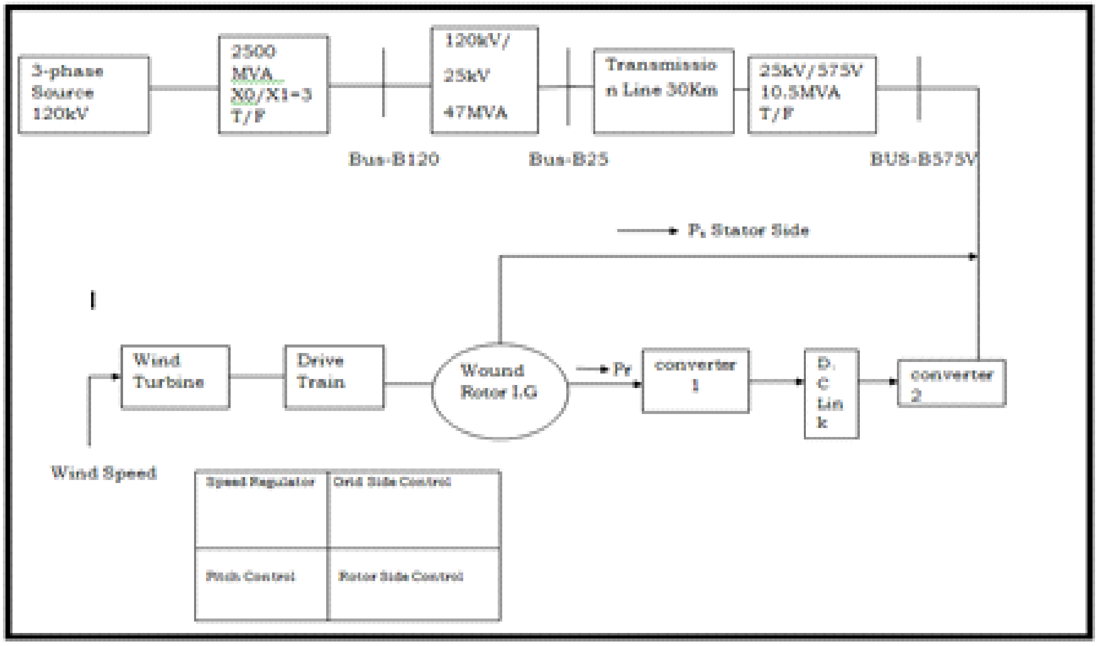

Figure-2: Block Diagram

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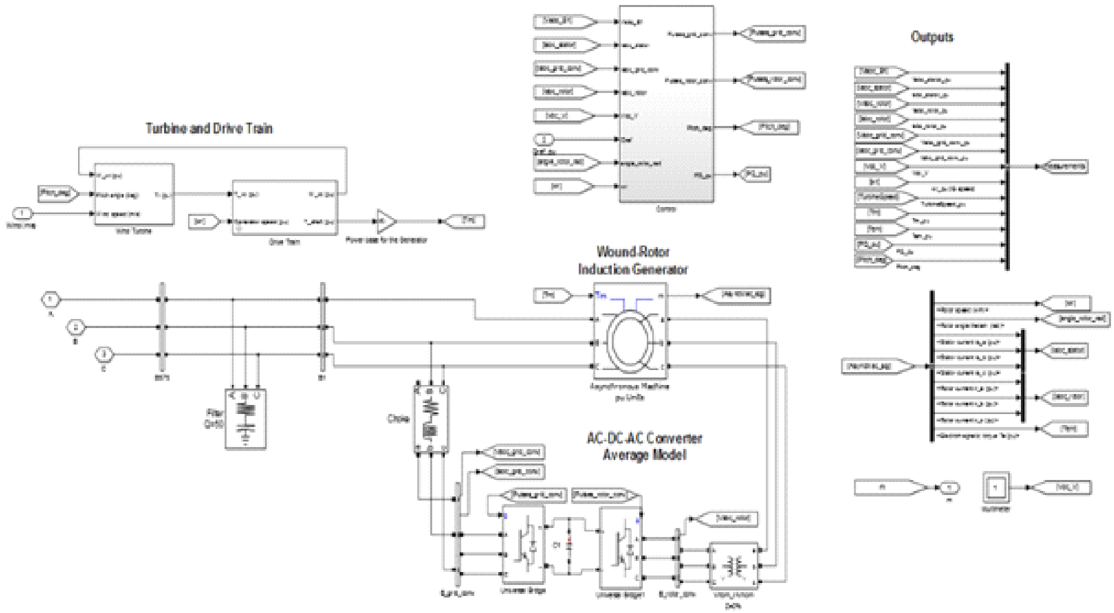

Figure-3: Simulation of DFIG wind turbine

V. ARIOUS BLOCK PARAMETERS OF SIMULINK DIAGRAM

1.120 kV Source Parameters

- V_{rms} (Ph-Ph) = 120kV
- Frequency = 60hz

2. 120/25 kV Y-Δ Transformer Parametres

- Power = 47 MVA
- R_m = 500 pu
- L_m = 500 pu

3. Transmission Line Parameters

- $[R_1\ R_0]$ = [0.1153 0.413]
- $[L_1\ L_0] = [1.05*10^{-3}\ \ 3.32*10^{-3}]$
- $[R_1\ R_0] = [11.33*10^{-6}\ \ 5.01*10^{-6}]$
- Line Length = 30km

4. 25kV/575V 1.75MVA Δ-Y Transformer

- R_m = 500 pu
- L_m = infinity

5. Universal Bridge Parameters

- R_s = 1000 ohms
- C_s = infinity
- $R_{on} = 10^{-4}$ ohms

6. DFIG Wind Turbine

- No of Wind Turbines = 1
- DC Bus Gains $[K_p\ K_i]$ = [8 400]
- Current Regulator Gains on Grid Side Converter $[K_p\ K_i]$ = [0.84 4]
- Speed Regulator Gains $[K_p\ K_i]$ = [3 0.5]
- Rotor Side Converter $[K_p\ K_i]$ = [0.6 8]
- Q and V Regulator Gains $[K_p\ K_i]$ = [0.05 20]
- Pitch Controller gain $[K_p]$ = 150
- Pitch Compensation Gain $[K_p\ K_i]$ = [3 30]
- Frequency of Grid side converter = 2700 Hz
- Frequency of Rotor side converter = 1620 Hz
- Maximum Pitch Angle = 27 degrees
- Sample Time = 0.5 micro sec

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VI. RESULTS

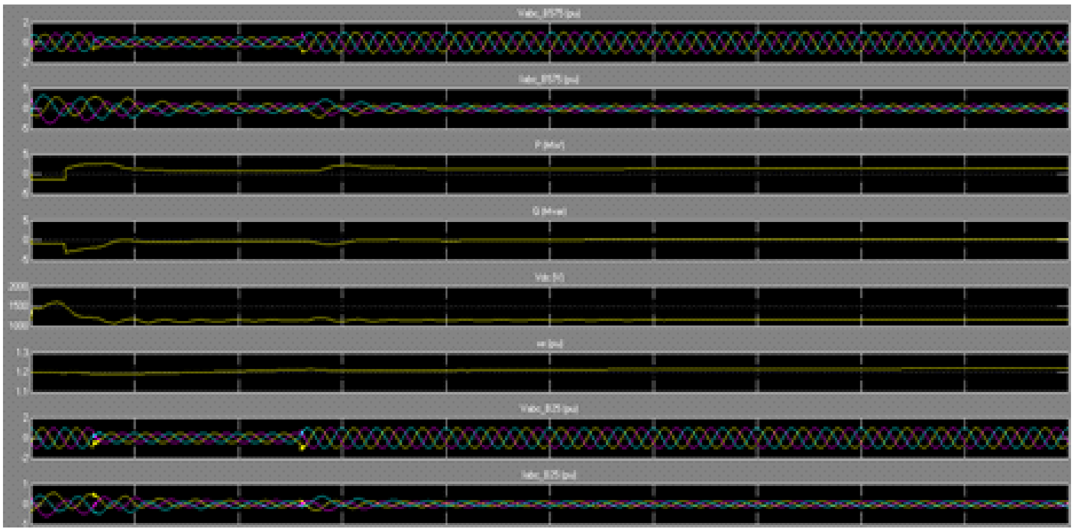

Figure-4: Various Graphs observed across Scope

Table: Values of Active Power Generated for Different Wind Speeds

S.no	Wind Speed (m/s)	Active Power Generated in Mw
1	1	1.038
2	9	1.175
3	11	1.282
4	13	1.401
5	14	1.445
6	16	1.543

VII. CONCLUSION

The basic operation of DFIG and its controls using AC-DC-AC Converter is analysed. The DFIG system which is connected to the grid side has better control and high efficiency. The grid-side converter (GSC) keeps the voltage of the DC-link Constant while the rotor side converter (RSC) provides active and reactive power control of the machine. Grid side and wind turbine side parameters are simulated and the results are displayed. Wind Turbine Doubly-Fed Induction Generator is a discrete-time version model. When compared to the grid side converter it is proved that the doubly-fed induction generator is a more reliable and stable system.

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