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DFIG Based Wind Turbine under Fault Conditions

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ABSTRACT: This paper gives study of DFIG based wind turbine power generation system. The proposed system reliability connected to grid under fault conditions is demonstrated in MATLAB/Simulink software. A wound type rotor based induction generator and back-to-back IGBT based converter used for design of DFIG. The proposed system has capability of generating maximum energy under low speed wind conditions. The control system was designed for pitch angle control, wind turbine power, DC bus voltage, grid voltage and reactive power control.

KEY WORDS*:* DFIG, wind turbine, fault analysis, pitch angle control, FFT analysis.

I.INTRODUCTION

Wind energy systems are the fast expanding and greater rising sustainable energy source between them due to financially practicable. In India, which is the huge greenhouse gas releasing country after the US and the China, renewable energy at present achieves about 16% of the total fixed size of 315,426MW. Various applications of wind power were found in a wide power range i.e., from a few kilowatts to several megawatts in the small scale off-grid standalone systems or one of the wind farms, named as large scale grid-connected wind farms.

Doubly-fed induction machines receives the rising observation for wind energy conversion system during such situation, because the main advantage of such machines is that, if the rotor current was determined by applying the field orientation control-carried out by using commercial double sided PWM inverters, decoupled control of the stator side active and the reactive power results and the power handled by the power converter was only a small fraction of the total system power [1]. With the rising penetration of wind-derived power in interconnected power systems, it becomes necessary to model the complete wind energy systems, in order to study their impact and also to study the wind power plant control [5]. Through the model which was developed in this paper, used for simulating all types of the induction generator configurations. The choice of synchronous rotating reference frame makes it especially suitable for the simulation of doubly-fed configuration in transient conditions. A complete simulation model has developed for such machine using MATLAB Simulink software [2].

II. WIND-TURBINE DOUBLY-FED INDUCTION GENERATOR

The wind turbine and the doubly-fed induction generator are shown in Fig. 1. The AC/DC/AC converter was basically divided into two components. They are: (i)The rotor-side converter and (ii) The grid-side converter. From the fig., Crotor and Cgrid are Voltage-Sourced Converters which use forced-commutated power electronic devices (IGBTs) to combine an AC voltage from a DC voltage source. A capacitor which was connected on the DC side, acts as the DC voltage source [3].

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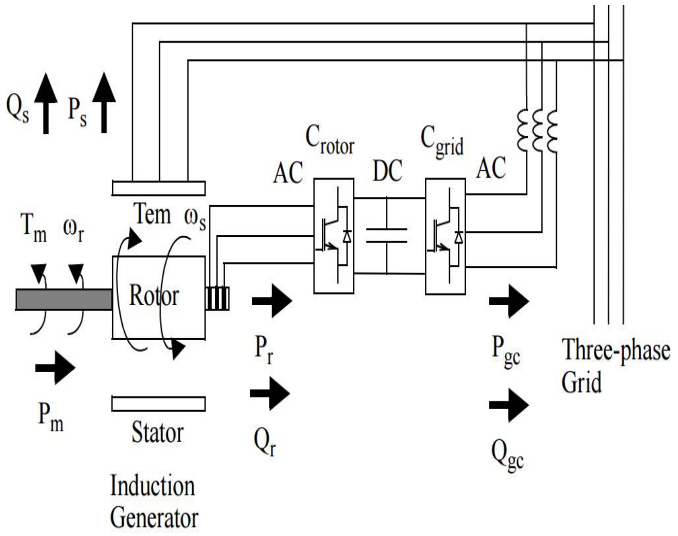

Fig 1: The wind turbine and the DFIG system (Power Flow)

The power which was captured by the wind turbine gets converted into electrical power by the induction generator and it transmitted to the grid by the stator and the rotor windings. The control system produces the pitch angle command and the voltage command signals V_r and V_{gc} for C_{rotor} and C_{grid} respectively in order to control the power of the wind turbine, the DC bus voltage and the voltage at the grid terminals [4].

The power flow, illustrated in Fig. 1, used to represent the operating principle. The mechanical power and the stator electrical power output are calculated as follows:

$$Pm = Tm * wr \quad \text{.....................} \quad 1$$

$$Ps = Tem * ws \quad \text{..............} \quad \text{.....2}$$

For a lossless generator, the mechanical equation is:

$$(dwr/dt) = Tm * Tem \quad \text{..............} \quad 3$$

In steady-state at fixed speed, for a lossless generator

$$Tm = Tem \text{ and } Pm = Ps + Pr \quad \text{........... .4}$$

It follows that:

$$Pr = Pm - Ps$$

$$Tm * wr - Tem * ws = -sPS \ldots\ldots\ldots .5$$

Where s = (ωs-ωr)/ωs was defined as the slip of the generator.

III. RSC AND GSC CONTROL SYSTEMS

3.1. Rotor Side Converter Control System

The rotor-side converter, used to control the wind turbine output power and the voltage measured at the grid terminals. The actual speed of the turbine ωr was measured and the corresponding mechanical power of the tracking characteristic, used as the reference power for the power control loop. The power control strategy was depicted in Fig. 2. For the rotor-side controller, the d-axis of the rotating reference frame used for d-q transformation was aligned with air-gap flux. The actual electrical output power, measured at the grid terminals of the wind turbine, was added to the total power losses and compared with the reference power obtained from the tracking characteristic .API controller which was used to compensate thepower error to zero. The output of this controller was the reference rotor current Iqrref that might be injected in the rotor by converter Crotor [6].

This is the current component which produces the electromagnetic torque Tem. The actual Iqr component was compared to Iqrref and the error that was reduced to zero by a current regulator (PI). The output of this current

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controller was the voltage Vqr generated by Crotor. The current regulator was assisted by feed forward terms which predict Vqr.

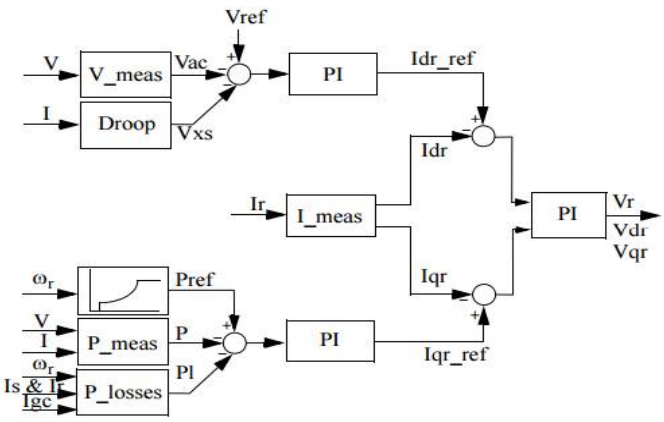

Fig 2: Rotor side converter control system

The voltage at grid terminals was controlled by the reactive power generated or absorbed by the converter Crotor .The reactive power which was exchanged between Crotor and the grid, through the generator. In the exchange process, the generator absorbs reactive power to supply its mutual and leakage inductances. The excess of reactive power has sent to the grid or to Crotor.

3.2. Grid side converter control system

The grid side converter was used to control the DC bus capacitor voltage .The control system was appeared in Fig 3. The grid-side controller which was designed as the d-axis of the rotating reference frame can be used for d-q transformation and was aligned with the positive sequence of grid voltage. The GSC controller includes the measurement of AC currents dq parameters that was to be controlled and Vdc. The GSC voltage magnitude and phase was controlled by the inner current controller by using reference current signal from DC voltage regulator [7].

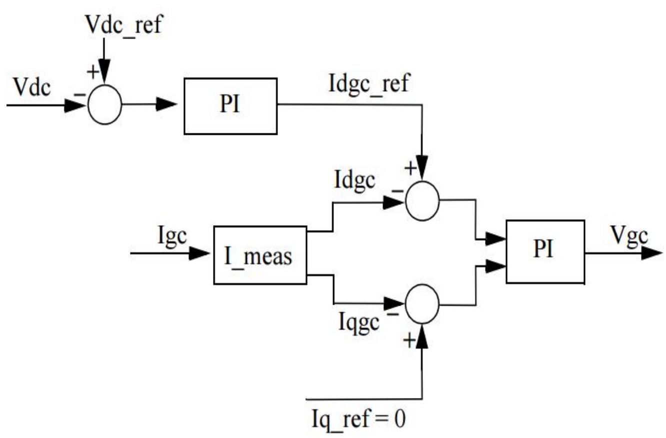

Fig 3: Grid side converter control system

3.3. Pitch angle controller

A Proportional-Integral (PI) controller was used to control the blade pitch angle in order to limit the electric output power to the nominal mechanical power. The pitch angle has kept constant at zero degree, when the measured electric output power came below its nominal value [8]. When it increases above its nominal value, the PI controller expands the pitch angle to bring back the measured power to its nominal value. The control system has given in fig 4.

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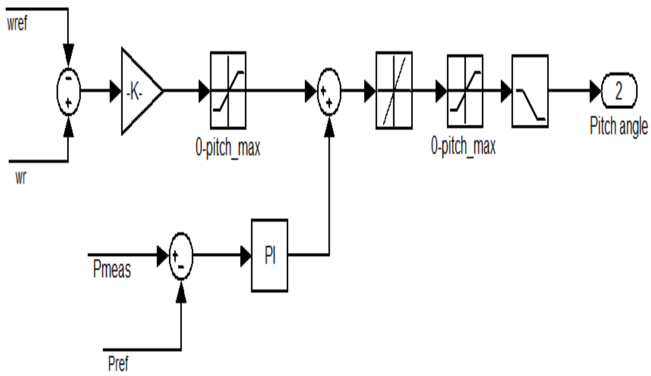

Fig 4: Pitch angle controller

IV. SIMULATION RESULTS

The simulation has done on 10 MW DFIG wind turbine. The DFIG based wind turbine was interconnected to grid of 120 kv system through the 25kv distribution line .A wound rotor type asynchronous generator and the back-to-back converters that are used to design Doubly Fed Induction Generator. Stator winding of induction generator was connected to grid through the distribution line and the rotor winding connected to PWM converters. The DFIG has an advantage of generating maximum power, below the oscillating conditions. The simulation design of proposed model has shown in fig 5. The systems that were simulated under constant wind speed of 15 m/s. The electromagnetic torque controller was used to maintain speed at constant value. The output power of the wind turbine is 1 pu at the estimated speed for wind speed of 15 m/s.

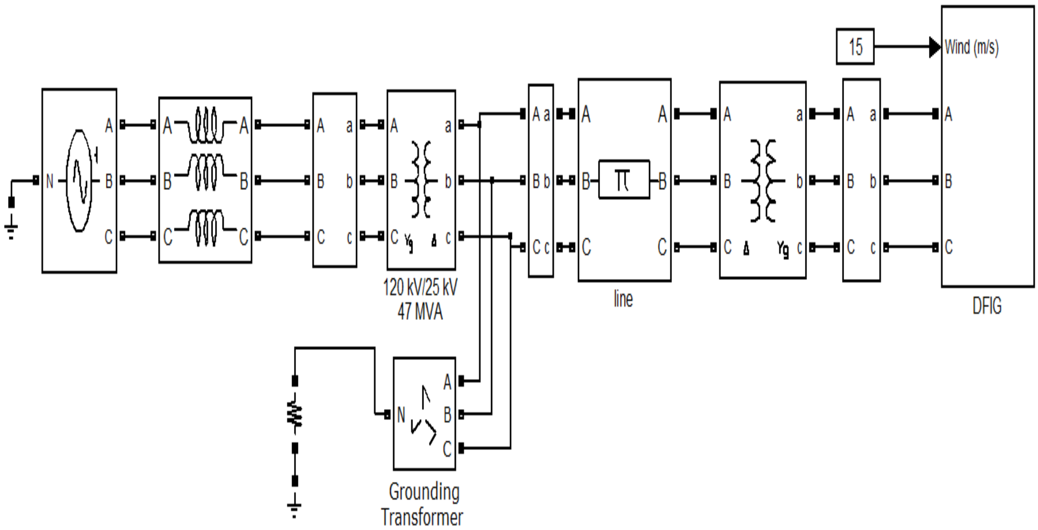

Fig 5: Simulation circuit of DFIG based WECS.

Initially, the system starts with steady-state condition by generating 9 MW. The dynamic response of the system gets verified by generating fault in the interconnected grid. The amplitude of the voltage source has reduced to half of its actual value i.e., from 0.2 to 0.3 sec in the grid.

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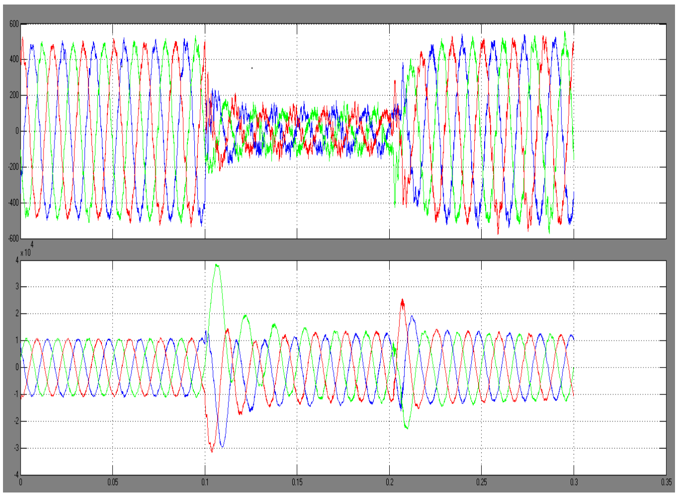

Fig 6: DFIG voltage and current

From fig 6., it was observed that, at the simulation time of 0.2 sec, the magnitude of voltage has dropped to 300 V i.e., from initial peak value of 500 V. But the system has started to recover oscillations from 0.25 sec.

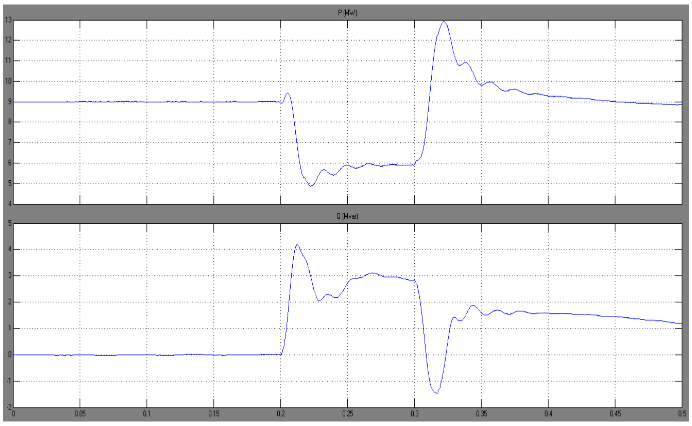

Fig 7: Active and reactive power

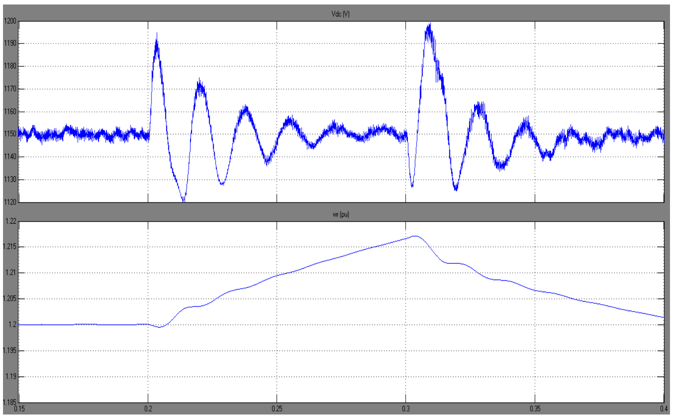

Fig 8: DC link voltage and rotor speed

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DC link voltage of the PWM converters was shown in figure 8. It was clearly observing that DC voltage was constant upto 0.2 sec at a value of 1150 V. It was observed that the dc link voltage gets started oscillating from 0.2sec due to the declining of grid voltage requirement to half of the amplitude. But after four cycles, the DC voltage was balanced to it's normal value due to the DC voltage controller in Grid Side Converter controller (see Fig 3). The rotor speed gets increased to 1.22 pu, during the fault time between 0.2-0.3sec by pitch controller (see Fig 4).

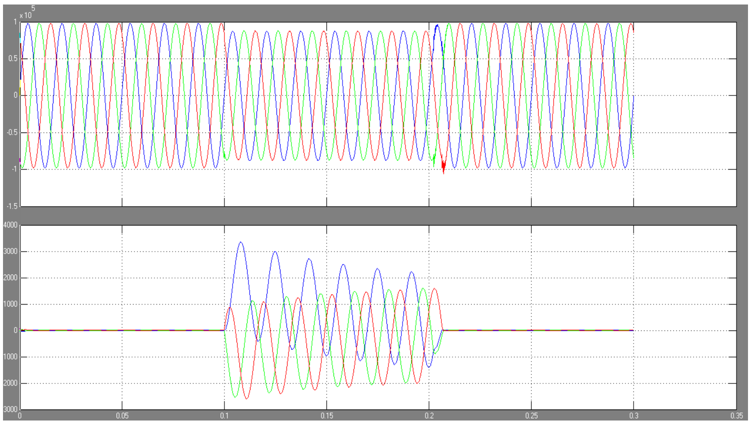

Fig 9: Grid voltage and current

It was clearly observed that the grid voltage was constant through-out the fault time i.e.,0.2-0.3sec. But the current which was getting fluctuation upto four cycles, then,after it was balanced to initial steady-state conditions.

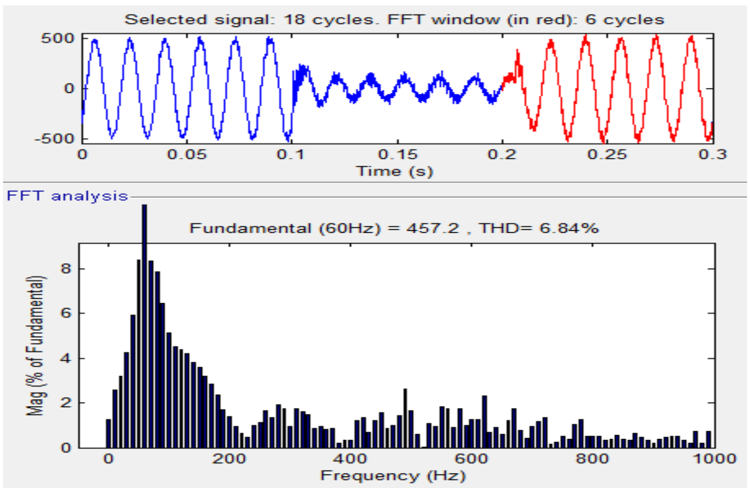

Fig 10: FFT analysis of DFIG voltage between (0.1-0.2) sec (6.84%)

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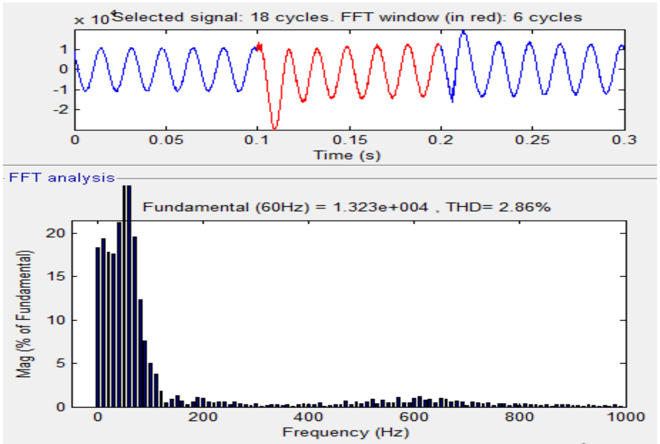

Fig 11: FFT analysis of DFIG current between (0.1-0.2) sec (2.14%)

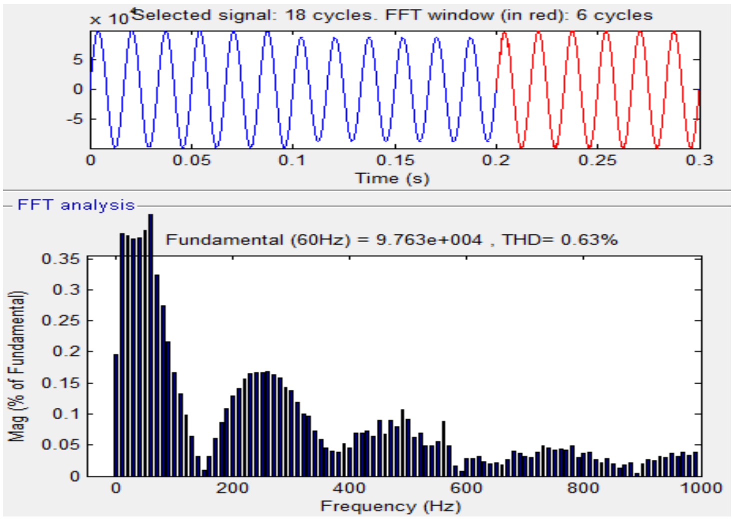

Fig 12: FFT analysis of Grid voltage between (0.1-0.2) sec (0.63%)

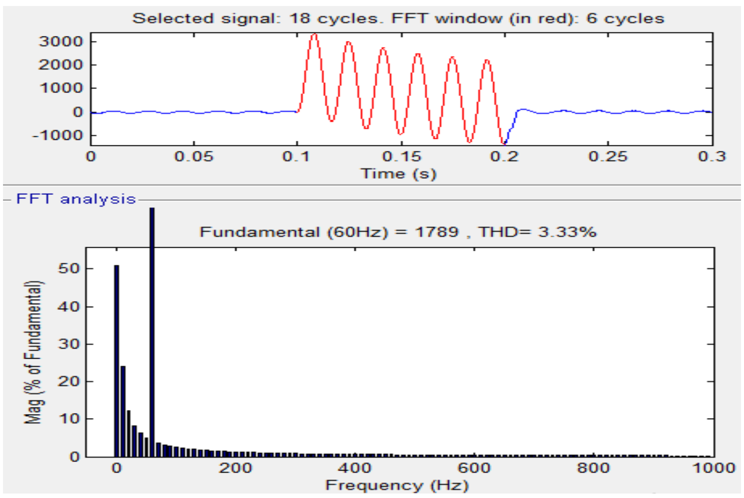

Fig 13: FFT analysis of Grid current between (0.1-0.2) sec (3.33%)

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From figures: 10, 11, 12 and 13, FFT analysis of DFIG voltage and currents and Grid voltage and current appeared that the Total Harmonic Distortion (THD) was decreased from first six cycles to second three cycles during the fault condition i.e., from 0.1 to 0.2 sec.

V.CONCLUSION

The modelling and the simulation analysis of Doubly Fed Induction Generator has conveyed in this paper. The dynamic modelling of DFIG based wind turbine was described in section 2. DC link voltage balancing was achieved by DC voltage controller. Steady-state and dynamic performances of DFIG interconnected to grid were mentioned using FFT analysis of DFIG voltage and currents and grid voltage and currents. The performance analysis of proposed technique has done in MATLAB/SIMULINK simpower systems software.

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