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Symmetrical Fault Analysis of Wind Generator under Heavy Load Condition

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Abstract

The expansion in the limit of wind turbines and improvement has accomplished a surprising high amid the most recent decade. The matrix associated breeze ranch must be ready to give quality power and just as grid dependability must be kept up with new guidelines and network code. It is a general practice to consider the power nature of network associated breeze ranch framework alongside its aggravation and how it influences the matrix to which it is associated. In this paper a near investigation of various breeze ranches and their framework associated exercises alongside PI-direct controller has been illustrated. A near investigation of wind turbine execution has been shown in this paper. Matlab Simulink demonstrates has been utilized for displaying of the framework and to concentrate on the execution of framework under matrix aggravations.

Index Terms: *Power Quality, PI, Linear Controller, Squirrel Cage Induction Generator, FSIG, DDSG*

1. INTRODUCTION

Power Plant bolstered renewable energy system has despite of quantities of pros and cons, reaping power from wind energy. Improvement in the field of wind vitality is by all accounts a developing industry despite the fact that it is encompassed by numerous issues. In our nation wind ranches are increasingly prominent in town or remote territory where there is an almost no entrance of power or separated zone from power [1]. These inexhaustible sources when coordinated with conventional matrix some of the time causes various aggravations and furthermore influences the power quality. It is beneficial to note here that the conventional framework or substation are not furnished with the programmed voltage controllers and there by influencing the Reactive power which at times prompts the vacillation of Voltage and Phase Angle and along these lines causing the power blackout. Along these lines it is required to think about the impact of Wind turbine interconnection with the Power matrix and their conduct amid consistent and just as transient condition. The greater part of the inverter utilizes voltage source inverter topology to interconnect the sustainable sources to the matrix and in this manner keeping up the framework synchronization and security [2].

In India the majority of the breeze ranch utilizes Fixed Speed Induction Generator (FSIG) for changing over the breeze vitality into power. There are fundamentally three kinds of wind generator framework which are generally utilized. Fixed speed wind turbine generator with a rigging box and SCIG which are associated with the network. In this sort of framework there is no influence over the yield age level. The aggregate sum of age will be specifically feed to the framework. The second sort of wind ranch utilizes a variable speed type wind turbine with a rigging box and a converter feed by input way from framework to the stator winding. Here the power rating of the believer is normally 30% of the generator limit. The third sort comprises of a PMSG and a full controlled electronic converter. While taking a choice about the best wind ranch under specialized thriving it is beneficial to note here that the decision of introducing the breeze turbine relies on its breeze speed and height of the zone [3]. There are several research papers on the dynamic re-enactment of wind ranch and their conduct.

2. WIND TURBINE TECHNOLOGY

2.1 SCIG Type

This is the most straight forward kind of wind turbine where the rotor is coupled to SCIG through a rigging box. Here the generator is specifically associated with the matrix this is because of the little variety of rotor slip. This component empowers it to work as a steady speed gadget and can ready to draw responsive power under consistent speed of activity. Pitch edge control is regularly connected to SCIG type wind turbine for assurance against the haul out torque created on the rotor shaft amid unequal breeze speed[4].

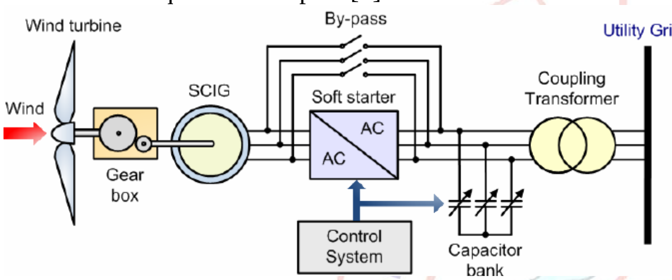

Fig.1. Squirrel Cage Type Induction Generator connected via a AC to AC Converter to the Grid

2.2 Doubly Fed Induction Generator

Doubly Fed Induction Generator (DFIG) utilizes a consecutive voltage hotspot for sustaining the rotor of Induction Generator. Because of variety in the Rotor speed in view of wind weight, an apparatus box is normally associated between the rotor and Induction generator. Here the rotor winding is associated with the Rotor Side Converter and the opposite side is associated with Generator Side Converter. As in light of the fact that the power hardware just procedure the rotor control, regularly under 25% of the general yield control, the DFIG offers the upsides of speed control with diminished expense and power misfortunes. So as to seclude the rotor circuit from the grid side converter a decoupled capacitor is normally associated between the RSC (Rotor Side Converter) and GSC (Grid Side Converter). The power factor of GSC is typically kept up at Unity Power Factor and in this way empowering the converter not to partake in the receptive power trade program [5].

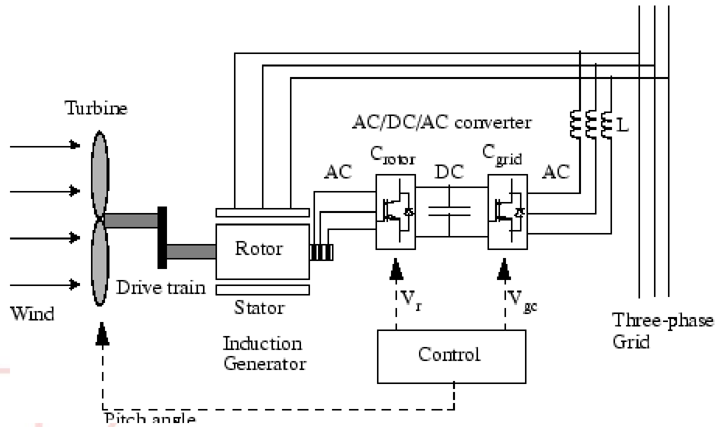

Fig.2. Block Diagram of Doubly Fed Induction Generator (DFIG) connected to Three Phase Grid

2.3 PMSG Type Wind Turbine

Permanent Magnet Synchronous Generator (PMSG) type wind turbine more often than not reacts to Variable breeze Speed. It utilizes two IGBT based consecutive converter specifically Machine Side Converter (MSC) and Grid Side Converter (GSC) by means of a typical DC Link. The rating of the Converter framework reacts to the appraised intensity of generator in addition to misfortunes. Stator side converter is intended to work at its greatest pinnacle and along these lines removing Maximum Amount of Power from the Generator, while the Grid Side Converter for the most part keeps up a consistent DC level for inverter task. Steady DC source activity by Grid Side Converter empowers it to trade the responsive power with the grid [6].

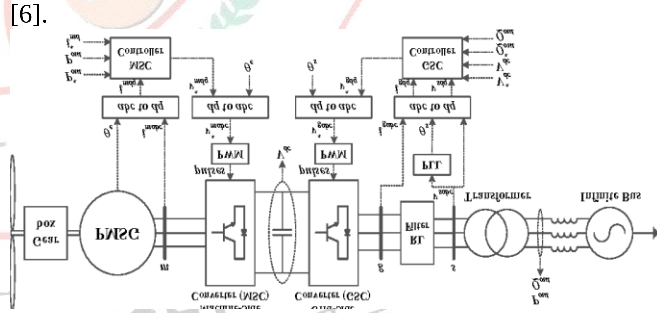

Fig.3. General Structure of PMSG Based Wind Turbine System

Power captured through Aerodynamic process is given by equation.1

$$P_w = \frac{1}{2}\rho\pi R^2 V^3 \quad \text{(i)}$$

Where P_w is the power captured, ρ represents the air density, R is the radius of blade in m. and V represents the wind velocity in m/s. The Mechanical Power extracted by wind blades is shown in equation no. 2

$$P_{mech} = C_p P_{wt} = \frac{1}{2} C_P \rho\pi R^2 V^3 \quad \text{(1)}$$

Here C_p represents the coefficient of power.

<u>Drive Train Modelling</u>

The shaft dynamic equations are

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$$T_{IN} = J_T \frac{d\omega_T}{dt} + k\Delta v + B\Delta\omega \quad (2)$$
$$k\Delta v + B\Delta\omega = J_G \frac{d\omega_G}{dt} + T_e \quad (3)$$
$$\Delta\omega = \omega_T + \omega_G \quad (4)$$
$$\Delta v = v_T + v_G \quad (5)$$

Where J_T and J_G represents the Moment Inertia of Turbine and Generator respectively in ($kg.m^2$), T_{IN} and T_e represents the input and generator electromagnetic torque in N-m , B represents the absorption of the shaft. Ω represents the angular speed of generator and the subscript G and T represents the angular speed of generator and turbine respectively. ν_T and ν_G represents the angle of turbine and generator in rad [7].

Generator Modelling

The stator voltage in d and q axis is given by

$$v_{ds} = R_s i_{ds} + \frac{d\varphi_{ds}}{dt} + \omega_s \varphi_{qs} \quad (6)$$
$$v_{qs} = R_s i_{qs} + \frac{d\varphi_{qs}}{dt} + \omega_s \varphi_{ds} \quad (7)$$

Similarly rotor voltage is given by

$$v_{dr} = R_r i_{dr} + \frac{d\varphi_{dr}}{dt} + s\omega_s \varphi_{qr} \quad (8)$$
$$v_{qr} = R_r i_{qr} + \frac{d\varphi_{qr}}{dt} + s\omega_s \varphi_{dr} \quad (9)$$

Flux linkage is given by

$$\varphi_{ds} = L_m i_{dr} - L_{sl} i_{ds} \quad (10)$$
$$\varphi_{qs} = L_m i_{qr} - L_{sl} i_{qs} \quad (11)$$
$$\varphi_{dr} = -L_m i_{ds} - L_{rl} i_{dr} \quad (12)$$
$$\varphi_{dr} = -L_m i_{qs} - L_{rl} i_{qr}$$

Electromagnetic Torque

$$T_{el} = \varphi_{qr} i_{dr} - \varphi_{dr} i_{qr} \quad (13)$$

Synchronous Generator

$$v_{ds} = -R_s i_{ds} - L_s \frac{di_{ds}}{dt} + L_s \omega_r i_{qs} \quad (14)$$
$$v_{qs} = -R_s i_{qs} - L_s \frac{di_{qs}}{dt} + L_s \omega_r i_{ds} + \omega_r \varphi \quad (15)$$

Here V_s, i_s and ψ_s represents stator voltage, current and flux respectively and V_r, i_r and ψ_r represents the rotor voltage, current and flux. The notion d and q represents the direct and quadrature axis respectively. L_{sl} and L_{rl} represent the stator, rotor leakage inductance and L_m represents the mutual inductance respectively [8].

Electromagnetic Torque

$$T_e = \frac{3}{2} p\varphi l_{qs} \quad (16)$$

DFIG Converter

The rotor real power and reactive power is given by

$$P_r = v_{dr} i_{dr} + v_{qr} i_{qr} \quad (17)$$
$$Q_r = v_{qr} i_{dr} + v_{dr} i_{qr} \quad (18)$$

Similar to rotor power the stator power is given by

$$P_s = v_{ds} i_{ds} + v_{qs} i_{qs} \quad (19)$$
$$Q_s = v_{qs} i_{ds} + v_{ds} i_{qs} \quad (20)$$

Total Output Power

$$P = P_r + P_s = v_{dr} i_{dr} + v_{qr} i_{qr} + v_{ds} i_{ds} + v_{qs} i_{qs} \quad (21)$$
$$Q = Q_r + Q_s = v_{qr} i_{dr} + v_{dr} i_{qr} + v_{qs} i_{ds} + v_{ds} i_{qs} \quad (22)$$

PMSG Converter

$$P = \frac{3}{2} v_d i_d \quad (23)$$
$$Q = \frac{3}{2} v_d i_q \quad (24)$$

3. MODELING & RESULT ANALYSIS

The Result examination segment portrays the recreation method and subtleties for concentrate the impacts of different occasions that are probably going to occur in the breeze ranch at any moment of time. The whole plan and re-enactment is done under the MATLAB programming condition for approving the outcome with that of the functional outcome.

Electromagnetic Transient reproduction ponders as far as its Root Mean Square Value is done for twenty minutes so as to figure the power stream in various parts of lattice associated breeze ranch framework. Amid the whole recreation, the breeze speed is kept up at a steady dimension in the breeze ranch and the program is structured so that variety in cut-in and cut-out speed is permitted from 3m/s to 22m/s.

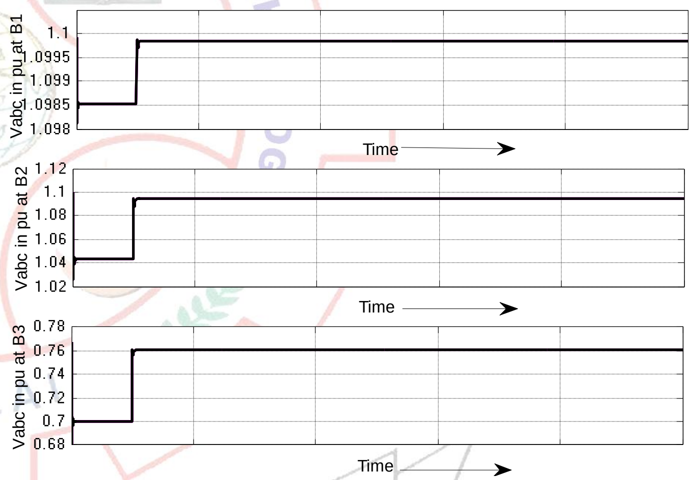

Fig.4, Bus voltage level at different buses

At the point when the breeze speed comes to over the estimation of 12m/s, the pitch control system comes into picture and it endeavours to keep up a fixed real power at the terminals of generator. Again when the breeze speed falls underneath the framework evaluated esteem, the precise pitch control component invalidates itself and accordingly permitting the change of real power.

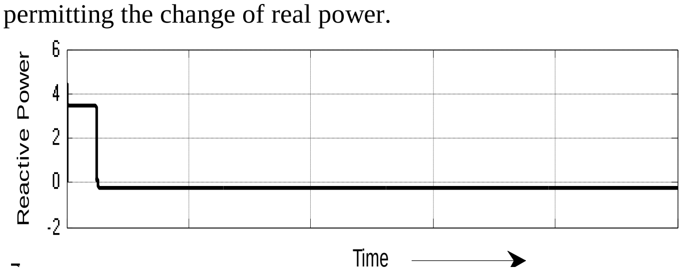

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Fig.5. Reactive Power exchanged between system and Grid

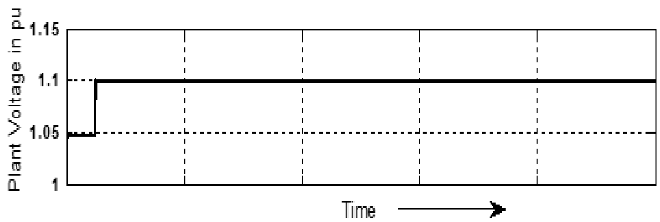

Fig.6. Plant Voltage between system and Grid

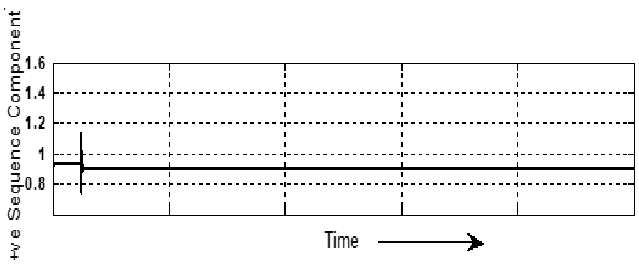

Fig.7. Positive Sequence Component

The example and variety of real power as for wind speed is appeared in Figure. From the figure it tends to be discovered that the real or dynamic power is consistently kept up at 0.6MW corresponding to twist speed over its evaluated esteem though the power shifts as 3D shape of the breeze speed when it falls beneath its appraised speed. In logical inconsistency to the trading of dynamic power, ingestion of responsive power from the framework additionally changes as for change in wind speed. As appeared in the figure the consumed responsive power ordinarily differs from 0.23 MVAR to 0.31 MVAR for every unit. Under full heap of activity condition, the aggregate sum of responsive power retentions and traded as for the matrix including the misfortunes and assimilation does by underground link is 1.97 MVAR and this receptive influence is remunerated by a 2 MVAR shunt capacitor associated following the 11kV transport which is simply close to that specific substation.

For breaking down the short out conduct of the breeze ranch a three-stage symmetrical blame for example for this situation a line to line blame is made over the 11kV bus bar of model at the moment of 3sec for a length of 50 cycles each having a timeframe of 0.02 Sec .The MATLAB re-enactment time for the said framework was set to 20 seconds. Amid the event of blame for example 1 sec, the transport voltage at the said 11kV transport will all of a sudden drop to zero while in the meantime the transport voltages toward the finish of different transports will diminish somewhat. After the leeway of blame voltage quickly increments to 1.005 p.u at t=4sec and a voltage undershoots of request 0.98 p.u was checked lastly it goes to a consistent state edge. The variance of current as discovered amid the recreation was appeared in figure. It very well may be closed from the assume that the RMS current at the contemplated transport all of a sudden increments from its ostensible incentive with a request of multiple times from the moment of event of blame and afterward diminishes to zero. Amid the procedure of blame lessening system, it is discovered that the concentrated generator has gone to a transient current of 3kA and afterward the impact will be settled down to 0.6kA after 3.4seconds.

Amid the blame condition, the real power traded between the matrix and wind ranch drops to zero and the circumstance remain wins amid the whole time of blame. As appeared in the figure it tends to be discovered that there is no indication of transient present in the real power traded bend. After the leeway of blame, an oscillatory reaction of dynamic power was found inside the 10 cycles of beginning reaction.

4. CONCLUSION

The power quality issues as talked about in the previous paper for wind age ranch demonstrates the conduct of wind substation at its distinctive working condition .A dynamic recreation show for the fixed speed squirrel enlistment generator has been created with MATLAB programming. A heap stream examination was done to think about the heap profiles along the considered buses. As appeared in the figure the dynamic power age is typically kept up at its appraised an incentive alongside pitch control instrument.

Amid the event of symmetrical blame, the generator bus bar voltage drops to zero and again increments to its enduring state an incentive after the freedom of blame. The generator RMS current at the contemplated transport all of a sudden increments from its ostensible incentive with a request of multiple times from the moment of event of blame and after that diminishes to zero.

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