Modelling and Design Control Mechanism of a 415/220V Distribution Network. Case Study: Port Harcourt International Airport

OTI ROBINSON CHIBU[1], ODIKE CHIGOZIRI MATTHEW[2]

[1,2] *Department of Electrical/Electronic Engineering, Rivers State University Port Harcourt, Nigeria*

Abstract -- This study is concerned with the modelling and control mechanism of a 415/220V distribution network, with a doubly fed wind turbine generator incorporated into the system. The distribution network is Port Harcourt International Airport distribution network. The model is carried out with Matlab model, with two special cases conducted. Case 1 is based on modelling the system with only wind turbine generator incorporated into the system while the second case considered the design control and protection system incorporated into the turbine system and distribution grid. Both cases were simulated and result are measured in terms of voltage, active power and reactive power of the buses. Results were tabulated and also presented. The result shows that when a control/protection section is introduced into the network the system becomes more stable and reliable than when it's operating without any control/protection system. Hence, the wind turbine generators were mostly used to argument strictly the technical and regularity of the entire network to ascertain safe, reliable and efficient operation just as in Case 2, it assist in regulating air pollution, improve the economy of grid power, reduces losses in distribution lines.

Indexed Terms: Control and Protection, Low Voltage, Distribution Network, Doubly Fed injection Generator.

I. INTRODUCTION

A wind turbine is a generating device that can extracts kinetic power from the wind through the movement of air with a designed blade size and then converts the power into electricity.

The establishment of a wind turbine with a fixed speed is mostly used in operation today because they do operate in a lower percentage that is less than unity, and it has a squirrel cage system that is directly powered to the grid system. The wind turbine is designed to produce a reliable output power base on their sizes and range of speed, meant to generate power at lower cost compare to most renewable source of energy, it also has the ability to withstand environmental stress by Ackermann, T. (2005).

In Nigeria the speed of wind varies based on the geographical location, within the Northern area speed of wind lies between 4.0 and 5.16m/s while in the Southern area of Nigeria it lies between 1.4m/s and 3.0m/s Sambo, A. S (2009). The distribution network comprises of low voltage transformers; 33kV/415V and 415V/33kV, eight (8) buses and nine (9) transmission lines are considered, three (3) feeders feeding 33kV into the network at three distinct positions.

Substation with 132/33kV transformer, injection substation with 33/11kV transformer, distribution substation with 33/0.415kV, 11/0.415kV, power transformer (2x15MVA). Elele substation is fed through the 132kV line coming from Rumuosi substation, 1x30/45MVA, with a stepping down transformer of 132/33kV, 1x45/60MVA (132/33kV), feeders 4x33kV by Kenneth et al, (2009).

1.1 Purpose of Study

The purpose is to incorporate a wind turbine into the existing distribution network with a protection system in order to send a tripping signal to the wind turbine in the event of three phase AC current, over voltage/under voltage, over current/under current and as well protect the grid side terminal from low voltage supply to high voltage supply from the turbine due to irregularities that may arise in the wind turbine speed as a result of weather condition.

1.2 Statement of Problem

The rate at which the use of wind energy in distribution network increases, poses threat on the network due to irregularities that may arise such as power quality PQ

issues, voltage variations and system stability. Hence, wind turbine generators are mostly needed to argument strictly the technical and regularity of the network to ascertain safe, reliable and efficient operation of overall network. (Rashad, K. N. et al, 2010).

1.3 Significance of Study

The significances are as follows:

(a) Energy saving: The design of the turbine helps in regulating the energy generated and is been seen as an acceptable tool for electric power industry.

(b) Regulates air pollution: The quality of air is much more tied with the quality of our lives, pollution of air is in a greater percentage at various fire power station.

(c) Improve the economy of grid power: Applying the necessary idea of wind generation, the request for recent centralized energy plants and long-range transmission lines will become less.

(d) Reduction in line loss: The connection of a wind turbine with a low voltage 415/220V network for a local power supply can bring a reduction of losses in a distribution line.

1.4 Scope and Limitation of Study

The following are limitations as contain in this research work:

This study is only performed at low voltage (415/220V) grid, because it focuses on the end users, or customers, or residential. The MV grid were not considered.

It limits the power distribution system behaviors for a wind turbine integration protection issues in the same network.

Matlab software was used because it is readily available as compare to other power system packages.

II. MODELING OF THE DFIG UNIT

The DFIG unit is calculated based on the existing d-q references rotating frame with stator just like the nominal induction machine. The stator terminal voltages and fluxes can be written

$$V_{ds} = R_s i_{ds} + \frac{dQ_{ds}}{dt} - \omega Q_{qs}$$

(2.1)

$$Q_{ds} = L_s i d_s + L_m \, ldr$$

(2.2)

$$Q_{ds} = L_s i q_s + L_m \, lqr$$

(2.3)

Where $*\omega$ = the flux speed on the stator side. For a steady state condition, when ignoring the stator phase resistance and bringing the magnetizing current, we have:

$$idm_s = \frac{Q_{ds}}{L_m}$$

(2.4)

Where $V_{ds} \approx 0$

(2.5)

$$V_{qs} \cong V_s \cong \omega Q_{ds}$$

(2.6)

Thus $id_s = \frac{L_m}{L_s} \left(i_{dms} - i_{dr} \right)$

(2.7)

$$i_{qs} = \frac{-L_m}{L_s} i_{qr}$$

(2.8)

Therefore, to achieve the active and reactive power as a function for the stator voltage and rotor components, the equation below will be needful;

$$p_s = -\frac{1}{3} V_S \frac{L_m}{L_s} i_{qr}$$

(2.9)

$$Q_s = -\frac{1}{3} V_S \frac{L_m}{L_s} \left[\frac{V_s}{2\pi f lm} - i_{dr} \right]$$

(2.10)

Though since the rotor reference frame is used; the active and reactive power when referred to the stator side will be

$$p_s = -\frac{1}{3}\left(V_{dS}\, i_{ds} + V_{qs}\, i_{qs}\right)$$

(2.11)

$$Q_s = -\frac{1}{3}\left(V_{dS}\, i_{ds} - V_{ds}\, i_{qs}\right)$$

(2.12)

From the assumption made above, electromagnetic Torque for the DFIG is given by

$$T_e = -\frac{1}{3} Z_p\, Q_{ds}\, \ell_{qs}$$

(2.13)

But the motor output is the amount of the angular speed of the rotor, hence,

$$P_m = T_m\, \omega_r$$

(2.14)

Neglecting, losses;

$$P_m = P_s - P_r$$

(2.15)

$$\therefore P_r = P_m - P_s = T_m\omega_r = T_m\omega_r - T_e\omega_s = -T_m\left(\frac{\omega_s - \omega_r}{\omega_s}\right)$$

$$\therefore P_r = -sT_m\omega_s = -sp_s$$

(2.16)

Hence $S = \dfrac{\omega_s - \omega_r}{\omega_s}$

(2.17)

But for this machine the slip is expected to be negative so that the value of p_r will be positive. Thus, we can come to a conclusion that the induction motor is now operating in the generator mode.

Where i_{ds} and i_{qs} = Direct stator current and quadrature axis stator current

i_{qs} and i_{dr} = Quadrature stator current and direct stator current

V_{ds} and V_{qs} = Direct stator voltage and quadrature stator voltage

V_{qr} and V_{dr} = Quadrature rotor voltage and direct rotor voltage

ω_s = rotational speed of the stator (p.u)

ω_r = rotational stator speed (p.u)

T_e = electromagnetic rotor torque as applied (p.u)

T_m = mechanical torque applied to the rotor (p.u)

p_s = electrical output power of the stator (p.u)

p_r = electrical output power of the rotor (p.u)

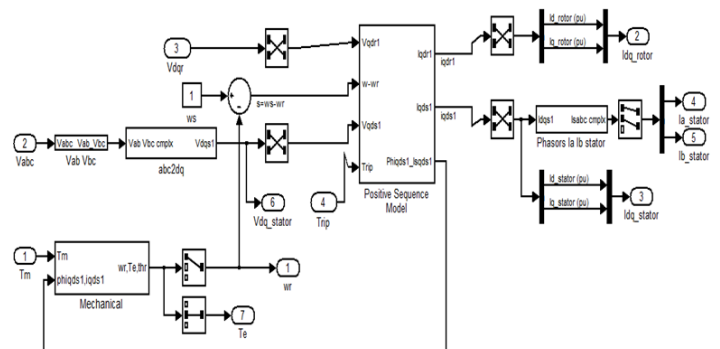P_m = mechanical power captured from the wind by the turbine (p.u).

Fig. 2.1 Matlab detailed model of the DFIG UNIT.

III. METHODOLOGY

Data collection for modelling of Wind Turbine
Table 3.1: Grid (Distribution parameters)
Section A: (BUS DATA); BMVA = 15MW; Bus
Voltage = 415V.

BUS/No.	BUS active power (p)	Parameter disruption (L–L) voltage	Values	Units
1	BMVA = 15e^6	Voltage of Bus 1.(415)	1.00	*p.u*
2	BMVA = 15e^6	Voltage of Bus 2.(415)	1.00	*p.u*
3	BMVA = 15e^6	Voltage of Bus 3.(415)	1.00	*p.u*
4	BMVA = 15e^6	Voltage of Bus 4.(415)	1.00	*p.u*
5	BMVA = 15e^6	Voltage of Bus 5.(415)	1.00	*p.u*
6	BMVA = 15e^6	Voltage of Bus 6.(415)	1.00	*p.u*
7	BMVA = 15e^6	Voltage of Bus 7.(415)	1.00	*p.u*
8	BMVA = 15e^6	Voltage of Bus 8.(415)	1.00	*p.u*

15MVA was taken based on the load capacity of the State secretariat can accept.

Table 3.2: Section B: LINES DATA

BUS/No.	From Bus to Bus	Resistance R(ohms/km)	Inductance (H/km)	Line distance (km)
	1 – 2	0.01273	0.9337e^{-3}	10km
	1 – 3	0.01273	0.9337e^{-3}	10km
	1 – 4	0.01273	0.9337e^{-3}	10km
	2 – 4	0.01273	0.9337e^{-3}	10km
	2 – 6	0.01273	0.9337e^{-3}	10km
	3 – 5	0.01273	0.9337e^{-3}	10km
	4 – 5	0.01273	0.9337e^{-3}	10km
	6 – 7	0.01273	0.9337e^{-3}	10km
	7 – 8	0.01273	0.9337e^{-3}	10km

IV. RESULT ANALYSIS AND DISCUSSION

The results are shown based on the simulation cases examined in this work.

Simulation Case 1:

Table 4.1: Result for Simulation Case 1

Bus No	Bus voltage V_{rms} *(p.u)*	Active Power p (p.u)	Reactive power Q (p.u)
1	1.00	−0.1160	−0.783000
2	0.86	−0.03638	−0.418000
3	1.00	−0.01784	−1.039000
4	0.71	−0.009549	−0.008287
5	0.78	−0.006152	0.4866000
6	1.00	0.0005817	0.0033160
7	1.00	0.0005815	0.0037710*
8	1.00	0.0005813	0.0042250*

The result given in table 4.1 shows the system simulation case when the wind turbine generator is only tied to the power system without any control /protection incorporated into it. The system performance is measured in terms of the voltage, for any active power (p) and reactive power Q of the distribution system.
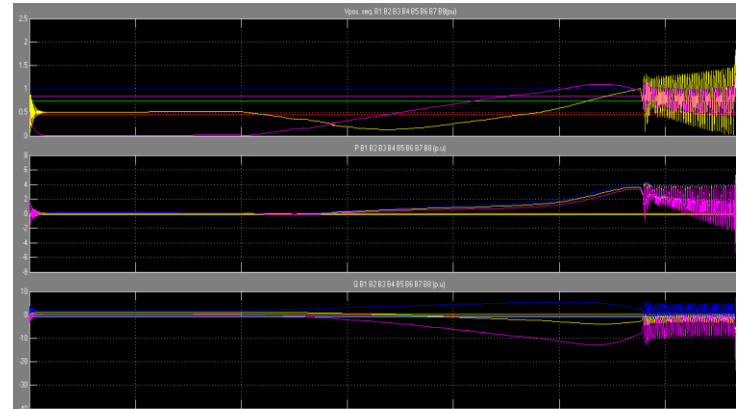

Fig 4.1.Waveform of system performance for non-controlled and non-protected system.

Simulation Case 2:
Table 4:2: Simulation Result for Case 2

Bus No	Bus voltage V_{rms} *(p.u)*	Active Power P (p.u)	Reactive power Q (p.u)
1	1.000	0.15770	−0.9719
2	0.910	−0.1460	−0.3042
3	1.000	−0.01482	−0.1978
4	0.900	0.27240	0.1621
5	0.950	0.14700	0.1754
6	1.000	$1.381e^{005}$	2011
7	1.000	$1.381e^{006}$	$4.791e^{005}$
8	1.000	$1.381e^{0015}$	$9.379e^{014}$

The result presented in table 4.2 shows that the proposed control/ protection scheme is valid. This is seen in the value of the Bus voltages as they are greatly improved and stabilized.

The same trend can also be seen in the active power and reactive power of the system.
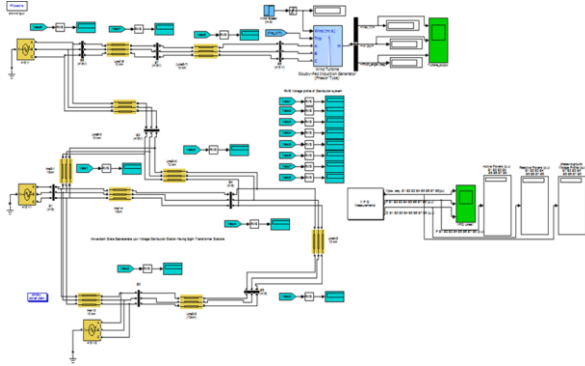

Fig. 4.2 Matlab Detailed Model of the distribution without Control-Protection Schemes
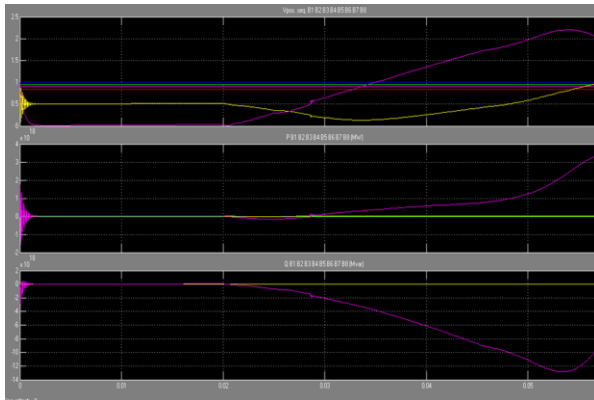

Fig. 4.2a Waveform of system performance for controlled and protected system.
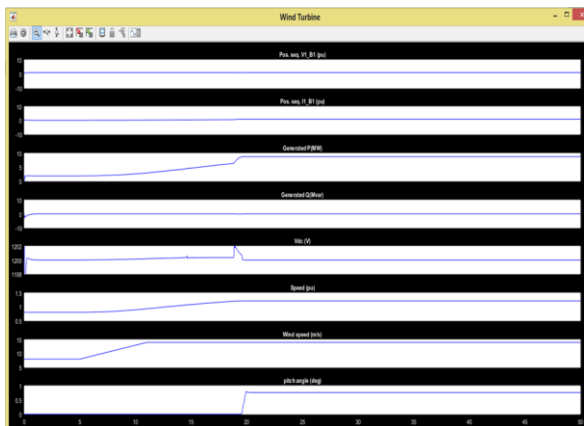

Fig.4.2b Waveform of system performance for controlled and protected system for bus 6 7 8.

The graphical illustration clearly shows the voltage stability level at different switching time of operation of the turbine and the power system.

V.   CONCLUSION

Modelling and design control mechanism of a 415/220V network with wind turbine integration have been discussed in this work. The case study is a distribution network in Port Harcourt International Airport distribution network having about eight (8) transformer stations with eleven (11) distribution lines, a Matlab simulink model was used in modeling the system with only wind turbine generator integrated into the system, it considered the modelling and design control mechanism of a 415/220V distribution network is been incorporate into the turbine system, its result were tabulated and presented. The results are presented accordingly to the simulation cases examined in this work,

It can be concluded that in both cases the system behaves differently, in the first case it tends to inject more than required value of reactive power that leads to a sudden rise in voltage of the entire network and for the second case, the values of the reactive power seems to be stabled.

VI.   RECOMMENDATION

Some of the method used in modeling of the low voltage (415/220V) network together with a wind-turbine doubly fed-induction generator can be improved to achieve the parameters of the controller for an improved stability and a dynamic performance of grid connection of the doubly fed induction generator.

REFERENCES

[1]   Ackermann, T. 2005. Wind power in power systems. John Wiley Chichester, West Sussex, England.

[2]   Kenneth, E. O., R. Uhunmwangho, 2009. Electrical Distribution Industry problems: Case of Akwa Ibom state, Nigeria. Pacific Journal of Science and Technology 10(2): 497-507.

[3]   Rashad, K. N., M. Kamel, and A. Chaouachi, 2010. Effect of wind generation system rating on transient dynamic performance of the micro-grid during islanding mode, Scientific Research, Low Carbon Economy, vol. 1, pp. 29–38.

[4]   Sambo, A. S. 2009. Renewable energy development in Nigeria A Paper Presented at the World Future Council strategy Workshop on Renewable Energy, Accra, Ghana.