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Impacts Of Integration Wind Power Plant On Small Signal and Transient Stability

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Abstract

Wind turbines are developed within the grid. However, when large wind farms are integrated into the weak grid, this may change the distribution of the energy flow, which ends up during a profound impact on the transient stability of the electricity grid. it's important to research the dynamic reaction characteristics of the wind turbine in the event of power system failure to make sure safe and reliable operation of the wind power.

This article creates a simulation model with the IEEE 9 and IEEE 14 bus systems by considering replacing the synchronous generator in these systems one by one with doubly fed induction generators DFIG-based wind turbines with an equivalent nominal MVA values and by changing the situation of the wind resources. The PSAT simulation environment supported Matlab software is employed to research the small stability of the grid interconnection signal for the various sorts of wind turbines. The results show that the combination of wind energy can have influence on the steadiness of small signals from the ability system, counting on the situation of the wind power.

Keywords: wind power, transient stability, Doubly Fed Induction Generators (DFIG), Small Signal Stability, Power System Analysis Toolbox (PSAT) .

I-Introduction

The development of installed capacity of renewable energy connected to the grid continues to grow due to environmental considerations to minimize the impact of conventional electricity generation [1]. Wind energy is the world's fastest growing renewable source.

Over the past decade, the average annual growth rate for wind turbine installation has been around 30%. One of the biggest problems with solar and wind systems is their dependence on weather conditions [2]. Compared to conventional production, the stability of the existing grid thus becomes important. Therefore, wind turbines should behave responsibly. For example, the important point in recent years is the continuous connection of the wind turbine to the grid at defined grid voltage disturbance levels to avoid voltage drops and sectional energy deficits when units are disconnected.

it's important to know the sources of disturbances affecting energy quality [3]. Currently, Integrate them into the just emerging problems like voltage stability, transient stability problem. the stability of the electrical system depends on the parameters of turbines, generators, regulators. They affect both the stability of the tiny signal and also the transient stability. Several studies have recently been conducted to spot the strengthening of the specified grid, reserve requirements and impact of wind energy on the stability of the electricity grid [4]. These studies address various issues associated with wind turbines, like the fluctuating nature of wind generation , location of wind power , different generator technologies, and control. The results generally represent a superposition of varied aspects of wind generation and predict the specified network strengths, reserve requirements, impact on grid stability.

This article is organized as follows: Section two is Impact On Power System Stability, In Section Three is a Transient Stability, In Section four is an introduction to the stability of small signals, the wind turbine model based on DFIG is described in Section five, , In Section six the study methods used in this article are briefly discussed the test system models built in the PSAT used in this paper are briefly discussed . while the simulation and conclusion is presented in Sections seven and eight.

II- Impacts On Power System Stability

After a disturbance, the variation in the electromagnetic torque of the synchronous machine can be characterized by two torque components, namely the synchronizing torque component and the damping torque component. Insufficient synchronization torque results in non-oscillating instability, while insufficient damping torque results in oscillatory instability. With the increase in the number of wind farms in operation, the system is undergoing a change in dynamic characteristics. These categories of instability in response to the penetration of wind energy are discussed in the following sections.

a)Transient Stability

For stability analysis, problems are generally divided into two broad categories:
• Stability in stable condition ; • Transient stability.
The ability of the power system to revive synchronization after small and slow interruptions.
In dynamic stability: transient stability studies relate to the results of major and sudden disturbances, such as the occurrence of a fault, the sudden interruption of a line. When a symmetrical fault is introduced into the system, the transient stability of the system is disturbed. Therefore, the control of transient stability is another challenge, especially when the system is integrated with an external source. There are certain ways to improve the short-term stability of the integrated system [5] .

b) Small-Signal Stability

Stability of small signals is that the ability of synchronous machines connected to an influence system to stay synchronized when the power system is subjected to small disturbances. The determination of the electro-mechanical oscillation methods is of particular importance within the analysis of the stability of small signals. Electromechanical modes involve rotors from individual generators or groups of generators that swing or swing against one another and may be divided into inter-zone, local-zone, and intra-station modes [6]. the stability of small signals requires that the electromechanical states be sufficiently attenuated; their depreciation depends on variety of things , system operating conditions, properties of machine excitation systems, use of power system stabilizers (PSS), line faults, etc
The dynamic behavior of a power system can be described by a set of n first order nonlinear ordinary differential equations :
Where:

$$\dot{X}(t) = f(x, u, t) \qquad (1)$$
$$Y(t) = g(x, u, t) \qquad (2)$$

Where Equation 1 has all state variables such that (u) is the input variables, (t) is time and (y) is the output function. Linearization of more than 2 equations will help to study the response to small variations. To achieve this, polynomial equations are developed using the Taylor series formula, where higher-order terms are overlooked. The linear combination of the system is presented as

$$\dot{X} = Ax + Bu \quad ; \quad y = Cx + Du \qquad (3)$$

Here A ,B,C and D are obtained from the Jacobean matrix which contains partial deviates of the functions in terms of 'f' and 'g' respectively to the input variable 'u' and the state variable X

$$A = \begin{bmatrix} \frac{\partial f_1}{\partial x_1} & \cdots & \frac{\partial f_1}{\partial x_n} \\ \cdots & \cdots & \cdots \\ \frac{\partial f_n}{\partial x_1} & \cdots & \frac{\partial f_n}{\partial x_n} \end{bmatrix}; B = \begin{bmatrix} \frac{\partial f_1}{\partial u_1} & \cdots & \frac{\partial f_1}{\partial u_r} \\ \cdots & \cdots & \cdots \\ \frac{\partial f_n}{\partial u_1} & \cdots & \frac{\partial f_n}{\partial u_{nr}} \end{bmatrix}; C = \begin{bmatrix} \frac{\partial g_1}{\partial x_1} & \cdots & \frac{\partial g_1}{\partial x_n} \\ \cdots & \cdots & \cdots \\ \frac{\partial g_m}{\partial x_1} & \cdots & \frac{\partial g_m}{\partial x_n} \end{bmatrix}; D = \begin{bmatrix} \frac{\partial g_1}{\partial u_1} & \cdots & \frac{\partial g_1}{\partial u_r} \\ \cdots & \cdots & \cdots \\ \frac{\partial g_m}{\partial u_1} & \cdots & \frac{\partial g_m}{\partial u_r} \end{bmatrix}$$

Where A, B, C and D are the state matrix, the input matrix, the output matrix and the coefficient matrix, respectively. To find the linearized equation state in the frequency range, these matrices must be transformed using the Laplace transform.

Finally, eigenvalues are obtained after the equation below has satisfied [7]:

$$\det (A - \lambda I) = 0 \qquad (4)$$

This leads to complex eigenvalues λ for A in the form : $\lambda = \sigma \pm j\omega$ (5)

Dynamic Model of DFIG and Wind Turbine

The final dynamic wind power model can be expressed by the subsystem equations that actually include the wind model with the drive, the induction generator and the control system. Detailed descriptions of these dynamic models are presented as follows,

The equations of the double feed induction generator in terms of the d and q axes and neglecting the stator and rotor flux transients can be written as [8]:

the stator circuit:

$$V_{ds} = -R_s i_{ds} + (x_s + x_m) i_{qs} + x_m i_{qr} \qquad (6)$$

$$V_{qs} = -R_s i_{qs} - (x_s + x_m) i_{ds} + x_m i_{dr} \qquad (7)$$

the rotor circuit :

$$V_{dr} = -R_r i_{dr} + (1 - \omega)(x_r + x_m) i_{qr} + x_m i_{qs} \qquad (8)$$

$$V_{qr} = -R_r i_{qr} + (1 - \omega)(x_r + x_m) i_{dr} + x_m i_{ds} \qquad (9)$$

Where: V_{ds}, V_{qs}: d and q axes stator voltages; ids, iqs: d and q axes stator currents; i_{dr}, i_{qr} d and q axes rotor currents; Rs, Rr, Stator and rotor resistances; xs Stator self-reactance; xr, Rotor self-reactance; xm Mutual reactance; ω Rotor speed.

The wind turbine generator shaft and the gearbox are modeled in [9] as a lumped inertia H; therefore, the motion equation can be represented by:

$$\frac{d\omega}{dt} = \frac{1}{2H}(T_m - T_e) \qquad (10)$$

Where:

Tm: Mechanical torque; Te: Electromagnetic torque

This simplification in the inertia is valid only if it is assumed that the controllers associated to the DFIGs are able to quickly minimize the shaft oscillations [9]. The electromagnetic torque is represented by:

$$T_e = x_m (i_{qr} i_{ds} - i_{dr} i_{qs}) \qquad (11)$$

the active power derived from the power velocity characteristic of the wind turbine Pw (ω) is associated with the flow of the rotor in the axis q as follows:

$$i_{qr} = \left(-\frac{x_s + x_m}{x_m v}\,\frac{Pw(\omega_m)}{\omega_m - i_{qr}}\right)\frac{1}{T_e} \qquad (12)$$

$$i_{dr} = \frac{K_V (V - V_0) V}{x_m - i_{dr}} \qquad (13)$$

: Actual terminal voltage; V_0: Desired terminal voltageV

to optimize the energy extracted from the wind. This controller uses the current rotor speed. For rotor speeds greater than 1 pu, the current is set to 1 pu. and for rotor speeds less than 0.4 pu. the current is set to zero. The rotor current limits are calculated in the PSAT as follows::

$$i_{qr\,max} = -\frac{x_s + x_m}{x_m} P_{min} \qquad (14)$$

$$i_{qr\,min} = -\frac{x_s + x_m}{x_m} P_{max} \qquad (15)$$

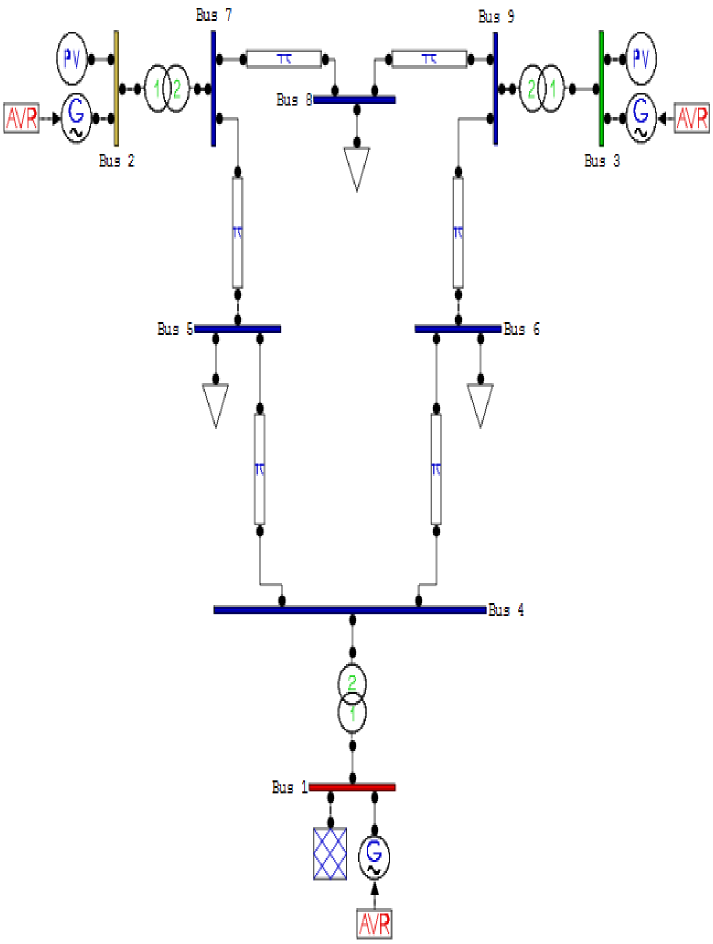
$$i_{dr\,max} = -\frac{x_s + x_m}{x_m} Q_{min} + \frac{x_s + x_m}{x_{m2}} \qquad (16)$$

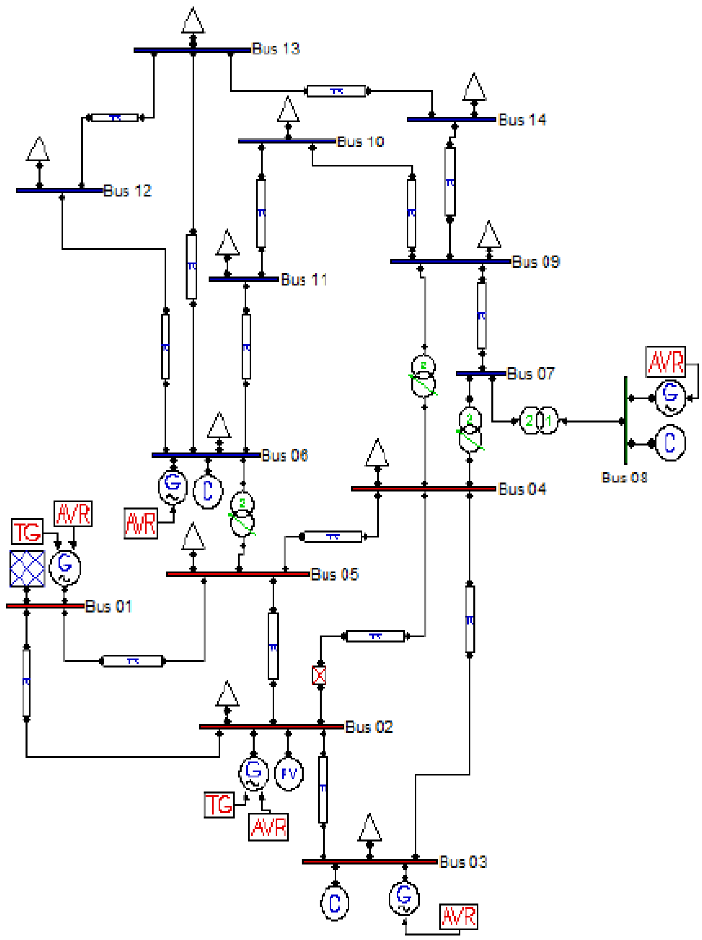
$$i_{dr\,min} = -\frac{x_s + x_m}{x_m} Q_{max} + \frac{x_s + x_m}{x_{m2}} \qquad (17)$$

for ensure proper dynamic and stable operation of the mode, The wind is modeled using the Weibull distribution available in with a form factor equal to two, which results.

Tested Systems

We use in this study "The simple line diagram of the IEEE 9 and IEEE 14 bus system models is made in the PSAT as shown in the figure. The first and second IEEE 9 bus systems, respectively, contain three synchronous generators that deliver active and reactive power to the system connected to buses 1, 2 and 3, the generators are fourth-order models with automatic voltage regulators (AVR) [9], the IEEE 14 bus system consists of 5 synch-ronous generators that provide active and reactive power to the system connected to buses 1, 2 , 3, 6 and 8, three synchronous capacitors connected to buses 3, 6 and 8. Automatic type II voltage regulators (AVR) are integrated into each machine and sort the turbine controller connecting to the generators connected to buses 1 and 2. The model of the bus connected to the synchronous generator 1 can be a 5^{th} order model as well as The models of generators connected to buses 2, 3, 6 and eight are 6 order models





Fig(1) The IEEE 9 bus system model

Fig(2) The IEEE 14 bus system model

3. Simulation

For this study, two main cases were investigated, in each case we verify the low stability of the signal from the tested system in keeping with the worth of the system's eigenvalues resulting from the linearization of the differential algebraic equations describing the dynamic function of the system tested round the equilibrium points within the calculation of power flow .

A): Replacing the synchronous generator on buses 2, 3, 6 and eight one at a time to the IEEE 14 bus system and on buses 2 and three to the IEEE 9 bus system with DFIG based WF having an equivalent MW output from synchronous generators.

B): the essential case where all generators within the system are synchronous generators and there's no power plant supported a dual feed induction generator within the system.

In this case, the small signal stability of the tested systems without connecting any wind turbine based on DFIG are computed with positive and zero eigen values of the system with its dominant states as shown in the two cases.

4. Conclusion

In this paper, the influence of DFIG penetration on the stability of small signals and transient stability for a large system is observed, the analysis is performed for small disturbances, which is then extended to observe the attenuation of the system for large disturbances. for the IEEE 14 bus system and IEEE 9 bus system for insertion of the ability generated by wind turbines supported DFIG rather than the synchronous generator on the generation buses one by one at an equivalent rated power and by changing the position of the wind power . Sensitivity to intrinsic values was wont to observe the influence of wind energy on the stability of the tiny signal within the system. These influences depend upon the situation of the wind park . during this study, the system may be a small signal of critical stability when it's no wind turbines supported DFIG, but it's stable small signal when the synchronous generator is replaced in certain places, the system is small signal unstable. PSAT may be a powerful and practical tool for modeling and analyzing electrical systems.

References

1) F. Grimaccia, M. Mussetta, R.E. Zich, "Neuro-fuzzy predictive model for PV energy production based on weather forecast," 2011 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), pp.2454-2457, 27-30 June 2011
2) M.Q. Duong, E. Ogliari, F. Grimaccia, S. Leva, M. Mussetta, "Hybrid model for hourly forecast of photovoltaic and wind power," 2013 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), 7-10 July 2013.
3) M. Q. Duong, K. H. Le, F. Grimaccia, S. Leva, M. Mussetta, and R. Zich, “Comparison of power quality in different grid-integrated wind turbines,” in 2014 IEEE 16th International Conference on Harmonics and Quality of Power, pp. 669-673, 2014
4) H. Schwarz, K. Pfeiffer, and L. Roskoden, “Integration of renewable eneries to the east German grid. Actual problems and possibe solutions,” in Proc. Of the 6th WSEAS International Conference on Power Systems, pp. 7-13, 2006
5) F. M. Hughes, O. A. Lara, N. Jenkins and G. Strbac, “Control of DFIGBased Wind Generation for Power Network Support,” IEEE Trans. On Power Systems, vol. 20, no. 4, pp. 1958-1966, Nov. 2005.]
6) P. Kndur, "Power System Stability and Control," Tata McGraw- Hill Publishing Company Limited-2001, New Delhi.
7) Y.U. Lopez, J.A.D. Navarro, “Small Signal Stability analysis of wind turbines with squirrel cage induction generators,” IEEE International Conference on Transmission and Distribution Conference and Exposition pp.1-10, 2008.
8) F. Milano, “PSAT, Matlab-based Power System Analysis Toolbox,” 2014, [Online]. Available: http://www.power.uwaterloo.ca/~fmilano.
9) G. Tousraki and B. M. Nomikos "Effect of wind parks with doubly fed asynchronous generators on small-signal stability," Electrical power system research 79 , 2009, pp. 190-200.