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ROTOR ANGLE & VOLTAGE STABILITY ANALYSIS OF DFIG INTEGRATED POWER SYSTEM USING BIFURCATION TECHNIQUE

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ABSTRACT:

The complexity of the power system and level of integration of Wind energy into the power system has significantly increased, causing voltage instability problem across many power systems. Voltage stability is concerned with maintaining appropriate voltage profile across all the buses in the power system .Maintaining a stable and secure operation of a power system is therefore a very important and challenging issue.In this thesis the voltage stability analysis of Doubly Fed Induction Generator (DFIG) integrated system was analyzed using Power system Analysis Toolbox.(PSAT)The analysis of voltage stability was carried out using Bifurcation methodology. The IEEE14 bus system was re modeled by integrating DFIG at bus number 1.The Power Flow analysis was carried out using Newton Raphson method and the Voltage profile at all the buses were noted.The Eigen value analysis was carried out for the given test bus system and it was identified that there are no positive Eigen values indicating that the system possesses voltage stability and there are eight complex pair indicating that the IEEE14 bus system may cause small signal instability.The Time domain analysis was carried out to study the Small Signal stability on rotor speed and Excitation voltage and it revealed that the system shows increased level of damping there by indicating that the integration of DFIG improves Small Signal Stability.

KEYWORDS: Wind Generator, DFIG, Rotor Angle and Voltage Stability, Bifurcation technique

INTRODUCTION:

Power system stability Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact.Power system consists some synchronous machines operating in synchronism. For the continuity of the power system, it is necessary that they should maintain perfect synchronism under all steady state conditions. When the disturbance occurs in the system, the system develops a force due to which it becomes normal or stable.The ability of the power system to return to its normal or stable conditions after being disturbed is called stability. Disturbances of the system may be of various types like sudden changes of load, the sudden short circuit between line and ground, line-to-line fault, all three line faults, switching, etc.

TYPES OF POWER SYSTEM STABILITY

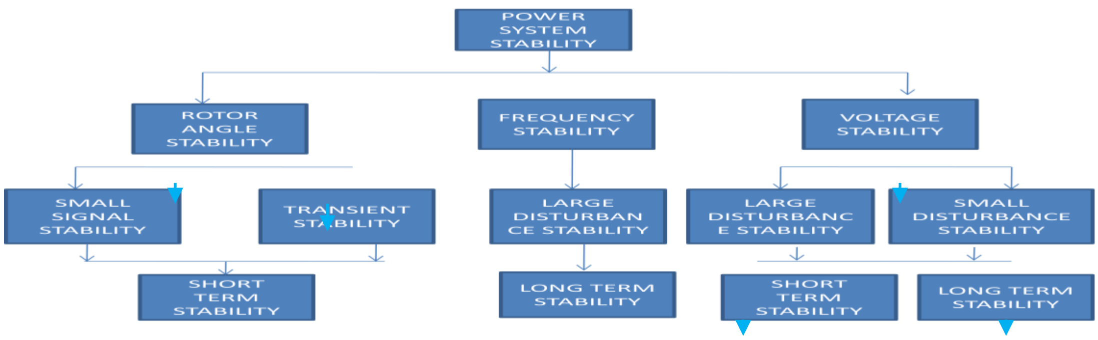

Fig 1:Types of Power System Stability

The stability of the system mainly depends on the behavior of the synchronous machines after a disturbance. The stability of the power system is mainly divided into two types depending upon the magnitude of disturbances

WORKING PRINCIPAL OF DFIG

Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. ... In the United States, wind turbines are becoming a common sight. The principle of the DFIG is that stator windings are connected to the grid and rotor winding are connected to the converter via slip rings and back-to-back voltage source converter that controls both the rotor and the grid currents. Thus rotor frequency can freely differ from the grid frequency (50 or 60 Hz).

- Steady state stability
- Transient stability

Steady-state stability – It refers to the ability of the system to regain its synchronism (speed & frequency of all the network are same) after slow and small disturbance which occurs due to gradual power changes. Steady-state stability is subdivided into two types

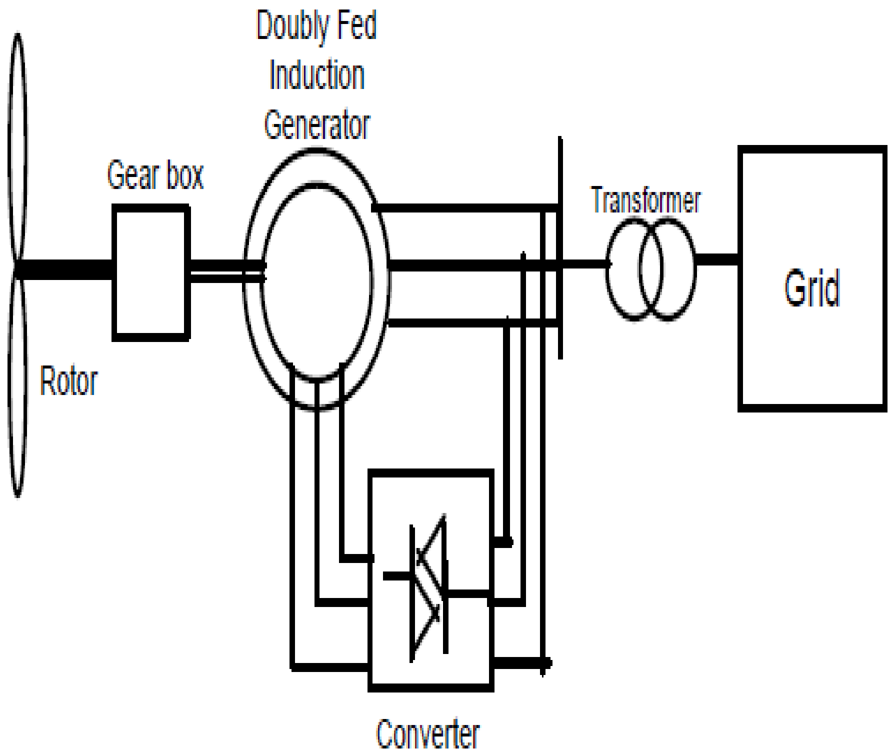

Fig 2 : DFIG Configuration

Dynamic stability – It denotes the stability of a system to reach its stable condition after a very small disturbance (disturbance occurs only for 10 to 30 seconds). It is also known as small signal stability. It occurs mainly due to the fluctuation in load or generation level.Static stability – It refers to the stability of the system that obtains without the aid (benefit) of automatic control devices such as governors and voltage regulators.

Stability Analysis :

Step 1: The power flow algorithm using the Newton Raphson method is executed and the initial power flow solution is obtained for the dynamic simulation.

Step2 :The Eigen Value Analysis was executed to obtain the Eigen values of the system State matrix, its most associated states, frequency, and participation factors were obtained.

Step 3: The Eigen values of the system state matrix are plotted and the Eigen value plot was obtained.

Step 4: The time-domain simulation incorporating the normal and single contingency (Line 2- 4 trips) is applied to the test bus system and the plots for those Eigen values obtained in step 3 are plotted.

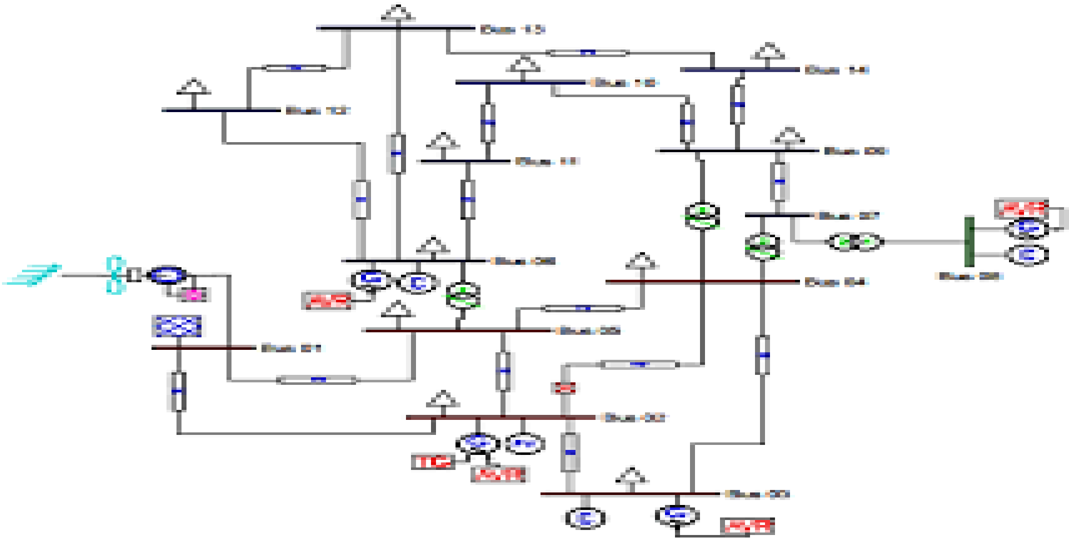

Fig 3:14 Bus System

Eigen Values Result of Modified Dynamic 14 Bus System

STATISTICS	
DYNAMIC ORDER	49
# OF EIGS WITH Re(mu) < 0	48
# OF EIGS WITH Re(mu) > 0	0
# OF REAL EIGS	30
# OF COMPLEX PAIRS	8
# OF ZERO EIGS	1

ROTOR OUTPUT:

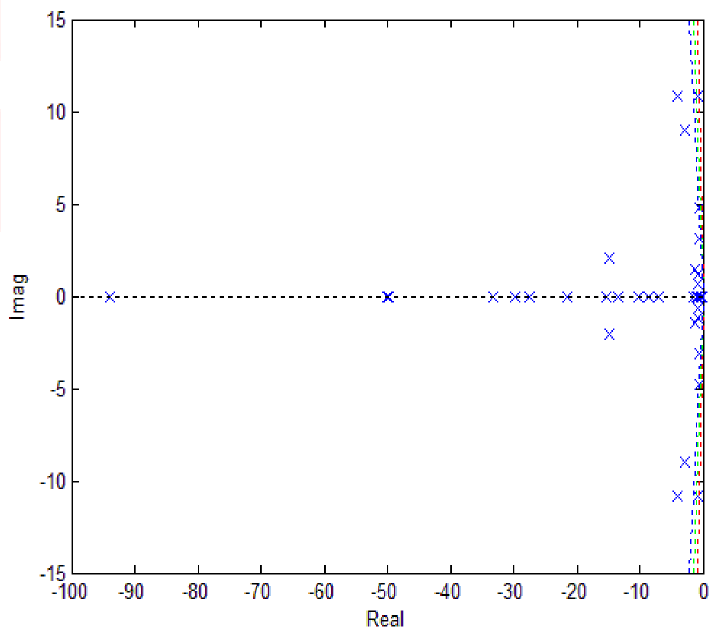

Fig 4 :Rotor Angle Output Graph

Eigen Number	Most Associated States	Eigenvalue	Frequency	Damping Ratio	Mode Of Oscillation
Eig As #14,15	omega_Syn_2, delta_Syn_2	-0.90866 10.79441	1.7	0.02	Local Mode of Oscillation
Eig As #16,17	omega_Syn_4, delta_Syn_4	-3.95546 10.80121	1.7	0.06	Local Mode of Oscillation
Eig As 22,23	omega_Syn_3, delta_Syn_3	-2.95514 8.97055	1.5	0.07	Local Mode of Oscillation
Eig As #27,28	omega_Syn_1, delta_Syn_1	-0.61438 4.78412	0.7	0.05	Inter area Mode of Oscillation

Complex pairs of Eigen Values close to the complex plane

Eigen Value and Rotor Speed of Wind integrated Power System

Eigen Values and Rotor Speed of wind integrated power system Eigen Number	Most Associated States	Eigenvalue	Frequency	Damping Ratio	Mode Of Oscillation
Eig As 14	omega_Syn_2	-0.90866 +j 10.79441	1.7	0.02	Local Mode of Oscillation
Eig As 16	omega_Syn_4	-3.95546 + j10.80121	1.7	0.06	Local Mode of Oscillation
Eig As 22	omega_Syn_3	-2.95514+j8.97055	1.5	0.07	Local Mode of Oscillation
Eig As 27	omega_Syn_1	-0.614384+j.78412	0.7	0.05	Inter area Mode of Oscillation

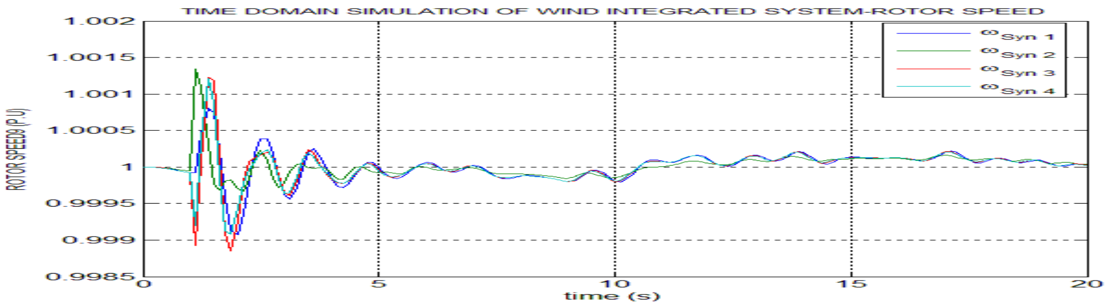

Fig 5: Eigen Values and Rotor Speed

The rotor speed variation of the bus test bus system when subjected to a disturbance is shown in graph. The rotor speed escalates initially to a higher value due to the damping torque associated with the rotor speed of synchronous machine 1,2,3,4 as given in table.

Eigen Values and Exciter Field Voltage

Eigen Number	Most Associated States	Eigenvalue	Frequency	Damping Ratio	Mode Of Oscillation
Eig As 32	vf_Exc_3	-1.15901-j 1.48117	0.29	0.66	Inter area Mode of Oscillation

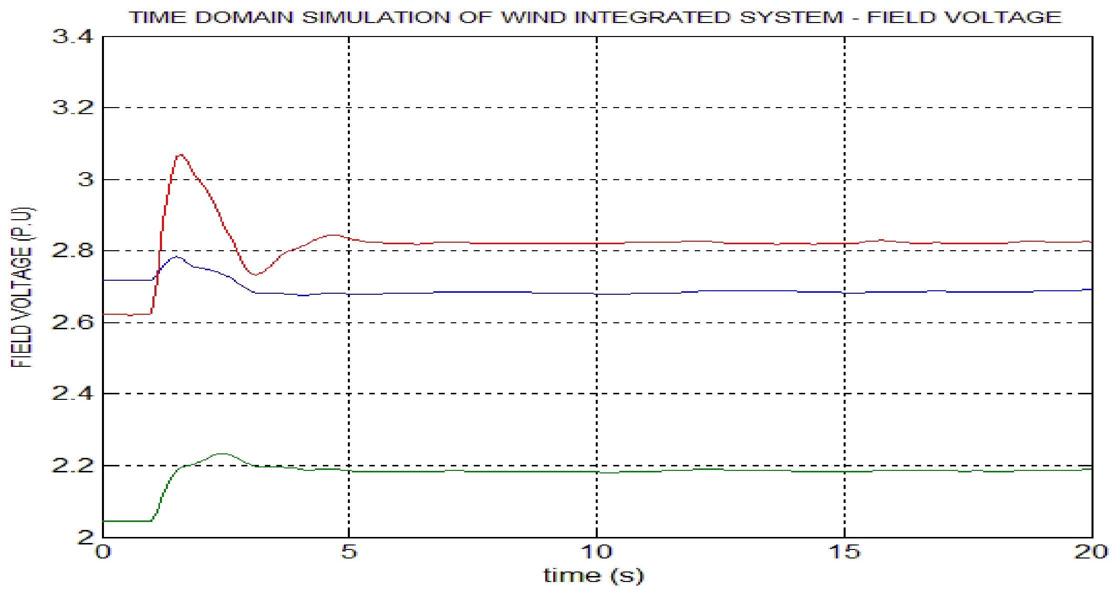

Fig 6: Eigen Values and Exciter Field Voltage

The variation in the exciter terminal voltage of the synchronous machine 3 is given in the table and depicted in figure.From the figure, it is observed that the peak overshoot is high as the synchronous machine 3 has a low-frequency oscillation. But the damping ratio of 66 % makes the system to get damped immediately

CONCLUSION:

From the Eigen value analysis it is evident that the absence of positive Eigen values indicate that the wind integrated system possesses voltage stabilityThe rotor speed oscillations in the case of the wind integrated system also shows significant level of damping which indicates that the wind integration improves the rotor angle stability of the system.The Excitation field voltage oscillations in the case of the wind integrated system also shows significant level of damping which indicates that the wind integration contributes significantly in improving the the rotor angle stability of the system.

Reference:

[1]. A Critical Eigenvalues Tracing Method for the Small Signal Stability Analysis of Power Systems, Shao-Hong Tsai1, Yuan-Kang Wu2, Ching-Yin Lee3, Energy and Power Engineering, 2013, 5, 677-682

The continuation power flow method combined with the Jacobi-Davidson method is presented in this research work to trace the critical Eigen values for power system small signal stability analysis. The critical Eigen values are found and thereby the trajectories of the critical Eigen values, Hopf bifurcation and saddle node bifurcation points are found by the proposed method.

[2]. Local and global bifurcations in a small power system, Nikos G. Sakellaridis a, Michael E. Karystianos b, Costas D. Vournas c,,Electrical Power and Energy Systems 33 (2011) 1336–1347.

In this research work a number of local and one global bifurcation observed in a small power system involving a load tap changer transformer has been observed .Besides the well-known generic local bifurcations (saddle-node and generic Hopf), the paper presents examples of higher codimension bifurcations, such as fold with double zero eigenvalues, degenerate Hopf, and swallowtail bifurcation.

[3]. Investigation of Wind Farm on Power System Voltage Stability Based on Bifurcation Theory, Zhiyuan Zeng, Xianqi Li, Jianzhong Zhou, Yongchuan Zhang, 978-1-4244-2487-0/ ©2009 IEEE

This research studies the impact of wind farm on voltage stability of power system with and without reactive power compensation devices. The static reactive compensation devices including static capacitor banks and static var compensators (SVC) are used to improve the maximum loadability.

[4]. Bifurcation Analysis of Static Unbalanced Power Networks with Distributed Generation, Ahmed Bedawy1, Mohamed M. Aly2, Mamdouh Abdel-Akher3, MIEEE , Hassan El-Kishky4, SMIEEE, 978-1-4673-5019-8/12/$31.00 ©2012 IEEE

Voltage stability has been well investigated for the traditional power system using bifurcation analysis: saddle-node bifurcation (SNB) and hopf bifurcation (HB). This paper studies the impacts of distributed generators (DGs) on the voltage stability of power system. The bifurcations analysis is applied on the steady state three-phase load-flow Jacobian-matrix of unbalanced distribution system.

[5]. Zhiyuan Zeng, Xianqi Li, Jianzhong Zhou, YongChuan Zhang (2009) "Investigation of Wind Farm on Power System Voltage Stability based on Bifurcation Theory ", IEEE Transactions on Circuits and Systems, Vol 50, December 2009.

[6]. Zhiyuan Zeng, Xianqi Li, Jianzhong Zhou, YongChuan Zhang (2009)[16],have analyzed the impact of wind farm integration on power system voltage instability. The causes of instability especially the Saddle node Bifurcation, Hopfs Bifurcation due to the integration of wind farms are analyzed using the Continuation Power flow method. The impact of Static Capacitors and Static Var Compensators are also analyzed.

[7]. Aliakbar Mohammadi (2012) "Detection Of Hopfs Bifurcation Using Eigen Value Identification ", International Conference on Problems of Cybernetics and Informatics, September 12 – 14, 2012.

[8]. Aliakbar Mohammadi (2012)[17], have developed a new algorithm that utilizes the complex Eigen Value properties to identify oscillatory instability of the power system .The new algorithm seems to be fast and accurate in identifying the oscillatory instability.