

e-ISSN: 2319-8753 | p-ISSN: 2320-6710

EDIA

International Journal of Innovative Research in SCIENCE | ENGINEERING | TECHNOLOGY

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

808

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 6, June 2021

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

### Impact Factor: 7.512

9940 572 462

6381 907 438

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| e-ISSN: 2319-8753, p-ISSN: 2320-6710| <u>www.ijirset.com</u> | Impact Factor: 7.512|

|| Volume 10, Issue 6, June 2021 ||

| DOI:10.15680/IJIRSET.2021.1006424 |

## **Dynamic Voltage Stability and Time Domain Analysis of Wind Integrated Power System**

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**ABSTRACT:** The power system has become complex and the level of penetration of Wind energy into the power system has increased, leading to voltage instability problem across many countries. However, the rapid growth in using renewable-based generation poses challenges for the system operators. In general, they experience intermittency, variability, partial controllability and location dependency. Some of the challenges introduced in include system security, power quality and system stability. Among power system stability concerns, voltage stability, which is addressed in this paper Voltage instability 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 paper the voltage stability analysis of wind integrated power system was analyzed using Power system Analysis Toolbox.(PSAT).

**KEYWORDS**: Eigen Value Analysis, IEEE 14 Bus system, voltage Stability, Bifurcation analysis MATLAB (PSAT)

#### I. INTRODUCTION

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.

**Rotor Angle Stability:** Rotor angle stability Ability of interconnected synchronous machines to remain in synchronous after being subjected to a disturbance. Depend on the ability to restore equilibrium between electromagnetic torque and mechanical torque of each synchronous generator. Output power of synchronous machines vary as their rotor angle swing.

*Casus of Rotor Angle In Stability:* Large-disturbance rotor angle stability or transient sta- bility, as it is commonly referred to, is concerned with the ability of the power system to maintain synchronism when subjected to a severe disturbance, such as a short circuit on a transmission line.

*Effects of Rotor Angle Stability:* Rotor angle stability is the ability of the interconnected synchronous machines running in the power system to remain in the state of synchronism. ... If the equilibrium is upset which results in the acceleration or deceleration of rotors of the machines.

#### II. VOLTAGE STABILITY

Voltage stability refers to the ability of a power system to maintain steady voltages at all buses in the system after being subjected to a disturbance from a given initial operating condition. It depends on the ability to maintain/restore equilibrium between load demand and load supply from the power system. Instability that may result occurs in the form of a progressive fall or rise of voltages of some buses.

*Importance of Voltage Stability:* A variety of factors (Financial, Regulatory, Environmental to name a few) make power systems to utilize maximum percentage of their transmission capacity and consequently operate close to stability limit with fewer margins. With a constant surge in the power system demand and the fast development in technologies



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associated with the power system especially the integration of renewable energy has great impact on the voltage stability of the system. Hence, it is of great significance to assess the voltage stability of the system and to develop appropriate control mechanism to improve the stability of the system Power systems world-wide have become increasingly concerned with voltage stability and collapse problems. Several major voltage collapse (VC) phenomena have been experienced by utilities in recent years.

*Causes of Voltage Stability:* A stronger transmission network and adequate reactive power reserves, to maintain voltages at key points in the network, are needed to avoid voltage instability. Voltage stability is triggered by having loads which attempt to draw power which is beyond the maximum capability of generation and transmission.

*Voltage stability analysis:* The analysis of voltage stability, for planning and operation of a power system, involves the examination of two main aspects:

- How close the system is to voltage instability (i.e. Proximity). When voltage instability occurs, the key contributing factors such as the weak buses, area involved in collapse and generators and lines participating in the collapse are of interest (i.e. Mechanism of voltage collapse). Proximity can provide information regarding voltage
- The mechanism gives useful information for operating plans and system modifications that can be implemented to avoid the voltage collapse
- Voltage stability analysis can be classified as static and dynamic analyses. In the static analysis, 'snapshots' of the system are taken from different time instances in the time domain trajectory, hence, useful information such as voltage stability and proximity to voltage collapse can be derived. In dynamic analysis, the sequence of events that leads to voltage instability can be analyzed. A complete study period would include the action of equipment with slow dynamics such as tap changers.

#### III. VOLTAGE STABILITY ANALYSIS USING BIFURCATION ANALYSIS

Bifurcation theory is the mathematical study of changes in the qualitative or topological structure of a given family, such as the integral curves of a family of vector fields, and the solutions of a family of differential equations. Most commonly applied to the mathematical study of dynamical systems, a bifurcation occurs when a small smooth change made to the parameter values (the bifurcation parameters) of a system causes a sudden 'qualitative' or topological change in its behavior. Bifurcations occur in both continuous systems (described by ODEs, DDEs or PDEs) and discrete systems (described by maps). The name "bifurcation" was first introduced by Henri Poincaré in 1885 in the first paper in mathematics showing such a behavior.

- Saddle-node bifurcation point, where two equilibrium coalesce and then disappear, at this point the reduced Jacobian has a zero Eigen value;
- Saddle node bifurcation is a collision and disappearance of two equilibria in dynamical system.
- In systems generated by autonomous ODE's,
- This occurs when the critical equilibrium has one zero eigenvalue.
- This phenomenon is also called fold or limit point bifurcation .
- Hopf bifurcation point, where there is an emergence of oscillatory instability, at this point, two complex conjugate eigenvalues of reduced Jacobian cross the imaginary axis;
- Hopf Bifurcation occurs when a periodic solution or limit cycle, surrounding an equilibrium point, arises or goes away as a parameter µ varies.
- When a stable limit cycle surrounds an unstable equilibrium point, the bifurcation is called a supercritical Hopf bifurcation.

*Time Domine:* Time domain refers to the analysis of mathematical functions, economic or environmental data, with respect to time. In the time domain, the signal or function's value is known for all real numbers, for the case of continuous time, or at various separate instants in the case of discrete time. signals or An oscilloscope is a tool commonly used to visualize real-world signals in the time domain. A time-domain graph shows how a signal changes with time, whereas a frequency-domain graph shows how much of the signal lies within each given frequency band over a range of frequencies.

*Damping Ratio:* Damping is an influence within or upon an <u>oscillatory system</u> that has the effect of reducing or preventing its oscillation. In physical systems, damping is produced by processes that dissipate the energy stored in the oscillation. Examples include <u>viscous drag</u> in mechanical systems, <u>resistance</u> in <u>electronic oscillators</u>, and absorption and scattering of



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light in optical oscillators. Damping not based on energy loss can be important in other oscillating systems such as those that occur in biological systems

- Although modern wind generators include power electronics converters which have some reactive power regulation capability that allows certain control over voltage disturbances, the capacity of the power electronics is limited.
- When a contingency occurs in the system, the inability of wind turbines to provide enough reactive power, it is necessary to worry about stability issues that can be originated by wind generation system.

The Voltage stability of a power system can be well analyzed by using bifurcation analysis. The bifurcation analysis gives a quantative and qualitative analysis of the voltage stability of the power system. The following are the types of bifurcation analysis:

- Saddle-node bifurcation point, where two equilibrium coalesce and then disappear, at this point the reduced Jacobian has a zero Eigen value.
- Hopf bifurcation point, where there is an emergence of oscillatory instability, at this point, two complex conjugate Eigen values of reduced Jacobian cross the imaginary axis.
- Singularity induced bifurcation, at this point, y (g) is singular, we know that ~>the inverse of y (g) will become infinity, which is called "singularity induced infinity", where it is not easy to compute and analyze the stability of the system.

#### **IV. SIMULATION RESULTS**

To investigate the impact of increased loading on stability of a wind integrated power system the IEEE14 bus dynamic model with DFIG integrated to it was for the research work. The wind farm was integrated at bus number1. The IEEE 14 test bus system consists of 14 buses and 20 transmission lines. There are four generators connected to the system. There are a total of 11 PQ bus in the IEEE test bus system. With a load of 259.3 MW ,73.6 MVAR. The WECS is connected to the bus number 1. The power flow algorithm using the Newton Raphson method is executed and the initial power flow solution is obtained for the dynamic simulation. 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. The Eigen values of the system state matrix are plotted and the Eigen value plot was obtained. 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 are plotted.



Fig.1. IEEE14 TEST BUS SYSTEM WITH SCIG WIND FARM INTEGRATED



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#### Table. 1. EIGEN VALUES RESULT OF MODIFIED DYNAMIC IEEE 14 BUS SYSTEM



Fig.2. EIGEN VALUE PLOT OF MODIFIED IEEE 14 BUS SYSTEM TIME DOMAIN SIMULATION OF WIND INTEGRATED SYSTEM EIGEN VALUES AND EXCITER FIELD VOLTAGE

The variation in the exciter terminal voltage of the synchronous machine 3 is given in 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

#### V. CONCLUSION

From the Eigen value analysis it is evident that the absence of positive Eigen values indicate that the wind integrated system possesses voltage stability. The 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



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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 rotor angle stability of the system.

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