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Time Domain Analysis of IEEE14 Test Bus System Using PSAT

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ABSTRACT—

The stable operation of power systems is a major challenge for many power system engineers. The rotor angle instability, voltage instability, and frequency instability affect the stable operation of the power system. From the work of Prabha Kundur et al. (2004), voltage instability has a widespread effect on the stable operation of the power system. The voltage instability event is a nonlinear phenomenon wherein for a small change in the system parameter there is a significant change in the behavior of the power system.. 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 time domain analysis of IEEE 14 dynamic model was analysed 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.

The time domain simulations are also carried out to study the transient stability of the system. In this, a fault is invoked into the system and various system parameters are studied to analyze the behavior of the system during a post fault condition.Some of the noteworthy incidents related to low-frequency oscillation that has taken place at the global level are listed below:

- United Kingdom (1980), frequency of oscillation about 0.5 Hz.
- Taiwan (1984, 1989, 1990, 1991, 1992), frequency of oscillation around 0.78 – 1.05 Hz.
- West USA/Canada, System Separation (1996), frequency of oscillation around 0.224 Hz.
- Scandinavia (1997), frequency of oscillation about 0.5 Hz.
- China Blackout on 6 March (2003), frequency of oscillation around 0.4 Hz.
- US Blackout on 14 August (2003), frequency of oscillation about 0.17 Hz.
- Italian Blackout on 28 September (2003), frequency of oscillation about 0.55 Hz.

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.

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.

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.

VOLTAGE STABILITY ANALYSIS USING BIFURCATION ANALYSIS:

Garng Huang et al. (2002)[35], have developed a mathematical model to analyze the dynamics of the power system by using a parameter-dependent Differential-Algebraic equation as follows:

$\dot{x}= f(x,y,p)$, $\quad f : \Re^{n+m+q} \rightarrow \Re^{n}$

$0 = g(x,y,p)$, $\quad g : \Re^{n+m+q} \rightarrow \Re^{m}$

where $x \in X \subset \Re^{n}, y \in Y \subset \Re^{m}, p \in P \subset \Re^{q}$

The state space is represented by X × Y, with x-the dynamic state variables and y-the instantaneous variables.

Equation represents the dynamics of the state variable. In the power system the stat variables are the time-dependent generator voltage (generator voltages vary for different models like E', E_d', E_d'', E_q', E_q''), rotor variables (ω,δ), variables of the Exciter, Speed Governor, dynamic of the load behavior, etc. The differential equation (5.4) is formed by taking into consideration, the dynamics of the generator, exciter, and load dynamics together. Constraint equation represents the dynamics of the instantaneous variables that include the power flow variables like magnitude and angles of the bus voltages. Constraint equation is formed from the Power Balance Equation.

The specific operating conditions and system state is defined by the parameter p that describes the system topography like lines, buses that are energized, equipment constants like inductance, capacitance, transformer turns ratio, etc. The Implicit function theorem is used in the analysis of the Differential-algebraic system. Let point (x,y,p) exists for which the algebraic Jacobian $D_y g$ is nonsingular. According to the implicit function theorem, after eliminating the algebraic variables there exists a locally unique smooth function F in the form

$\dot{x}= F(x,p)$

For a fixed value of p, equilibrium is a solution of the system:

$f(x, y, p) = 0$

$g(x, y, p) = 0$

The stability of equilibrium points can be determined by liberalizing the around the equilibrium point:

$$\begin{bmatrix} \dot{\Delta x} \\ 0 \end{bmatrix} = J \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$$

where J is the unreduced Jacobian of the differential-algebraic system:

$$J=\begin{bmatrix} f_x & f_y \\ g_x & g_y \end{bmatrix}$$

Assuming g_y is nonsingular, we can eliminate Δ y from

$$\Delta\dot{x} = [f_x - f_y g_y^{-1} g_x]\, \Delta x$$

$$A = F_x = [f_x - f_y g_y^{-1} g_x]$$

The three bifurcation sets are the boundary of the feasible region of the system). The system will lose its stability when one equilibrium point passes through the boundary.

TIME DOMIN

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 oscillatory system 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 viscous drag in mechanical systems, resistance in electronic oscillators, and absorption and scattering of 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:

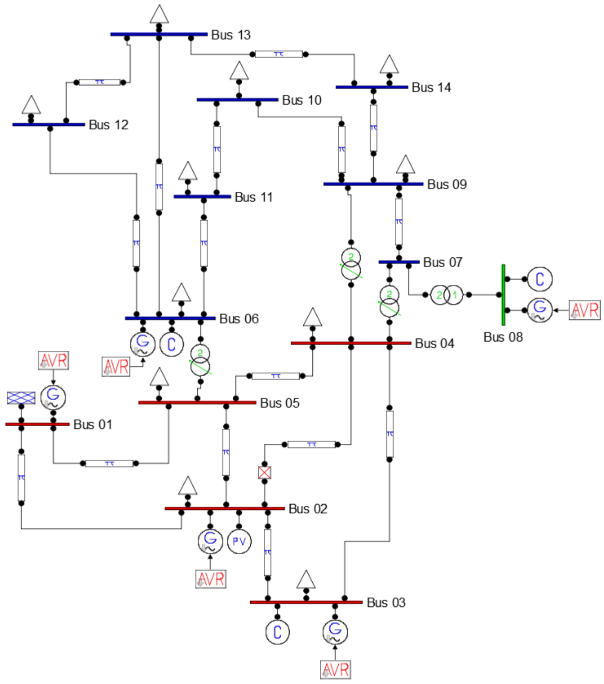
Saddle-node bifurcation point, where two equilibrium coalesce and then disappear, at this point the reduced Jacobian has a zero Eigen value.

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.

SIMULATION RESULTS:

To investigate the impact of increased loading on stability of a wind integrated power system the IEEE14 bus dynamic model. .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.



IEEE14 TEST BUS SYSTEM WITH DYNAMIC COMPONENTS

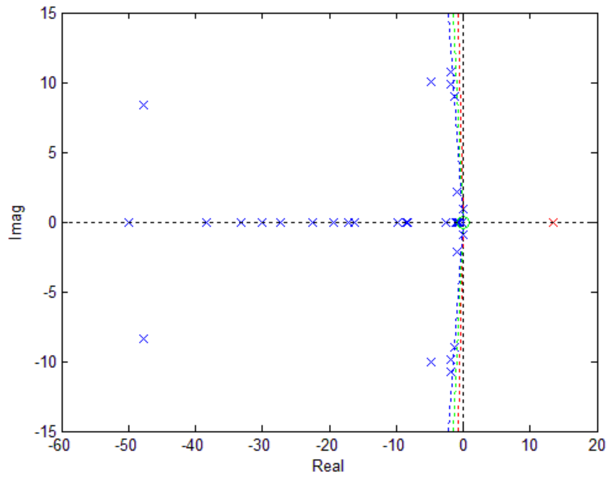
POWER FLOW RESULT OF MODIFIED DYNAMIC IEEE 14 BUS SYSTEM

TOTAL GENERATION	
REAL POWER [MW]	392.0304
REACTIVE POWER [MVar]	204.2345
TOTAL LOAD	
REAL POWER [MW]	362.6
REACTIVE POWER [MVar]	113.96
TOTAL LOSSES	
REAL POWER [MW]	29.43042
REACTIVE POWER [MVar]	90.27453

EIGEN VALUES RESULT OF MODIFIED DYNAMIC IEEE 14 BUS SYSTEM

STATISTICS	
DYNAMIC ORDER	49
# OF EIGS WITH Re(mu) < 0	47
# OF EIGS WITH Re(mu) > 0	1
# OF REAL EIGS	33
# OF COMPLEX PAIRS	7
# OF ZERO EIGS	1

The table gives the Eigenvalue results. The dynamic order of the system is 49 indicating that there are 49 Eigenvalues. The number of negative Eigenvalues is 47, one positive Eigenvalue, 33 Eigenvalues that have the only real part, and 8 complex pairs. The same Eigenvalues are plotted in the Eigen Value plot as shown in the following figure :



TIME DOMAIN SIMULATION OF IEEE 14 TEST BUS SYSTEM

Rotor Speed Excursions of the Synchronous Machines

In the Dynamic IEEE 14 bus system, there are five synchronous machines. Machines 1 and 2 are synchronous generators and machines 3, 4, and 5 are synchronous compensators for providing reactive power support. It has been identified from Table 5.8 that the rotor speed of synchronous machines 2, 3, and 4 are oscillating with a frequency ranging between 1.4 Hz and 1.7 Hz. And also they have very low damping. Whereas the rotor angle of Machine 1 does not have any oscillations. When this system is subjected to a fault, it is evident from Figure 5.12 that all the machines 2, 3, 4, and 5 have oscillations whereas the rotor angle of synchronous machine1 does not have any oscillations. The values of the rotor speed are provided in Table 5.10.

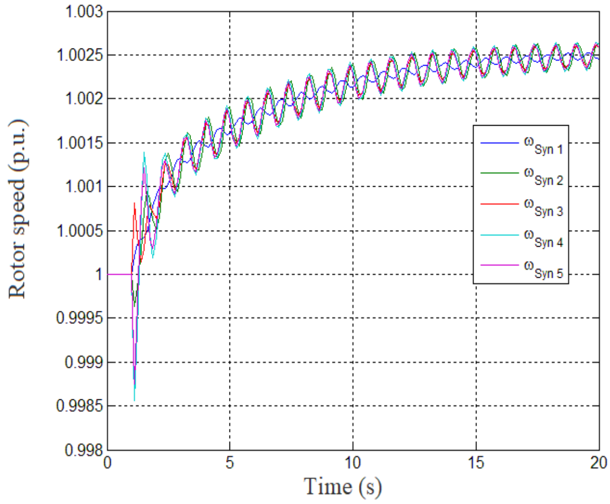


Figure 5.12 Time-Domain Simulations Of Rotor Speed

Table 5.10 Eigen Values and Rotor Speed

EIGEN VALUES	FREQUENCY	DAMPING RATIO	MODE OF OSCILLATION
-1.7939+j 10.7604	1.7362	0.07	Local mode of oscillation
-1.8848+j 9.9033	1.6044	0.03	Local mode of oscillation
-1.3202+j 8.9543	1.4405	0.03	Local mode of oscillation

CONCLUSION:

From the Eigen value analysis it is evident that the absence of positive Eigen values indicate that the system possesses voltage stability The rotor speed oscillations in this system also shows low level of damping which indicates that the system has poor the rotor angle stability of the system.

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