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RESEARCH ARTICLE

Evaluation of Modal Analysis Using Qr Approach To Determine The Oscillations Of The Power System

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ABSTRACT

Voltage stability has become an important issue to many power systems around the world, the large interconnected system being no exception. There is a great interest in the development and application of computational tools and methodologies to voltage stability problems detected in power system planning and operation studies This paper reports modal based analysis and its application in the evaluation of voltage stability of bulk power system. This method makes use of the power system Jacobian matrix to determine the eigen values necessary for the evaluation of the voltage stability. For a steady state power system, a positive eigen value shows that the system is stable while a negative eigen value indicates that the system is instable. The least eigen value indicates the proximity of the system to voltage instability. The stability oscillations are determined critical and super critical levels. The method was implemented on 12 bus system with QR method and it calculated the various eigen values with the least value used to calculate the participation factors that indicated the generator, branches and buses that will contribute most to the bulk system voltage instability. The output simulation is done by using dig silent power factory version 14.1.

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I Introduction

Voltage stability issues are of major concern worldwide because of the number of blackouts that have occurred in recent times in which it was involved. For many power systems, assessment of voltage stability and prediction of voltage instability or collapse have become the most important types of analysis performed as part of system planning, operational planning and real-

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time operation. It is complex important to have an analytical method to investigate voltage stability in the power system, particularly with a and large interconnected network. The work presented in this paper used modal analysis to evaluate the voltage stability of a bulk power system It involves the calculation of a small number of eigen values of the reduced Jacobian matrix obtained from the load flow solution. For a steady state power system, a positive eigen value shows that the system is stable while a negative eigen value indicates that the system is instable. The least eigen value indicates the proximity of the system to voltage instability. The stability oscillations are determined critical and super critical levels. The method was implemented on 12 bus system and it calculated the various eigenvalues with the least value used to calculate the participation factors that indicated the generator, branches and buses that will contribute most to the bulk system voltage instability.

II. Power System Problems

Oscillations in power systems are classified by the system components that they effect. Some of the major system collapses attributed to oscillations are described. Electromechanical oscillations are of the following types:

- Intraplant mode oscillations
- Local plant mode oscillations
- Interarea mode oscillations
- Control mode oscillations
- Torsional modes between rotating plan

In intraplant mode oscillations machines on the same power generation site oscillate against each other at 2.0 to 3.0 Hz depending on the unit ratings and the reactance connecting them. This oscillation is termed as intraplant because the oscillations manifest themselves within the generation plant complex. The rest of the system is unaffected. In local mode, one generator swings against the rest of the system at 1.0 to 2.0 Hz. The rest of the system is normally modelled as a constant voltage source whose frequency is assumed to remain constant. This is known as the singlemachine-infinite-bus (SMIB) model. The damping and frequency vary with machine output and the impedance between the machine terminal and the infinite bus voltage.

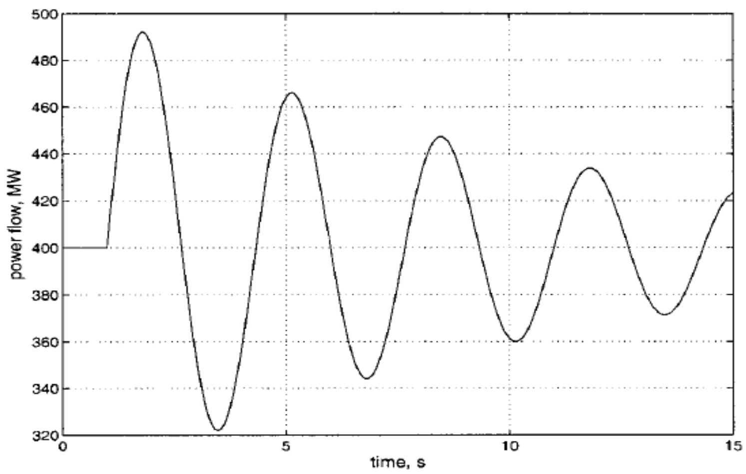

Fig 1 Intraplant mode oscillations

In intraplant mode oscillations is observed over a large part of the network. It involves two coherent group groups of generators swinging against each other at 1 Hz or less. The variation in tie-line power can be large as shown in Fig. 2.2. The oscillation frequency is approximately 0.3 Hz and control mode oscillations are associated with generators and poorly tuned exciters, governors, HVDC converters and SVC controls. Loads and excitation systems can interact through control

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modes. Transformer tap-changing controls can also interact in a complex manner with non-linear loads giving rise to voltage.

III. Modal Analysis

3.1 *Introduction*

Modal analysis is a powerful and helpful tool in order to locate and mitigate power system oscillations. Modal analysis assumes a linearized model of the system in a state space form. Analyzing power system oscillations require a combination of analytical tools. Oscillations are often observed in transient non linear simulations and a complete understanding of the system will therefore require programs both for linear analysis and for non-linear analysis. Programs capable of analyzing power system oscillations have historically been, due to the mathematical nature of the techniques required, restricted to fairly small networks.

3.2 *Theory of modal analysis*

The calculation of eigen values and eigenvectors is the most powerful tool for oscillatory stability studies. When doing such a study, it is highly recommended to first compute the 'natural' system oscillation modes. These are the oscillation modes of the system when all controller and power plant models are deactivated so every synchronous machine will have constant turbine power and constant excitation voltage. After determining these 'natural' modes, the effects of controllers (structure, gain, time constants etc.) and other models can be investigated. After the initial conditions have been calculated successfully, which means that all time-derivatives of the state variables should be zero (the system is in steady state), or the simulation has been stopped at a point in time, the modal analysis calculates the complete system A-matrix using numerical, iterative algorithms. The representation of the electro-dynamic network model is equivalent to the representation used for the balanced RMS simulation, except for the general load model, for which the frequency. More formally, assuming that one of the conjugate complex pair of eigenvalues is given by,

$$\lambda_i = \sigma_i \pm j\omega_i$$

The period and damping of this mode are given by:

$$T_i = \frac{2.\pi}{\omega_i}$$

$$d_i = -\sigma_i = \frac{1}{T_p}.l_n\left(\frac{A_n}{A_{n+1}}\right)$$

where An and An+1 are amplitudes of two consecutive swing maxima or minima respectively.

The oscillatory frequencies of local generator oscillations are typically in the range of 0.5 to 5 Hz. Higher frequency natural oscillations (those that are not normally regulated), are often damped to a greater extent than slower oscillations. The oscillatory frequency of the between areas (inter-area) oscillations is normally a factor of 5 to 20 times lower than that of the local generator oscillations. The absolute contribution of an individual generator to the oscillation mode which has been excited as a result of a disturbance can be calculated by:

$$\omega(t) = \sum_{i=1}^{n} c_i \,.\, \phi_i.\, e^{\lambda_i.t}$$

Normalization is done by assigning the generator with the greatest amplitude contribution the relative contribution factor 1 or n-1 respectively. For a n-machine power system, n-1 generator oscillation modes will exist and n-1 conjugate complex pairs of eigenvalues λ_i will be found. The mechanical speed ω of the n generators will then be described by:

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$$\begin{bmatrix}\omega_1\\ \omega_2\\ \cdots.\\ \omega_n\end{bmatrix} = c_1.\begin{bmatrix}\phi_{11}\\ \phi_{12}\\ \cdots\\ \phi_{1n}\end{bmatrix}.e^{\lambda_1 t} + c_2.\begin{bmatrix}\phi_{21}\\ \phi_{22}\\ \cdots\\ \phi_{2n}\end{bmatrix}.e^{\lambda_2 t} + \cdots + c_n.\begin{bmatrix}\phi_{n1}\\ \phi_{n2}\\ \cdots\\ \phi_{nn}\end{bmatrix}.e^{\lambda_n t}$$

The problem of using the right or left eigenvectors for analyzing the participation of a generator in a particular mode i is the dependency on the scales and units of the vector elements. Hence the eigenvectors ϕ_i and λ_i are combined to a matrix P of participation factor by:

$$p_i = \begin{bmatrix}p_{1i}\\ p_{2i}\\ \cdots\\ p_{ni}\end{bmatrix} = \begin{bmatrix}\phi_{1i}.\psi_{i1}\\ \phi_{2i}.\psi_{i2}\\ \cdots.\\ \phi_{ni}.\psi_{in}\end{bmatrix}$$

The elements of the matrix pij are called the participation factors. They give a good indication of the general system dynamic oscillation pattern.

$$\mathrm{A_i} = \mathrm{R_i Q_i}$$

They can be used to determine the location of eventually needed stabilizing devices to influence

the system damping efficiently. Here for oscillations QR approach will be applied.

IV. Results and Discussions

The Modal Analysis command calculates the eigen values and eigenvectors of a dynamic multi-machine system including all controllers and power plant models. This calculation can be completed at the beginning of a transient simulation and at every time step when the simulation is stopped. A digsilent power factory software is preferable for modal analysis to calculate eigen values. For calculation of eigen values it needs to do load flow analysis and the output datas are follows. figure 7.1 shows the general 12-bus system with interconnected grid. Adjust the filter settings in the box below to determine which eigen values will not be shown in the report. Alternatively, to display a report for a single eigen value, choose the eigen value index from this box.

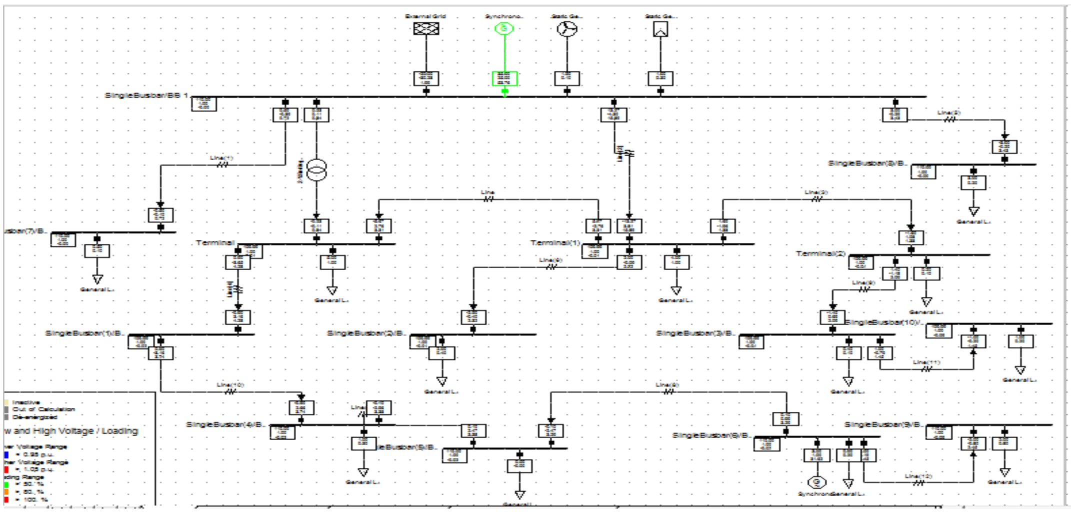

Fig.2 general 12-bus system with interconnected grid

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Load Flow Calculation	Complete System Report: Voltage Profiles, Grid Interchange

AC Load Flow, balanced, positive sequence		Automatic Model Adaptation for Convergence	No
Automatic Tap Adjust of Transformers	No	Max. Acceptable Load Flow Error for	
Consider Reactive Power Limits	No	Nodes	1.00 kVA
		Model Equations	0.10 %

Grid: Grid	System Stage: Grid	Study Case: Study Case	Annex:	/ 2

Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen- sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
110.00	40.00	0.00	20.00	0.00	-20.00			0.00	0.00	0.00
	26.40	0.00	4.40	0.00	-30.28			-8.28	0.00	-8.29
Total:	40.00	0.00	20.00	0.00	-20.00		0.00	0.00	0.00	0.00
	26.40	0.00	4.40	0.00	-30.28		0.00	-8.28	0.00	-8.29

Fig.3. load flow system report of 12-bus system

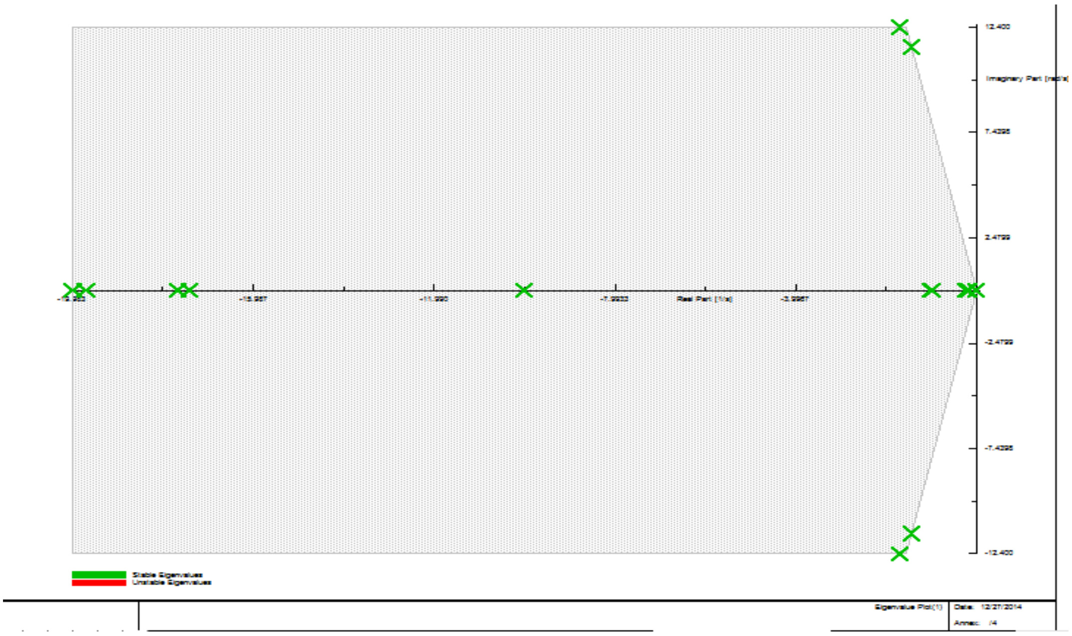

Fig.4. The eigenvalue plot

The horizontal axis shows the real part. Stable eigenvalues are shown in green. Each eigenvalue can be inspected in detail by double clicking it on the plot. In figure.4 shows the plot of eigenvalue.

Conclusion

This study has shown the step by step the modal based analysis and its application in the evaluation of voltage stability of bulk power system using AL method. For a steady state power system, a positive eigen value shows that the system is stable while a negative eigen value indicates that the system is instable. The least eigen value indicates the proximity of the system to voltage instability. The stability oscillations are determined critical and super critical levels. The method was implemented on 12 bus system and it calculated the various eigen values with the least

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value used to calculate the participation factors that indicated the generator, branches and buses that will contribute most to the bulk system voltage instability.

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