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Dynamic Voltage Stability Analysis of Dynamic IEEE 14 Test Bus System

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ABSTRACT: Dynamic voltage stability analysis involves studying the power system's ability to maintain acceptable voltage levels over time in response to disturbances. Unlike static voltage stability analysis, which focuses on steady-state conditions, dynamic analysis deals with the system's transient response to changes and disturbances. This is crucial for ensuring that the system can recover from faults or sudden changes in load or generation without experiencing voltage collapse.. In this paper the Dynamic voltage stability analysis of Dynamic IEEE 14 bus system was analysed using Power system Analysis Toolbox. (PSAT)

KEYWORDS: Modal Analysis, Dynamic IEEE 14 Bus system, MATLAB (PSAT)

I. INTRODUCTION

Voltage stability refers to the ability of a power system to maintain steady voltages at all buses in the system under normal operating conditions and after being subjected to disturbances. It's important because voltage instability can lead to voltage sags, swells, or even blackouts, affecting both the power supply and the end-users.

Dynamic Stability refers to the system's ability to maintain voltage stability over time, particularly after disturbances such as faults, sudden load changes, or generator trips. Dynamic stability analysis examines how voltage levels evolve and stabilize after a disturbance.: Unlike static analysis, which looks at the system's response at a specific moment, dynamic analysis considers how system variables change over time. This includes the effects of system control actions, such as automatic voltage regulators (AVRs) and generator controls Common disturbances analyzed in dynamic stability studies include faults (e.g., short circuits), sudden load increases or decreases, generator outages, and changes in generation or reactive power support.

Voltage instability has been given much attention by power system researchers and planners in recent years, and is being regarded as one of the major sources of power system insecurity. Maintaining a stable and secure operation of a power system is therefore a very important and challenging issue.

Several incidences of voltage collapse have been observed, in the past few decades, in different parts of the world. Some of the incidences of voltage collapse are:
New York State Pool disturbance of September 22, 1970.
Jacksonville, Florida system disturbance of September 22, 1977.
Sri Lanka Power System disturbance of May 2, 1995.
Northern Grid disturbance in the Indian Power System of December 1996.
North American Power system disturbance of August 14, 2003.
National Grid System of Pakistan disturbances of September 24, 2006.

National Scenario
Northern Regional grid security violation, January 2001 leading to 1500mw loss in a generation.
Northern Regional failure 23rd December 2000.
Southern Regional grid failure on 13th October 1995.
Western Regional Grid failure on 10th November 1995.
Western Regional Grid failure on 9th December 1995.

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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.

III. METHODS OF ANALYSING VOLTAGE STABILITY

Steady-State Analysis: Involves the use of load flow studies to assess the system's ability to maintain voltage stability under steady conditions. Tools like Power Flow Analysis (using methods like Gauss-Seidel or Newton-Raphson) are often employed.
Dynamic Analysis: Evaluates how the system responds to disturbances over time. Time-domain simulations are used to study the system's behavior under transient conditions.

Voltage Stability Indices: These are mathematical measures used to evaluate voltage stability. Examples include the Voltage Stability Index (VSI) and the L-index.

Continuation Power Flow Analysis: A technique used to track the system's voltage stability as the load increases. It involves incremental changes in load and tracking the resulting changes in system stability.

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

IV. DYNAMIC VOLTAGE STABILITY ANALYSIS

Dynamic voltage stability analysis involves studying the power system's ability to maintain acceptable voltage levels over time in response to disturbances. Unlike static voltage stability analysis, which focuses on steady-state conditions, dynamic analysis deals with the system's transient response to changes and disturbances.Steps in Dynamic Voltage Stability Analysis

Modelling the Power System:
○ Develop dynamic models for all relevant components of the power system, including generators, transformers, transmission lines, loads, and control devices. This involves defining the equations governing the time-dependent behavior of each component.

Defining Disturbances:
○ Identify and model typical disturbances that could affect voltage stability. This might include faults, sudden changes in load, or generator trips. Each disturbance is characterized by its type, location, and magnitude.
○ **Simulating the Response**:
Use dynamic simulation tools to study how the power system responds to the defined disturbances over time. This involves solving differential equations that describe the system's behavior, which can be done using specialized software.

Analyzing Stability:
○ Examine the results of the simulations to assess voltage stability. Key metrics include:
▪ **Voltage Recovery Time**: How quickly the system returns to stable voltage levels after a disturbance.
▪ **Voltage Magnitude**: The minimum voltage levels reached during the disturbance and how they compare to acceptable limits.
▪ **Oscillations**: The presence of oscillatory behavior in voltage levels, which can indicate potential stability issues.

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Practical Considerations

1. **Model Accuracy**: Ensure that the dynamic models accurately represent the real system, including control mechanisms and system dynamics. Inaccurate models can lead to incorrect stability assessments.
2. **System Complexity**: For large power systems, simulations can be computationally intensive. Simplifications or reduced-order models might be used to manage computational demands.
3. **Validation**: Validate simulation results against historical data or real system performance to ensure that the analysis is realistic and reliable.
4. **Real-Time Monitoring**: For operational systems, dynamic voltage stability can be monitored in real-time to detect and respond to potential stability issues promptly.

Applications of Dynamic Voltage Stability Analysis

- **System Planning**: Helps in designing and planning power systems to ensure they can handle expected disturbances and maintain voltage stability.
- **Operational Decisions**: Guides operators in real-time decisions, such as adjusting control settings or reconfiguring the system to maintain stability.
- **Control System Design**: Assists in designing and tuning control systems to enhance dynamic voltage stability.

Dynamic voltage stability analysis is crucial for ensuring that power systems can maintain stable voltage levels during and after disturbances, preventing potential outages and maintaining reliable power supply.

Methods of Analysis

1. **Power Flow Analysis**: This method involves solving the power flow equations to determine the operating point of the system. Voltage stability can be assessed by examining how voltages and power flows change with increasing load or changes in generation.
2. **Voltage Stability Margin**: This is the difference between the current operating point and the point at which the system becomes unstable. It is often analyzed using techniques like the continuation power flow method.
3. **P-V Curve Analysis**: This curve represents the relationship between the load (P) and the voltage (V) at a particular bus. By plotting the P-V curve, you can identify the critical point where voltage collapse may occur.
4. **Q-V Curve Analysis**: This curve shows the relationship between reactive power (Q) and voltage (V). It helps in understanding how reactive power support impacts voltage stability.
5. **Sensitivity Analysis**: This involves analyzing how changes in system parameters (like load or generator output) affect voltage stability. Sensitivity indices can help in identifying critical buses or lines that are vulnerable to stability issues.
6. **Continuation Power Flow**: This is an advanced method used to trace the changes in voltage stability as the system load is incrementally increased. It helps in identifying the stability limit and the critical points where the system may become unstable.

V. METHODOLOGY

Step1. The Power flow analysis is executed using the Newton Raphson Method and the initial power flow results are obtained.
Step2: Continuation Power Flow algorithm is executed on the Dynamic IEEE 14 test bus system.
Step3: The Eigenvalue analysis is then carried out to obtain the Eigen Values, Participating Factor, Most associated State Variable Frequency.
Step4: The Eigenvalue plot is plotted to study the pattern of Eigenvalues.
Step5: From the Eigen Values the stability of the system, Saddle Node Bifurcation, Hopf Bifurcation are identified.
The presence of anyone positive Eigenvalue indicates that the system is unstable.
The Eigenvalue with zero indicates the occurrence of the Saddle Node Bifurcation.
The presence of Complex Conjugate pair with zero or positive real part indicates the presence of Hopf Bifurcation that is the system is in a state of Oscillatory instability.
Step9: The prospective state variables that can set up oscillatory instability by the crossing of the imaginary axis invoking oscillatory instability is identified from the magnitude of the complex Eigenvalue. Lower the value closer is the Eigenvalue to the imaginary axis of the complex plane.
Step10: The type of oscillatory instability whether Local area oscillation mode or inter-area mode is detected from the frequency of oscillation.

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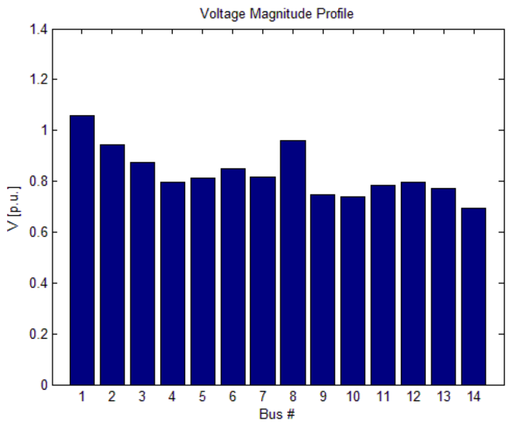
Step 11: The time-domain analysis is carried out by introducing a normal and single contingency (Line 2- 4trip) and the variables that are identified to cause oscillatory instability are plotted to study their transient behavior.

VI. EXPERIMENTAL RESULTS

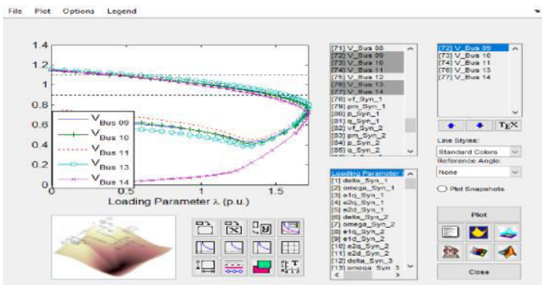
The plot of voltage magnitude at various buses is shown in figure 5.6. From the voltage profile, it is evident that buses 4,5,9,10 and 14 have less voltage magnitude and so they are considered to be weak bus which may provoke voltage instability.



Voltage Magnitudes of Dynamic IEEE14 bus System with Dynamic components

PV Curve of Dynamic IEEE14 bus System

Continuation Power Flow completed in 3.8338 s



Continuation Power Flow Diagram**.**

From the power flow result and figure 5.9, it is identified that buses 14, 9, 10 have the least voltage magnitude when compared with other buses. This indicates that they are the weak buses which may contribute to voltage instability during the contingent condition.

From the CPF plot, as shown in figure 5.10, the Maximum Loadability limit is 1.7188 p. u at which the power flow Jacobian matrix becomes singular and beyond which if the power system is loaded will end up in instability.
From the Continuation Power Flow result, it is evident that the Hopf bifurcation occurs at 71 % (0.71734 p.u) of the load.

VII. CONCLUSION

In this paper, the dynamic voltage stability analysis of Dynamic IEEE 14 bus was carried out based on Static voltage stability analysis using Modal and Continuation power flow technique. Power system Analysis Tool Box (PSAT) on

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MATLAB 2014 was used for analyzing the voltage stability of the IEEE14 bus and it was identified that the system does not possess voltage stability.

REFERENCES

1. Li X., Bao L., Daun X., He Y., Gao M., "Effect of FACTS Controller Small-Signal Voltage Stability", IEEE Power Engineering Society Winter Meeting, pp.2793-2799, 2000.
2. Jafari M., Afsharnia S., "Voltage Stability Enhancement in Contingency Conditions Using Shunt FACTS Devices", IEEE EUROCON 2007, pp.1660-1665, 2007.
3. Candelo J. E., Caicedo N. G., Aranda F. C., "Proposal for the Solution Voltage Stability Using Coordination of FACTS Devices", IEEE Transmission, Distribution Conference, pp.1-6, 2006.
4. Kundur, P., "Power System Stability and Control", McGraw Hill, 1994.
5. B. Gao, G. K. Morison, P. Kundur, "Voltage Stability Evaluation Using Modal Analysis," Transactions *on* power Systems, Vol. 7, No. 4. November 1992.
6. B. Gao, G. K. Morison, P. Kundur, "Voltage Stability Analysis Using Static and Dynamic Approaches," IEEE Transactions *on* power Systems, Vol. 8, No. 3, August 1993.
7. P. Pal, "*Voltage Stability Conditions Considering Load Characteristics*", IEEE Trans. on Power Systems, Vol. 7, No. 2, pp. 243-249, Feb. 1992.
8. P. Kessel and H. Glavitsch, "*Estimating the Voltage Stability of a Power System*,‖ IEEE Trans. on Power Delivery, vol. 1, pp. 346-353, July 1986.
9. C. D. Vournas, P. W. Sauer, and M. A. Pai(1996), "Relationships between voltage and angle stability of power systems", Electric Power Systems Research, vol. 18, no. 8, November 1996, pp: 493-500.
10. Antonio C. Z. de Souza, Claudio A. Canizares, Victor H. Quintana (1996), "New Techniques to speed up voltage collapse computations using tangent vectors", IEEE Transactions on Power Systems, 1996.
11. Scott Greene, Ian Dobson, Fernndo L. Alvarado (1997), "Sensitivity of the loading margin to voltage collapse concerning arbitrary parameters", IEEE Transactions on Power Systems, Vol. 12, No. 1, February 1997, pp:262-231.
12. D.L.H. Aik; and G. Andersson (1998), "Use of participation factors in modal voltage stability analysis of multi-infeed HVDC system", IEEE Transactions on Power Delivery, Vol. 13, No. 1, January 1998, pp: 203 – 211.