Scilab case study project
on

Voltage Stability
Estimation of Electric Power System using L-index

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1. ABSTRACT

Voltage stability is a critical aspect of power system operation, especially in industrial loads where high demand and dynamic changes in load conditions are common. Most of major black outs that have been experienced in many countries is due to system operation closer to their stability limits. Many indices were proposed to analyse the voltage stability of a power system. This work uses L-index to assess the voltage stability of an industrial consumer that estimates the distance of the consumer in reaching voltage instability. In this case study project, series of SCILAB code are written to estimate the L-index of that varies between 0 (No load point) and 1 (voltage instability point) for a consumer under static loading conditions. The codes are used to evaluate the L-index of all load buses in a standard 6 bus test case and the results are presented.

2. INTRODUCTION

Voltage stability is critical for the reliable operation of power systems, preventing outages, equipment failures, and blackouts. Assessing voltage stability involves analyzing a system's ability to maintain acceptable voltage levels under varying conditions, which requires calculating stability indices, evaluating stability margins, and analyzing load flow behavior.

Voltage instability can lead to voltage collapse, resulting in a major outage or system failure. Therefore, it is crucial to monitor and analyze voltage stability to ensure a reliable and stable power supply.

One of the most effective indices used to assess voltage stability is the L-index. This index quantifies the proximity of the system to voltage instability. It provides an efficient way to detect voltage instability and helps operators to take proactive measures to avoid system failure.

The L-index is a mathematical method to measure voltage stability, introduced by researchers in the field of power systems. The index is based on the bus voltage magnitudes and their corresponding power injections, considering the loading conditions of the system. A higher L-index value suggests the system is closer to a voltage collapse, whereas lower values indicate a stable operating point.

The key advantage of using the L-index for voltage stability analysis is its simplicity, computational efficiency, and ability to provide clear insights into the stability of large and complex power systems.

Scilab is an open-source software used for numerical computation and provides a robust platform for simulation, modeling, and analysis of power systems. With built-in functions for matrix operations, linear algebra, and optimization, Scilab is ideal for implementing voltage stability analysis algorithms such as the L-index. The integration of Scilab in voltage stability analysis allows researchers and engineers to perform simulations, conduct parameter sensitivity studies, and visualize results easily.

This case study project focuses on performing voltage stability analysis using the Lindex with Scilab programming, with the goal of identifying voltage instability points and evaluating the system's proximity to a voltage collapse under various loading conditions. By computing the L-index, it will be possible to detect voltage collapse risks and suggest corrective actions to improve the system’s stability.

3. METHODOLGY

The methodology for estimating voltage stability using the **L-index** in a power system involves a series of steps, including power flow analysis, L-index calculation, and interpretation of results. Below is the detailed methodology: **I. Power Flow Analysis:**

The first step in estimating voltage stability using the L-index is to solve power flow problem to obtain the system's operating conditions (voltage magnitudes, active and reactive power at each bus). Power flow is essential for understanding the distribution of power in the system under normal and stressed conditions.

- **Choosing the Method:**
  - **Newton-Raphson Method:** A fast and efficient iterative method, often preferred for large systems.
- **Input Data:** The input data required for power flow analysis includes:
  - **Bus data**: Voltage magnitude and angle, load, and generation at each bus.
  - **Line data**: Impedance values and admittance.
- **Power Flow Results:** The output of this step will provide:
  - To difference in scheduled to calculated power.

$$\Delta P_i^{[k]} = P_{i,sch} - P_i^{[k]}$$

$$\Delta Q_i^{[k]} = Q_{i,sch} - Q_i^{[k]}$$

  - Active and reactive power flows between buses.

$$P_i^{(k)} = |V_i| \sum_{j=1}^{n} |V_j| \, |Y_{ij}| \cos(\theta_{ij} + \delta_j - \delta_i)$$

$$Q_i^{(k)} = -|V_i| \sum_{j=1}^{n} |V_j| \, |Y_{ij}| \sin(\theta_{ij} + \delta_j - \delta_i)$$

  - Jacobian Matrix

$$\begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{bmatrix}^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}$$

- Voltage magnitudes and angles at each bus.

  $$\delta_i^{[k+1]} = \delta_i^{[k]} + \Delta\delta_i^{[k]}$$

  $$\left|V_i^{[k+1]}\right| = \left|V_i^{[k]}\right| + \Delta\left|V_i^{[k]}\right|$$

- Power losses.

  $$S_{ij} = V_i^2 (y_{ij} + y_{i0})^* - V_i y_{ij}^* V_i^*$$

  $$S_{ji} = V_j^2 \left(y_{ij} + y_{j0}\right)^* - V_j y_{ij}^* V_i^*$$

  $$S_{lossij} = S_{ij} + S_{ji}$$

II. Calculation of L-index:

P.Kessel and H.Glavitsch [1] proposed L-index for detection of voltage instabilities in a power system, which varies between 0 and 1. The advantage of the method lies in the simplicity of the numerical calculation and the expressiveness of the result. The L-index is mathematically expressed as,

$$L_j = \left|1 + \frac{V_{0j}}{V_j}\right| = \frac{S_j^+}{Y_{ij} V_j^2}$$

where $\underline{S}_j^+ = \underline{S}_j + \underline{S}_j^{corr}$, $\underline{S}_j$ is the nodal power in node j and $\underline{S}_j^{corr}$ is an equivalent power that stems from other loads of the system.

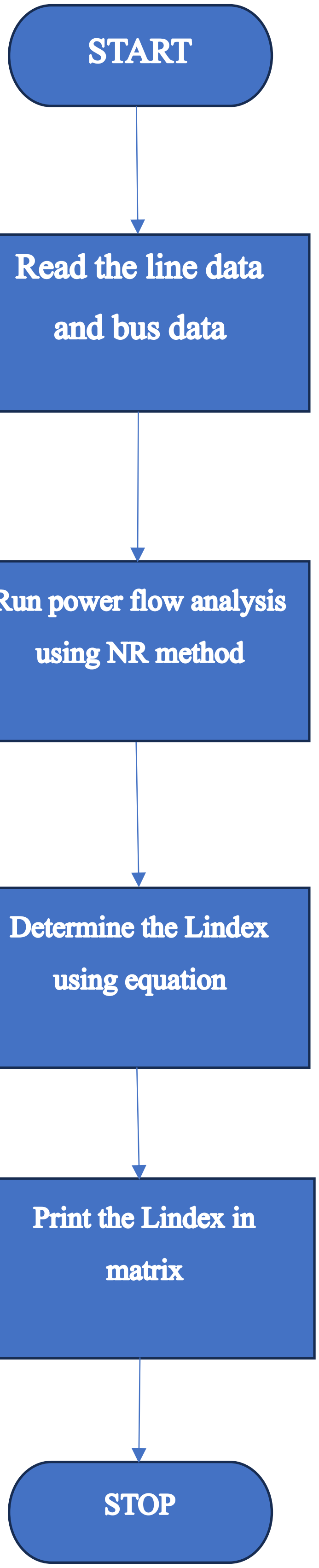
- **Low L-index Value:** A lower L-index value (closer to 0) indicates that the system is operating in a stable voltage region, and there is sufficient reactive power support for voltage maintenance.

- **High L-index Value:** A higher L-index value (closer to 1) indicates that the system is approaching voltage instability, with insufficient reactive power support at one or more buses. If the L-index approaches 1, the system is on the verge of voltage collapse.

The system operator can use this information to take corrective actions such as:

- **Increasing reactive power compensation** at weak buses.
- **Optimizing generator reactive power output** to support voltage stability.
- **Redistributing load** or shedding unnecessary load to avoid voltage collapse.

4.FLOW CHART


START
Read the line data and bus data
Run power flow analysis using NR method
Determine the Lindex using equation
Print the Lindex in matrix
STOP

5.SOFTWARE USED

In this section,using the software of Windows 11 version, Scilab 2024.1.0 version used in this case study.

6.PROCEDURE OF EXECUTION

CONTAIN FILES: Here contain the sci files are **Ybus.sci**, **loadflowNR.sci, Initialization.sci**, **Lindex.sci** & **Scorrected.sci** with including data files as **dataline.sci** & **databus.sci** .

SUB FILES: loadflowNR.sci is the main file contain sub files orderly execute are

i) Ybus.sci
ii) Initialization.sci
iii) Lindex.sci
iv) Scorrected.sci

EXECUTION: Execute the file **loadflowNR.sci** to get the bar graph and give input as L in output console for get Lindex of 6 bus system. Bus data also executed.

7.RESULTS

The code developed in SCILAB is used to estimate the L-index of load buses of a 6 bus system whose data are available in two files (bus data and line data). The L-index of load buses is presented in Figure 1. The plotted L-index shows the results of base case loading. The value of L-index will increase with increased loading. In the considered test case, bus 6 has the larger L-index value and it is prone to voltage instability compared to other buses in the system.

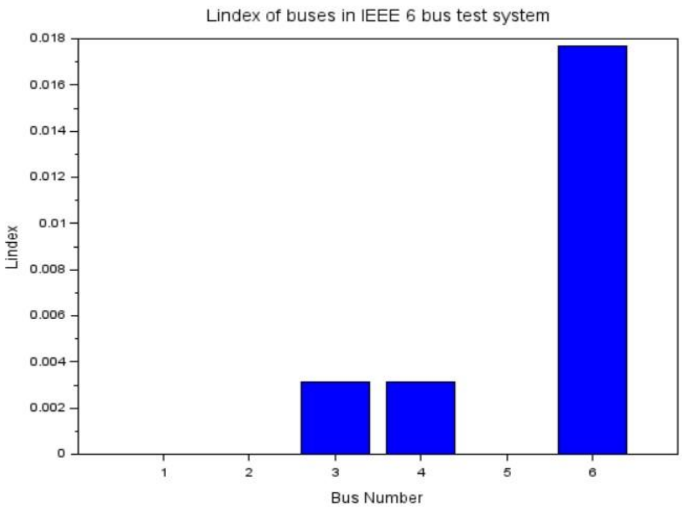


Figure 1 L-index for 6-bus test system

NOTE**I have the data as sci.file so when execute the main file as loadflowNR.sci.The bar graph will be automatically execute and In output console automatically bus data get.

If want L index value please type L in output console.**

8.CONCLUSION

In conclusion, the **L-index estimation using SCILAB** is an powerful tool for analyzing and managing voltage stability in power systems. The **L-index** effectively assesses voltage stability, helping identify issues, optimize performance, and maintain reliable power supply.

As power grids evolve with renewable energy and smart technologies, integrating the Lindex will be crucial for enhancing grid stability and reliability in the future

9.REFERENCES

1. P. Kessel and H. Glavitsch, "Estimating the Voltage Stability of a Power System," in IEEE Transactions on Power Delivery, vol. 1, no. 3, pp. 346-354, July 1986, doi: 10.1109/TPWRD.1986.4308013.
2. Shashi Kumar Yadav, Ashok Soni , " Voltage Stability Estimation of Electric Power System Using L-Index ", International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, Vol. 4, Special Issue 4, November 2016.