Observations of Thevenin Equivalent Parameters and Their Effects on the Long-Term Dynamics of Bus Voltage

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Author: Sean Zilberdrut (szilberd@uncc.edu, 704-942-1314)

Major: Electrical Engineering

School: University of North Carolina at Charlotte

Education Level: Undergraduate

Faculty Advisor: Dr. Valentina Cecchi (vcecchi@uncc.edu, 704-687-8730)

Increasing amounts of distributed generation, specifically renewables such as solar and wind, are presenting distribution systems with a variety of problems. One of those problems is voltage variation in the system. Distribution systems supply power to loads that depend on a steady voltage, therefore, a photovoltaic array that has a large rise and fall in output during the course of a day could cause a protective element to bring load offline. To avoid this, something must be done to minimize the variation in the long-term variation of the voltage over the course of the day, which shall be termed the long-term dynamics of the voltage.

A well-known practice in the analysis of circuits is to utilize the Thevenin equivalent of a circuit from a pair of terminals of interest [1]. This simplifies the rest of the circuit into an equivalent voltage, impedance and the load or source connected to those terminals. Utilizing this tool, the voltage characteristics at the terminals of interest can be easily observed. Thus, the Thevenin equivalent parameters can be related to the voltage at any bus in a distribution system.

Changes to the Thevenin equivalent parameters can be caused by a reconfiguration of the topology of the system. Distribution systems have switches and sectionalizers that will change the topology of the network in the event of a fault or extreme loading condition. Utilizing these devices will change the Thevenin voltage and impedance as seen from each bus and could possibly reduce the long-term voltage variation caused by a photovoltaic array.

Simulating a power system to find the voltages at its buses requires power flow calculations. The Gauss-Seidel equation is one method at finding an iterative solution to bus voltages. It was found that through the Gauss-Seidel equation, a mathematical relationship could be made between the Thevenin equivalent parameters and the original system voltages. Therefore, it is possible to predict the bus voltages on the original system from its Thevenin parameters for a given configuration.

This relationship was verified through a 9-Bus Test System, in which graphical relationships between the Thevenin parameters and the long-term dynamics of the bus voltages were shown. The results revealed several observations: (1) the long-term dynamics of the bus voltage were negatively related to the Thevenin voltage, (2) the long-term dynamics of the bus voltage were directly related to the Thevenin impedance and (3) in some cases the Thevenin voltage and impedance would work against one another; the parameter with the largest effect would then cause the long-term dynamics of the bus voltage to behave in (1) and (2).

With these observations in mind, this research could be extended into an optimization problem. If given a system with a known configuration and a number of switches that connect different buses together that could form loops, then what configuration would lend towards an optimal voltage profile across the system? This can be taken another step towards the addition of constraints on how many and which switches could be closed at any time.

Word Count: 498

References

[1] Nilsson, James William, and Susan A. Riedel. 2011. *Electric circuits*. Boston: Prentice Hall.

[2] Saadat, Hadi. 2010. *Power system analysis*. [United States]: PSA Pub.