Using multidimensional scaling to represent a power system according to the electric distances between nodes

Florence Fonteneau-Belmudes
University of Liège
Florence.Belmudes@ulg.ac.be

Damien Ernst
University of Liège
dernst@ulg.ac.be

Louis Wehenkel
University of Liège
L.Wehenkel@ulg.ac.be

In power systems, graphical representations of the electric networks are systematically used when designing and operating a network. Being able to visualize the elements of a power system in a two-dimensional space is of paramount importance at these two stages of power system analysis and control. The graphical representation commonly used by all the Transmission System Operators (TSOs) is based on the geographic position of each equipment of the network, which seems to be the most evident way to represent a power system.

However, we can wonder whether this representation is totally appropriate, or should be completed by another representation that would help the operators to have a better perception of the electrical phenomena that are likely to happen in their network. In current practice, system operators can only create a mental representation of the physical properties of the equipments. For example, they can associate to each transmission line the value of its impedance, or at least an approximation of it. Thanks to these indicators, they are able to figure out to which equipments an incident (such as a line overflow) is more likely to propagate. However, these conclusions are only based on the human interpretation and are therefore neither completely accurate nor perfectly reliable. This is why a dedicated tool representing the electrical properties of the equipments of a network would provide a helpful complement to the existing tools used by the transmission system operators. Whereas in-depth studies about the necessity to have user-friendly and adequate representations of a power system in order to operate it correctly have already been reported in the literature (see, e.g., [1], [2] and [3]), no alternative to the geographic coordinate system has been investigated yet.

We propose in this work to develop a graphical representation of a power system based on the impedances between nodes, and no longer on the geographic distance between them. The choice of impedances to define a "new" distance between the nodes of an electricity transportation network is based on the assumption that the impedances provide a good image of the electric proximity between nodes. To be as close as possible to the electric reality of a power system, we define here the distance between two nodes of an electric network as being the reduced impedance between these two nodes, which is computed by reducing the whole network to these only nodes.

By computing the reduced admittance between each pair of nodes of the studied system, we obtain a matrix expressing the electrical proximities between all the nodes of the network. In this context, our objective is to visualize the information contained in the n-by-n electrical proximity matrix (where n is the number of nodes of the studied electric network) in a low-dimensional space. For this purpose, we chose to use multidimensional scaling algorithms. As explained in [4], multidimensional scaling is a method that aims at representing measurements of similarity between pairs of objects as distances between points of a low-dimensional multidimensional space. This technique is therefore appropriate to extract from the electrical proximity matrix the coordinates of the nodes in a two-dimensional space.

We have implemented our approach to create an "electric" graphical representation of the IEEE 118 bus test system, vastly used in the literature as benchmark problem, and also of the Belgian electric network. The power system engineers to which these graphical representations were shown found them very informative.

References

[1] R. Fujiwara and Y. Kohno, "User-friendly workstation for power system analysis," *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-104, No. 6, pp. 1370–76, June 1985.

[2] P. Mahadev and R. Christie, "Envisioning power system data: Concepts and a prototype system state representation," *IEEE Transactions on Power Systems*, vol. 8, no. 3, pp. 1084–90, August 1993.

[3] ——, "Envisioning power system data: Vulnerability and severity representations for static security assessment," *IEEE Transactions on Power Systems*, vol. 9, no. 4, pp. 1915–20, November 1994.

[4] I. Borg and P. J. Groenen, *Modern Mutlidimensional Scaling: Theory and Applications*. Springer New York, 2005.