Reliability Engineering & System Safety

Volume 101, May 2012, Pages 67 – 74

Analyzing the topological, electrical and reliability characteristics of a power transmission system for identifying its critical elements

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http://dx.doi.org/10.1016/j.ress.2011.11.009, How to Cite or Link Using DOI

Abstract

The subject of this paper is the analysis of an electrical transmission system with the objective of identifying its most critical elements with respect to failures and attacks. The methodological approach undertaken is based on graph-theoretical (topological) network analysis. Four different perspectives of analysis are considered within the formalism of weighed networks, adding to the purely topological analysis of the system, the reliability and electrical characteristics of its components. In each phase of the analysis: i) a graph-theoretical representation is offered to highlight the structure of the most important system connections according to the particular characteristics examined (topological, reliability, electrical or electrical-reliability), ii) the classical degree index of a network node is extended to account for the different characteristics considered. The application of these concepts of analysis to an electrical transmission system of literature confirms the importance of different perspectives of analysis on such a critical infrastructure.

Highlights

► We analyze a power system from topological, reliability and electrical perspectives. ► We rank critical components within a vulnerability assessment framework. ► We compute an extended degree to rank critical energy paths. ► We compare several analytical approaches and provide a table for choosing among them. ► We suggest network changes to increase the reliability of highly loaded energy paths.

Keywords

Critical infrastructures; Vulnerability assessment; Electrical transmission system; Network analysis; Reliability; Connectivity degree

Figures and tables from this article:

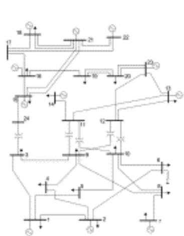

Fig. 1. IEEE RTS 96.

Figure options

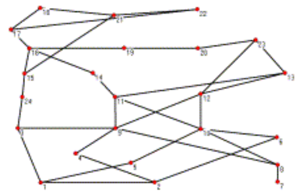

Fig. 2. Topological graph of the IEEE RTS 96.

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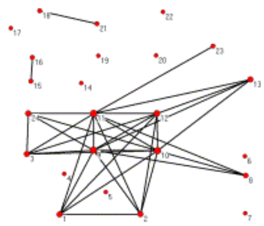

Fig. 3. IEEE RTS 96 redrawn to highlight the structure of the 34 most reliable connections.

Figure options

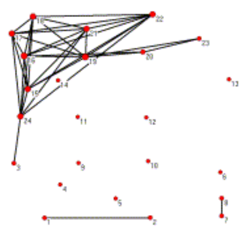

Fig. 4. IEEE RTS 96 redrawn to highlight the structure of the shorter electrical connections.

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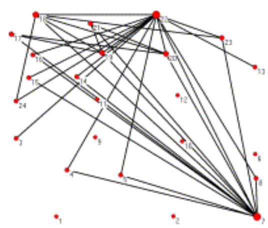

Fig. 5. IEEE RTS 96 redrawn to highlight the structure of the most reliable electrical connections.

Figure options

Table 1. Degree indicators of the 24 network nodes.

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Table 2. Ranking of network connections with respect to the reliability, electrical and reliability-electrical distances.

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Table 3. Evaluation of the four perspectives based on literature review and developed criteria.

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