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An efficient method of robustness analysis for power grid under cascading failure ☆

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ABSTRACT

The robustness of power grids is a central topic in the design of the so called "smart grid". As the total amount of load in the power grid is becoming more and more each day, and the sizes of power grids are becoming larger and larger each year, it will result in larger damages to the society if the power grids broke down. For example, the Northeast blackout of 2003 in the US resulted in a loss of 61,800 MW of electric load that served more than 50 million people ELCON (2003). In this paper we try to analyze the measures of importance of the nodes in a power grid under cascading failure. Moreover, we introduce the notion of degree correlation for the case where only the statistical information of a power grid is known. Mean field theory is used for our analysis. With these efforts, we can distinguish the most vulnerable nodes and protect them, improving the safety of the power grid. Also we can measure if a structure is proper for power grids. Above all, a new multi-loop structure for smart grid is shown to be better than the contemporary one.

1. Introduction

In recent years the robustness of power grids has attracted much attention, since the blackout in North America, 2003, which is reported to cause a large amount of damages ELCON (2003). It is reported that the causes are: Group one, that FirstEnergy (FE) and its reliability council failed to assess and understand the inadequacies of FEs system, particularly with respect to voltage instability and the vulnerability of the Cleveland–Akron area, and FE did not operate its system with appropriate voltage criteria. Group two, inadequate situational awareness at FirstEnergy, that FirstEnergy did not recognize or understand the deteriorating condition of its system. Group three, that FirstEnergy failed to manage adequately tree growth in its transmission rights-of-way. Finally, group four, the failure of the interconnected grid's reliability organizations to provide effective real-time diagnostic support U.S.-Canada Power System Outage Task Force, xxxx. We can see that a local failure finally became a large scale damage.

Natural as it is to view the power grids as complex networks, many researchers have analyzed the structure of power grids in this way. Cohen et al. (2000) uses the method in mean field theory to calculate the threshold of the Internet under which the network is not robust under random attack on its nodes. This threshold only takes means of degree and its square into consideration. Sol et al. (2008) has applied the analysis of Cohen et al. (2000) to European power grids, which are assumed to have exponentional degree distributions. This research has designed two methods of attack to the nodes of power grid: random attack and selective attack by the degree. It is found that, although only dealing with the network structure, the measures based on the theory of complex network has a close correlation with the physical reliability measures. Later, Wang et al. (2010) found that in fact the degree distribution of real power grids is a sum of a truncated Geometric random variable and an irregular discrete random variable. With these findings they obtained better estimates of the threshold under selective node breakdowns which would predict the numerical thresholds more correctly.

In the above way, one network is considered as a whole. For one network, there is a single threshold to represent its robustness. There is another way to view it: considering the influence of each node to the robustness of the network. To analyze this way, a distribution of load and redistribution rules are needed. The simplest method is to assign the load on a node just by its own degree. A popular but much more complicated method is to estimate the betweenness of a node as its load. And the redistribution load are forwarded following the shortest path. However, the principle based on betweenness is reasonable only for small or medium-sized networks due to the requirement of structural information of the whole networks; while the principle based on node degree outweighs by its simplicity, but is inferior owing to its only

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A coordinate gradient descent algorithm to compute the minimum volume enclosing ellipsoid

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Some properties of the spectral radius for general hypergraphs

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A B S T R A C T

In this paper, the adjacency tensor of a general hypergraph is investigated. We study the Perron–Frobenius theorem for the general hypergraphs and obtain some relevant results based on it. In particular, the techniques of weighted incidence matrix and moving edge are extended to general hypergraphs for determining the structure with the maximum spectral radius. A nearly m-uniform supertree is both connected and acyclic, in which each edge contains either $m-1$ or m vertices. To begin with, the structures obtaining the maximum spectral radius in two classes of nearly uniform supertrees are determined, where one class is with given number of edges and the other is with given number of vertices.

1. Introduction

In 2005, the concept of tensor eigenvalues and the spectra of tensors were independently introduced by Qi [10] and Lim [4]. Then, in 2012, Cooper and Dutle [3] defined the eigenvalues (and the spectrum) for the uniform hypergraph, and obtained a num-

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The spectra of uniform hypertrees ☆

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In this paper we study the spectra of uniform hypertrees by using the generalized weighted incident matrix. We show that λ is a nonzero eigenvalue of the hypertree H corresponding to an eigenvector with all elements nonzero if and only if λ is a root of the polynomial $\varphi(H) = \sum_{i=0}^{m}(-1)^i|\mathcal{M}_i|x^{(m-i)r}$, where $|\mathcal{M}_i|$ is the number of matchings of order i in H.

1. Introduction

The spectrum plays an important role in the study of graph theory. A lot of results have been developed on the relation between the structural parameters of a graph and

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