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A Statistical Assessment Tool for Electricity Distribution Networks

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Abstract

Many interesting studies are being carried out globally to analyze the impact of new low carbon technologies on the energy distribution networks. Most of these studies are focused on synthetic and real grid samples. Research findings of such studies are case specific and have very limited applicability to other networks making them unsuitable to make generalized conclusions. An ensemble of realistic distribution network models with similar topological and technical/electrical properties can provide a good basis to conduct statistical studies on an electricity distribution network, opening up the opportunity to make robust conclusions in a more generalized manner. With these motivations, this paper presents a methodology to develop a statistical assessment tool to facilitate large scale simulation studies on electricity distribution networks. A simple case study is presented to demonstrate how such a framework can be used to perform a statistical study to analyze the impact of new low carbon technologies on electricity distribution networks.

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Keywords: Low carbon technologies; Electricity distribution networks; Statistical studies.

1. Introduction

In recent years, Low Carbon Technologies (LCT) have gained wide acceptance as many countries are determined to decarbonize their energy systems. However, the traditional electricity distribution networks are not designed to admit the complexities caused by the integration of these new technologies and numerous studies are being carried out to quantify the impact of new LCTs on energy distribution networks. Most of these studies are based on real grid samples or standard synthetic systems such as the IEEE test cases, partially due to limited availability of representative test systems suitable for large scale simulation analysis. As a result, most reported analysis in the literature is only useful for evaluating a

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specific test case. Conclusions made from such studies cannot be easily applied for networks with similar characteristics in a meaningful way. Therefore, there is a clear need for a network modelling and simulation framework with the ability of providing realistic test cases of High Voltage (HV), Medium Voltage (MV) and Low Voltage (LV) networks enabling network and system level analysis of electricity distribution networks. With above motivations, this paper presents the rationale and design of a statistical assessment tool for electricity distribution networks and demonstrate how such a tool can be used to make generalized and robust conclusions on various network studies.

1.1. Related research

The importance of conducting statistical studies on many test networks in order to make statistically significant conclusions, has been highlighted in some of the previous research. The ability of creating many test cases whose characteristics are similar to those of real networks, is the key requirement of this kind of a study. The research work of C.K Gan [1], describes a statistical approach to investigate the technical and cost performance of alternative network design strategies for electricity distribution networks under different development scenarios. A fractal based software tool was developed in their study for the modelling of electricity distribution networks. Zhifang Wang [2] developed a simulation platform that generates electrical power grid test cases with realistic topologies, scalable network size, and realistic electrical parameter settings. In [3], Jiale Hu identified the similar need for statistical generative models of electric power networks and proposed a Cluster and Connect algorithmic approach for generating synthetic graphs for electrical power networks. The necessity of making generalized conclusions on similar types of networks was noted by Jeremy Watson [4] in his study of analyzing the impact of solar photovoltaics on the LV distribution network in New Zealand. While all above mentioned research demonstrate the value of network model generation capturing statistical properties, they use limited set of modelling parameters supported by limited set of real network data, which are not designed for wider statistical analysis of energy networks and hence not suitable to make generalized statistical studies.

Mathematical modelling of the networks plays a critical role in providing a statistical platform for the electricity distribution networks. Advances in complex networks theory together with well-established graph theory provide a platform to mathematically model networks [5]. Since 1950s, many generalized network models have been developed to represent different types of real world networks. Few other network models which are coming from an interesting research area called ‘Fractal Theory’ [6] are also able to give graph representations of the networks. According to the recent survey conducted by G.A. Pagani [7], a lot of research studies have been carried out in order to identify the most suitable complex network model to represent the power grid. Starting from the classical random graph model (ER model) the applicability of Small World (SW) network model, Barabasi-Albert (BA) model and many other complex network models [8] has been tested with regards to the statistical properties of sample real world networks. The majority of the works surveyed belongs to the High Voltage (HV) electricity networks and studies done in Medium Voltage (MV) and LV levels of the networks are very limited.

2. Statistical Assessment Tool for Electricity Networks

The key features of this tool are (i) capturing essence of real networks using a few statistical parameters. (ii) ability to generate many realistic, random test-networks which are statistically similar in terms of the selected topological and technical features which are decisive for a given network study and (iii) the ability of performing power flow studies on many such statistically similar networks to come up with statistically significant conclusions. The concept of the tool is illustrated in the Fig. 1.