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An Advanced Software Tool to Simulate Service Restoration Problems: *a case study on Power Distribution Systems*

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Abstract

This paper presents a software tool to simulate a practical problem in smart grid systems. A feature of the smart grid is a system self-recovery capability in the occurrence of anomalies, such as a recovery of a power distribution network after an occurrence of a fault. When this system has a capacity for self-recovery, it is called self-healing. The intersection among areas as computer science, telecommunication, automation and electrical engineering, has allowed power systems to gain new technologies. However, because it is a multi-area domain, self-recovery simulation tools in smart grids are often highly complex as well as presenting low fidelity by using approximation algorithms. The main contribution of this paper is a simulator with high fidelity and low complexity in terms of programming, usability and semantics. In this simulator, a computational intelligence technique and a derivative method for calculating the power flow were encapsulated. The result is a software tool with high abstraction and easy customization, aimed at a self-healing system for a reconfiguration of an electric power distribution network.

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Keywords: Software Tool, Restoration Problem, Self-Healing Smart Grid, Reinforcement Learning

1 Introduction

Studies have been dedicated to different segments of electric power systems as generation, transmission and distribution of energy. The need to make these segments more reliable, secure and efficient has increased the intersection of areas such as computing, telecommunications, automation and electrical engineering. The new applications with these areas in the electrical infrastructures have emerged the intelligent energy systems, called smart grids (Liserre *et al.*, 2010).

In the energy distribution segment, smart grids include, in particular, the use of distributed systems, artificial intelligence and power systems as a way to automate the process of recovering a distri-

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bution network in the event of an abnormality (e.g., failures in network devices, nature damage or vandalism to the distribution system). Normally, these events generate a fault, causing the non-electricity supply to consumers. One of the fundamental aspects in a smart grid power distribution network is the ability of the system to identify and recover the network in the event of a fault. This ability characterizes a self-healing system (Ghosh *et al.*, 2007).

Several works have proposed self-healing mechanisms for the recovery of electrical networks (Lu *et al.*, 2009), (Zidan and El-Saadany, 2012), (ZakiEl-Sharafy and Farag 2016). Due the multidisciplinary problem domain, some proposed approaches often require human experts from the subareas of computing (Distributed Systems, Programming and Artificial Intelligence), telecommunication (signal transmission and reception), and electrical engineering (power and electrical systems). This multidisciplinary often makes simulation tools highly complex for smart grids, as well as they present low fidelity, as they require the use of non-exact approaches to service restoration through switching operation.

Here we encapsulate, in a software tool framework for smart grid, the concepts of computational intelligence to simulate a practical problem of reconfiguration of an electric energy distribution network. A well-known reinforcement learning algorithm and a method for calculating power flow are simplified through a UML component diagram, while a graphical and semantic interface is used to guide customization. The results are defined in terms of network quality, loss parameters and maintenance.

2 Learning Systems for Smart Grids

Electricity networks are being improved due to the demand increasing and the development of new technologies. This can be seen in studies that show the use renewable sources of energy, generation and distribution, energy efficiency, microgrids, consumer participation and generation of clean energy.

The smart grid concept proposes alternatives and innovations to conventional power grids, such as allowing the recovery of a network after a fault. This capability comes from steps in a smart grid subarea, called self-healing. Self-healing can be used to restore a system, with techniques that generally change the topology of the network considering the quality of the electrical energy (e.g., voltage stability, network restrictions, priority load, etc.) delivered to consumers (Lim *et al.*, 2013). Figure 1 shows restoration process on the network.

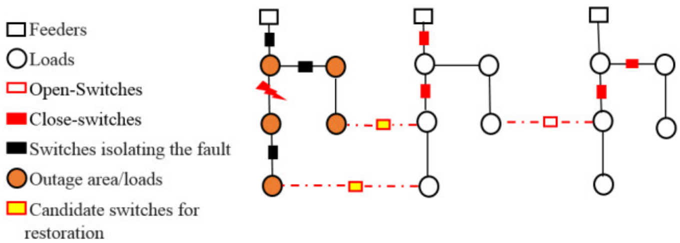

Figure 1: Restoration process on the network

Detect and isolate fault locations and restoring service are important functions of distribution automation and form the cornerstone of strategies for developing smart grids (Mamo *et al.*, 2009). Service restoration is defined as finding suitable feeders and laterals to transfer the loads in out-of-service areas using operational criteria through a series of switching operations (Chen, 2010). Restoration is achieved through the switching operation of tie switches (normally opened). Different restoration methods thus entail different configurations, which may affect service quality. In addition, because the task of restoration is usually performed under emergency conditions, time constraints can complexity the problem (Chen, 2010) (Tsai, 2008).