Electric Power Systems Research 80 (2010) 287–295

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Generic reconfiguration for restoration

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ARTICLE INFO

Article history:
Received 1 July 2009
Received in revised form
10 September 2009
Accepted 14 September 2009
Available online 27 October 2009

Keywords:
Reconfiguration
Dependencies
Graph Trace Analysis
Priority

ABSTRACT

This paper introduces and compares four algorithms by which reconfiguration for restoration of an arbitrary number of interdependent critical infrastructure systems can be achieved. A method of modeling systems called Graph Trace Analysis is used to enable generic operation on various system types. The algorithms described are compared with each other and with prior work when run on a model of an actual electrical distribution system. The described algorithms are also run on an example model to demonstrate the ability to reconfigure interdependent infrastructure systems.

1. Introduction

Modern society depends on a set of critical infrastructure systems. These systems include electrical distribution, potable water, sewage, gas, and others. When a problem occurs in one of these systems, it can cause disruption of services not only in its system but also in other systems.

In this paper loads are considered to be any device which requires service from a system. Based upon the mission of the system, some loads are more important than others, and the mission of the system may change. Thus, the importance of a load may change. Reconfiguration for restoration is the process whereby disruption in services to loads is responded to and the system or systems in question are altered to restore service to the loads.

In all of these systems there are devices which can be operated to alter the system topology or even cut off entire sections of the system in order to isolate faults. These sectionalizing devices are the core of reconfiguration. In this paper all sectionalizing devices that are available for use, whether they be valves in fluid systems or breakers in electrical systems, will be referred to as switches.

The goal of reconfiguration is to operate switches in order to arrive at a system state where service disruptions are minimized while adhering to system constraints. Also, based upon the desire to keep service flowing to certain loads, system operating constraints may change.

Loads on a system are not of equal importance. Often there is a hierarchy of importance among system loads, and thus reconfiguration must take this prioritization into account when determining where to restore service. Priorities can come from multiple sources. Utilities frequently maintain lists of critical customers which can be used to derive discrete priority assignments for individual loads. In addition, some loads may have their priorities implied by the goals of the system, or its 'mission'. For example, a warship not engaged in battle would consider its propulsion systems more important than its weapons systems, and load priorities would flow from that [1]. Furthermore the importance of a load may change based upon what the system is being asked to do, or its mission.

Critical infrastructure systems are not independent of each other. Each has elements which depend on elements in another system. For example, water systems employ pumps. These pumps are often driven by electrical motors, which are loads on the electrical system. These intersystem dependencies must be considered by reconfiguration.

The work here considers a "system of systems" model. A disruption in one system often results in a disruption in another system. For valid solutions these interdependencies must be considered. An electrical outage can result in an outage in the potable water system, and depending upon the length of the outage, the potable water system may need to be flushed for some period of time prior to using the water. In some systems electrical power equipment depends upon cooling water. If the cooling water suffers a disruption, after some period of time the electrical equipment needs to be turned off or suffer failure due to overheating.

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doi:10.1016/j.epsr.2009.09.011