Optimal allocation of distribution maintenance resources with limited information

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Abstract

Maintenance of distribution systems plays a central, although often overlooked, role in determining both the reliability and cost of supply. In previous work, an approach was developed that optimizes the effectiveness of distribution protective devices. This paper extends that framework to the optimal use of maintenance resources for reliability. Firstly, a framework is established assuming constant failure rates for the components. Secondly, that framework is extended to optimization given limited information about equipment condition. That is, the failure rates and impact of the reliability are known only approximately. The objective in this framework is to maximize reliability as measured by typical reliability indices. This formulation is demonstrated on a set of numerical examples. Results are analyzed and difficulties that may arise in the proposed approach are investigated. Further, the concept of the value of additional information is introduced. The problems are solved through a two-stage analysis procedure based on linear programming and approximate reasoning using fuzzy sets.

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1. Introduction

A radial network is the most common and the simplest distribution network used by utilities. A typical radial network consists of a main line and several lateral feeders, distribution transformers, and a secondary network [1]. The main line and lateral feeders can be overhead, underground or a combination of both. Customers served by a distribution network may experience frequent outages for many reasons, including loss of supply from a substation, component failure, a lightning strike, car-pole accident, tree and animal contacts, and insulator flashover due to accumulation of dirt and the presence of moisture. Major components contributing to outages in underground circuits consist of transformers, switches, transformers, elbows, splices and cables. The overhead circuit components of concern are transformers, switches, fuses, capacitors, reclosers, sectionalizers, voltage regulators and conductors [2].

A detailed study by Duke Power between 1987 and 1990 indicates that distribution outage causes can be divided into the following different categories with these given failure percentages [3]: equipment 14%, trees 19%, animals 18%, lightning 9%, and others 40%. A study of 85 rural and 95 urban overhead distribution circuits from the Pacific Gas and Electric System [4] indicates that component failures contributed to about 15% of the total permanent outages. For the remaining 85% of the outages, 75% were due to external factors such as lightning strikes, trees, car-pole accidents and third party contacts and 10% were attributed to substation or transmission outages. These two studies are generally consistent and appear representative of distribution outage causes in many locales.

The utility industry takes various preventive actions to minimize those failures that have a direct impact on service reliability. These actions consist of routine maintenance on testable and repairable components, replacement of non-repairable components, tree trimming, installation of animal guards and washing of insulators. Specific device maintenance actions include monitoring, testing, and repairing of components that deteriorate due to aging and contain...
There are various reasons why the reliability of equipment is important. As mentioned, it is essential to ensure that equipment can perform its function reliably and safely. Maintenance and monitoring are critical factors in improving reliability. The following text elaborates on the importance of maintenance and monitoring of equipment:

The importance of maintenance and monitoring of equipment cannot be overstated. Regular maintenance and monitoring can help prevent equipment failures and identify potential issues before they become critical. This can result in improved efficiency, reduced downtime, and lower operating costs. Maintenance and monitoring also help ensure that equipment is in proper working condition and can perform its intended function. Regular maintenance and monitoring can also help extend the lifespan of equipment and reduce the need for replacements, which can be costly.

In general, maintenance and monitoring can be categorized into two types: preventive maintenance and predictive maintenance. Preventive maintenance involves performing routine checks and inspections to ensure that equipment is in good working condition. Predictive maintenance involves monitoring the performance of equipment and identifying potential issues before they become critical.

In addition to routine maintenance and monitoring, there are several other factors that can affect the reliability of equipment. These factors include design, manufacturing, and environmental conditions. Design and manufacturing issues can affect the reliability of equipment, and environmental conditions such as temperature, humidity, and vibrations can also impact reliability.

The following text highlights the importance of maintenance and monitoring of equipment:

Reliability is a critical factor in ensuring that equipment can perform its intended function. Regular maintenance and monitoring can help prevent equipment failures and identify potential issues before they become critical. This can result in improved efficiency, reduced downtime, and lower operating costs. Maintenance and monitoring also help ensure that equipment is in proper working condition and can perform its intended function. Regular maintenance and monitoring can also help extend the lifespan of equipment and reduce the need for replacements, which can be costly.

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