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Real-time reconfiguration of distribution network with distributed generation

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ABSTRACT

This paper presents a new methodology to perform the automatic reconfiguration of distribution networks incorporating distributed generation in normal operation. The power generation availability of wind turbines, solar photovoltaic panels and small hydropower are considered in the reconfiguration process. The real-time reconfiguration methodology is based on a heuristic method to determine the best settings. The method assumes that only remote controlled switches are considered in the analysis. The multicriteria analysis AHP (Analytic Hierarchy Process) method is employed to determine the best sequence of switching. The developed algorithms are integrated into a supervisory system, which allows real-time measurements and commands to the equipment. The proposed methodology is tested in a real network of a power utility and results are presented and discussed. To evaluate the performance and efficiency of the proposed method, different network reconfiguration scenarios with distributed generation were tested.

1. Introduction

The need to improve the quality and reliability of power systems, as well as environmental needs with the quest for reducing greenhouse gas emissions and replacing fossil fuels in power generation, insert Distributed Generation (DG) using renewable energy sources in discussions about the future of distribution of electric power systems.

New methodologies and analysis tools for distribution systems with distributed generators are necessary and have been receiving great attention from researches of Smart Grids and Microgrids. Smart grids are characterized by a number of technologies, methodologies and integrated procedures, including the ability for self-reconfiguration under changing operating conditions [1].

The reconfiguration of the network can be responsible for promoting more efficient use of distributed generators of renewable primary sources, such as solar radiation and wind energy, by analyzing the availability of each source for injecting energy into the system. As a result, it is possible to obtain a significant reduction of losses and to improve the reliability of power supply.

Several researches are related to the reconfiguration of distribution network with distributed generators, based on mathematical methods, heuristics and artificial intelligence techniques [2].

In recent years, new methodologies of reconfiguration of distribution network have been presented, exploring the greater capacity and speed of computer systems, the increased availability of information and the advancement of automation, particularly, the SCADA (Supervisory Control and Data Acquisition). With the increased use of SCADA and distribution automation through remote controlled equipment, the reconfiguration of distribution network became more viable as a tool for planning and control in real-time. Most of recent researches [3–5], however, do not take into account reconfiguration in real-time. The works of Wang et al. [6] and López et al. [7] present an online reconfiguration approach, the first with emphasis on the reduction of load flow calculation time and the last on the demand characterization. The work of Vargas and Samper [8] presents fast algorithms for a smart distribution management system, which include load estimation, load flow calculation and optimal feeder reconfiguration considering DG.

Rao et al. [9] present a meta-heuristic algorithm to reduce losses of distribution networks and the allocation of DG units simultaneously. In these works, however, the optimization approach is for monocriterial analysis, and some feasibility aspects for real-time application are not taken into account, such as a proper definition of the frequency of reconfiguration and the coordination of protection devices.

A multicriteria analysis is discussed in the work of Martins and Borges [10], using the reconfiguration of network as an alternative to system expansion. In general, the vast majority of works which involve DG, focuses on the planning of distribution systems and allocation of DG, and does not apply to the reconfiguration under normal operation and real-time.

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The work of Celli et al. [11] considers the short-term variations in generation due to meteorological conditions. In real-time applications it is necessary consider this information because the generation profiles can change significantly.

In this work, a methodology and a computational tool for automatic reconfiguration of distribution network considering DG in real-time are developed from the standpoint of Smart Grid. The methodology uses the information and functionality of remote controlled equipment installed in distribution systems, applying them in a computer system that allows the reconfiguration of the network in normal operation. The analysis consider the demand curves of feeders and generation curves based on Wind, Solar Photovoltaic and Small Hydropower energies, highlighting that these systems are interconnected to the distribution network.

The developed methodology is an evolution of the works [12,13], but with significant contributions:

(i) analysis of generation profiles related to distributed generators of different technologies;
(ii) specific constraints for distributed generation;
(iii) heuristic technique for selecting configurations incorporating DG;
(iv) case studies considering real data of power utilities;
(v) integration of the developed tool with SCADA system, allowing the automatic network reconfiguration.

The proposed methodology is tested in a real distribution network, ensuring the practical applicability of the heuristic optimization algorithm employed.

2. Problem formulation

The reconfiguration of distribution network can be characterized as an optimization problem. To improve network performance, one or more objectives (e.g. reduce losses and improve reliability) are established, and then one verifies which configuration produces the best result, without violating constraints on proper and safe operation of the network. This configuration is defined as the optimal solution for the system. When more than one objective is set, the analysis should incorporate methods for multicriteria decision making, which may include expert opinion on the definition of a preference for one objective over another.

The main problem is that optimization of real networks allows a number of configurations quite high due to the number of switching devices on the network. In general, it may be unfeasible to test all possible combinations and perform, for each one, the necessary calculations – such as load flow – in order to identify the configuration that results in best performance. To solve this problem, optimization methods that reduce the search space of the optimal solution are commonly used.

In this work, the developed optimization algorithm is based on a heuristic method and on the AHP multicriteria decision making method to identify the best network configuration. In the sequence, some fundamental considerations are predefined to perform automatic reconfiguration in real-time.

2.1. Real-time characteristics and requirements

Reconfiguration of distribution network in normal operation usually has as main objective the reduction of energy losses. When considering automatic reconfiguration in real-time, some aspects have to be included in the study:

a) it is necessary to establish a cost-benefit relationship to determine the necessity and the effectiveness of the reconfiguration;
b) the network must be flexible to allow the reconfiguration;
c) the technical feasibility of the switching should be studied in real-time, considering the availability of current measurements of the network.

The diagram in Fig. 1 shows the architecture employed in this work to meet these premises.

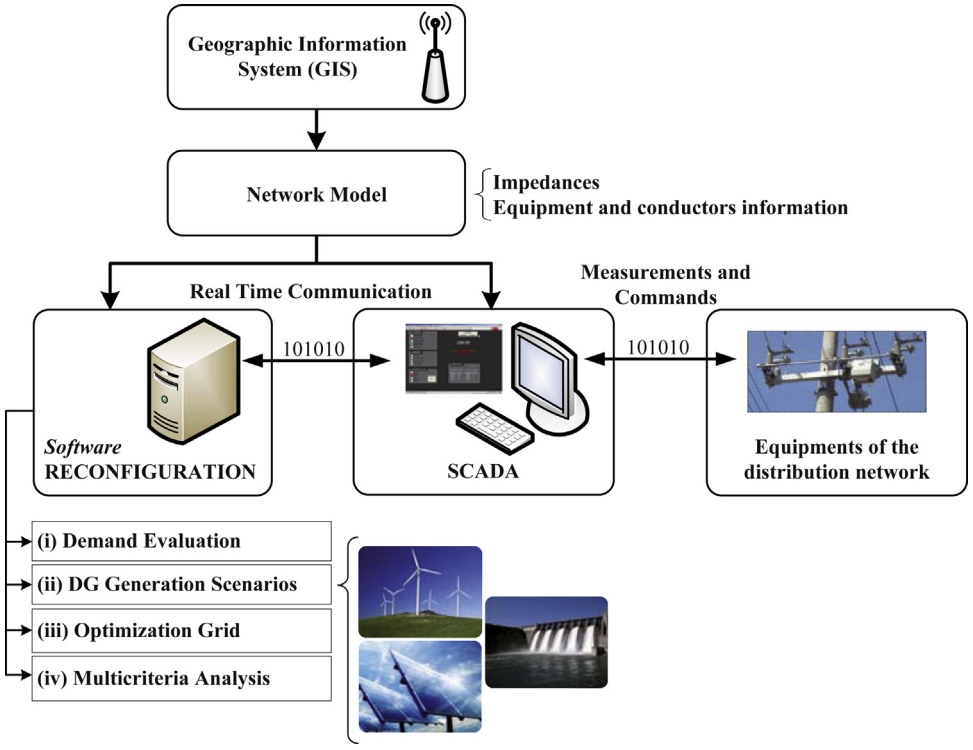

Fig. 1. Architecture of the proposed system.