Electric Power Systems Research 79 (2009) 1400–1407

Contents lists available at ScienceDirect

Electric Power Systems Research

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

Electric distribution network reconfiguration based on a fuzzy multi-criteria decision making algorithm

D.P. Bernardon[a,*,1], V.J. Garcia[a], A.S.Q. Ferreira[a], L.N. Canha[b]

[a] UNIPAMPA – Federal University of Pampa, 97546550 Alegrete, Rio Grande do Sul, Brazil
[b] UFSM – Federal University of Santa Maria, Brazil

ARTICLE INFO

Article history:
Received 11 February 2009
Received in revised form 20 April 2009
Accepted 21 April 2009
Available online 19 May 2009

Keywords:
Fuzzy algorithms
Multi-criteria decision making
Reliability
Power losses
Network reconfiguration

ABSTRACT

Topological reconfiguration is an important tool for the planning and operation of electric power distribution systems. The amount of time that an algorithm spends to obtain an alternative topological status for the system is not a primary concern, as the main goals of distribution operation planning are the reduction of power losses, the enhancement of the voltage profile, and the increase of reliability levels. The utility can use multiple criteria regarding the observation of regulation policies and public awareness to drive the topological reconfiguration. Several researchers are looking for new optimization methods, as the complexity of this combinatorial issue is high in large systems and the classic optimization methods are failing to address the problem reasonably. Therefore, a new fuzzy multi-criteria decision making algorithm for the proper processing of the information sources available at the utilities in the context of distribution network reconfiguration is proposed. The algorithm is evaluated through the use of a proof-of-concept implementation in a set of case studies based on actual distribution systems.

1. Introduction

Although power distribution systems are usually configured radially, the act of opening or closing switches or protection devices (located at strategic points) can possibly change the topology of such systems. In this context, the network is reconfigured to maintain its radial topology and also to reduce power losses at the feeders, to enhance the voltage profile for customers, and to increase the reliability levels.

Such reconfiguration problem is combinatorial, making prohibitive the use of classical methods to solve it optimally [1]. In general, this reconfiguration problem cannot be optimally solved without considering (i) the proper modelling of the distribution networks elements and the electrical loads, (ii) the algorithms to handle configuration changes in the network topology in a timely manner, (iii) the load flow calculations, (iv) the composition of the objective functions and constraints, and (v) the optimization and decision making techniques used to define the ideal electrical configuration.

Several researchers have been working on the multi-criteria reconfiguration problem. Baran [2], Hong [3], Nara [4], and Su [5] describe the concepts and techniques used to address this problem. Minimization of power losses and maximization of the load balance are the two most common criteria used to reconfigure networks. The reconfiguration has also to consider radial topology, limits on voltage and current profiles constraints. Considering multi-criteria methods in the resolution methodology, another aspect that must be considered is the uncertainty present in the input data and in the degree of importance. This aspect is considered in the approaches of Das [6], Kagan [7] and Venkatesh [8]. These approaches, however, do not successfully explain how membership functions are defined to all the included fuzzy sets.

This paper presents a new algorithm for reducing power losses and improving reliability on network reconfigurations. The algorithm is based on fuzzy multi-criteria decision making and is implemented in a proof-of-concept tool. The Bellman–Zadeh method [9] for the fuzzy resolution methodology was chosen, as it has been successfully applied to multi-criteria problems and promotes final solutions belonging to the Pareto objective space [10]. The algorithm can be configured according to the needs of the utilities, helping in the decision making process. Tool support helps to choose the option that meets the objective functions best, while still observing the proposed constraints.

2. Modelling of power load profiles

The modelling of power loads can help to correctly represent their changes over time. It is one of the first issues considered in the development of efficient methods and tools to analyse distri-

* Corresponding author. Tel.: +55 5192811760.
E-mail address: dpbernardon@gmail.com (D.P. Bernardon).
[1] Member, IEEE.

0378-7796/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsr.2009.04.012

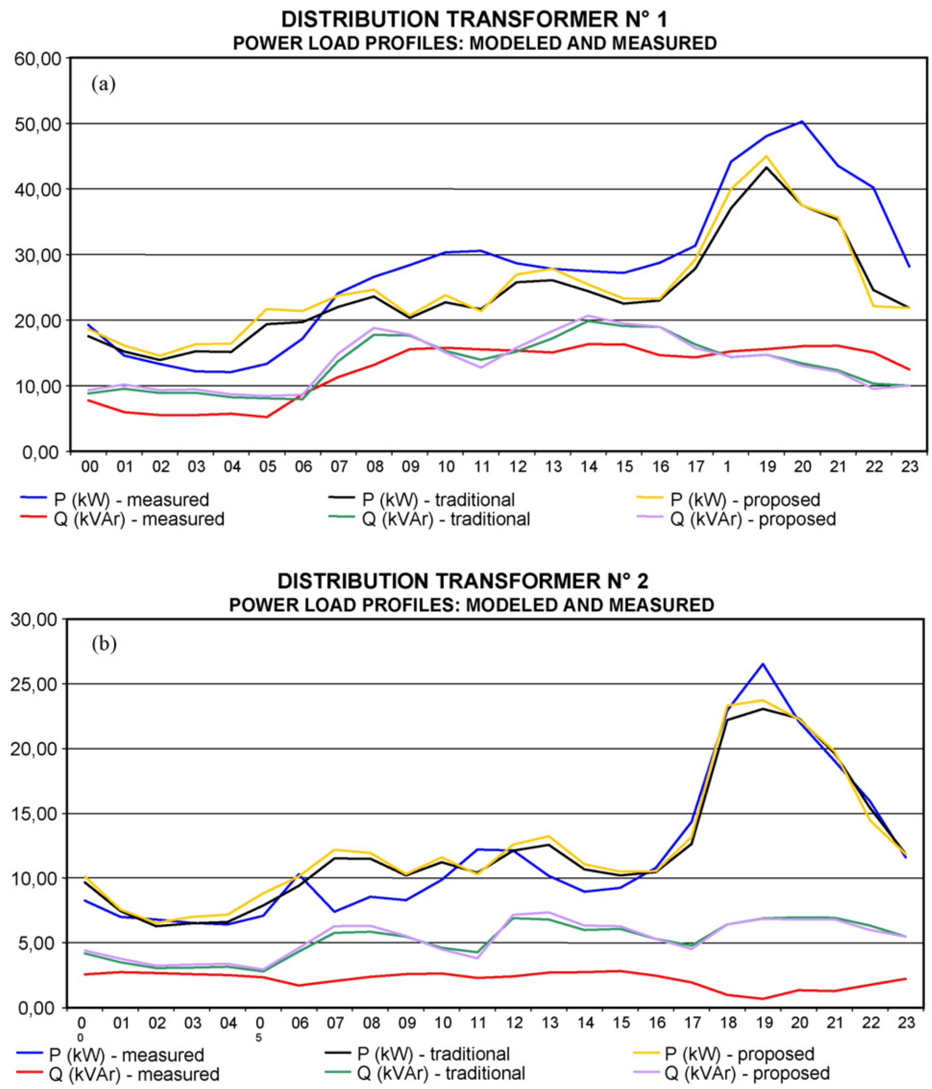

Fig. 1. Comparison between power load profiles measured and modelled by the proposed and traditional methods considering work days: (a) TR-1 and (b) TR-2.

bution systems. Modelling methods need to work optimally with the available information. Unfortunately, lack of information is an inherent characteristic of distributions systems, which are usually composed of several network sections, with several branches, and covering wide geographical areas. In Brazil, for example, the utilities charge the customers based on the monthly electric energy consumption, which has been proven insufficient to the distribution system analysis as it does not represent the day behaviour of energy consumption.

Typical load curves have been used to satisfactorily represent the hourly demand. Usually, they are normalized according to the maximum active demand. The main challenges for the construction of typical load curves are related to the diversity of load types (customers) found in distribution systems and to the huge number of measurements needed [11]. Therefore, an alternative method for constructing the typical load curves is proposed, with the following advantages compared to the traditional statistical methods: the reduction of the influence of random values and the decrease of the quantity of required measures to obtain representative samples of load types [12]. Instead of using the simple average to obtain the active and reactive power values for an ordinate of the load typical curve, the use of the following equation is proposed:

$$X_t = \frac{1}{5}\left[2M\left\{X_t\right\} + 2\mathrm{Me}\left\{X_t\right\} + \mathrm{Mo}\left\{X_t\right\}\right] \qquad (1)$$

where X_t is the active (P_t) or reactive (Q_t) power value for hour t of the typical load curve; $M\{X_t\}$ the sample average; $\mathrm{Me}\{X_t\}$ the sample median (central number of a sample); $\mathrm{Mo}\{X_t\}$ is the sample mode (more repeated value of a sample).

Each customer is associated to a typical load curve, according to the monthly electric energy consumption and the economic activity data. This association also enables to know the load factor of a typical load curve. The maximum demand for a group of customers k is calculated based on the load factor and on the monthly electric energy consumption values:

$$P_{\mathrm{Max}_k} = \frac{W_k}{T\,f_{Ck}} \qquad (2)$$

where P_{Max_k} is the maximum demand for a group of customers k (kW); W_k the monthly electric energy consumption (kWh); T is the monthly period (h); f_{Ck} is the load factor.

Since the typical curves used are normalized according to the maximum active demand, the load curve for a group of customers k can be built by multiplying each ordinate by this value:

$$P_{kUt} = P_{\mathrm{Max}_k} P^{*}_{kUt};$$

$$P_{kSt} = P_{\mathrm{Max}_k} P^{*}_{kSt};$$