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Methodology for the calculation of the factor of priority for smart grid implantation using fuzzy logic

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ABSTRACT

The smart grid deployment requires high investments in infrastructure and human resources and can take years or even decades to be fully implemented, particularly in large countries, such as Brazil. A deployment plan that uses well-defined criteria to develop the deployment process is necessary to provide the best cost-benefit ratio for the electrical systems.

This paper proposes a methodology to indicate the order of priority, based on the characteristics of each system where there is the possibility of deployment of the smart grid. The methodology is to assess and quantify relevant criteria (technical, economic and environmental) for this deployment and apply the fuzzy logic to calculate a priority factor. This factor will help in the decision-making process for choosing the order of priority for deployment of smart grid analysed systems. This method was applied in the analysis of six local dealership systems and the results are presented in this paper.

Introduction

The growing complexity of electrical systems associated with the expansion of markets is a worldwide phenomenon and a result of the significant growth of the electric network, which has modified the number of consumer units, and the use of renewable energy sources, which can supplement the supply of energy, thus avoiding issues of energy shortages [1].

The goal of this modernisation process is to provide more dynamism in the networks of electrical systems, making more information available to increase the quality, reliability and efficiency of the system. The deployment of the smart grid will work precisely towards this end [2,3].

To achieve the successful deployment of smart grids in a country, a more complex electrical system will obviously pose greater challenges to all of the components in the system. In many cases, the total deployment time of a network can be several years or even decades.

In several countries, the majority of the electrical companies started smart grid projects with pilot projects or deployment in specific areas. Independent of the deployment strategy, to leverage further results, it is crucial that the benefits of the project are felt by all involved. For this to occur, it is essential to consider all regulatory aspects regarding the integration of generation, transmission, and distribution and the necessary infrastructure for deploying the projects, including human resources and consumer involvement [4–7].

In Brazil, the electric generation and transmission systems employed by electric utilities are already supervised by automated systems that use digital technology to monitor consumption processes in virtually all major centres. But, the reality of the distribution system in Brazil (which features a voltage of less than 34.5 kV) is very different. The measurement of energy consumption is manual in 95% of consumers [8].

The idea is to develop a deployment plan for the smart grid system according to criteria deemed the best, based on a cost-benefit analysis for each system.

This article proposes a system using fuzzy logic to calculate a priority index for each system reviewed, using indicators based on criteria to be used by power utilities. Second section presents the determination of variables that can affect the deployment of the smart grid. Third section presents the most relevant criteria used for deployment of the smart grid. Fourth section presents the fundamentals and basic concepts associated with fuzzy logic. Fifth section presents the application of fuzzy logic for the calculation of the priority factor. Sixth section presents the steps to be followed for the application of the proposed method in the evaluation of electrical systems. Seventh section presents the conclusions.

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Table 1
Variables to be evaluated in the smart grid deployment.

Technical features	Importance of the loads supplied by the system The system load factor System power factor System load level Technical losses and level of non-technical losses (commercial) Electric system infrastructure (automation, protection and metering) Telecommunications infrastructure and information Failure or defect rate Technical resources for operation and maintenance Lifetime of the assets (degree of ageing) Potential for the development of energy efficiency programmes Inclusion potential of distributed generation sources (wind, solar and biomass) Critical connection or border (important)
Economic characteristics	Invoicing of the electrical systemDelivery cost (kW)Cost of maintenance and operation
Location of installation	Underground installation Distance from the Centre of operation and research centres Border with other concessionaires Region with growth forecast (demographic, financial investment) Region with government social policies Region with historic towns or tourist cities Region with natural resources (agriculture, water, minerals) Region of interest to large companies Region with harsh weather conditions
Human resources	Availability of skilled professionals in the area Technical staff with potential for training in the area
Environmental conditions	Fossil fuel energy sources (greenhouse gas emissions, carbon footprint) Regional climate conducive to natural disasters for the electric system Environmental incentives program
Possibility of partnerships	Research institution (University, Research Centre) Telecommunications operator Manufacturers of equipment or related area Software developers Electric utilities (national or international with projects developed in the area)
Socioeconomic conditions of consumers	Purchasing power of the community HDI (Human Development Index) of the community History of involvement in community projects Region with social programs in progress Community bonded to the incorporation of new services

Variables that can affect the deployment of smart grid

The practices adopted for smart grid deployment involve high investment in several areas. The results must be of strategic interest to all, including the electric power utilities, consumers, public authorities, suppliers, regulators, the research institutions, funders and development agents. For this reason, the smart grid deployment must be conducted primarily in locations that can add value to the electrical system through gains in productivity gains and improved energy efficiency [9–14].

One of the main gains must be in the area of operational efficiency, which includes: better control of asset life, ease of locating of defects, avoidance of unnecessary offsets, gains in quality of planning, and lower system loading, among other aspects. In the area of energy efficiency, the reduction of both technical losses and non-technical losses should enable a more effective distribution of energy, from the generation until the final consumer [14–18].

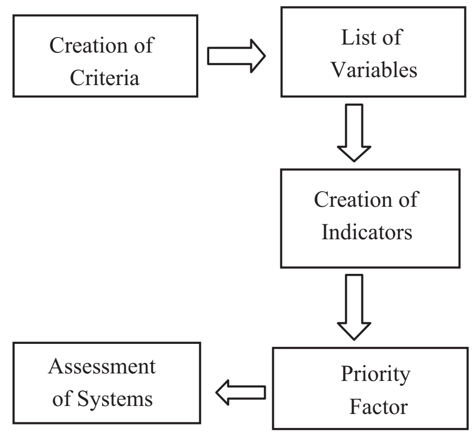

Fig. 1. Steps to evaluate systems for smart grid deployment.

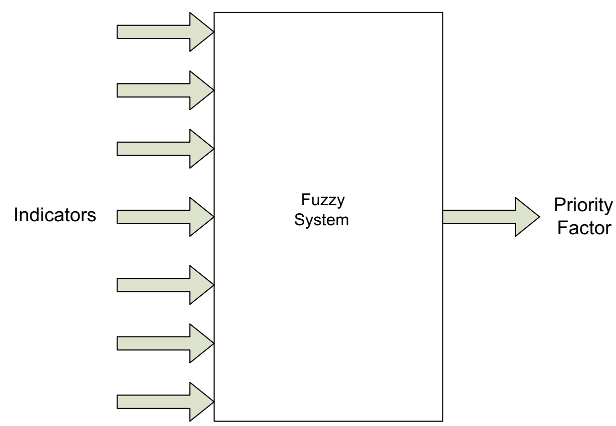

Fig. 2. Diagram of the calculation of the priority factor using a fuzzy system.

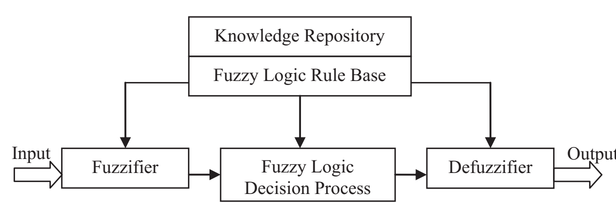

Fig. 3. Block diagram of a fuzzy system.

Table 2
List of fuzzy system input variables.

	Indicators	Acronym in the system fuzzy
1	Importance of system (load)	IpC
2	Level of system losses	NiP
3	Electrical system infrastructure	IfE
4	Telecommunications infrastructure	IfT
5	Ageing system assets	EnA
6	Energy efficiency potential	PEf
7	Potential of distributed generation	PGd
8	Community participation in the development of projects or with high HDI	Pco