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Determining Distribution Power System Loading Measurements Accuracy Using Fuzzy Logic

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Abstract

This paper presents a fuzzy logic method and experimental investigation to determine distribution power systems loading measurements accuracy. The method is applied on loading measurements associated with a real South African power systems network, and includes manufacturing supply loading measurements. The results show fuzzy logic as an efficient strategy in determining loading data accuracy in comparison to a traditional approach of manually human analysis. The method is less time consuming relative to the traditional method of going through the data manually. The paper further illustrates that the approach can be applied in manufacturing plants' power systems distribution networks.

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1. Introduction

A power system is comprised of a multitude of equipment and measurements. These measurements allow the monitoring of the power system. These measurements can be used for planning, to better understand the power system, to optimize the power system and many other applications [1-5]. A framework for utility big data analysis is presented by Zhu et al. [6]. The authors state that utilities have invested billions of dollars to install modern data collection devices for smart grid deployment and IT infrastructure for real-time data and events management. For useful application of these collected measurements, they have to be accurate. To obtain quality knowledge and

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accurate software prediction, the quality of data in the development and validation of machine learning classifiers is an important issue in software engineering [7]. Metering and recording errors have led to non-technical losses [5]. There has been research in power systems measurements accuracy [8-11]. These studies are mostly focused on the accuracy of measurement instruments and the algorithms involved in the measuring techniques. The shortfall of this approach is that the measurements' end-user is sometimes not involved in the recording of the data. This means that the end-user does not know the shortfalls or inaccuracy of the measurement instrument. Hence, the user needs to determine the accuracy of the measurements before using them for multiple uses, as mentioned above. The users of measurements will tend to use a traditional approach which is a method based on experience in determining the measurements' accuracy. Some of the drawbacks of this approach include; it is time consuming, requires experience, can have different results depending on who is analyzing the measurements, the experience can leave with an individual leaving the company, and it may be difficult to improve the level of expertise.

Fuzzy logic is a computational method that allows the modelling of imprecise models of reasoning, like common sense reasoning, for complex and uncertain processes [12]. Hence, fuzzy logic could be faster than manually analysing the data, performance (accuracy) can be improved by evaluating the model and adding or modifying the experience and rules, and the fuzzy logic model produces the same results for the same data (consistency of results between individuals, irrespective of experience). This paper presents a computational method (fuzzy logic) for an end-user to determine accuracy of power measurements in distribution networks. The paper also illustrates the efficiency with respect to the time taken to determine the measurements accuracy in relation to the traditional method.

2. Fuzzy Logic

Fuzzy logic reflects the manner in which people think [13, 14]. Fuzzy logic (FL) is an expert system that was developed in 1930 by Lukasiewics and introduced as logic that extends between 0 and 1 [14]. Fuzzy logic has been applied in many power system problems. Fuzzy logic has been used to do short-term load forecasting [15]. A weather-sensitive artificial neural network approach, multiple linear regression, and a non-weather-sensitive moving average approach have been used to forecast the Slovenian transmission active power loss [16]. Here a fuzzy-weighted decision approach is used to increase the robustness of the forecast procedure. In Barchi et al. [17], a load curtailment method using fuzzy logic was presented. The evaluation of fuzzy systems was performed using fuzzy inference systems (FIS). Mandani-type and Sugeno-type are the two popular fuzzy-inference types. Mandani-type was the most commonly used inference technique. This inference type is applied in four steps: input variable fuzzification, rule evaluation, rule outputs aggregation, and then defuzzification [14]. In the first step, the crisp input variables are fuzzified against the linguistic fuzzy sets by determining the degree of associativity to each set. The fuzzified inputs are then applied to the antecedents of the fuzzy rules. In cases where a fuzzy rule has more than one antecedent, the AND or OR fuzzy operator is used to obtain the result. The aggregation unification of all rules outputs is done by taking membership functions of all rules and combining them into one fuzzy set and then deffuzifying to obtain one final number. The most common deffuzification method is the centroid technique [14]. This method can be expressed as:

$$\mathrm{COG} = \frac{\int_j^k \gamma_A(x)\, x dx}{\int_j^k \gamma_A(x)} \qquad (1)$$

where $\gamma_A(x)$ is the degree of membership of output fuzzy set A. To determine the accuracy of the loading data network optimization engineers normally use experience. The loading data can be clearly accurate, seem suspicious and need a further analysis to conclude accuracy, or it can be clearly inaccurate. In Adhimantoro and Gaol [18], the researchers used ultrasonic and fuzzy logic to determine fruit maturity. Fuzzy logic was used since the maturity of the fruit is not linear. The maturity was measured based on water content and texture. Type 2 fuzzy logic has also been used to analyze microarray gene expression [19]. Type 2 fuzzy is a Type 1 fuzzy extension, where the fuzzy