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Long-term load forecast modelling using a fuzzy logic approach

Danladi Ali*, Michel Yohanna, M.I. Puwu, B.M. Garkida

Department of Pure and Applied Physics, Adamawa State University, Mubi, Nigeria

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ABSTRACT

The importance of long-term load forecasting in the power industries cannot be over-emphasised, as it provides the industries with future power demand that may be useful in generating, transmitting and distributing power reliably and economically. In recent times, many techniques have been used in load forecasting, but artificial intelligence techniques (fuzzy logic and ANN) provide greater efficiency compared to conventional techniques (e.g., regression and time series). In this paper, a fuzzy logic model for long-term load forecasting is presented. A fuzzy logic model is developed based on the weather parameters (temperature and humidity) and historical load data for the town of Mubi in Adamawa state to forecast a year-ahead load. The fuzzy logic model forecast a year-ahead load with a MAPE of 6.9% and efficiency of 93.1%. The result obtained reveal that the proposed model is capable of predicting future load.

1. Introduction

Forecasting is the estimation of the value of a variable (or set of variables) at a future point in time. This definition is adopted from [18]. The main aim of power companies is to provide their customers with a sufficient and reliable power supply. The power they generate, transmit or distribute is very costly and too precious to be wasted. However, load demand is never constant; it fluctuates due to reasons such as variation in weather parameters, breakdown of power facilities as a result of over-usage, limited capacity and lack of proper maintenance. Additionally, the increase in the number of customers cannot be predicted accurately. There may be error in the knowledge of when these challenges and changes will occur. This usually results in a shortage or interruption of the power supply which causes inconveniencies and sometimes losses depending on the classes of consumers. Therefore, load forecasting is an important and useful tool for power companies in terms of operation and planning for the future demand of their customers [1]. Also load forecasting remains an indispensable factor for power system planning and evaluating the cost effectiveness of investing in new techniques and strategy for effective power delivery [3]. The types of load forecasting are classified into four categories.

- Very short-term load forecasting: forecasting for few minutes to a few hours.
- Short-term load forecasting: forecasts within a time period of few hours to few days.
- Mid-term load forecasting: forecasting for few weeks to a few months.
- Long-term load forecasting: forecasting within the period of one year to more than one year.

Based on the reasons and needs, any of the above categories can be chosen. In this work, long-term load forecasting is used to forecast future load. In most of the literature several methods of forecasting have been developed. These include linear regression, exponential smoothing, stochastic processes, the ARMA model, data mining models, fuzzy logic and artificial neural network (ANN) [2]. Among these methods, fuzzy logic and ANN are widely used. However, fuzzy logic seems to take the lead over ANN because of its distinct characteristics, for example, when there is a reasonable fluctuation between the weather parameters and load, fuzzy logic can handle it with less forecast error.

Abbreviation: ANN, Artificial Neural Network; PHCN, Power Holding Company of Nigeria; MF, Membership Function; MW, Megawatts; H, Humidity; T, Temperature; FL, Forecasted load; LH, Low Humidity; MH, Medium Humidity; HH, High Humidity; LT, Low Temperature; HT, High temperature; LL, Low Load; ML, Medium Load; HL, High load; APE, Absolute percentage Error; MAPE, Mean Absolute Percentage Error; n, number of sample data.

* Corresponding author.
E-mail address: alishalangwa@gmail.com (D. Ali).

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In this work, long-term load forecasting for future planning using fuzzy logic is proposed and the following objectives can be achieved; the development of a fuzzy logic simulation model in order to forecast a future load, the development of a fuzzy rule base to enable us determine accurate load forecasting and to confirm the effect of the weather parameters on the electrical load.

1.1. Fuzzy systems

The basic concept of fuzzy set theory was first introduced by Zadeh in 1965 [6]. Fuzzy set theory can be considered as a generalized classical set theory. Normally, in classical set theory an element can either belong to a particular set or not. Therefore, the degree of being a member of that set is its crisp value. However, in fuzzy set theory, the degree of membership of an element can be continuously varied. Fuzzy set maps from the universe of discourse to the close interval $\{0, 1\}$. The continuous nature of data can be represented by a membership function in fuzzy sets. Fuzzy set theory is one of the dominant technologies in artificial intelligence (AI) and it has broad application in load forecasting. For example, it can model ordinary linguistic variables which may be imprecise or vague in nature at a cognitive level [1,7]. Load forecasting involves many uncertainties, such as the variation in such factors as temperature, humidity, rainfall, wind speed, atmospheric pressure and solar radiation with respect to load, and its value cannot be exactly determined numerically. Therefore, a fuzzy logic approach will be the most suitable method to use under such conditions.

Fuzzy logic is used to map the highly non-linear relationship (using membership function) between the weather parameters and their consequences on the peak load in every month of the year. In this paper, the two parameters of temperature and humidity are used as inputs to the fuzzy logic model while load is an output. The end expectation is that the two weather parameters may have an impact on the load peak as observed in this research.

2. Methodology

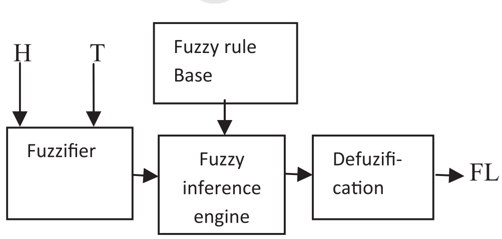
2.1. Method of data collection

The data are collected from two places. The weather parameters of temperature and humidity are collected from the meteorological centre of the Department of Geography of Adamawa State University, while the historical load data comes from Power Holding Company of Nigeria (PHCN), a Mubi business unit of Adamawa
Q5 state.

The block diagram of Fuzzy interface shows how to forecast the future load.

2.2. Fuzzy interface

The fuzzy interface can be actualized using the block diagram of Fig. 1. The weather parameters are fed to the fuzzifier and the output of the fuzzifier and fuzzy rule base enter into the Fuzzy inference engine which is the heart of the system as it processes input data and gives out the forecasted load. The inference system accomplishes the task of forecasting by the use of a fuzzy rule base prepared by the forecaster.



Q6 **Fig. 1.** Fuzzy interface.

In practice, the accuracy of the forecast depends on the cognizance of the forecaster and the prepared rules. Q7 The output from the fuzzy inference engine is still fuzzy in nature. It is then converted into a crisp value by defuzzification, which produces the forecasted load.

Figs. 2–4 show the variation in load for the years 2013 and 2014 and their average loads with temperature and humidity, respectively. It is observed from the figures that the load increases with an Q11 increase in temperature while an increase in humidity does not produced much impact on the load as in [2] where the relationship

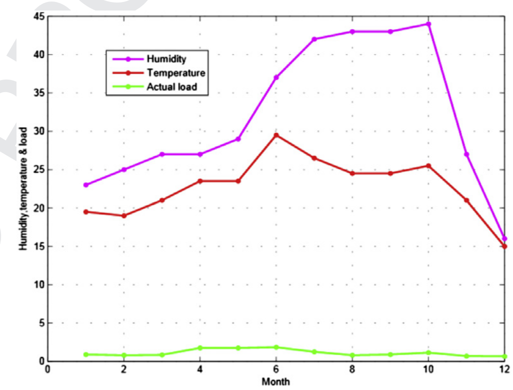


Fig. 2. Load, temperature and humidity vs. month for 2013. Q8

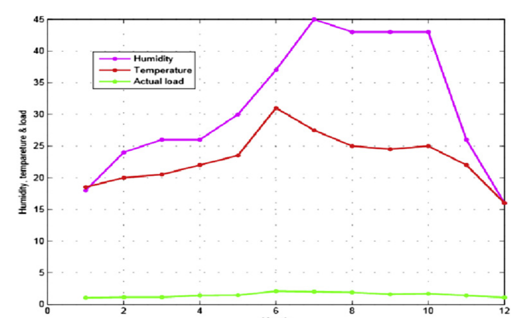


Fig. 3. Load, temperature and humidity vs. month for 2014. Q9,10

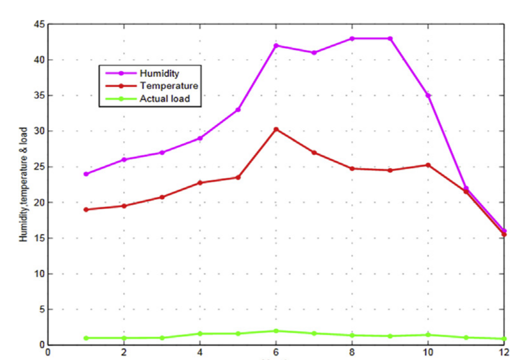


Fig. 4. Average load, temperature and humidity vs. month.

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