SHORT TERM LOAD FORECASTING FOR LOW-VOLTAGE SUBSTATIONS USING GENETICALLY OPTIMIZED FUZZY INFERENCE SYSTEMS

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1. Introduction

Load forecasting is an important element for the economically efficient operation and effective control of power systems and therefore it is used for advanced planning. Hence, short-term electricity demand forecasting, is one of the most important tasks in all electric utility plans, scheduling the generating unit operations in order to meet the system demand. An inaccuracy or large error in the forecast simply means that load matching is not optimized and consequently the generation and transmission systems are not being operated in an efficient manner. Furthermore, depending on power system characteristics, significant forecasting errors can be the cause of heavy economic penalties [1].

Load forecasting can help to estimate load flows and to make decisions that can prevent overloading. Timely implementations of such decisions lead to the improvement of network reliability. The economic and reliable operation of power systems depends, to a significant extent, on the accuracy of the load forecast [2].

On one hand, the expansion of distribution management systems has put in evidence the need of good load estimation at the nodes of medium-voltage networks, so the ability to estimate 24 hour load curves at low-voltage (LV) substations, as part of the whole network, is of great importance both in the planning and operation of distribution systems [3]. On the other hand, new advances in micro-generation technologies have lead to the concept of microgrid, a network of low voltage consumers and producers able to export electric energy to the electric distribution network [4]. Microgrids can also operate in emergency situations isolated from the distribution network. But in both cases (connected or isolated), it is necessary to have accurate forecasts of the load demand and of the power generation.

2. Key words

Short-term load forecasting, Fuzzy logic, Low-voltage substation, Peak daily load, Hourly load.

3. Study of a low-voltage substation

Most of the short-term load forecasting models published in literature have been developed for large networks with thousands or millions of consumers (industrial, commercial, domestic, etc.) not to the scale of a LV substation. However, this paper presents a short-term load forecasting model developed for a particular LV substation situated in the middle of a metropolitan area in a medium size town (150000 inhabitants) with approximately 400 customers, most of them domestic.

The results obtained from the study of this LV substation have supplied us with information about demand patterns that could be easily extrapolated to most of the facilities with similar characteristics.

On the other hand, we have to note the considerable differences between the hourly patterns of the load in a typical national or regional power system with a large number of customers and in a LV substation. Figure 1. shows the hourly load pattern (deviations from the mean value) of a typical regional power system (regional power system in Aragon, Spain). Figure 2. shows the hourly load pattern in the LV substation used for this study. Both of them present, in general, a similar hourly load pattern. However, an important difference arises from the deviations around the average value. In both graphics, the percentage deviation from the average load during the day and the hourly loads, are totally different. In Fig.1, the maximum deviation is around 15%, meanwhile, in Fig 2., the maximum deviation is around 60%. This situation causes the forecasted results obtained for a single LV substation, to be less accurate than the results obtained for a regional power system.

4. Proposed short-term load forecasting model

Many of the published papers on load forecasting models show models based on time series analysis. The classical load forecasting models have their simplicity as a main advantage. However, since the relationship between the load and factors that can influence it is non-linear, it is difficult to identify its non-linearity by using classical models [2].

Thus, a meta-heuristic technique such as fuzzy inference systems (FISs) has been used for our study because of its advantages with respect to classical methods. Other meta-heuristics techniques as artificial neural networks, ANNs, has achieved good results, but the non-linear relationship between their inputs and outputs values are not obvious and it is very difficult to include any empirical knowledge in the models. FISs have emerged as a good alternative for short-term load forecasting, since the empirical knowledge about load forecasting can be easily represented by the rules of the inference system.

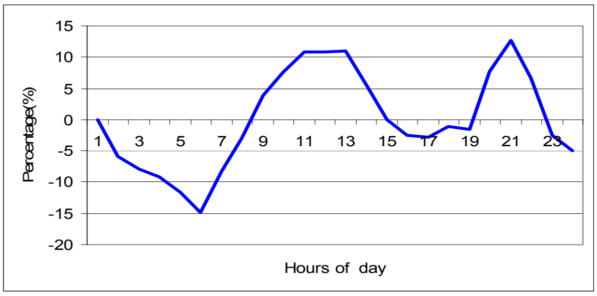

Fig. 1. Deviations from average value in the hourly load demand in a regional power system.

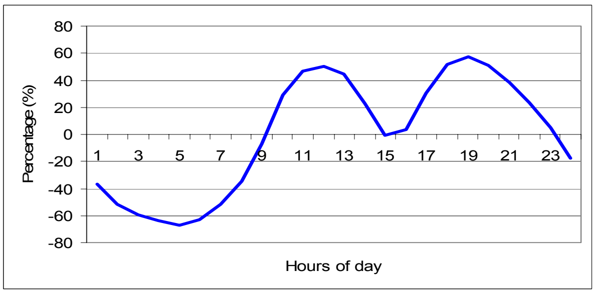

Fig. 2. Deviations from average value in the hourly load demand in the LV substation used in this paper.

With classical methodology, one of the most important tasks in an implementation of a FIS is the selection of the relevant input variables. Unfortunately, there is no systematic way to follow. However, an acceptable practical solution consists of the iterative process of trial and error, where one adds some new variables or subtracts irrelevant ones in order to obtain a better model. Typical inputs to a load forecasting model are forecasted weather variables, past values of weather variables, and the corresponding previous load values.

In this paper first-order Takagi-Sugeno (TSK) FISs models have been selected for the hourly load forecasting and peak load forecasting of the abovementioned LV substation. The forecasting horizons have a range of 15 to 39 hours, because the forecasts are obtained at 9:00 am and covering the 24 hours of the next day. Data corresponding to three of the last years were recorded and include hourly load and daily peak value for the LV substation and forecasted and real weather variable values. Data were divided into two sets, the first set with 80% of the data, for training or fitting the models, the second with 20%, for testing and comparing the models.

In previous works, we have detected that the best results with FISs in load forecasting problems were achieved using the subtractive clustering algorithm (for reducing the number of rules of the system) and an adaptive training (this kind of FISs are known, in literature, as adaptive neuro-fuzzy systems, ANFIS). However, we verified that the final results were dependent on the values of the parameters for the subtractive clustering algorithm.

An optimization process has been used in the development of the proposed FISs. It is based on genetic algorithms. An initial population is generated randomly. Each individual in the population corresponds to a feasible configuration for the FIS used as the forecasting model. Each individual is coded into a string with digits. The first digits correspond to the candidate input variables used as inputs in the corresponding FIS, so the optimization process can select the input variables among those available. Also, the parameters for the subtractive clustering algorithm are coded into the string. The FIS corresponding to each individual is constructed and trained (FISs with more than 5 rules are rejected). The individuals are ranked according to the lowest RMS error obtained with the training data set. After applying genetic operators, a new generation is created, and the process goes on until a stopping criterion is accomplished. The final resulting FIS is used as the forecasting model.
The obtained results show a mean absolute percentage error (MAPE) for the data in the testing set (not used to train or fit the models) lower than 5.6% for the working days and lower than 4.25% for weekend days, for the maximum power demand for the next day. In the prediction of the hourly loads for the 24 hours of the next day, the achieved results show a MAPE lower than 8.1% in the worst case.

5. Conclusions

This papers presents a set of short-term load forecasting models for a LV substation. The models are based on TSK fuzzy inference systems. Although the load forecasting for LV substations has not been considered in international literature, it could become an important subject to consider in a near future in the context of microgrids.

An optimization process based on genetic algorithms for the selection of the best first-order TSK FISs models has been used. The FISs models were constructed applying the subtractive clustering algorithm and a training phase. The optimization process allowed for the selection of the input variables and the proper parameters for the subtractive algorithm.

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