Applied Energy 101 (2013) 489–501

Contents lists available at SciVerse ScienceDirect

Applied Energy

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

A new hybrid day-ahead peak load forecasting method for Iran's National Grid

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HIGHLIGHTS

- ▶ A new hybrid day-ahead PLF engine for ING is developed.
- ▶ The impact of the weather condition on ING daily peak load is analyzed.
- ▶ The proposed method gives a better PLF error for ING and EUNITE test case.
- ▶ The processing time of the method is acceptable for real time applications.

ARTICLE INFO

Article history:
Received 23 January 2012
Received in revised form 21 May 2012
Accepted 6 June 2012
Available online 23 July 2012

Keywords:
Peak Load Forecasting (PLF)
Wavelet decomposition
Artificial Neural Network (ANN)
Genetic optimization
Iran's National Grid (ING)

ABSTRACT

This paper presents a new hybrid forecasting engine for day-ahead peak load prediction in Iran National Grid (ING). In this forecasting engine the seasonal data bases of the historical peak load demand on the similar days with their weather information given for three cities (Tehran, Tabriz and Ahvaz) have been used. Wavelet decomposition is used to capture low and high frequency components of each data base from original noisy signals. A separate ANN with an iterative training mechanism which is optimized by genetic algorithm is employed for each low and high frequency data base. A day-ahead peak demand is determined with the reconstruction of low and high frequency output components of each ANN. Simulation results show the effectiveness and the superiority of the proposed strategy when compared with other methods for daily peak load demand forecasting in ING and EUNITE test cases.

1. Introduction

Peak load forecasting is one of the most important problems for power system planning and secure operation. Power system loading scenario prediction is required for generation dispatch, maintenance planning, and reliability analysis, especially in market environment. PLF also has an important role for the evaluation of the security condition and voltage stability margin in future operation [1]. However, PLF is a difficult approach because there are different complex factors such as nonlinear and random behaviors of power system loads, weather conditions, social and economic environments variation and time frame [2]. Therefore, the system peak load estimation without enough accuracy may lead to have inadequate spinning reserve and causes the power system operation in a vulnerable region.

Different short term load forecasting (STLF) models have been employed in power systems. These models are categorized as classical approaches which are mainly designed based on linear models and artificial intelligence-based algorithms. Regressions models and time series, state estimation, Kalman filter are the most popular classical methods. However, these linear models are not usually sufficient to model the complexity and nonlinearities of short term load forecasting problem [3].

Artificial intelligence-based algorithms have been introduced based on expert system, evolutionary programming, fuzzy system, ANN, and a combination of these algorithms [4]. Among these algorithms, ANN has received more attention because of its clear model, easy implementation, good flexibility and robustness. ANN is able to learn the relation between weather variables such as temperature, humidity, wind speed and historical load patterns [5]. The structure of the ANN is highly dependent on some factors such as the ANN model, training algorithm, and input variables selection. In this regard, since the characteristics of every power system are different, determining an exact ANN model for all systems is not possible. In order to solve this problem, ANN is usually used in a hybrid structure with other techniques such as fuzzy logic [6], support vector machine (SVM) [7], particle swarm optimization (PSO) [8], genetic algorithms (GAs) [9] and wavelet transform [10] for carrying out a better training process and increasing the accuracy of the load forecasting engine.

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http://dx.doi.org/10.1016/j.apenergy.2012.06.009

Nomenclature

ANN	Artificial Neural Network
ARIMA	Autoregressive Integrated Moving Average
ARMA	Autoregressive Moving Average
ARMCRN	Autoregressive Multi-Context Recurrent Neural Network
CA–CA	Two Stage Correlation Analysis
Db	Daubechies
EA	Evolutionary Algorithm
FFFB-MCANN	Feed Forward and Feed Back Multi Context Artificial Neural Network
GA	Genetic Algorithm
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GFF	Generalized Feed Forward
IDE	Improved Differential Evolution
IGMC	Iran Grid Management Company
IMO	Iran Meteorological Organization
ING	Iran's National Grid
LM	Levenberg–Marquardt
LMBP	Levenberg–Marquardt Back Propagation
LS-SVM	Least Squares Support Vector Machine
LWR	Locally Weighted Regression
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
MLP	Multilayer Perceptrons
MSE	Mean Square Error
PLF	Peak Load Forecasting
PAPE	Peak Absolute Percentage Error
PCA	Principal Component Analysis
PSO	Particle Swarm Optimization
RMSE	Root Mean Square Error
SARIMA	Seasonal ARIMA
SOFNN	Self-Organizing Fuzzy Neural Network
STLF	Short Term Load Forecasting
SURE	Soft Heuristic Stein's Unbiased Risk Estimate
SVM	Support Vector Machine
SVR	Support Vector Regression
WUO	Weather Underground Organization

A fuzzy inductive reasoning is used for the day-ahead short term load forecasting in power systems in [6]. In this structure a simulated rebounding algorithm which is an evolutionary one is proposed to choose the inputs to the fuzzy inductive reasoning. A SVM learning algorithm has been proposed in [11] for hourly building cooling prediction load. A modified version of the support vector regression (SVR) for solving the load forecasting problem is given in [12]. In this method, with keeping the regularization of the original SVR form, the risk function of the SVR algorithm is modified by using a locally weighted regression (LWR).

An adaptive artificial neural network with PSO optimization has been proposed in [8] to adjust the network's weights in the training step of the ANN for hourly load demand forecasting. Similar to [8], a GA based neural network has been given in [9] for short term daily home electric load forecasting. Wavelet decomposition is used for smoothening ANN input load and weather signals by deleting the high frequency signal components [13].

In [14] a neural network framework with Multilayer Perceptrons (MLP) structure is given for short term and midterm demand predictions in power system. This method uses a hybrid training mechanism composed of Levenberg–Marquardt (LM) learning algorithm and a stochastic search method that is called Improved Differential Evolution (IDE).

Most of the above methods are used for hourly STLF. However, in a dispatching center the daily peak load is very important for day-ahead unit commitment programming for a secure power system operation [15]. A 24-h-ahead short term peak and average load forecasting have been employed in [16] using a self-organizing fuzzy neural network. In [17,18] a daily PLF method for HVPNL Ltd., is presented by using ANN with different neural network models such as LM, quasi-Newton and conjugate gradient. A short term hourly load forecasting using time-series modeling with peak load estimation capability was proposed in [15]. In this paper the time series modeling of the ARIMA with the knowledge of experienced human operators has been incorporated. In some previous works such as [19], the daily PLF is a part of STLF. In these methods, forecasting the horizon time is limited to day-ahead.

This paper develops a new hybrid PLF method for ING to improve the day-ahead PLF accuracy in which the benefits of the previous forecasting methods are also considered. This technique involves a combination of the seasonal data base information, similar day peak load demand, weather variables, wavelet decomposition and genetic training optimization of ANN. Although the proposed method is a day-ahead PLF framework and all data is updated every day, the forecasting engine also has an acceptable forecasting accuracy for a month ahead daily peak load without updating data.

The seasonal data base of peak load demand on similar day is considered for about 5.5 years (February 4, 2006–July 22, 2011) and related weather condition data including daily average and maximum temperature, daily average humidity and daily maximum wind speed for three cities in ING (Tehran, Tabriz and Ahvaz). These cities have the peak load demand with different weather conditions in ING. The peak load signal is noisy and contains low and high frequencies data. A neural network cannot map these features with an acceptable precision. Therefore, first the similar days of the weak are determined by using multiple-correlation coefficient (r^2) analysis. Based on these results, three similar day data base in every season have been established. Wavelet decomposition is then used for all signals of each data base to separate low and high frequency components which vary slowly and fast respectively. Two separate ANNs for low and high frequency components are employed. Generalized feed forward (GFF), MLP and SVM neural network models with levenberg–marquardt back propagation (LMBP) learning algorithm are evaluated. Genetic algorithm has been employed as an iterative stochastic method to handle the optimization training mechanism. The goal of the genetic optimization is to find the parameter settings of the ANN that result in a minimum error. The final peak load amount is obtained by reconstructing the two forecasted low and high frequency components. This method has been tested for the period of July 23–August 22, 2011 and its accuracy is compared with four other methods. The EUNITE test case [20] has been also considered in which the accuracy of the suggested technique is compared with 11 different methods. The simulation results show that the method given in this paper has a superior precision with appropriate processing time.

2. ING daily peak load analysis

Iran National Grid load pattern varies rapidly [14] and, in this regard temperature has a great impact for increasing the peak load level. The load demand is mostly increased in the summer due to using cooling systems, especially in the southern part of the country. Therefore, ING has often experienced the maximum value of