Integration of new evolutionary approach with artificial neural network for solving short term load forecast problem

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HIGHLIGHTS

- A novel evolutionary based algorithm (FTL) is being proposed.
- FTL is validated by COCO experimental framework on the set of 24 BBOB functions.
- To enhance the accuracy of STLF, we integrate FTL with ANN termed as ANN-FTL.
- Experimental results demonstrate higher prediction accuracy of ANN-FTL.

ABSTRACT

Due to the explosion in restructuring of power markets within a deregulated economy, competitive power market needs to minimize their required generation reserve gaps. Efficient load forecasting for future demands can minimize the gap which will help in economic power generation, power operations, power construction planning and power distribution. Nowadays, neural networks are widely used for solving load forecasting problem due to its non-linear characteristics. Consequently, neural network is successfully combined with optimization techniques for finding optimal network parameters in order to reduce the forecasting error. In this paper, firstly a novel evolutionary algorithm based on follow the leader concept is developed and thereafter its performance is validated by COmparing Continuous Optimizers experimental framework on the set of 24 Black-Box Optimization Benchmarking functions with 12 state-of-art algorithms in 2-D, 3-D, 5-D, 10-D, and 20-D. The proposed algorithm outperformed all state-of-art algorithms in 20-D and ranked second in other dimensions. Further, the proposed algorithm is integrated with neural network for the proper tuning of network parameters to solve the real world problem of short term load forecasting. Through experiments on three real-world electricity load data sets namely New Pool England, New South Wales and Electric Reliability Council of Texas, we compared our proposed hybrid approach to baseline approaches and demonstrated its effectiveness in terms of predictive accuracy measures.

1. Introduction

Deregulation of electricity industry needs accurate load forecasting for proper electricity load planning and management strategies. Increased complexity and demand of 3–7% electricity load every year require high accuracy of forecasting. An accurate forecast can minimize the gap between electricity supply and demand. To meet the future demand and to decrease energy shortage pressure, some real-time technology innovations are required. In 1985, it was estimated that 1% increase in forecasting error increases the associated operating costs of up to 10 million pounds every year in the thermal British power system [1]. Various new techniques of electricity load forecasting have been proposed in last few decades in order to improve prediction accuracy [2]. Due to the non-linear and random behavior of system loads and weather conditions as well as economic behavior, it is difficult to deal with electricity load forecast problem.

Electricity market has become a central point of interest for researchers in the field of energy sector and load forecast has become one of the most challenging tasks being faced by electricity market entities. The real motivation lying behind load forecasting is purely economic [3]. With the increase in load forecasting accuracy, the negative impact on the economy is reduced. The electricity market players need precise load forecast in order to generate profits and optimize utilities [4].

Generally, four types of load forecaster are used by energy
management systems (EMS) to establish operational planning and their
generations in power systems: (1) very short term load forecast
(VSTLF), for generating load demand for few minutes; (2) short term
load forecast (STLF), forecast load demand for one day to one week
ahead; (3) forecasting load for more than a week to few months is done
by medium term load forecaster (MTLF); (4) long term load forecast
(LTIF) is referred for time horizon between few months to several
years. STLF produces an accurate load demand for controlling and
scheduling of the power system. Electricity load forecasting models can
be broadly classified into four categories: (1) Statistical models; (2)
knowledge-based expert systems; (3) hybrid models and (4) artificial
intelligence-based models [5].

Statistical models, such as the autoregressive (AR) model, auto-
regressive moving average (ARMA) model, and autoregressive in-
tegrated moving average (ARIMA) model examine qualitative rela-
tionships between load and load affecting factors and are easy to
implement. Other statistical models such as regression trees [6], and
multiple linear regression [7,8] have gained interest among researchers
for load forecast. Charytoniuk et al. [9] described a load model in the
terms of probability density function of between the load and load
factors to solve short term load forecasting problem. Haida and Muto
[10] presented a transformation technique based on multivariate re-
gression for daily peak load forecasting by considering seasonal load
change, annual load growth and latest daily load change as load af-
fected factors. El-keib et al. [11] developed a hybrid model by in-
tegrating adaptive AR modeling technique with weighted recursive
least square estimate algorithm for STLF. Taylor et al. [12] predicted a
da day ahead load for 10 European countries. The case study compares
different univariate models, including ARIMA modeling, periodic AR
modeling, Double Seasonal Holt-Winters ES, Intraday Cycle ES Model
for Double Seasonality and PCA. However, these statistical models
hugely rely on the correlation between the load and its previous load,
faces great difficulty in selection of an appropriate non-linear function
and suffer from high computational cost [13]. Fortunately, with the
rapid advancement in intelligent techniques in last few decades, various
soft computing approaches such as fuzzy logic, expert systems, artificial
intelligence and many more have been deployed in electricity load
forecast problem.

Expert systems are rule-based models that take decisions based on
the experience of experts. Ho et al. [14] proposed a knowledge-based
expert system for solving STLF of Taiwan power system and proved it
to be more effective than Box-Jenkins statistical model. Kandil et al. [15]
proposed an expert system that obtains a set of decision rules by rel-
ating key variables. Decision rules are stored in the knowledge base,
and the best model is used for medium/long term power system plan-
ing.

From earlier mentioned limitations of statistical models, researchers
started showing their interest towards artificial intelligence, where non-
linear relationship from historical data is extracted. Artificial in-
telligence techniques, such as fuzzy logic system, neural network,
evolutionary computation, and support vector machine (SVM), are
capable of resolving the non-linear behavior and are highly dynamic to
load fluctuation problems. Artificial intelligence models generate
slightly better forecast but with longer computation time [16]. Among
available intelligence based techniques, artificial neural network has
been widely used for solving electric load forecasting problem in last
few decades. Mamlook et al. [17] implemented a fuzzy logic controller
to decrease the forecasting error on hourly basis. In early 19s, Park et al.
[18] proposed neural network for a day ahead hourly load forecast by
finding proper correlation among previous, present and future tem-
peratures and loads. Ho et al. [19] proposed a multi-layer neural net-
work with an adaptive learning algorithm to speed up the network
training process. The effectiveness of the proposed approach is de-
monstrated on Taiwan power system for short term load forecasting by
showing higher convergence rate than traditional backpropagation
learning approach. Chen et al. [20] presented a non-fully connected
artificial neural network, capable of forecasting hourly loads for
weather sensitive loads. Non-fully connected neural networks have
fewer connections which provide the advantage of shorter training time
than the fully connected ANN. Taylor et al. [21] analyze the use of
weather ensemble predictions in the application of artificial neural
networks for load forecasting. Hippet et al. [22] broadly discussed the
applications of neural networks and deeply analyzed its performance
for short term load forecasting.

In the later stage of research, hybrid methods came into existence by
collaborating two or more feasible models to overcome some weak-
nesses of the original methods. Thus, to find an advanced forecasting
method and achieve a higher level of accuracy, hybrid models have
emerged. Lately, several hybrid forecasting models have been in-
troduced to improve the load precision with the aim of achieving su-
perior forecasting results. For example, Pai et al. [23] integrated genetic
algorithm (GA) with support vector machine (SVM) to find free par-
meters of SVM for predicting regional electricity load of Taiwan. Liao
et al. [24] combined chaos-search genetic algorithm (CGA) with fuzzy
system and integrated simulated annealing to find the optimal para-
meters of fuzzy neural network and applied to short term power system
load forecasting. Bashir and El-Hawaiy [25] combined PSO with arti-
ficial neural network (ANN) to find the best network weight solution.
Niu et al. [26] implemented ant colony optimization (ACO) for the
feature selection of SVM to reduce forecasting error. Li et al. [27],
combined generalized regression neural network (GRNN) with fruit fly
optimization algorithm (FOA) to find appropriate spread parameters of
GRNN for power load forecasting model. Yu and Xu [28] integrated
real-coded GA with backpropagation neural network (BPNN) for fore-
casting short-term gas load and the result shows that improved BPNN
obtains higher learning convergence. Quan et al. [5] implemented
neural network based method to find prediction intervals by combining
PSO integrated with the mutation. Jurado et al. [29] integrated en-
tropy-based feature selection method with soft computing, and machine
learning approaches (fuzzy inductive reasoning, random forest, and
neural network) for electricity load forecasting. Recently, Khwaja et al.
[30] combined two most popular algorithm bagging and boosting with
neural network (NN) to improve load forecast of New England Pool
region.

Among all available forecasting models, artificial neural network
based models have attracted the most for solving STLF problem [22].
Neural network is best known for their learning capability even in a
complex non-linear environment. Simplicity of network structure, fault
tolerance, and non-linear learning capability of ANN make it widely
acceptable. But, the degree of freedom of ANN model reduces with
increase in model complexity and it further causes the problem of
overfitting or underfitting of the model. For precise forecasting, ANN
must have generalization ability for finding the best trend between the
load and its affecting factors. On the other hand it requires rigorous
network training. The random initialization of weight parameters may
generate forecasting error which needs to be updated. To overcome
these issues, the network parameters need to be chosen very approp-
riately. From literature, we observe that hybrid models reduce the
magnitude of prediction errors if feasible models are integrated to
prevail over some weaknesses of the primitive models. Ling et al. [31]
and Azadeh et al. [32] integrated genetic algorithm with artificial
neural network (ANN) for selecting appropriate network parameters
and compared with traditional neural network and time series models
respectively. In similar context, ANN can be combined with other op-
timization models as a training algorithm in order to achieve optimal
neural network weight parameters which may generate least fore-
casting error. More importantly, accuracy is very significant factor
during load forecasting. So, to achieve good forecasting results, lim-
itations of traditional ANN need to be removed by combining with
other models.

In this paper, we propose a novel evolutionary algorithm based on
the concept of moving behavior of a sheep within a flock. Thereafter,
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