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Research and application of a combined model based on multi-objective optimization for electrical load forecasting

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ABSTRACT

Short-term load forecasting (STLF) plays an irreplaceable role in the efficient management of electrical systems but remains an extremely challenging task. To achieve the goal of load forecasting with both accuracy and stability, a combined model based on a multi-objective optimization algorithm, the multi-objective flower pollination algorithm (MOFPA), is developed in this study. In this combined model, MOPFA is used to optimize the weights of single models to simultaneously obtain high accuracy and great stability, which are two mostly independent objectives and are equally important to the model effectiveness. Data preprocessing techniques, such as the fast ensemble empirical mode decomposition and multiple seasonal patterns, are also incorporated in this model. Case studies of half-hourly electrical load data from the State of Victoria, the State of Queensland, and New South Wales, Australia, are considered as illustrative examples to evaluate the effectiveness and efficiency of the developed combined model. The experimental results clearly show that both the accuracy and stability of the combined model are superior to those of the single models.

1. Introduction

Short-term load forecasting (STLF) is a significant task in power systems for scheduling power generation and maintenance plans, switching loads, assessing security, understanding market demands, reducing costs and ensuring a continuous supply of electricity [1–3]. Meanwhile, many uncertain factors, which influence the forecasting performance, make the study of STLF a challenging task [4,5].

The development of effective forecasting methods to enhance forecasting abilities has become imperative. Classical statistical techniques [6–10] are widely used in STLF. However, when data are affected by certain events such as holidays, the time-series method may exhibit poor performance [11]. Thus, a variety of artificial intelligence methods have been applied to time series forecasting, typically yielding forecasting results of extremely high accuracy [12], such as the fuzzy logic [13,14], support vector machines (SVMs) [15,16] and artificial neural networks (ANNs) [17–21]. A combined forecasting model, composed of multiple single models, was pioneered by Bates and Granger to represent a forecasting improvement over single models [22]. According to the combined forecasting theory, the result of a combined model is obtained from M types of single forecasting models, whose results are summed according to the corresponding weight coefficients [23]. To take advantage of the strength of each single model, different varieties of ANNs have been introduced to electrical power forecasting [24,25].

Generally, the goal of the combined model with the optimal weights is to minimize the forecasting errors [26]. To find the optimal combination, several optimization algorithms, such as the adaptive particle swarm optimization (APSO) [27], particle swarm optimization (PSO) [28] and cuckoo search (CS) algorithm [29], have been applied to STLF.

In previous studies [27–29], the combined models are focused on the accuracy improvement or stability improvement when the weights for all single models are optimized. However, both accuracy and stability are important when evaluating the effectiveness of a forecasting model. Considering only one criterion

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(accuracy or stability) is insufficient. When an optimization algorithm is applied to optimize the weight coefficients of the single models in a combined model, it should simultaneously provide both accuracy and stability. Obviously, to make the combined model achieve both accuracy and stability simultaneously is a multi-objective optimization problem (MOP) instead of a single-objective one.

Over the past few decades, MOPs have attracted considerable interests from researchers motivated by real-world engineering problems [30–32]. Meanwhile, it is difficult to achieve a satisfactory result in a limited amount of time by using the traditional approaches because a huge solution space must be explored over multiple runs to collect a set of optimal solutions. Evolutionary algorithms (EAs) have been demonstrated to be an effective way for solving MOPs because the population-based search used in EAs can generate multiple Pareto-optimal solutions in only a single run [33–36].

In this study, to improve the accuracy and stability of a forecasting model simultaneously, a combined model based on multi-objective optimization is developed for STLF. The optimization of the weight coefficients for the single models in the combined model depends on a multi-objective flower pollination algorithm

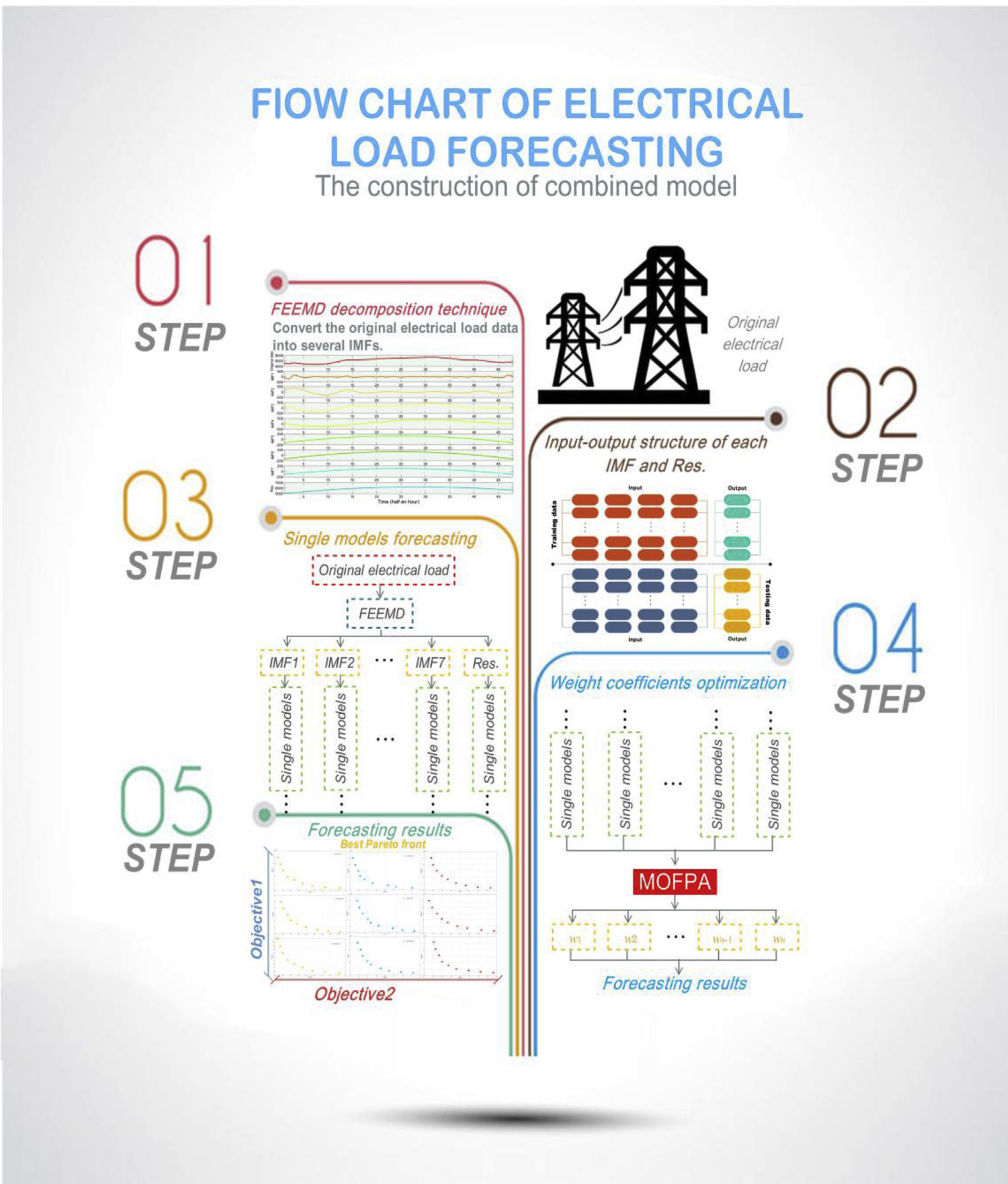

Fig. 1. Flowchart of the combined model.