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Model selection mechanism of Interactive Multiple Load Modeling

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ABSTRACT

Accurate load modeling with fluctuate loads has been one of the most challenging problems of modern power system. In this paper, a model selection mechanism is proposed for the Interacting Multiple Load Modeling (IMLM), to achieve the adaptive adjustment of best model set. A large number of models with different characteristics are chosen to compose the model set in order to completely cover the load characteristics of transformer substation, which brings severe competitions between these models and increases the complexity of load modeling. Equivalent asynchronous machine parallel ZIP load model is adopted as the interacting load model structure, and the Normalized Innovation Square Sum is chosen as the test statistic of model selection. Under the system of IMLM, this paper exhibits the processes to choose the best-matched models from the model set to participate in model mixing. Finally, a simulation case and the results illustrate the effectiveness and advantages of the proposed model selection mechanism.

1. Introduction

The power system load characteristics are affected by many factors, such as the voltage fluctuations, frequency changes and other uncertainty factors, which lead to periodic changes in load characteristics. Fluctuation load, which means power load with time-varying characteristics, has brought great challenges for power system planning and operation [1]. Accurate load modeling is the foundation for the evaluation of the power system stability and the determination of the desired control as well as protection measures [2], where precise load model plays a great impact on power system credible dynamic analysis [3,4], consequently. Recently, the emergence and wide applications of nontraditional types of loads and rapid development of distribution generators have attracted more and more attentions to load modeling [5,6]. The connecting of distributed renewable energy resources, such as wind power and solar power, brought uncertain to consumer power load, deriving great difficulties and challenges to the already complex modeling procedure. Consequently, it is of great necessity and significance for the research of more valid load modeling algorithms of distribution network, especially for the network connecting with wind power generators.

The traditional load modeling methods can be roughly divided into two aspects: the component-based modeling approach [7] and the measurement-based modeling approach [8].The former approach depends on the statistical survey of load data, which is restricted to simulate the dynamic load characteristics. The latter one identifies the load parameters according to the live measurement data and updates the load model in real time to some extent. However, the parameter identification of complex motor structure cannot avoid the convergence and multi-value problems [9], which brings difficulties to describe the different change rules of load characteristics. What's more, the traditional load model structure always adopts one single model with fixed structure and parameters, thus limiting the establishment of accurate load model under the changes of the load component. On account of the excellent performance, Interactive Multiple Model (IMM) [10–12] algorithm has been applied in many state estimation problems with complex structure and time-varying parameters since it was proposed in 1988 [13–15], which also provides a theoretical basis for accurate load modeling of power systems.

To overcome the time-varying characteristics of power system loads, one of the effective approaches is to employ IMM algorithm for load modeling, which is a dynamic multiple-model maneuvering target tracking algorithm with high tracking accuracy and low computational capacity. In order to solve the contradiction between the integrity of model set and the model competition brought by large model set, a model selection mechanism is proposed for IMLM to choose a best model set for interaction. This paper applies the structure of asynchronous machine parallel static load model as the Interactive Multiple Load Model structure. Based on the load model set determination and initialization, all the state calculators work in parallel to obtain the innovation errors between each model and the actual system. Calculations offer the Normalized Innovation Square Sum of each

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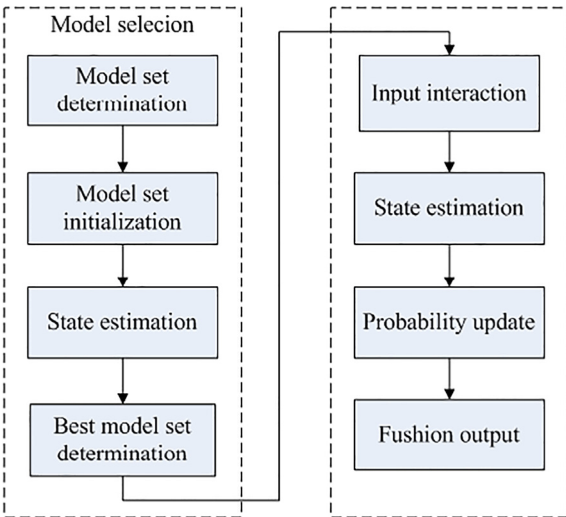

Fig. 1. Structure of the Interactive Multiple Load Modeling.

model in terms of the innovation vectors and covariances, which provides the key point of the load model selection mechanism. With the selection mechanism, several best-matched load models can be selected from the overall load model set to participate in the process of model interacting. Finally, the effectiveness of the proposed load model selection rule is validated by numerical simulations.

2. Model section mechanism

The main steps of Interacting Multiple Load Modeling include model selection, input interaction, state estimation, probability update and fusion output. Among these 5 steps, model selection is performed in the overall model set, involving model set determination, model set initialization, state estimation, and best model set determination; while other 4 steps are based on the best model set generating from model selection. The structure diagram of IMLM is shown in Fig. 1.

Based on the maneuvering target detection [16], the essence of model selection is to choose several best-matched load models from the overall model set according to the errors between models and the actual system, in order to guarantee the high accuracy and the strong mobility of modeling. The algorithm proposed in this paper consists of four main steps:

(1) Model set determination. Establish a load model set which contains models representing different state characteristics. To represent the basic variation of load characteristics, the parameters of sub-model can be obtained through characteristics clustering and the respective modeling of each characteristic category
(2) Model set initialization. This process mainly involves the initialization of state variables and the initialization of measurement variables. The purpose of initialization is to provide the relevant parameters of state estimation
(3) State estimation. Each filter is matched with one model from the model set, and all the filters work in parallel to finish the calculation of innovation errors
(4) Best model set determination. Model selection need to be conducted after the state estimation of each moment. Through this step, the best model set including models best-matched the true system at the present moment can be obtained

The application of model selection in load modeling will be illustrated as below.

2.1. Load model set determination

In this paper, the interacting load model structure is selected as the generalized load model considering wind generators [17]. In China, most of the wind generators work with constant speed and constant frequency wind turbines, which belong to asynchronous generators. In this situation, the model of wind generator can be regarded as a dynamic load with negative power consumption, which can be described with an asynchronous generator [18]. What's more, the model structures of asynchronous generator and the induction motor can be consistent. On this basis, the interactive load model structure can be identified as the equivalent asynchronous machine parallel static load model structure, namely the ZIP static model parallel three-order induction motor model under the electromechanical transient process.

Model set determination contains the determination of both model amount and model parameters. Theoretically, the model amount of the mode set should be established as large as possible to cover the whole load characteristics. However, the large number of models can cause severe competition, which brings out errors of load modeling and increases the computational amount at the same time. As a consequence, choosing a suitable model amount is essential for load modeling. The model parameters involve parameters of induction motor models, wind generators and static models. In order to roundly cover the load characteristics of substations, the measurement data under disturbance can be adopted to conduct parameter identification and clustering analysis [19]. After these processes, the load models correspond with different load characteristics can be obtained, namely establishing a load model set that effectively describes the load components, power level and the time-varying behavior of voltage.

As an important part of the interactive load model structure, the asynchronous machine is equivalent to the parallel structure of wind generator and induction motor, where the wind generator is regarded as a dynamic load with negative power consumption. The power flow direction of wind generator and induction motor are opposite with each other, as shown in Fig. 2. By comparison of the power values of the two machines, the operating state of asynchronous machine can be obtained.

The total power radiated by the bus is described as

$$P_0 = P_{IM} - P_{WG} + P_{ZIP} \tag{1}$$

where, P_{IM} denotes the active power absorbed by induction motor, P_{WG} denotes the active power provided by wind power, and P_{ZIP} denotes the active power absorbed by ZIP load.

The difference value of P_{IM} and P_{WG} means the active power of the equivalent asynchronous machine, so the proportion of asynchronous machine is

$$K_{PM} = \frac{P_{IM} - P_{WG}}{P_0} \tag{2}$$

When $P_{WG} < P_{IM}$, the asynchronous machine works in a electric motor, $0 < K_{PM} < 1$;

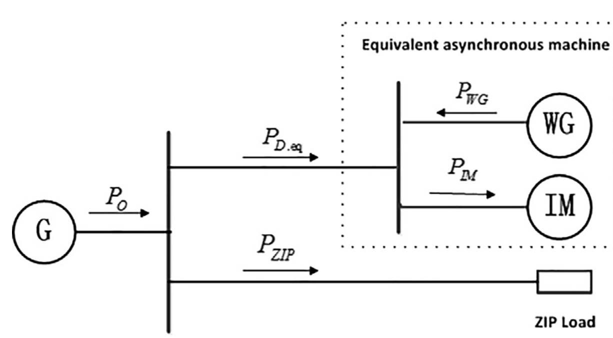

Fig. 2. Structure of the Interactive Load Model.