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A Robust Economic Region Considering Load Uncertainty for Security and Economic Operation Optimization in Power Systems

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Abstract

Random errors are unavoidable in the security and economic operation (SEO) optimization of power systems due to load uncertainties, such as load forecasting deviations and random load fluctuations. Meanwhile, strictly adjusting the real power outputs of units with a given decision solution of the SEO model is difficult to achieve by decision makers in practice. In this paper, the robust optimization (RO) model is formulated by combining load forecasting deviations and the base model, which adopts the comprehensive cost and system equilibrium (SE) as objectives. Based on the proposed RO model, the economic region considering load uncertainty (ERCLU) concept is illustrated, and applied to solve the load forecasting deviation problem and provide the practical optimization reference for decision makers. Moreover, the adjustment strategy is given for the real power outputs of units out of the ERCLU. Finally, the proposed model and method have been implemented on the IEEE 30-bus test system.

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Keywords: Economic region; Load uncertainty; Security and economic operation optimization; Robust optimization; Adjustment strategy

1. Introduce

The security and economic operation (SEO) of power systems is crucial for the economical development around the world [1]. In the conventional power system operation, the hourly load, available water, wind speed and solar radiation should be forecasted to prevent errors. For example, the SEO of power system operation depends on the

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Nomenclature

a_i , b_i , c_i	cost coefficients of unit *i*
α_i , β_i , γ_i , μ_i , λ_i	emission characteristic coefficients of unit *i*
$DP(i)$,$UP(i)$	downward and upward climbing speeds of unit *i*
N, B, L	number of units, buses and lines
K ,r	environmental cost coefficient ($/ton) and load forecasting deviation coefficient
P_G , P_{Gi}	total real power output of *N* units and real power output of unit *i*
$P_{Gi,\min}$, $P_{Gi,\max}$	minimum and maximum real power output of unit *i*
$\overset{*}{P}_G$, $\overset{*}{P}_{Gi}$	total real power output and real power output of unit *i* considering each load node forecasting deviation
$\overset{*}{P}{}_G^j$, $\Delta P'_{Gi}$	*j*-th sample individual of $\overset{*}{P}_G$ and random value in a given interval
$\underline{P_{Gi}}$, $\overline{P_{Gi}}$, d_i	lower and upper limits of $\hat{P}_{Gi}$, adjustment distance of unit *i*
P_D , P_{Dj}	total real load demand and a certain load forecasting value for load node *j*
P_{loss} , $\overset{*}{P}_{loss}$	real power loss and real power loss considering each load node forecasting deviation
$Q_{Gi,\min}$, $Q_{Gi,\max}$	minimum and maximum reactive power output of unit *i*
S_{li} , $S_{li,\max}$	actual power flow and maximum power flow of line *i*
$U_{j\min}$,$U_{j\max}$	minimum and maximum voltage magnitude of bus *j*
$\rho\%$, $\overline{\delta}$	network loss rate and network loss rate maximum permitted

forecasting deviations, are not considered [2]. However, errors are unavoidable in these forecasted values in practice [3]. Because the load power of each node is random fluctuation all the time, it can not be accurately predicted in practical operation, which brings in random biases and has negative effects on the SEO of power systems. Moreover, there are many uncertainties with respect to different load characteristics and operating condition, which have great effects on the stability control and security operation of power systems [4]. Hence, load uncertainties can not be ignored in the SEO of power systems.

On the other hand, up to now, much attention has been paid to the SEO of power systems by establishing different multi-objective optimization models [5,6]. Then many heuristic methods, such as differential evolution (DE) [7], genetic algorithm (GA) [8], particle swarm optimization (PSO) [9], are used to obtain the Pareto optimal solutions of the proposed models. Finally, a decision solution is obtained by adopting decision making method [10]. However, due to the complexity of power systems [11] and particularity of running circumstance [12], it is difficult for decision makers to strictly adjust the real power outputs of units based on a given decision solution.

In this study, the robust optimization (RO) model is presented to consider the load forecasting deviation in the SEO of power systems. Then the economic region considering load uncertainty (ERCLU) concept and the adjustment strategy are proposed for decision makers to optimize the SEO of power systems. The ERCLU considers the load forecasting deviation, an important load uncertainty, based on the RO model. In addition, after referring to the ERCLU, decision makers can adjust the real power output of units into a region rather than a given decision quite easily.

2. Formulation and solution of base model

The paper presents the base model to make preparation for the follow-up work. Compared with general models, two differences of the base model are that system equilibrium (SE) is used as the objective function of security operation, and the network loss is considered as the constraint of economic operation. The process is introduced briefly as follows: