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Integrated Planning of Distribution Systems with Distributed Generation and Demand Side Response

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Abstract

The planning and operational issues of distribution systems have attracted more and more attentions from researchers with the development of Smart Grids. A new integrated planning model of distribution systems and the solution methods are proposed in this paper to investigate the way of improving the economy and reliability of distribution system planning by making full use of distributed generation (DG) and demand side response (DSR) resources. The planning objective function is formed by taking consideration of the investment and operation cost of DG, transmission loss cost, compensation cost for interruptible loads, purchasing electricity cost, and the environmental benefits after integration of DG. The integrated planning scheme will be acquired by introducing price induced interruptible load to distribution system planning model. A hybrid intelligent algorithm consisting of support vector machines (SVM) and particle swarm optimization algorithm (PSO) is proposed to solve the integrated planning model. The effectiveness and advantages of the model and algorithms and the necessity of considering the demand side resources are verified by simulation cases based on a real regional distribution system in China.
Keywords: Distribution network planning; integrated planning; distributed generation; demand side response; hybrid intelligent algorithm

1. Introduction

The problems of traditional energy shortage and environmental pollution are becoming more and more serious, and people pay more attention to renewable energy generation and demand side response (DSR) mechanism. DSR is very important for integrated planning of power distribution network, especially the current large-scale access of DG. The price of the interruptible load is an important content of DSR. The power companies and users signed the agreed price of interruptible load contract, and the power companies can cut off part of the users' load by making appropriate economic compensation. The load

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characteristics will be improved through determining the interruptible load and the interruption duration correctly.

Distribution network planning is a multi-objective integer programming problem, and with the addition of DSR and DG the planning dimension and the difficulty is increased. On the DG locating and capacity problem, an improved multi-objective harmony search algorithm is used to solve this optimization problem in [1]. In [2] the genetic algorithm is used to solve the optimization problem for minimizing system cost and maximizing DGs reliability. However, the power distribution network planning considering DG and DSR needs to be further studied.

In order to reflect the impact of DG and DSR on distribution network planning, the comprehensive planning framework based on DG and DSR (here mainly adopts the interruptible load management) is proposed in this paper. The planning objective function is formed by taking consideration of the investment and operation cost of DG, transmission loss cost, compensation cost for interruptible loads, purchasing electricity cost, and the environmental benefits after integration of DG. The hybrid intelligent algorithm based on SVM and PSO is used to get the best DSR plan and the position and capacity of DG. Finally, based on an actual 42 nodes distribution system in China, the economy and reliability of three schemes are compared to verify the effectiveness of integrated planning and the necessity of DSR.

2. Mathematical Model of Integrated Planning based on DG and DSR

Stochastic chance constrained programming (SCCP) is proposed by Charnes and Cooper, whose remarkable characteristic is that the constraints are satisfied at a certain confidence level.

SCCP model is usually expressed as follows [1]:

$$\begin{cases} Min\ \overline{f} \\ s.t.\ \ p_r\{f(x,\xi)\le \overline{f}\}\ge \beta \\ \qquad p_r\{g_i(x,\xi)\le 0, j=1,2,\cdots,v\}\ge \alpha \end{cases} \tag{1}$$

where x and ξ respectively present the decision vector and the random vector, $p_r\{\bullet\}$ presents the probability of an event, α and β are the confidence levels which decision makers given in advance. $\overline{f}$ is the minimum value of the objective function at the confidence level β .

2.1. Objective Function

The planning objective function considers the investment and operation annual cost of DG, transmission loss cost, compensation cost for interruptible loads, purchasing electricity cost, and the environmental benefits after integration of DG.

The optimization objective is follows [2] in this paper.

$$\min C = C_{loss} + C_{DSR} + C_{DG} - C_b - C_e \tag{2}$$

where C_{loss} is the annual loss cost, C_{DG} is the investment and operation annual cost of DG, C_{DSR} is the compensation cost for interruptible loads, C_b is the saving cost for purchasing electricity, C_e is the environmental benefits.

1) Annual loss cost:

$$C_{loss} = C_{ps} \times \sum_{i=1}^{k}(P_{loss\_i} \times \tau_{\max\_i}) \tag{3}$$

where C_{ps} is the unit electricity selling price, k is the number of branches in the distribution system, P_{loss_i} is the active power loss of the *i-th* branch, $\tau_{\max\_i}$ is the annual maximum load loss hours of the *i-th* branch.

2) Compensation cost for interruptible loads:

$$C_{DSR} = \sum_{i=1}^{n_{DSR}} P_{DSR\_i} \times T_{DSR\_i} \times (C_{ps} + C_{pi}) \tag{4}$$

where n_{DSR} is the number of interruptible loads, P_{DSR_i} and T_{DSR_i} respectively presents the interruptible load and interrupt time of the *i-th* interruptible load, C_{pi} is the unit compensation cost for interruptible load.