Chapter 44
Optimization for the Logistics Network of Electric Power Enterprise Based on a Mixed MCPSO and Simulated Annealing Algorithm

Lin Yuan, Dong Wang and Canquan Li

Abstract Recently the Electric Power Enterprise have many problems showing up. Combining the characters of Electric power enterprise supplies, researchers build an optimized network model to solve the irrationality of warehouse network, the simplex distribution and the high storage cost. This new model uses a method different from gravity and radius method which usually used by the general models. Researchers also discuss the penalty costs, construction costs and the operation costs in this paper. They use simulated annealing algorithm based on a mixed MCPSO (Multi-swarm Cooperative Particle Swarm Optimizer) in the new model. Fortunately, in an actual project of Power Supply Company, this optimized scheme is verified to be rational and effective.

Keywords Electric power enterprise · Logistics network · Mixed MCPSO and simulated annealing algorithm

44.1 Introduction

With the opening of electric power market, the power materials and goods management become one of the main factors to affect the core competence and cost, which faces a huge drastic market competition and challenge [1].

Although the power material management share some similarities to the other industries' material management, a higher demand of the selection and matching of goods is made by the characteristics of the electric power industry [2]. The storage is an important link of modern logistic management. The effective warehouse would simly integrating production, reducing cost and optimizing logistics network. The warehouse cost, which has direct influence on the cost of power

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production and construction, is related to the economy efficiency of electric power enterprise [3]. Therefore, this paper focus on how to optimize the logistics network. It provides reference and theoretical support to enhance resource integration capability, reduce cost and maintain the security of the power grid.

44.2 Logistics Network Optimization Model of Electric Power Enterprise

44.2.1 The Model of Logistics Network

It proposes a network topology of logistics network with three layers as shown in Fig. 44.1. The first layer stands a hypothesized central warehouse. On the second layer, a small amount of district warehouses are controlled by central warehouse. Those district warehouses delivery materials to the third layer which presents the turnover warehouses. The function of turnover warehouses is to support the operation of power companies.

Based on the network topology, an optimization model is established.

44.2.1.1 The Logistics Demand of District Warehouses and Turnover Warehouses

Because the material demand prediction of power industry cannot be accurately obtained by traditional demand prediction, the electricity consumption is combined [4]. The expression is as follow:

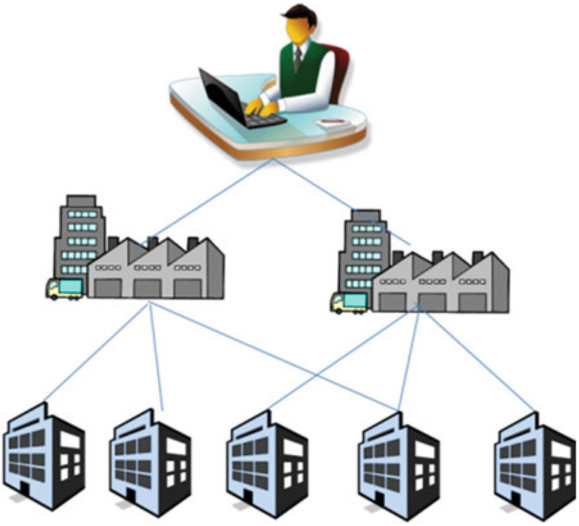

Fig. 44.1 A network topology of logistics network

$$\mathrm{R} = \mathrm{Ec} \times \mathrm{Q} \tag{44.1}$$

In this function, Q means the amount of inventory used by the unit electricity consumption. R stands for the amount of annual inventory. Ec is annual electricity consumption.

We hypothesized that there are i kinds of materials. R_m represents the delivery quantity of district warehouse m. R_{mi}, as the delivery quantity of the ith kind materials from district warehouse m, transports the ith kind materials to several turnover warehouses. The ith kind of materials in a turnover warehouse can be transported by only one district warehouse. We can get the formula:

- The Sum of Storage Material

$$\mathrm{R} = \mathrm{Ec}\sum_{\mathrm{i}=1}^{\mathrm{I}} \mathrm{Q}_{\mathrm{i}} \tag{44.2}$$

- The Logistics Demand of District Warehouses

$$\mathrm{R}_{\mathrm{m}} = \sum_{i=1}^{I} \mu_{mi}\mathrm{R}_{\mathrm{mi}} \tag{44.3}$$

$$\mathrm{R}_{\mathrm{mi}} = \sum_{n=1}^{N} \omega_{\mathrm{mni}}\mathrm{R}_{\mathrm{ni}}, \mu_{mi} = 1 \tag{44.4}$$

$$\sum_{m=1}^{M} \omega_{\mathrm{mni}} = 1 \tag{44.5}$$

ω_{mni} 0–1 variable, the ith kind materials of Turnover Warehouse n is distributed from District Warehouse m or not;
R_{ni} delivery quantity of the ith kind materials from Turnover Warehouse n;

- The Logistics Demand of Turnover Warehouses

$$\mathrm{R}_{\mathrm{n}} = \sum_{i=1}^{I} \mathrm{R}_{\mathrm{ni}} \tag{44.6}$$

$$\mathrm{R}_{\mathrm{ni}} = \sum_{k=1}^{K} \sigma_{\mathrm{nk}}\mathrm{R}_{\mathrm{ki}} + \mathrm{r}_{\mathrm{ni}} \tag{44.7}$$

$$\textstyle\sum_{n=1}^{N} \sigma_{\mathrm{nk}} = 1, \forall \mathrm{k} \tag{44.8}$$

K the sets of cancelled warehouses;
σ_{nk} 0–1 variable, if the materials of cancelled warehouse k is distributed from turnover warehouse n, $\sigma_{\mathrm{nk}}= 1$;

R_{ki} delivery quantity of the ith kind materials from cancelled warehouse k;
r_{ni} output of the ith kind materials from turnover warehouse n;

44.2.1.2 The Reconstruction Cost of District Warehouses and Turnover Warehouses

According to the logistics demand, it is possible that warehouses need reconstruction. Eqs. (44.9)–(44.12) reflect the reconstruction cost.

- The Reconstruction Cost of District Warehouses

$$W = \sum_{m=1}^{M} \delta_m \left(A_1 S_{m1} + A_2 S_{m2} + A_3 \gamma_m \left(\frac{R_m}{TB} - S_{m1} - S_{m2}\right) + d_m\right) \tag{44.9}$$

$$\gamma_m = \begin{cases} 0, S_{m1} + S_{m2} \geq \frac{R_m}{TB} \\ 1, S_{m1} + S_{m2} < \frac{R_m}{TB} \end{cases} \tag{44.10}$$

- The Reconstruction Cost of Turnover Warehouses

$$U = \sum_{n=1}^{N} \delta_n \left(A_1 S_{n1} + A_2 S_{n2} + A_3 \gamma_n \left(\frac{R_n}{TB} - S_{n1} - S_{n2}\right) + d_n\right) \tag{44.11}$$

$$\gamma_n = \begin{cases} 0, S_{n1} + S_{n2} \geq \frac{R_n}{TB} \\ 1, S_{n1} + S_{n2} < \frac{R_n}{TB} \end{cases} \tag{44.12}$$

T	Turnover rate;
B	The average stock value per square meter;
A_1	Inside reconstruction cost;
A_2	Outside reconstruction cost;
A_3	The average of construction cost
S_{m1}, S_{n1}	The indoor storage area of Warehouse;
S_{m2}, S_{n2}	The outdoor storage area of Warehouse;
S_m, S_n	The area of Warehouse;
γ_m, γ_n	0–1 variable, Warehouse needs to be newly built or not;
d_m, d_n	The fixed cost of the construction of Warehouse;
δ_m	Warehouse m is district warehouse or not;
δ_n	Warehouse n is turnover warehouse or not.

44.2.1.3 The Operation Cost of District Warehouses and Turnover Warehouses

$$\begin{aligned} V = {} & \sum_{m=1}^{M} \delta_m (m_1 + m_2)\left[S_{m1} + S_{m2} + \gamma_m\left(\frac{R_m}{TB} - S_{m1} - S_{m2}\right)\right] \\ & + \sum_{n=1}^{N} \delta_n (n_1 + n_2)\left[S_{n1} + S_{n2} + \gamma_n\left(\frac{R_n}{TB} - S_{n1} - S_{n2}\right)\right] \end{aligned} \tag{44.13}$$

The operation cost consists of two parts: the labor cost and maintenance cost. In (44.13), means the labor cost per square meter, standing for the maintenance cost per square meter.

44.2.1.4 The Penalty Cost

In electric power company, they delivery materials from district warehouses to turnover warehouses by their own trucks. Combining the actual situation, we use penalty cost instead of traffic cost.

$$\mathrm{Y} = \sum_{\mathrm{m}=1}^{\mathrm{M}} \sum_{\mathrm{n}=1}^{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{I}} \varphi_{\mathrm{mn}} (\mathrm{d}_{\mathrm{mn}} - \mathrm{D}_1)\theta_1 \boldsymbol{\omega}_{\mathrm{mni}} \mathrm{R}_{\mathrm{ni}} + \sum_{\mathrm{n}=1}^{\mathrm{N}} \sum_{\mathrm{k}=1}^{\mathrm{K}} \sum_{\mathrm{i}=1}^{\mathrm{I}} \boldsymbol{\sigma}_{\mathrm{nk}} (\mathrm{d}_{\mathrm{nk}} - \mathrm{D}_2)\theta_2 \mathrm{R}_{\mathrm{ki}} \tag{44.14}$$

$\boldsymbol{\varphi}_{\mathrm{mn}}$	Turnover Warehouse n is covered by the service radius of District Warehouse m;
$\boldsymbol{\sigma}_{\mathrm{nk}}$	Cancelled Warehouse k is covered by the service radius of Turnover Warehouse;
d_{nk}	road distance from Turnover Warehouse n to Cancelled Warehouse k;
D_1	The service radius of District Warehouse to Turnover Warehouse;
D_2	The service radius of Turnover Warehouse;
θ_1	Service penalty rate of District Warehouse;
θ_2	Service penalty rate of Turnover Warehouse.

44.2.1.5 The Total Storage Cost

Based on the above, the whole network model is as follow:

$$\mathit{Minimize} \quad \mathrm{U} + \mathrm{W} + \mathrm{V} + \mathrm{Y} \tag{44.15}$$

$$\begin{cases} \sum_{m=1}^{M} \mathrm{\delta_m R_m} = \sum_{n=1}^{N} \mathrm{\delta_n R_n} \\ \sum_{m=1}^{M} \mathrm{\omega_{mni}} = 1 \\ \sum_{n=1}^{N} \mathrm{\sigma_{nk}} = 1, \forall k \\ \mathrm{S_m} \geq \frac{\mathrm{R_m}}{\mathrm{TB}} \\ \mathrm{S_n} \geq \frac{\mathrm{R_n}}{\mathrm{TB}} \end{cases} \tag{44.16}$$

44.3 A Mixed MCPSO and Simulated Annealing Algorithm

44.3.1 The Framework of Algorithm

According to Ref [5], a mixed MCPSO and simulated annealing algorithm is proposed in this paper as shown in Fig. 44.2.

44.3.2 Optimal Design Steps of Algorithm

- Initialize the Particle Swarm.
  S groups with N particles are generated. Annealing temperature is T.
- Operate PSO Algorithm by Every Subgroup.
  Before updating the status of subgroups, a main group M is selected by tournament selection to compare with the global best position of each subgroup. Every subgroup Q sends information of the personal best position to M. The positions of ith particle in d-dimensional space are expressed into$x_i = (x_{i1}, x_{i2}, \ldots, x_{id})$. The speed is represented in $v_i = (v_{i1}, v_{i2}, \ldots v_{id})$. Particle swarm is updated according to the velocity update rule of MCPSO.

$$v_{id}^{M} = v_{id}^{M} + c_1 r_1 \left(p_{id}^{M} - x_{id}^{M}\right) + c_2 r_2 \left(p_{g}^{M} - x_{id}^{M}\right) + \phi c_3 r_3 (p_{g}^{Q} - x_{id}^{M}) \tag{44.17}$$

$$x_i(t+1) = x_i(t) + v_i(t) \tag{44.18}$$

c_3 Learning factors;
r_3 Random numbers obeying the (0, 1) uniform distribution;
ϕ 0–1 variable, removal factor;

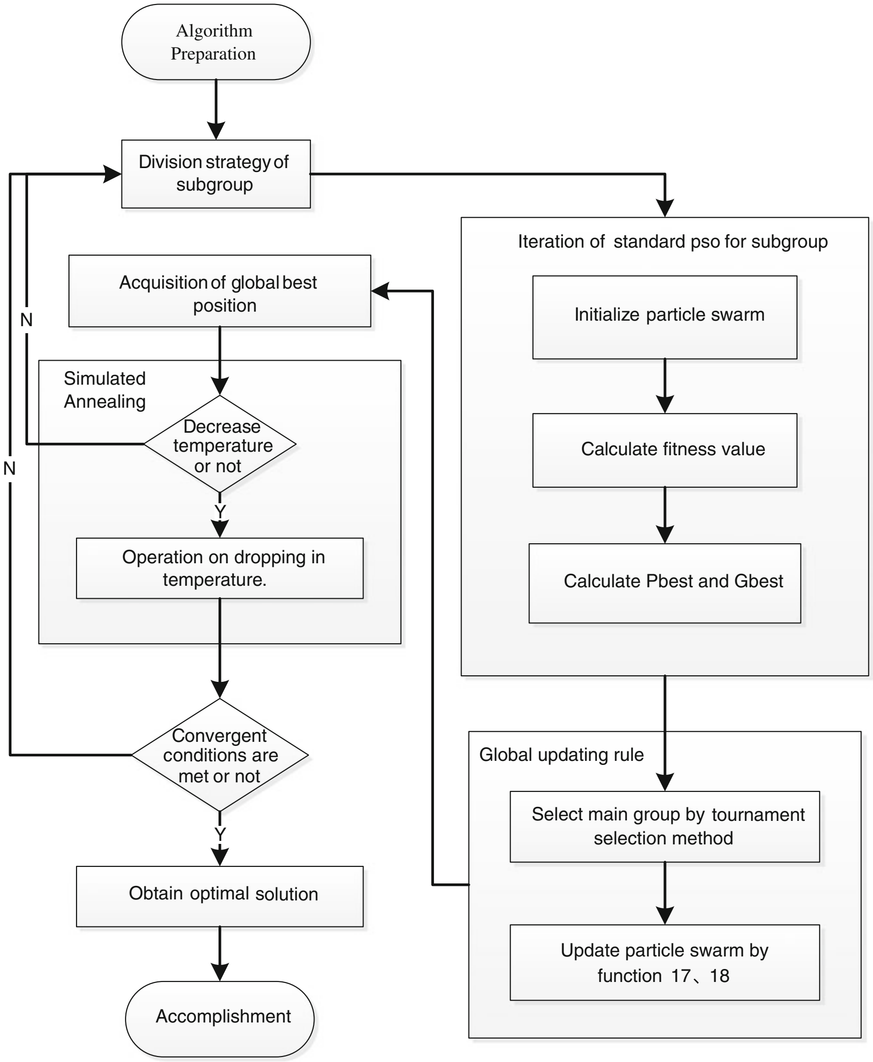

Fig. 44.2 The framework of algorithm

- Simulated Annealing
  SA is used to deal with each individual generated from the step 2. If the evolving times are less than the maximum times, return step 2.
- Accomplishment
  When a given maximum number of iteration has been performed, or the algorithm has satisfactory results, the algorithm is accomplishment.

Table 44.1 The relationship of district and turnover warehouse

District warehouse	Turnover warehouse
1	6,7,8
2	9,15,22
3	23,24
4	25,26
5	27,28

Table 44.2 The relationship of turnover and cancelled warehouse

The service radius of turnover warehouse	The service radius of cancelled warehouse
9	10,11,12,13,14
15	16,17,18,19,20,21

The service radius of No.9 warehouse covers the service radius of No.10–14

The service radius of No.15 warehouse covers the service radius of No.16–21

Table 44.3 Comparison diagram of optimized results

	District warehouse amount	Turnover warehouse amount	Cost
Before optimizing	–	28	250015167.3
After optimizing	5	12	228652211.3

44.4 Examples and Results Analysis

A power supply company somewhere in China has 28 warehouses. Compared with current situation, the results are presented. We build a network of warehouses in Table 44.1 (Tables 44.2, 44.3).

Obviously, the number of warehouse is reduced. The cost of transportation, storage and service is also reduce by 14 %.

44.5 Conclusion

Logistics network of electric power enterprise is a multiplicity and complexity network. Combining with the features of enterprise, a mathematical optimization model is put forward in this paper. In order to solve this model, a mixed MCPSO and simulated annealing algorithm is presented. In the end, the validity of the method is verified with an actual project.

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