2012 International Conference on Applied Physics and Industrial Engineering

Optimization Research of Generation Investment Based on Linear Programming Model

Juan WU[1], Xueqian GE[2]

[1]*College of Business Administration*
Zhejiang Gongshang University
Hangzhou, People's Republic of China
[2]*Security Response Center of the Qiantang River*
Qiantang River Administration of Zhejiang Province
Hangzhou, People's Republic of China

Abstract

Linear programming is an important branch of operational research and it is a mathematical method to assist the people to carry out scientific management. GAMS is an advanced simulation and optimization modeling language and it will combine a large number of complex mathematical programming, such as linear programming LP, nonlinear programming NLP, MIP and other mixed-integer programming with the system simulation. In this paper, based on the linear programming model, the optimized investment decision-making of generation is simulated and analyzed. At last, the optimal installed capacity of power plants and the final total cost are got, which provides the rational decision-making basis for optimized investments.

1. Linear Programming Model

1.1 Introduction of Linear Programming

In economic activities, such as economic management, traffic transportation and industrial and agricultural production, increasing economic results is indispensable request of the people[1]. Generally, there ara two ways to improve the economic effects: first is the technology improvements, such as improve the production technology, and use new equipment and new materials. The second is the

improvement of production organization and planning, that is a reasonable arrangement of human and material resources[2]. The linear programming studies: under certain conditions, reasonable arrangements of human and material resources to achieve the best economic results[3]. In general, the issue of solving the maximum or minimum value under linear constraints is collectively known as the linear programming problem[4]. The solution to meet the linear constraints is called feasible solution. The decision variables, the constraints and objective function is the three elements of linear programming[5]. The concept of linear programming was produced in 1947 and related issues had been proposed in 1823 and 1911 by Poussin and Fourier[6][7]. So far the development of the linear programming history is nearly 100 years[8]. Now, the linearing programming has become the decision basis of the manufacturing, marketing, bank loans, stock quotes, taxi fees, co-ordinate transportation, telephone charges, computer access and so hot practical problems.

1.2 Linear Programming Model

Generally, estblishing mathematical model from practical problems has the following three steps[9][10]:

- Find the decision variables according to the factors which will affect achieveing the purpose.
- Define the objective function by the functional relationship between the decision variables and the achieving goal.
- Define the constraints which will satisfy the decision variables from the limited conditions determined by the decision variables.

The mathematical model has the following features[11]:

- Each model has a number of decision variables $(x1, x2, x3 ... ..., xn)$, where n is the number of decision variables. A set of values of decision variables indicate a option, while the decision variables are non-negative generally.
- The objective function is a linear function of decision variables. According to the specific problem, the objective function can be maximized (max) or minimum (min), and the both referred to as the most optimal (opt).
- The constraints are aslo the linear function of the decision variables.

So the mathematical model can be called linear programming model whose objective function is linear function, and the constraints are the linear equality or inequality.

2. GAMS Simulation Model of Generation Investment Optimization Based on Linear Programming

Four power plants are needed to constructed to meet the electricity need of a city. Each power plant has three kinds of operating mode, and different modes of operation will have different operating costs. For policy makers, how to determine each plant's installed capacity to meet the demand of the electricity in the city, and makes the final total cost (including investment costs and operating costs) minimum to meet the technical and economic win-win results? In this paper, GAMS simulation model is used to optimize.

GAMS means General Algebraic Modeling System[12]. GAMS includes models and languages which can be used both for the simulation, but also for the optimization, but also for combining the simulation and optimization[13]. In this paper, this model includes the following components[14]:

2.1 SETS

SETS is a collection of elements in a model, which is essential to any part of GAMS model.

After investigation, the city plans to invest in the construction of the four types of power plants: the types of power plants is i, which includes plant-1, plant-2, plant-3, plant-4. Each power plant has three operating mode, and the number of operating mode is j, which includes mode-1, mode-2, mode-3 respectively. Figure1 has shown the 12 operation mode of the four power plants.
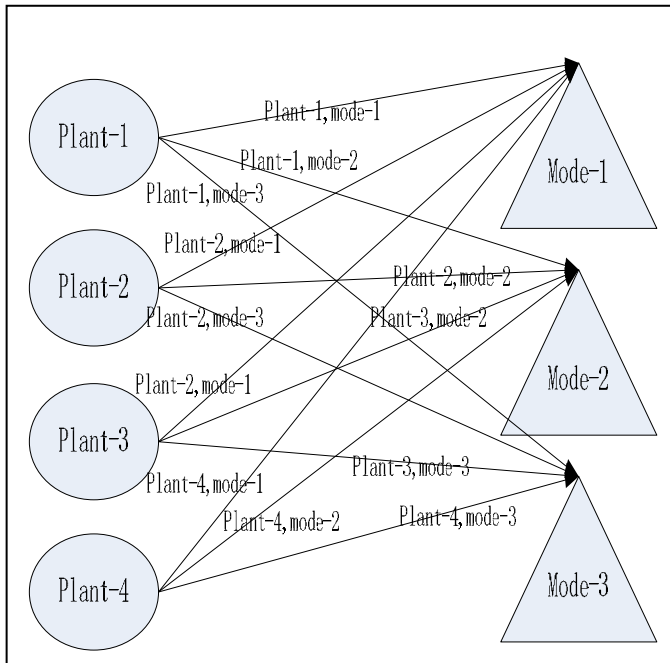

Figure 1. 12 operation mode of the four power plants

2.2 PARAMETER

PARAMETER: is the assignment of the model parameters.

$c(i)$ is the investment cost for the unit installed capacity of power plant: plant-1 is 10 million yuan, plant-2 is 7 million yuan, plant-3 is 16 million yuan, and plant-4 is 6 million yuan. $d(j)$ is the electricity demand for each power plant in three operating modes: mode-1 is 3 million kilowatts, mode-2 is 3 million kilowatts, and mode-3 is 2 million kilowatts.

2.3 TABLE

In the GAMS model, a known constant matrix called TABLE.

$f(i,j)$ is the unit operating cost of each power plant in different operating mode. The unit is 10000 yuan. The investigation result of the operating cost is shown in Table 1.

Table I. The Unit Operating Cost of Eeach Power Plant in Different Operating Mode

	mode-1	mode-2	mode-3
Plant-1	40	24	4
Plant-2	45	27	4.5
Plant-3	32	19.2	3.2
Plant-4	55	33	5.5

2.4 SCALARS

SCALARS in GAMS model is used to declare or initialize a zero-dimensional parameter (the constant term).

In order to meet the demand of electricity in the city, a minimum total installed capacity of the four power plants is identified. m is the minimum total installed capacity of power plants of the four power plants, and the value is 12 million kilowatts. In order to complete the construction of four power plants more economically, the total investment budget of the four power plants has a planning limit. b is the minimum of the total investment budget of the four power plants，and the value is 120 million yuan.

2.5 VARIABLES

VARIABLES is the decision variables in a GAMS model. In this paper the VARIABLES of this model are as follows:

$x(i)$ is the installed capacity of the i power plants;

$y(i, j)$ is the operating level of the i power plants under the j operation mode;

cost is the total cost of the four power plants (mainly including investment costs and operating costs);

2.6 EQUATIONS

In GAMS, EQUATIONS has broad implications, which includes equality and inequality relations. In the EQUATIONS section, the objective function of the problem must be statemented and the various constraints problems must be expressed. The constraints and the objective function of the simulation model are as follows:

1)   Total cost of the four power plants

The total cost of the four power plants includs the investment costs and the operating costs. The investment costs depend on the investment cost for the unit installed capacity of power plant $c(i)$ and the installed capacity of the i power plants $x(i)$. The operating costs depend on the operating level of the i power plants under the j operation mode $y(i, j)$ and the unit operating cost of each power plant in different operating mode $f(i, j)$. Therefore, the equation of the total cost of the four plant is expressed as follows:

$$\text{cost} =e= \text{sum(i, c(i)*x(i)) + sum((i,j), f(i,j)*y(i,j))}$$

2)   The constraint equation of total installed capacity of the four power plants

According to the plan, at least total installed capacity of four power plants meets m, so the constraint equation is expressed as follows:

$$\text{sum(i, x(i)) =g= m}$$

3)   The constraint equation of total investment budget of the four power plants

According to the plan's requirements, the total investment budget in four power plants can not exceed b, so the constraint equation is expressed as follows:

$$\text{sum(i, c(i)*x(i)) =l= b}$$

4)   The constraint equation of the installed capacity for each power plant

For each power plant, the installed capacity should not be less than their operation level of three modes, so the constraint equation is expressed as:

$$\text{sum(j, y(i,j)) =l= x(i)}$$

Further expand:

when i =plant-1,

x(plant-1)>= y(plant-1, mode-1)+ y(plant-1, mode-2)+ y(plant-1, mode-3)

when i =plant-2,

x(plant-2)>= y(plant-2, mode-1)+ y(plant-2, mode-2)+ y(plant-2, mode-3)

when i =plant-3,

x(plant-3)>= y(plant-3, mode-1)+ y(plant-3, mode-2)+ y(plant-3, mode-3)

when i =plant-4,

x(plant-4)>= y(plant-4, mode-1)+ y(plant-4, mode-2)+ y(plant-4, mode-3)

5)   The constraint equation of the electricity demand under each operating mode

If each power plant use the same operating mode, then the power plant's total operating level of demand for electricity need are greater than $d(j)$, so the constraint equations can be expressed as follows:

$$\text{sum(i, y(i,j)) =g= d(j)}$$

Further expand:

when j= mode-1,

y(plant-1, mode-1)+ y(plant-2, mode-1)+ y(plant-3, mode-1)+ y(plant-4, mode-1)>=d(mode-1)

when j= mode-2,

y(plant-1, mode-2)+ y(plant-2, mode-2)+ y(plant-3, mode-2)+ y(plant-4, mode-2)>=d(mode-2)

when j= mode-3,

y(plant-1, mode-3)+ y(plant-2, mode-3)+ y(plant-3, mode-3)+ y(plant-4, mode-3)>=d(mode-3)

3. Running Results Analysis

After running the simulation model on the computer, the results obtained are as follows:

2.1 Computational Results of the Installed Capacity $x(i)$ for Each Power Plant

Table 2 has shown the results of the installed capacity for each power plant.

Table 2. The Results of the Installed Capacity For each Power Plant

	Installed capacity (10000 kilowatts)
plant-1	2
plant-2	0
plant-3	3
plant-4	6

From the optimization simulation results, we can see that the installed capacity of the second power plant is 0. It can be deduced that the second power plant in the three different operating modes can't meet the optimal request to in the investment and operation. So, it may consider that adjust the number and types of the power plants.

3.2 The Results of the Total Investment Cost of the Four Power Plants

After the computation, the optimized cost of the four power plants (investment costs and operating costs) is 293 million yuan.

4. Conclusion

This paper has proposed the optimized simulation models to how to determine the installed capacity to achieve the optimal technical and economic effect, which can guide the investment of the power plant and the optimal design of the operation in power plants. At the same time of meeting the electricity demand, the total cost is the least, and finally increase the social and economic benefits of the power plants. The application shows that the application of GAMS can not only solve the linear programming problem, but according to the requirements of decision makers can conduct the man-machine dialogue, to reach the satisfactory results with the decision-makers. In this paper, the case analyzed a simulation model of the design installed capacity for the four power plants under the three different operation modes. Calculated by the computer, the optimal installed capacity of the various constraints has got, which provide an effective method of quantitative analysis of for rational optimized design.

Acknowledgment

References

[1]Dantzig G B. Linear programming and extensions. Princeton : Princeton University Press, 1963

[2]Curet N. A primal-dual simplex method for linear problems. *Operations Research Letters*, Vol.16(13),1974, pp.233~716.

[3]Pan P Q. A variant of the dual pivoting rule in linear programming. *Journal of Information & Optimization Sciences*, Vol. 15 (3),1994, pp. 405~413.

[4]DantzigG B, Orden A, wolfe P. The generalized simplex method for minimizing a linear form under linear inequality restraints. *Pacific Journal ofMathematics*, Vol. 5(8), 1955, pp. 183~195.

[5]Khachiyan L G. A polynomial algorithm for linear programming. *SovietMathematics Doklady*, Vol. 20(1), 1979, pp. 191~194.

[6]Goldfarb D, ToddM J. Modifications and implementation of the ellipsoid algorithm for linear programming. *Math Programming*, Vol. 23(1), 1980, pp. 1~19.

[7]Gill P E,Murray W, Saunders M A. Primal-dual methods for linear programming. *Mathematical Programming*, Vol. 70 (13), 1995, pp. 251~277.

[8]PENG Shuang, LIXiaohui, NIE Songlin, XIONG Zhibin, "An Interval Parameter Mutistage Stochastic Linear Programing Method for Hydralic Contamination Control", *MACHINE TOOL&HYDRAULICS*, Vol.36(10), 2008, pp. 27~30.

[9]ZHU Li et al, "Comparison of Stochastic Programming and Linear Programming Application in Animal Feed Formulation", *Journal of Anhui Agri. Sci.* Vol.34(9), 2006, pp. 1778~1779.

[10]XUN Fang-fei, GE Ya-jun, MA Jing-yi, "Application the Linear Programme to Calculate Water Environmental Capacity", *Journal of Water Resources & Water Engineering.* Vol.20(5), 2009, pp. 180~183.

[11]Rosegrant, M.W., C. Ringler, D.C. McKinney, X. Cai, A. Keller, and G. Donoso, "Integrated economic-hydrologic water modeling at the basin scale: the Maipo river basin", *Agricultural Economics*, Vol.24(1), 2000, pp. 33~46.

[12]Brooke, A., D. Kendrick, A. Meeraus, and R. Raman, *GAMS Language Guide, RELEASE 2.25, Version 92,* GAMS Development Corporation, Washington D.C., 1997.

[13]Brooke, T., Kendrick, D. and Meeraus, *GAMS: A User's Guide*. The Scientific Press, Redwood City, California, 1988.

[14]Anthony Brook , David Kendrick &Alexander Meeraus . Release 2. 25 GAMS A USER'S GUIDE. Boyd &fraser publishing company. 1992.