

Research of self-power Generation Scheduling Model Base on Multi-objective in Iron and Steel Enterprises

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Abstract. With the targets of the minimum cost of power generation and the lowest rate of gas emission in iron and steel enterprises, a multi-objective self-power generation optimal scheduling model was built based on multi-objective particle swarm optimization the research of coupling relationship of gas and power. And by using the hierarchical decomposition method, the model was broken down into two parts: optimization of gas system and optimization of thermal and power system. The case analysis indicated that: the model could distribute the energy of gas and power reasonably, safely and efficiently when the production condition was changed, and improve the energy utilization efficiency.

Keywords. Iron and steel enterprises, multi-objective particle swarm optimization, cooperated optimization, self-power generation optimal scheduling.

1 Introduction

Iron and steel industry is an energy intensive industry, which accounts for more than 15% of energy consumption [1]. High energy consumption not only leads to increase cost of steel products, but also means more pollution and emissions. In actual production, considering the changes in production, maintenance plans and other factors, the amounts of gas generation and consumption are always fluctuating and the gas system is in an imbalance state, which leads the low utilization of gas. All the problems above are needed by the system optimize scheduling to resolve.

A large amount of by-product gas is generated in the production process of Iron and steel enterprises. The recycling utilization of the gas surplus in power generation of the steel industry is an important measure to develop recycling economy. Gas boiler, CCPP and other gas generating device are widely used in the iron and steel enterprises. At the same time, the optimal scheduling technology of surplus gas in the gas generating devices and the gas holder is much more concerned.

In recent years, many scholars have carried out extensive researches on steel enterprise energy optimization models. Literature [2] shows the relationship between the respective units of the gas pipeline network, which is modeled and solved by the method of partial least squares matrix. In Literature [3-5], a gas supply and demand forecasting model is established, which achieves the maximum integrated power efficiency and safety control of the gas holder.

Although the above algorithm theory is reasonable and simulation results are also very good, but in practice, they cannot meet the requirements of the real-time and effective gas scheduling. Meanwhile, the objective function of the models above is single, which cannot solve the problem of multi-objective, considering the minimum cost of power

generation, diffusion and others. Therefore, a multi-objective self-power generation optimal scheduling model is proposed in this paper which based on multi-objective particle swarm optimization (MOPSO) the research of coupling relationship of gas and power.

According to the features of gas pipeline network system, combined with the actual scheduling situation, the by-product gas system is modeled and analyzed based on MOPSO rules and priorities. The results proved that this model is useful to reduce gas emission, achieve the balance of the entire gas system and have important theoretical and practical benefits.

2 Principle and algorithms

2.1 Mathematical description of PSO [6]

PSO is a population-based optimization approach. The basic idea behind the algorithm is to use a collection of particles to explore the fitness landscape of a particular problem. Each particle is a vector that describes a candidate solution, and can be evaluated along several quality dimensions. The algorithm is iterative, and at each iteration each particle moves through the fitness landscape according to its current fitness values as well as those of nearby particles, and the swarm as a whole.

Formal description of multi-objective optimization problem is shown as below:

$$\begin{aligned} \min Y = f(X) &= (f_1(X), f_2(X), \dots, f_r(X)) \\ g_j(X) &\geq 0, (j = 1, 2, \dots, r) \\ h_j(X) &= 0, (j = 1, 2, \dots, r) \end{aligned} \quad (1)$$

Where X is the decision vector, Y is the target vector, $f(X)$ is the objective function, $g_j(X)$ and $h_j(X)$ are the restriction conditions.

The exact steps of the PSO algorithm for the single-objective case are as below:

- (1) Initialize the swarm;
- (2) For each particle in the swarm:
 - (a) Select leader
 - (b) Update velocity
 - (c) Update position
- (3) Update global best;
- (4) Repeat.

2.2 Mathematical description of MOPSO

Multi-Objective Particle Swarm Optimization (MOPSO) was proposed by Coello in 2004. It is a multi-objective version of PSO which incorporates the Pareto Envelope and grid making technique, similar to Pareto Envelope-based Selection Algorithm to handle the multi-objective optimization problems. Just like PSO, particle in MOPSO are sharing information and moving towards global best particles and their own personal (local) best memory. However, unlike PSO, there is more than one criterion to determine and define the best (global or local).

Most current researches are focused on this approach based on Pareto by Drawing on the successful experiences of previous evolutionary algorithm to solve multi-objective optimization problem. In the evolutionary process there are usually two groups, one is 'population': the basic evolution population and the other is the population 'archive' which is used to store the elite individuals in the evolution. First, the merits of individuals of the basic population are determined through evaluate, and then by determining the overall best individual and its location in basic population and using PSO formula to update, the next generation of basic groups is obtained. There are two operations in archive which are update

and truncate, the former is used to update the archive of the individual which remains the best individual in evolution; the latter is used to remove the extra individuals when the number of actual individuals which enter the archive is greater than the capacity.

Typically MOPSO algorithm has a retention mechanism for elite solutions, the MOPSO algorithm steps are shown in Figure 1.

Where Quality (pbest) is the selection of individual history best position; Quality (gbest) is the selection of the optimal particles.

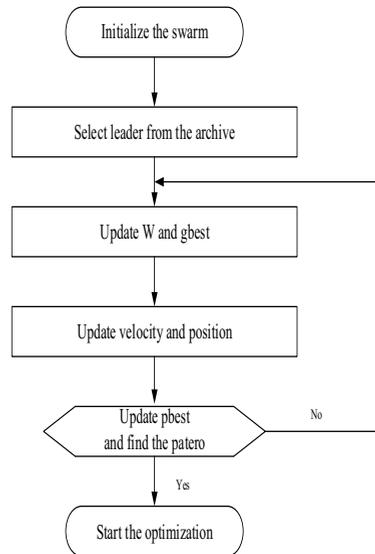


Fig. 1. MOPSO algorithm flow chart.

3 Modelling

Based on the above algorithm, with the target of the minimum cost of power generation and the lowest rate of gas emission in iron and steel enterprises, a multi-objective self-power generation optimal scheduling model was built based on MOPSO.

3.1 Problem description

The byproduct gas generated from iron making and steel making are supplied to gas users after pressurization. Surplus gas is sent to power plants' boilers for power generation. The small quantity of gas imbalance frequently aroused by fluctuation of working condition is absorbed by gas holder, when surplus gas is insufficient, the boiler will be switched into the model of coal firing or gas coal co-firing. Detail as Figure 2.

Generally, heating furnace and boiler have fuel interchangeability, that's to say, if allowed technically, such devices may use different fuels; when different fuels are used, the devices have differences in fuel consumption of unit output. Therefore, reasonable gas scheduling may lower the energy consumption of the system. Meanwhile, similar devices running in parallel have differences in conversion efficiency when manufacturing different energy resources, so self-power generation scheduling model optimization may be used to solve the following problems:

(1) In the precondition of knowing enterprises' production plan and equipment maintenance plan, we may reasonably allocate various fuels (blast furnace gas, converter gas, mixed gas, coal) to different energy consumption devices; in condition of meeting production demand, we shall minimize the loss of energies caused by the mixture of energy resources of different qualities, lower the energy diffusion of the system, and control the energy consumption of the whole enterprises' fuel system within the minimum scope;

(2) Buffer surplus gas between gas holder and power plant boiler reasonably, realize the optimum allocation of stem turbine's steam and electrical load according to the dynamic characteristics of steam turbine.

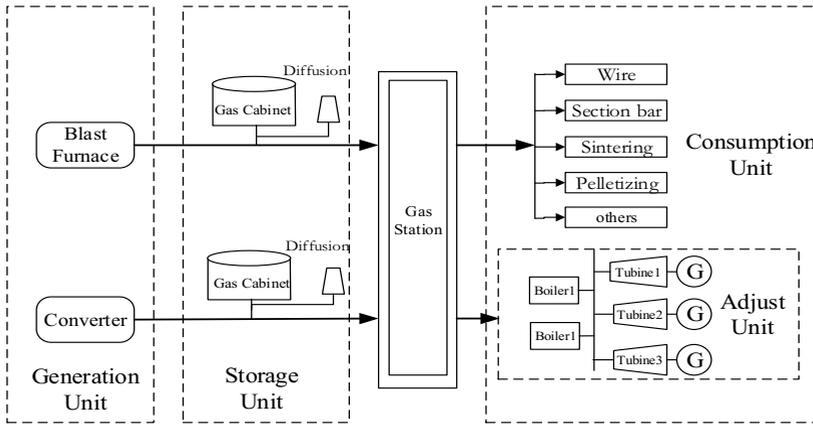


Fig. 2. Gas system flow chart.

3.2 Objective function

The objective function of steel and iron enterprises' multi-energy cooperated optimization model is as shown in Formula (1): the first equation indicates the consumption cost of various energy resources; the second equation indicates gas diffusion cost; the third equation indicates the minimum total costs.

$$\begin{aligned} \min A &= \min \left(\sum_{i=1}^{m+n} \sum_{k=1}^4 \varphi_k (G_{i,k} + B_{i,k}) \right) \\ \min B &= \min \sum_{k=1}^3 \varphi_k V_k \\ \min C &= \min \left(\sum_{i=1}^{m+n} \sum_{k=1}^4 \varphi_k (G_{i,k} + B_{i,k}) \right) + \min \sum_{k=1}^3 \varphi_k V_k \end{aligned} \quad (2)$$

Where $G_{i,k}$ is The fuel costs of energy resource k of equipment i, m^3/h or t/h , $k=1$ indicates blast furnace gas, $k=2$ indicates converter gas, $k=3$ indicates mixed gas, $k=4$ indicates coal; $B_{i,k}$ is The power conversion costs of energy resource k of equipment i, m^3/h or t/h ; φ_k is the value coefficient of energy resource k, kJ/kg or kJ/m^3 ; V_k is the diffusion of energy resource k, m^3/h ; m, n are the main working procedure has m sets of equipment and the power plant has n sets of machine.

3.3 Restriction conditions

(1)Restriction on fuel heat value:

$$Q_{i_max} \geq Q_i \geq Q_{i_min} \quad (3)$$

Where Q_i is The heat value of gas i, kJ/m^3 ; Q_{i_max} is the maximum heat value that the production unit i can bear, kJ/m^3 ; Q_{i_min} is the minimum heat value that the production unit i can bear, kJ/m^3

(2)Restriction on energy demand of the production unit i:

$$\sum_{k=1}^3 \varphi_{i,k} \theta_k = q_i * p_i \quad (4)$$

Where p_j is the product output of the production unit i , t/h; q_i is the fuel consumption per unit output of the production unit i , kJ/t; θ_k is The standard coal coefficient of energy resource k , kJ/kg or kJ/m³; δ_{is} is the proportion of coke oven gas in mixed coal gas.

(3)Restriction on the unit capacity of different unit types:

$$U_{\min,y}^z \leq U_{t,y}^z \leq U_{\max,y}^z \quad (5)$$

Where $U_{\min,y}^z$ is the minimum unit capacity; $U_{\max,y}^z$ is the maximum gas proportioning; z is the unit type; y is the unit number.

(4)Restriction on unit ramp rate:

$$\left| U_{k+1,y}^z - U_{k,y}^z \right| \leq v_y^z \quad (6)$$

Where v_y^z is the unit ramp rate, MW/s.

(5)Restriction on the capacity of gas holder:

$$S_{\min} \leq S_k \leq S_{\max} \quad (7)$$

Where S_{\min} is the minimum gas holder capacity, m³; S_{\max} is the maximum gas holder capacity, m³.

The above restrictions are obtained by means of statistical analysis and regression analysis, which are used to solve the model based on MOPSO.

4 Examples and analysis

Use the above mentioned model to carry out multi-energy cooperated optimization with a steel and iron plant as example. The plant consists of five blast furnaces, five converter s, a BFG gas holder, and a LDG Gas holder, 8 gas pressurized stations ,respectively. There are four kinds of rolling plants and five boilers in generation system. Use the model mentioned in Section 1 to optimize the following two production conditions:

Working condition 1: Normal production; Working condition 2: Based on working condition 1, tubular production factory is stopped, the optimization results of gas system are as shown in Table1, and those of thermal power production system are as shown in Table1.

This model was found with rapid response and Accurate target characteristics. Table 1 show that volatility has been effectively controlled; thereby gas emission is avoided. Fluctuation caused by the remaining gases is stabilized by the cooperation between the gas holders and boilers. The method proposed in this study can be used to guide the rational allocation of byproduct gases and arrange the production in steel plants . Multi-energy cooperated optimization model may re-allocate the energy resources without energy diffusion, and meanwhile, thermal power generation system is also optimized.

Table 1. Comparison of the optimization results of gas system in different conditions.

Working uint	Working condition 1		Working condition 2	
	Blast furnace gas (m ³ /h)	Converter gas (m ³ /h)	Blast furnace gas (m ³ /h)	Converter gas (m ³ /h)
Sintering	14837	0	14837	0

Iron making	440638	0	440638	0
Steel making	4050	7772	4050	7772
Bar steel	66802	0	66802	0
Section steel	12990	0	0	0
Power plant	192958	15745	205968	15745
Diffusion	0	0	0	0

5 Conclusions

Comprehensively considering the coupling relationship between the production and consumption of coal gas, steam, and electric power, the steel and iron enterprises' multi-energy cooperated optimization model is established by MOPSO. This model is based on hierarchical theory and contains two objective functions which refer to gas system and thermal power system for optimization respectively. The result shows that, in condition of knowing production plan and maintenance plan, we may use the model to optimize and adjust energy production and distribution, avoid energy diffusion, and raise energy utilization rate. Meanwhile the scheduling model is helpful to enhance the security and stability of the production of the gas holder, get a good application results in practical applications, reduce gas emission and achieve balance of the entire gas system, which has important theoretical and practical benefits.

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