Study on Integrated Energy System Scheduling Optimization Based on Runoff Algorithm

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Abstract. With the advancement of economic globalization, set energy production, supply and use of integrated energy system has become the current social indispensable material base, its advantage is to utilize the energy such as natural gas, wind energy, solar energy is transformed into each other basic conditions, based on the use of renewable function between the electric energy development model, in order to reduce harmful emissions and effectively promote the consumption of energy storage, supply and its efficiency for the development goals, finally realizes the comprehensive optimization of energy system operation and development. However, the practice based on integrated energy scheduling can not achieve the best expected results, and there is a paradox between the theoretical basis and the fact. Therefore, based on the study of integrated energy system scheduling optimization, combined with different research status at home and abroad, this paper proposes a runoff algorithm to realize the economic operation mode of energy system, in order to solve the problems in the implementation process of integrated energy system scheduling, and promote the development trend of high efficiency and stability.

Key words: Integrated energy system scheduling, Energy conversion, Runoff algorithm

1. Introduction

Based on the vigorous development of domestic politics, economy and technology, people's living standards have been gradually improved, and the need for energy technology has been growing day by day[1]. At the same time, energy, as the essential material basis of human life and the dependent condition of survival and development, puts forward higher requirements and goals for its own efficient combination and rational utilization. Therefore, as the cornerstone of innovative science and technology,
energy issue has gradually become one of the emerging research objectives and research hot spots in the process of increasingly mature development and utilization, relying on the global environment.

Therefore, this article based on the research status of integrated energy system scheduling optimization at home and abroad, discusses the characteristics and development model of comprehensive energy system, give priority to with the specific usage of the integrated operation mode, in a controlled balance scheduling optimization process as the research target, put forward mainly flow algorithm[2] and the optimization model of practice, fully demonstrated effective combination scheme of energy economy and environmental protection, finally to achieve control of the optimal result, high energy cascade thus become an important social and economic changes and development direction.

2. Related Work

Maximum running benefit in order to realize the integrated energy system, our country has passed the 863 plan, 973 plan, the national natural science foundation of scientific research projects, such as start-up has carried out many involves the integrated energy system scheduling optimization research of science and technology research and development projects, and actively participate in the UK, Germany and other countries in theory review, core technology, and engineering demonstration argumentation of international cooperation[3] and collaboration with institute of Tsinghua University, Tianjin University and other famous universities of integrated energy system scheduling optimization more in-depth and professional in the field of research.First based on the development of domestic economy tone, as a developing country[4], China needs to greatly improve the cognition of IES and practice, and in the process of practice, in order to reduce energy operation power function as randomness[5], practice will take energy system and the connection mode of electric heating system, determine the fixed value of grid-connected energy and power, to update the existing calculation data, construct the new operation steps[6], fully ensure comprehensive energy operation system of environmental protection and economic benefit.

3. Construction of integrated energy system scheduling optimization

3.1. Scheduling model based on integrated energy system

Fuel cost of energy supply includes power generation, heating and cooling, and continuous supply system. Under the action of fuel cost of different characteristics, three different fuel costs are generated.

The fuel cost (in USD/h) of the power generation system is:

\[ C_i^t(P_i(t)) = a_i + b_i P_i(t) + c_i P_i^2(t) \quad , \quad i = 1, 2, \cdots, N_p \]  (1)

In this equation, \( C_i^t(P_i(t)) \) represents the fuel cost of \( P_i(t) \) generated by the \( i \) generating set system at the \( t \) time period.

The fuel cost of heating and cooling system (unit USD/h) is:
\[ C_k(P_k(t)) = a_k + b_k H_k(t) + c_k H_k(t)^2, \quad k = 1, 2, \ldots, N_h \quad (2) \]

In this equation, \( C_k(P_k(t)) \) represents the fuel cost of the cold/hot power generated by the k heating and cooling system in the t period.

The fuel cost (unit USD/h) of the integrated energy supply link unit system is:

\[ C_j(P_j(t), H_j(t)) = a_j + b_j P_j(t) + c_j P_j(t)^2 + \delta_j H_j(t) + \theta_j H_j(t)^2 + \varepsilon_j P_j(t) H_j(t), \quad j = 1, 2, \ldots, N_c \quad (3) \]

In this equation, \( C_j(P_j(t), H_j(t)) \) represents the fuel cost incurred by the j continuous supply system under the hot/cold \( H_j \) system conditions during the t period.

To sum up, taking t as the total time period, all the fuel costs generated during this period are the final total fuel costs (unit USD/h):

\[ f_1^t = \sum_{i=1}^{N_p} C_i(P_i(t)) + \sum_{k=1}^{N_h} C_k(H_k(t)) + \sum_{j=1}^{N_c} C_j(P_j(t), H_j(t)) \quad (4) \]

In this equation, \( a, b, c, \delta, \theta, \varepsilon \) represents the model coefficient of the fuel cost system; \( N_p, N_h, N_c \) represents the number of attributes of power generation system, heating and cooling system, and energy supply.

As a distributed source of renewable energy equipment, its comprehensive daily operating cost and equipment maintenance cost need to solve its own equipment depreciation maintenance and innovation model simplified design. When the power energy supply is set to a fixed price within a certain range, its electricity purchase cost is:

\[ f_3^t = \lambda_w P_w(t) + \hat{\lambda}_w P_w(t) \quad (5) \]

In this equation, \( \lambda_w \) represents the unit price of wind power sold; \( P_w(t) \) represents the power in t time period; \( \hat{\lambda}_w \) represents the unit purchase price of solar power; \( P_w(t) \) represents the solar power generation rate in time period.

Therefore, in the setting period of t, the comprehensive generation cost, including fuel cost and
electricity purchase cost, is:

\[ f_{\text{alt}} = \sum_{t=1}^{T} \left( f_{1}^{t} + f_{2}^{t} + f_{3}^{t} \right) \] (6)

Integrated energy co-supply systems include power-only systems, heating or cooling systems, and different emission models of co-supply systems. This model USES harmful gas \( CO_{2} \) as the experimental model to test the emission coefficient.

\( CO_{2} \) emission function (unit: t) of power generation system alone is:

\[ E_{CO_{2}}(P_{i}(t)) = 0.01 \left[ \alpha_{i} + \beta_{i} P_{i}(t) + \gamma_{i} P_{i}^{2}(t) \right] + \varepsilon_{i} \exp \left( \lambda_{i} P_{i}(t) \right) \] (7)

The \( CO_{2} \) emission function (in unit t) for heating or cooling alone is:

\[ E'^{\text{co}_{2}}(P_{i}(t)) = 0.0 \left[ \alpha_{i} + \beta_{i} P_{i}(t) + \gamma_{i} P_{i}^{2}(t) + \varepsilon_{i} \exp(\lambda_{i} P_{i}(t)) \right] / \rho \] (8)

The \( CO_{2} \) emission function (unit: t) of the combined energy supply system is:

\[ E'^{\text{co}_{2}}(P_{i}(t)) = 0.01(1 + 1/ \rho) \left[ \alpha_{i} + \beta_{i} P_{i}(t) + \gamma_{i} P_{i}^{2}(t) + \varepsilon_{i} \exp(\lambda_{i} P_{i}(t)) \right] \] (9)

In this equation, \( P_{i}(t) \) is the force on system \( i \) at time \( t \); \( \alpha_{i}, \beta_{i}, \gamma_{i}, \varepsilon_{i} \) refers respectively to the emission function of \( CO_{2} \) gas in the \( i \) power carrier; \( \rho \) represents the equivalent performance coefficient.

As mentioned above, environmental cost refers to the environmental penalty incurred in the process of system action,

i.e. the total unit emission of \( E_{CO_{2}}(P_{i}(t)) \), \( E'^{\text{co}_{2}}(P_{i}(t)) \) \( \leq \) \( E'^{\text{co}_{2}}(P_{i}(t)) \) in \( t \) time period.

3.2. Optimization model based on integrated energy system

Taking the sum of fuel cost, environmental cost and electricity purchase cost as the ultimate goal,
the objective function is as follows:

\[ f = \min \left( f_{\text{all}} \right) = \min \left( \sum_{t=1}^{T} (f_1^t + f_2^t + f_3^t) \right) \]  \hspace{1cm} (10)

In this equation, \( f_1^t \), \( f_2^t \), \( f_3^t \) represents the fuel cost, environmental cost and electricity purchase cost in time period \( t \), and \( t \) represents the overall scheduling cycle. Its specific function formula is (4) and (5).

The function of equilibrium constraint for each cost is:

\[ \sum_{t=1}^{N_p} P_i^t(t) + \sum_{j=1}^{N_c} P_j^0(t) + P_j(t) + P_j(t) = P_D(t) \]

\[ \sum_{t=1}^{t+M} \left[ \sum_{j=1}^{N_p} N_j^h(t) + \sum_{k=1}^{N_k} H_k(t) \right] = \sum_{t=1}^{t+M} H_D(t) \]  \hspace{1cm} (11)

The upper formula represents the real time balance constraint function equation of electrical power, and the lower formula represents the real time balance constraint equation of thermal power. Where, \( \Delta t \) refers to the equilibrium constraint delay value of thermal energy in the characteristic time of the stage.

The upper and lower bound constraint function for each cost is:

\[ P_i^\text{min} \leq P_i(t) \leq P_i^\text{max}, \quad i = 1,2,..., N_p \]  \hspace{1cm} (12)

\[ P_j^\text{min} \leq P_j(t) \leq P_j^\text{max}, \quad j = 1,2,..., N_c \]  \hspace{1cm} (13)

\[ H_j^\text{min} \leq H_j(t) \leq H_j^\text{max}, \quad j = 1,2,..., N_c \]  \hspace{1cm} (14)

\[ H_k^\text{min} \leq H_k(t) \leq H_k^\text{max}, \quad k = 1,2,..., N_k \]  \hspace{1cm} (15)

In this equation, \( P_i^\text{min} \) and \( P_i^\text{max} \) respectively represent the upper and lower limits of generating power output period for the integrated energy system; \( P_j^\text{min} \) and \( P_j^\text{max} \) respectively expresses the upper and lower limits of the output period of the power generated by the unit for the integrated energy system; \( H_j^\text{min} \) and \( H_j^\text{max} \) respectively expresses the upper and lower limits of the heating and cooling power output of the co-production units for the integrated energy system; \( H_k^\text{min} \) and \( H_k^\text{max} \) respectively represent the upper and lower limits of the power output period of the integrated energy system for the thermal or cold generating units only.
Therefore, according to the force of different energy sources on the integrated energy system, this paper further calculates the energy conversion process of the integrated energy system based on the regularity of its invariant characteristics, parameter specifications and scheduling optimization model, and its schematic diagram is shown as follows:

![Figure 1. The process of energy conversion in an integrated energy system](image)

In different documents, the comprehensive energy system reflects the close connection between its parent system and its sub-system, the innovative management mechanism of overall management and coordinated planning, the development of complementary and replaceable innovative technologies among various energy sources, and the emerging market operation mode of transforming and utilizing energy in the value of social and economic development.

### 3.3. Runoff algorithm scheduling optimization

On the basis of energy conversion, combined with the operation of planning algorithm and intelligent algorithm IES working mode, this paper proposes a new intelligent algorithm: runoff algorithm.

Suppose in the runoff algorithm, the runoff group is composed of N pieces of runoff, and the total runoff group generated by m times of runoff optimization is:

\[
pop(m) = \left[ Y_i(m) \right]_{i=1}^{n} = \left[ Y_1(m), Y_2(m), ..., Y_n(m) \right]
\]

In this equation, \(i=1,2,...,n\); \(Y_i(k)\) is the \(i\) period of the runoff group.

Runoff algorithm originated from the natural law of runoff derivation. It is the most effective method for the optimization of comprehensive energy system scheduling. Taking the Yangtze River as an example, the source of the Yangtze River as the starting point, as the snow melts, the snow water flows from the mountains up to 6000 meters from top to bottom. Through different mountain linearity, it is assumed that the three-dimensional space is formed by the respective Watersheds Based on the extension
direction, watershed length, runoff and the vertical height of the mountains. The algorithm is used to schedule and optimize the calculation process of its motion trajectory to ensure the actual data accuracy and practicality of object range.

Therefore, as shown in Figure 2, runoff algorithm refers to balance control of energy system through controllable means to achieve optimal effect.

![Flow chart of runoff algorithm](image)

**Figure 2.** Flow chart of runoff algorithm

4. Experimental Design and Analysis

In this paper, the optimal scheduling model, the optimal runoff algorithm and the simulation of the test function of the integrated energy system are analyzed.

First of all, when the dispatching period is 24h, calculate and analyze the energy distribution and output in different periods, and the result trend chart is as follows:
Figure 3. Trend chart of comprehensive cost

As shown in Figure 3, in the intermediate test stage, the comprehensive cost is the highest and the initial consistency is the lowest. Therefore, it can be concluded that: in the case of different operation modes of electric power load and heating or refrigeration unit, the demand benefit will gradually increase the corresponding quota and carry out more adequate output quota, so as to give priority to the adjustment and distribution of energy comprehensive cost, more directly and effectively carry out the interaction between the comprehensive system and cost, and gradually reduce its comprehensive operation cost.
Figure 4. 50 times of independent calculation and optimization process distribution

After many independent calculations, the optimization results are stochastic to a large extent, but from the economic point of view, we can still use the optimization scheduling method to further control the calculated parameters and consider the variables. By considering the specific conditions of each parameter and variable, we can get the corresponding total comprehensive economic cost. The specific results are shown in the following figure:

Table 1. Comparison of algorithm optimization results

| Variable | Maximum | Minimum | Average | Standard Deviation |
|----------|---------|---------|---------|--------------------|
| GA       | 874235.1| 872276.6| 873781.3| 638.0806           |
| PSO      | 873920.6| 872595.5| 873345.4| 351.3059           |
| RA       | 873758.9| 872791.9| 873344.6| 304.7395           |

From table 1, it can be concluded that the detailed case analysis of runoff algorithm (RA), genetic algorithm (GA) and standard particle algorithm (PSO) shows that the algorithm has great advantages in optimization speed and scheduling effect, and there are very few errors in the calculation of comprehensive cost and economic cost, and it is the most effective way to solve nonlinear and other variable optimization problems and based on comprehensive energy system. Excellent effect plays an important practical significance.
In addition, taking the comprehensive energy system optimization model in Chapter 3 as an example, the simulation study is carried out, that is, considering the power generation, heating or cooling effect of each unit on the system and the output quota of each combined supply unit, the parameters obtained are as follows:

**Table 2. Unit treatment optimization results**

| Unit Number | $G_1$ | $G_2$ | $G_3$ | $G_4$ | $GP_5$ | $GP_6$ |
|-------------|-------|-------|-------|-------|--------|--------|
| Max (kw)    | 48    | 53    | 50    | 66    | 28     | 26     |
| Min (kw)    | 33    | 44    | 34    | 47    | 17     | 18     |
| Average (kw)| 36.5  | 47.4  | 38.8  | 55.7  | 24.9   | 22.8   |

Therefore, based on the characteristics of various types of energy and the mode of joint supply, it can be seen from Table 4.4 that the comprehensive energy system model construction and scheduling optimization are carried out with heating, cooling and electric power as the two basic modes of joint supply, the adaptability and parameter stability of the system for random variables can be seen from the algorithm mode, and the economic applicability of the supply mode and benefit between different energy sources can also be seen from the economic perspective. Based on the above data, the feasibility and environmental protection of the new energy supply mode of the comprehensive energy system can be provided with theoretical basis and practical basis.

**5. Conclusion**

With the increasing attention of the public to the use of energy resources and the concept of environmental protection, the energy ladder principle of comprehensive energy system based on runoff algorithm is discussed in detail, which is in line with the needs and operation objectives of various types of energy, and plays an important role in social and economic benefits, environmental protection benefits and political and economic development.

Therefore, based on the practical application of fuel cost, environmental cost and power purchase cost to the comprehensive energy system, this paper proposes a new operation model and artificial intelligence algorithm for the overall operation of the comprehensive energy system in terms of power generation, output distribution share and various costs. By using the function formula of cost-benefit to demonstrate the model, and objectively comparing the optimization of traditional algorithm and artificial intelligence algorithm, finally aiming at the typical case of linear energy problem, the advantages and disadvantages of comprehensive energy system in its own structure, energy conversion and environmental protection operation are analyzed in detail, and a new optimization method is proposed. Artificial intelligence algorithm realizes the control and global features of constraint variables, and has a certain development prospect for practical application.
However, due to the non renewable character and randomness of various energy sources, based on the existing research and this paper's research, we also need to conduct more in-depth and comprehensive research on the cut in mode of each energy system, the re optimization of scheduling optimization model device, the significance of energy to social economy and environmental protection in the future.

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