# Coordination of Multistage Scheduling Strategy in Cogeneration System

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**Abstract.** Due to the characteristics of wind intermittent, fluctuating, anti peak, and large prediction error, large-scale wind power access to the grid has brought negative impact on the planning and operation of the power grid. The contradiction between the power load and the peak and valley of the heating load expands the difficulty of the power grid to reduce the wind power. In addition, the thermoelectric coupling characteristic of the cogeneration unit determines the limit of the electric output regulating range of the thermoelectric unit, and the planning and operation policy of the thermoelectric co production unit with thermal power intensifies the problem of the high incidence of the discarded wind in the heating season. According to the analysis of the energy flow model of the electric heating combined system, the energy flow method is used to optimize the dispatching model and improve the capacity of wind power consumption during the heating period. The results show that the use of the electric heating station can increase the low valley electric load, reduce the thermal power output of the unit and leave the space for the wind power network. The indoor temperature of the user affects the heat load, and then affects the total amount of the wind power consumption, and the optimal scheduling results calculated by the optimized scheduling model considering the constraints of the heat transfer link are more accurate and feasible.

## 1. Introduction

At present, the major trend of the energy revolution has no doubt been the development and reuse of wind energy and other renewable energy sources. At this stage, the issue of wind erosion is significant, especially in the Three North region of China, while meeting the heating needs of users. It is also necessary to satisfy the “heat-set” operation mode of the cogeneration unit, which undoubtedly limits the peak-shaving capacity of the power grid, and in turn enables the unit to significantly reduce its capacity for absorbing wind power.

Considering the power and thermal systems as a whole and considering them in a unified manner, and then adopting the dispatching measures of the power grid, this method has become the main idea for solving the problem of serious wind curtailment during the winter valley period. To this end, scholars at home and abroad have been working on this idea. A lot of research has been done: The literature [1] concluded that when wind power is connected to large-scale grids, the grid is peaked. FM capabilities have been reduced. The literature [2] analyzes large-scale wind power grid connection, which has a great impact on grid dispatch and economy in the United States. Literature [3] pointed out that in order to ensure the stable operation of the power system, a reasonable amount of wind rejection is desirable and can improve the capacity of wind power absorption. The literature [4]-[5] proposes to quantify the quantity of electricity that has been discarded at different time scales, and to find out the reasons for the frequent occurrence of wind abandonment during the heating season.

Danish scholars detailed in [6], [7] the method of configuring electric boilers and heat pumps for cogeneration units to increase the capacity of wind power absorption and compare the economics. The literature [8] describes that in Finland, the heat storage unit is equipped with a cogeneration unit to achieve the power balance of the power generation and consumption of the power system at the national level. In addition, studies have also shown that the provision of heat storage devices next to a suction-type cogeneration unit can also improve the peak-shaving capability of the power grid and the absorption of wind power, which was analyzed in [9]. In summary, all the mentioned research methods need to transform existing electric or thermal power systems. This undoubtedly poses a huge challenge to the investment and construction cycle. The literature [10] pointed out that the heating pipe network can be regarded as a dynamic heat storage system to store excess thermal energy to solve the thermo-electric coupling due to its heat storage capacity and thermal inertia. Therefore, the centralized heating pipe network is regarded as a heat storage system. Helps the power system improve its ability to absorb new energy. The literature [11] is similar to [10], considering that the heating network can act as an energy storage system, taking into account the differences in the transfer of electricity and heat energy and use, and formulating a coordinated scheduling strategy.

In this paper, by studying the thermal system, using the thermal system, the response time is slow, the inertia is large, and the human temperature sensing interval. In the heating season, we use the characteristics of multiple electrothermal and thermal coupling elements and the thermal system characteristics of the combined thermal and electric system to develop an electric thermal joint. The energy flow model of the system realizes multi-level coordination and coordination of provincial and local coordination and electric and thermal coordination, promotes the consumption of renewable electricity, and consumes as much wind energy as possible.

## 2. Energy flow model of combined heat and power system without additional heat source

### *2.1. Energy flow model of cogeneration units*

The heating heat load of the heat source depends on the heat source outlet circulation, the outlet water supply temperature, and the inlet return water temperature:

$$Q_h = G_h \cdot c(t_{hc} - t_{hr}) \tag{1}$$

### *2.2. Heating network model*

The heating pipeline and its internal thermal medium together form a heating pipe network. During the conduction process, the temperature of the heating medium is directly changed by the thermal characteristics of the pipeline, and because of the high internal energy, a large amount of high-temperature heating medium exists in the first-level heating network. In the heating pipeline, usually, under the condition of ensuring the heat transfer of the first and second heat networks is stable, a method of reducing its internal energy is adopted to soften the hard connection between the heat load and the heat source tip, so as to reduce the heating demand of the heat network. This breaks the "heat-set" limit, decouples the thermo-mechanical coupling of the thermal motor, and ultimately increases the capacity of the unit to absorb wind power. Compared with adding additional heat sources, this method can make better use of the heat storage characteristics of its own pipe network, and does not require initial investment and has a short construction period. This way of improving wind power absorption capacity has better economic and timeliness.

Since the heat medium present in the primary heating pipe has a high temperature, these heating pipes all have pressure bearing characteristics. In order to improve its pressure bearing capacity, generally higher strength steel pipes are used in the inner layer of the heating pipe, and a certain thickness of insulation material is used as the insulation layer on the outer layer of the steel pipe to reduce the heat loss generated by the heat medium during the transmission process. The outermost protective layer of the heating pipe is used to prevent corrosion and damage.

The heat source emits heat to the heat medium. After the heat medium absorbs heat, the temperature rises, and the heat network then enters the water supply pipeline of the primary heat network. The operation of the circulating water pump provides kinetic energy to continue to move toward the heat load at a certain speed. Therefore, the temperature of the heat medium when it is output from the heat source is closely related to the temperature at the heat load, and there is a certain delay effect of the temperature change of the heat medium at both places (and the heat load and the heat source). The definition of the thermal delay time for the heating pipeline is defined as the time required for the temperature to change during the transition from the heat medium temperature at the heat source outlet to the end of the corresponding heat load inlet.

Neglecting the frictional heat of the heat medium and the inner wall of the pipe, the heat medium exchanges heat with the pipe during the process of passing through the pipe. Therefore, the unit volume of the heat medium at the outlet of the pipe can be lower than the inlet, and the main performance is that the temperature drops.

The temperature relationship at both ends of the heating pipeline is:

$$T_{end} = (T_{start} - T_e)e^{-\frac{\lambda L}{CpM}} + T_e \tag{2}$$

According to equation (1-2), the temperature difference at the beginning and end of the heating pipeline can be determined.

$$\Delta T = T_{start} - T_{end} = (T_{start} - T_e)(1 - e^{-\frac{\lambda L}{Cp\dot{m}}}) \tag{3}$$

As can be seen from the above equation, the distance between the pipeline and the temperature difference between the beginning and the end is proportional to. Therefore, due to the short distance of the secondary pipeline, the distance from the thermal load is also very close, and the temperature change of the working fluid in the pipeline during the transfer process can be ignored, and only the temperature change of the pipeline is considered.

### *2.3. Heat load model*

Contains the thermal load of a person's psychological reaction to the temperature-sensing behavior (humans are subjected to high and low temperature intervals and reaction times, that is to say, people do not have to maintain a comfortable constant temperature, appropriately higher or lower, from the human behavioral psychology Academic considerations can be tolerated, or given appropriate compensation), the building's thermal characteristics.

Take a counterflow heat exchanger as an example, as shown in Figure 1.

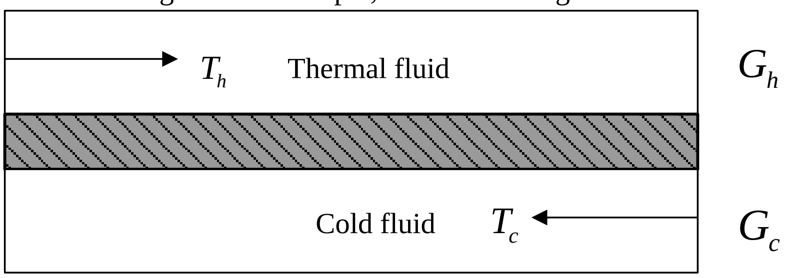


**Figure 1.** Countercurrent heat exchanger model.

The dissipation rate of the countercurrent heat exchanger can be expressed as

$$\phi_H = \frac{1}{2}G_h(T_{h,i}^2 - T_{h,o}^2) - \frac{1}{2}G_c(T_{c,i}^2 - T_{c,o}^2) \tag{4}$$

## 3. Provincial coordination and coordination strategy

The research on the power load shows that during the peak hours and waist-load period, the power demand is higher, and the heat-powered cogeneration units are less affected by the “heat-set” model, and the power system can consume wind power more than normal. However, during the load phase of the power load, the load is greatly reduced, so the required power output is relatively reduced. At this time, due to the influence of the outdoor temperature, a relatively high thermal load is required. Contradiction arises. At the same time, the thermal power unit The “heat-set” model and thermo-electric coupling restriction result in the inability of the electric output to be reduced. In order to ensure the power balance of the power grid, the wind is the only choice, which is the reason why the amount of wind curtailment in the valley was significantly higher than in other periods. In addition, during the daily actual operation of the power grid, the technology of load forecasting is not yet very mature. Coupled with the influence of wind speed, the actual net load of the system is far from the predicted load. This large net load error worsens the grid seriously. With regard to the capacity of wind power consumption, the occurrence of the wind abandonment phenomenon has been exacerbated in the period of Guru. Therefore, in order to better realize the acceptance of wind power, it has become a key issue to consider the coordination and scheduling strategies of provincial-territorial coordination, combined heat and power systems, ie, primary heat networks, cogeneration units, and additional heat sources.

First of all, the provincial regulation will conduct safety check and check on the transmission channel to ensure that the channel can fully absorb wind power. Secondly, considering the size of power grids in each region from the provincial grid, the size of the power supply will be determined by the type and capacity of each region. Finally, the minimum cost of coordinated scheduling is used as an objective function to develop a rolling plan for combined heat and power systems. The specific method is: based on the well-established daily power generation and heating plan, adjust the intraday rolling power generation plan based on the power grid load forecasting information and the ultra-short time wind power. Among them, it is necessary to pay attention to the recent prediction that the wind power output, electricity, and heat load should all be taken into consideration, and the heat load should be specifically reflected in the air temperature.

The cost of coordinating and dispatching mainly consists of two parts: the dispatching cost of the cogeneration unit and the operating cost of the additional heat source system. Additional heat sources include electric boilers and thermal storage devices. Because the primary heat network is an inherent device of the heat network itself, the use of its heat storage characteristics to dissipate the scheduling costs incurred by the wind power is negligible. Therefore, the objective function can be expressed as:

$$\min C_{dis} = C_{CHP} + C_{EB} + C_{HS} \tag{5}$$

In the combined heat and power system, the electric heating load needs to maintain the balance between supply and demand at all times. Arranging a reasonable dispatching plan is the primary task of the dispatching department, and secondly meeting the user's electricity consumption and heat demand on the premise of satisfying the system constraints. The goal of optimal scheduling is to reduce the power supply and heating costs to a minimum on this basis. The day before the optimization of the scheduling is the need to schedule the schedule of the second day before the operation day by the load and wind power forecast data. Prior to scheduling, an optimization scheduling model was established, including objective functions and constraints for each aspect. Then the model was solved according to a suitable algorithm to obtain the output of various units and thermal network equipment at various time periods.

In this combined heat and power system, it is assumed that each of the blocks in the thermal power plant R contains Ri cogeneration unit and i represents the number of each thermal power plant. Each thermal power plant supplies heat to its corresponding area and is responsible for its heat load; each secondary heat network is heated by its corresponding heat exchange station, and there are Li heat exchange station equipped with a suitable capacity peaking electric boiler. The system also contains S-station thermal power units. The Ri thermal power units on the same station supply power to the entire power grid. Therefore, thermal power units are not divided by thermal power plants. All wind turbines can also be grouped into a wind park to act approximately as an equivalent generator.

With the aim of energy conservation and emission reduction, the minimum total coal consumption of the system is the goal. In response to the country's call for energy conservation and emission reductions, wind energy costs are encouraged, and clean energy wind power is encouraged to go

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online. The day-to-day optimization scheduling objective function of the combined heat and power system can be expressed as follows:

$$\min F = \sum_{t=1}^{T}\left(\sum_{i=1}^{R}\sum_{n=1}^{N_i} F_{CHP}^{t,i,n} + \sum_{j=1}^{s} F_{CON}^{t,j}\right)\Delta t \tag{6}$$

In addition, it is necessary to pay attention to adjusting the outlet temperature of the heating pipe network, the user's feelings about the temperature change, and the withstand time.

## 4. Analysis of examples

The This example uses the provincial grid as the main research object, and the specific research is mainly between the provincial network and the city network. The dispatching departments corresponding to the two grids are provincially adjusted. The types of power in the network include firepower, hydraulic power, wind power, and thermal power.

The system used in this example is a six-node system. As shown in the following figure, the grid structure includes three units and one wind farm. The installed capacity of the wind farm is 220MW, and the three units are a thermal power plant and two thermal power plants. There are three secondary pipelines connected to the thermal power plant and each station is equipped with an electric heating station. Each heating station has a conversion efficiency of 1 and the enthalpy drop is 2 327.53 kJ/kg. All the units in the system are in the starting state. In the example, a mass-adjusted heat network dispatching method is adopted. This method changes the heat source on the basis that the circulating water volume of the network is constant and the heat resistance of the heat exchanger is constant. The system water supply temperature. In addition, the hot user room temperature was set to 25° C.

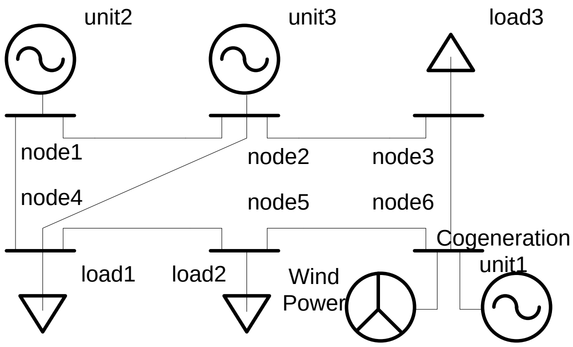


**Figure 2.** Example system.

Matlab optimization toolbox can be used to solve the optimal scheduling results. The following figure shows how to optimize the distribution unit's power output and pumping capacity during dispatching.

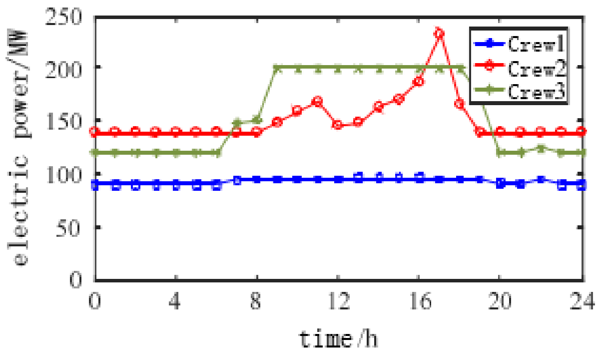


**Figure 3.** Optimal distribution of power output of each unit.

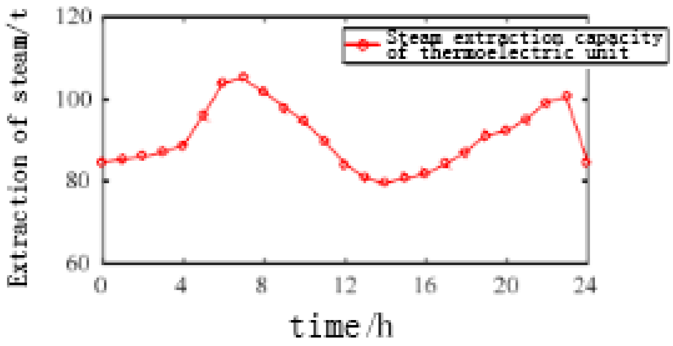


**Figure 4.** Optimal distribution of exhaust gas in a thermoelectric unit.

Excluding the heat transfer constraint and other constraints unchanged, the total wind volume of the system is not 1793.73 MW•h, which is 1073.11 MW•h, and there is a large error. The following figure shows the wind power output under different conditions.

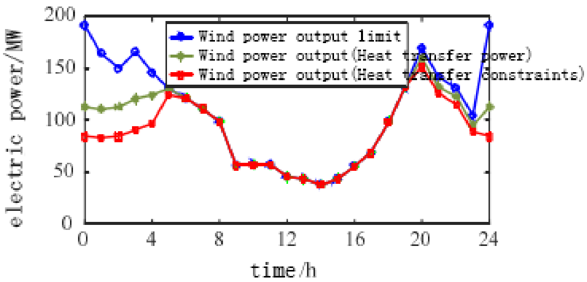


**Figure 5.** Wind power output under different circumstances.

As can be seen in the above figure, wind power output results are not the same in different situations. Because heat transfer between the heat exchange between the working fluids and the flow of the working fluid itself does not consider the irreversibility of the transport process once the heat exchange process is not considered, most of the thermal energy required by the hot users is required. Scheduled to achieve delivery, the equivalent heat load also increases. In order to realize the supply of thermal energy to thermal consumers, wind power heating can be used to dissipate more wind power. Therefore, there is a certain degree of error in the application of scheduling in an electrothermal integrated energy system. That means that not considering the heat exchange process does not mean that it can include All the constraints have caused the incompleteness of the research, so the heat exchange process can not be ignored.

## 5. Summary

In this paper, the unified heat and power system is realized by studying the established electro-thermal compatible energy flow model, and the two are unified into the power grid dispatch. Then the optimal dispatch model is proposed to improve the capacity of the combined heat and power system to eliminate and wind the wind, effectively The problem of severe wind abandonment during the winter grain load was solved and the power grid's capacity for dissipating the wind was also improved. According to the results of the study example, it can be concluded that the heating of the electric heating station can be used to increase the electric load during the period of the Dutch dynasty. This can reduce the electricity output of the unit and also allow room for wind power to be connected to the grid. Therefore, the grid is improved to consume wind power. Ability. In addition, from the point of view of behavioral psychology, people's adaptation to comfortable temperature is not limited to a constant temperature, and a reasonable high or low temperature at this temperature is acceptable, so the consumption of wind power can be controlled by Hot user room temperature to judge. At the same time, in the establishment of the optimization scheduling model, the heat exchange link should be taken into account, which will increase the accuracy and credibility of the results to some extent.

## 6. References

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