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# Research on Automation System of Dispatching Control Operation in Intelligent Substation

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## Abstract

**The current electricity market has undergone reforms, and the implementation of bidding and time-of-use electricity prices have changed the current optimization goals of cascade hydropower stations and optimized dispatching criteria. Traditional optimization goals are no longer suitable for current development needs. Therefore, in the process of optimizing the dispatching of cascade hydropower stations, it is very important to carry out comprehensive bidding for the Internet. This article analyses the impact of bidding on the Internet during the optimization of the current cascade hydropower stations. After considering many situations, this paper chooses genetic algorithm and pattern search algorithm. Experimental research shows that the power dispatch algorithm proposed in this paper effectively improves the efficiency of power generation.**

## Keywords

**Internet bidding; short-term optimal dispatch; time-of-use electricity price; maximum power generation benefit.**

## 1. Introduction

Although there are more water resources on the earth, how to use these water resources reasonably and bring us more welfare is also a problem that people have been studying. There are a lot of water resources in river basins, and these flowing waters also generate kinetic energy. People invented the hydroelectric generator set can use the water flowing down the uneven terrain to generate electricity. Our country's hydropower already has a large scale, and the technology is very mature. Our country is also one of the countries with richer water resources in the world.

Although the development speed of small hydropower is relatively fast, due to the lack of relevant specifications in the early development process, there have been some staking situations. This situation severely damaged the local ecosystem [1]. Moreover, in the management process of some small hydropower, there are no relevant standards and principles. These small hydropower stations are not coordinated with the grid, and internal conflicts have arisen together. Moreover, most small hydropower plants that do not have the ability to self-regulate are runoff-type power plants. Therefore, power generation has very obvious seasonal characteristics. During the flood season, water sources are abundant, and small hydropower generates more electricity. During the dry season, the amount of water is relatively small, and the power generation of small hydropower is also relatively low. Due to restrictions in the transmission process, small hydropower and power transmission channels may be congested with each other. This will also affect the transmission of large hydropower. This will lead to a series of situations such as water and electricity waste. In recent years, the amount of small hydropower has been increasing year by year. There are more and more

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related issues, so government departments have paid attention to these issues. How to coordinate the contradiction between small-scale hydropower and large-scale hydropower, reduce the occurrence of abandoned water nests, and minimize ecological damage and rational use of water resources are also problems that need to be resolved immediately. This also directly affected the development of our country's hydropower industry.

We analysed the existing cases. It is found that the joint optimized dispatching of cascade hydropower stations will not increase the overall cost, but can also increase the power generation compared with the previous method. Moreover, this type of cascade hydropower station can be closely linked with water power and electricity. Different levels of hydropower stations can be compensated and adjusted. In this case, the utilization efficiency of water resources can also be improved. Solve the problems caused by the current shortage of water resources. This approach can support the stable development of power companies and can also improve local economic benefits.

## 2. Proposal and application of time-by-period electricity prices

### 2.1. Division of peak, flat and valley time periods

In the process of dividing the time period of the time-of-use electricity price, the daily load curve is used as the basis. Different regions of our country have different daily load curves, and the load curve in the same area is also constantly changing. However, relevant principles must be followed in the process of specific time division.

In the process of time division, it must conform to the load curve. It can accurately express the characteristics of the load curve [2]. Each time period cannot be less than two hours, so as to improve the operability. Through the division of these time periods between peaks, flats and valleys, the time of electricity consumption can be adjusted to adjust the load structure. The reason for the division of time periods is to meet the needs of both power suppliers. Taking Lijiang City, Zhejiang Province as an example, based on the above factors, combined with the actual situation of the East China Power Grid, the peak period of power consumption is 10:00~12:00 and 20:00~24:00 as the peak period and the low power consumption period. A total of 8 hours from 24:00 to 8:00 is set as the valley section, and the rest of the time from 8:00 to 10:00 and a total of 10 hours from 12:00 to 20:00 are set as the flat section. The 24 hours a day is divided into 3 periods, peak section $T_f$, flat section $T_p$, and valley section $T_g$. Obviously:

$$T_f+T_p+T_g=24 \tag{1}$$

Among them, $T_f \in N, T_p \in N, T_g \in N, T_f \geq 2, T_p \geq 2, T_g \geq 2$.

### 2.2. Determination of peak, flat and valley electricity prices

The time-of-use electricity price is to set different electricity prices in different time periods. The reason for the difference in electricity prices between peaks, flats and valleys is because of different power supply costs. The peak load of a regional power grid directly affects the capacity of a power system equipment. If the electricity load is high, then the fixed cost will be higher. If the load on the valley section increases, the cost will not be affected. From the perspective of marginal cost, the electricity price in the peak section must be higher than the electricity price in the valley section [3]. This is because whether the setting of electricity prices is scientific or not will also affect the economic benefits of each store in the online bidding environment. If the formulation is not reasonable and too high or too low, it will have certain impact and waste of resources. The current bidding environment in our country is not mature enough. Government departments have not clearly defined time-of-use electricity prices. In the process of setting up grid benchmark electricity prices, considering that the overall cost fluctuations of power generation companies before and after time-of-use electricity prices are not too large, the

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selected flat-segment electricity prices are specifically calculated as follows. The benchmark electricity price is selected for the flat section. In the peak period, on the basis of the benchmark electricity price, it has increased by 33.5%. On the basis of the benchmark electricity price, the valley section has dropped by 50%. That is, the peak-to-valley price ratio is: 1.335:1:0.5. In this paper, the electricity price symbol is set as c, and the grid-connected benchmark electricity price of the power station is $c^b$. According to the above, we can get: the electricity price in the flat section is $c^b = c^p$, the electricity price in the peak section is $c^f = 1.335c^b$, and the electricity price in the valley section is $c^g = 0.5c^b$.

## 3. Optimized dispatch of small hydropower grid-connected

### 3.1. Model for maximizing power generation benefits

One day is the cycle of optimal scheduling. Divide a day into 24 hours as different time periods. Taking into account the development of the power system, hydropower stations are required to obtain the greatest power generation benefits. After understanding the specific conditions of each cascade hydropower station [4]. Looking for a kind of constraint conditions that can ensure the power output of the power station and meet the operation of the cascade hydropower station. In this way, the overall power generation benefit of cascade hydropower stations can be maximized during the dispatch period. And on this basis, optimize and set up the objective function. Objective function:

$$E = \max\left\{\sum_{i=1}^{n}\sum_{t=1}^{T} F_{i,t} B_{i,t}\right\} \tag{2}$$

$$F_{i,t} = A_i Q_{i,t} H_{i,t} \Delta T \tag{3}$$

In the formula: $E$ represents the maximum daily power generation benefit of cascade hydropower stations (yuan); $n$ represents the total number of cascade hydropower stations; $F_{i,t}$ represents the power generation of i power station during t period (degrees); $B_{i,t}$ represents the electricity price of i power station during t period (yuan/kWh); $A_i$ represents the comprehensive output coefficient of the i power station; $Q_{i,t}$ represents the power generation flow of the i power station during the t period (m3/s); $H_{i,t}$ represents the average power generation head of the i power station during the t period (m); $\Delta T$ represents the duration of the t period (h or s) .

Restrictions:

(1) Water balance restriction

$$V_{i,t+1} = V_{i,t} + \left(R_{i,t} - Q_{i,t} - S_{i,t}\right)\Delta T \qquad \forall i \in n, t \in T \tag{4}$$

In the formula: $V_{i,t}, V_{i,t+1}$ represents the initial and final storage capacity of power station i in time t; $R_{i,t}$ represents the average inflow flow of power station i in time t; $Q_{i,t}$ represents the average power generation flow of power station i in time t; $S_{i,t}$ represents the average waste water of power station i in time t Water flow.

(2) Water volume connection restriction

$$R_{i,t} = Q_{i-1,t-\tau_i} + I_{i,t} \qquad \forall i \in n, t \in T \tag{5}$$

In the formula: $Q_{i-1,t-\tau_i}$ represents the outgoing flow of the upstream power station, where $\tau_i$ represents the number of time periods corresponding to the water flow lag from the i-1th

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power station to the ith power station; $I_{i,t}$ represents the time period between the i-1th power station and the ith power station The interval inbound flow.

(3) Water storage capacity restriction

$$V_{i,t\min} \leq V_{i,t} \leq V_{i,t\max} \quad \forall i \in n, t \in T \tag{6}$$

In the formula: $V_{i,t\min}, V_{i,t\max}$ represents the minimum water storage capacity and the maximum water storage capacity required during the dispatch period of the i power station, respectively.

(4) Discharge flow restriction

$$Q_{i,t\min} \leq Q_{i,t} \leq Q_{i,t\max} \quad \forall i \in n, t \in T \tag{7}$$

In the formula: $Q_{i,t\min}, Q_{i,t\max}$ respectively represent the upper and lower limits of the discharge flow required during the dispatch period of i power station.

(5) Output balance constraint

The cascade hydropower stations are uniformly dispatched by the power grid. As a branch of the power system, the daily load curve must be distributed to all levels of hydropower stations through dispatch calculations after the intermediate adjustment is issued. Therefore, the total output of all levels of hydropower stations should be consistent with the daily load curve:

$$\sum_{i=1}^{n} N_{i,t} = N_t \quad \forall i \in n, t \in T \tag{8}$$

In the formula: $N_{i,t}$ represents the output of the i power station during the t period; $N_t$ represents the total output of the cascade power station during the t period.

## 3.2. Short-term power generation benefit maximization model

Taking into account the specific circumstances of electricity production. During the development of most cascade hydropower stations, relevant allocations will be made according to the dispatch of the power system. Affected by the bidding environment, the short-term power generation benefit maximization model is combined with the time-of-use electricity price theory. In this way, different peak and valley tariffs can be applied to different load demands in different time periods. The study analysed the optimal load distribution within a day, hoping to maximize the benefits for the power station. In the process of optimal scheduling, we perform short-term optimal scheduling. Divide the day into 24 time periods. The scheduling period is one day. Every hour is a dispatch unit. After that, it is divided into three different time periods of peak, flat and valley, and the electricity price is different.

Objective function:

$$E = \max\left\{\sum_{i=1}^{n} N_i^f T^f c_i^f + \sum_{i=1}^{n} N_i^p T^p c_i^p + \sum_{i=1}^{n} N_i^g T^g c_i^g\right\} \tag{9}$$

In the formula: $E$ represents the maximum power generation benefit of cascade hydropower stations (yuan); $n$ represents the total number of power stations; $N_i^f$ , $N_i^p$ , $N_i^g$ are the output of i power station load during peak, flat, and valley periods; $T^f$ , $T^p$ , $T^g$ represent peak, flat and valley periods, which are determined by the regional power grid; $c_i^f$ , $c_i^p$ , $c_i^g$ indicate the electricity price of i power station in peak, flat and valley sections (yuan/kWh). Restrictions:

(1) Peak, flat and valley time constraints

$$T^f + T^p + T^g = 24 \tag{10}$$

(2) Output constraints of each step

$$\begin{cases} N_{i,t\min} \le N_{i,t} \le N_{i,t\max} \\ N_{i,t} = A_i Q_{i,t} H_{i,t} \end{cases} \quad \forall i \in n, t \in T \tag{11}$$

In the formula: $N_{i,t\min}$ represents the minimum allowable output of the i power station, which depends on the type and characteristics of the turbine, and generally takes the guaranteed output; $N_{i,t\max}$ represents the maximum output of the i power station, which is generally taken as the installed capacity.

(3) Peak-level valley output ratio constraints:

$$\frac{N_i^f}{a_i} = N_i^p = \frac{N_i^g}{b_i} \quad \forall i \in n \tag{12}$$

In the formula: $a_i$ represents the output ratio between the peak section and the flat section of the i power station, generally taken between (1~2): 1; $b_i$ represents the output ratio between the valley section and the flat section of the i power station, generally taken (0.5~1): Between 1.

(4) Other constraints are the same as the model for maximizing power generation benefits.

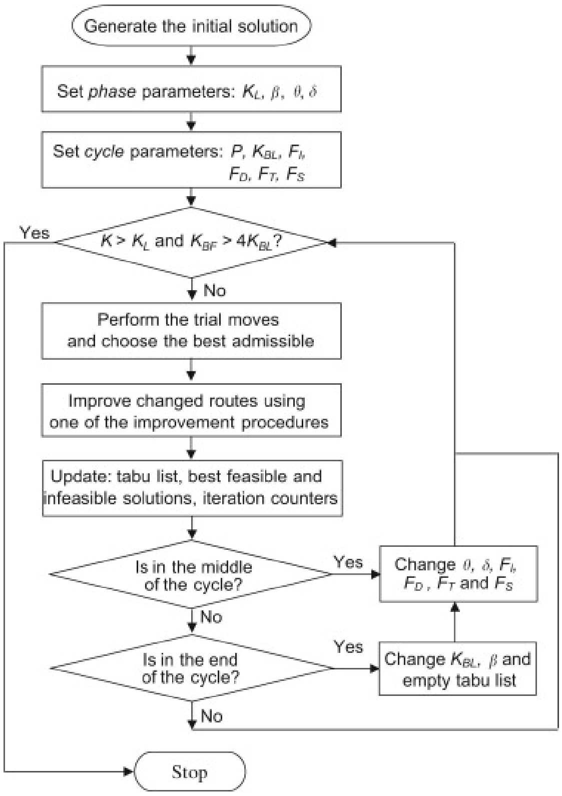


Figure 1. Search taboo algorithm flow

## 4. Analysis of Optimal Scheduling Algorithm

The pattern search algorithm can directly search for the minimum value. In the process of solving, it can directly search without gradient information, just in the process of repeated cycles. Hooke and Jeeves proposed this algorithm, so it is also called the Hooke-Jeeves method. There are two kinds of movement processes, one is detection movement, and the other is pattern movement. These two modes of movement are advancing in the process of constant transformation. In order to show the process of this algorithm more intuitively, we can express the optimization problem as a curved surface. When determining a new singularity, we can apply the detection movement [5]. The pattern movement is continuously promoted to become

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the valley movement search. In the application of these two methods, the function, the valley of the minimum value, is obtained. Finally find the minimum point of the function. We can see through Figure 1.

Features of pattern search algorithm:

(1) This method pays more attention to the objective function value. This method makes the process easier. Simplified, the entire programming procedure can be applied in many ways, and can deal with linear equations of constraint conditions as well as the problem of non-differentiable and discontinuous objective functions.

(2) In this way, the surrounding points can be obtained based on an initial point, and the optimization can be performed again. Therefore, it is very important to ensure the accuracy of the initial point, which will affect the overall accuracy and calculation efficiency. But this method has no group information. Therefore, a global search cannot be performed. Therefore, the local search method is mainly adopted. The statement to call the pattern search function is:

$[x, fval]=pattern\ search(fitnessfcn, x_0, A, b, Aeq, beq, lb, ub, nonlcon, options)$

$x$ represents the final point; $fval$ represents the objective function value corresponding to $x$; $x_0$ represents the starting point of the pattern search algorithm; the meaning of other symbols is consistent with the genetic algorithm. Called through GUI graphical user interface. The operation steps of the pattern search algorithm are consistent with the genetic algorithm.

## 5. Optimized scheduling case analysis

This paper studies the selection of the daily optimal dispatching model of cascade hydropower stations. The optimization criterion is the dispatch period (day), which maximizes the total power generation benefit of the cascade hydropower station system while satisfying various constraints of the cascade hydropower station. The mathematical model is as follows:

$$E=\max\left\{\sum_{i=1}^{4} N_i^f T^f c_i^f+\sum_{i=1}^{4} N_i^p T^p c_i^p+\sum_{i=1}^{4} N_i^g T^g c_i^g\right\} \tag{13}$$

According to the actual situation of the East China Power Grid, the initial peak-flat-valley period is set as peak period: 10:00~12:00, 20:00~24:00, a total of 6 hours; flat period: 8:00~10:00, 12:00 ~20:00, a total of 10 hours; valley section: 24:00~8:00, a total of 8 hours; the peak-to-valley electricity price ratio is: 1.335:1:0.5. Substituting the known data of the four cascade hydropower stations from A to D into the constraint conditions can be obtained:

Peak, flat and valley time constraints

$$T^f=6,\ T^p=10,\ T^g=8 \tag{14}$$

Output constraints of each step

$$\begin{cases} N_1=N_1^f+N_1^p+N_1^g, 489\le N_1\le 1225 \\ N_2=N_2^f+N_2^p+N_2^g, 152\le N_1\le 440 \\ N_3=N_3^f+N_3^p+N_3^g, 82\le N_1\le 220 \\ N_4=N_4^f+N_4^p+N_4^g, 93\le N_1\le 230 \end{cases} \tag{15}$$

(3) Peak-to-valley output ratio constraint

$$1\le \frac{N_i^f}{N_i^p}\le 2,\ 0.5\le \frac{N_i^g}{N_i^p}\le 1 \tag{16}$$

(4) According to the East China Power Grid, the on-grid tariffs of the four-level cascade power stations A, B, C, and D are 0.227 yuan/kW·h, 0.115 yuan/kW·h, 0.115 yuan/kW·h, 0.240 yuan/

kW·h, the electricity price at each time period can be calculated from the peak-to-valley electricity price ratio, as shown in Table 1.

Table 1. Peak, flat and valley electricity prices in different periods of time for each power station (yuan/103KW·h)

| Hydropower station | Peak section | Flat section | Tanidan |
|---|---|---|---|
| A | 303.05 | 227.00 | 113.50 |
| B | 153.53 | 115.00 | 57.50 |
| C | 153.53 | 115.00 | 57.50 |
| D | 320.40 | 240.00 | 120.00 |

Assuming that the four cascade power stations of A, B, C, and D are operating normally every day, the unit performance is good, and there is no need for maintenance and shutdown, then the operation time of the four cascade power stations in the dispatch cycle (one day) is 0:00~24:00, a total of 24 Hour. According to calculations, the benefits of cascade power stations during peak, flat and valley periods before optimal dispatching are:

$$\begin{bmatrix} N_1^f & N_1^p & N_1^g \\ N_2^f & N_2^p & N_2^g \\ N_3^f & N_3^p & N_3^g \\ N_4^f & N_4^p & N_4^g \end{bmatrix} \begin{bmatrix} T^f & 0 & 0 \\ 0 & T^p & 0 \\ 0 & 0 & T^g \end{bmatrix} \begin{bmatrix} c_1^f & c_2^f & c_3^f & c_4^f \\ c_1^p & c_2^p & c_3^p & c_4^p \\ c_1^g & c_2^g & c_3^g & c_4^g \end{bmatrix}$$
$$= \begin{bmatrix} N_1^f & N_1^p & N_1^g \\ N_2^f & N_2^p & N_2^g \\ N_3^f & N_3^p & N_3^g \\ N_4^f & N_4^p & N_4^g \end{bmatrix} \begin{bmatrix} 6 & 0 & 0 \\ 0 & 10 & 0 \\ 0 & 0 & 8 \end{bmatrix} \begin{bmatrix} 303.05 & 153.53 & 153.53 & 320.40 \\ 227.00 & 115.00 & 115.00 & 240.00 \\ 113.50 & 57.50 & 57.50 & 120.00 \end{bmatrix} \tag{17}$$

It can be seen from the above formula that the maximum power generation benefit of cascade hydropower stations depends on the output value of each power station during peak, flat and valley periods. In order to facilitate further solution, the output of each power station during the optimal operation of different periods is re-adjusted, as shown in Table 2.

Table 2. The output of each power station during optimized operation at different time periods

| Plant number | Time period | | |
|---|---|---|---|
| | Peak section | Flat section | Tanidan |
| 1 | $N_1^f=x(1)$ | $N_1^p=x(2)$ | $N_1^g=x(3)$ |
| 2 | $N_2^f=x(4)$ | $N_2^p=x(5)$ | $N_3^g=x(6)$ |
| 3 | $N_3^f=x(7)$ | $N_3^p=x(8)$ | $N_3^g=x(9)$ |
| 4 | $N_4^f=x(10)$ | $N_4^p=x(11)$ | $N_4^g=x(12)$ |

The genetic algorithm in Matlab has a very powerful function, not only can solve unconstrained optimization problems, but also can solve constrained optimization problems, and the constraint conditions can be nonlinear [6]. Analyse the above 10 sets of data, and select the 9th set of data with the greatest benefit as the final result of genetic algorithm optimization at time $a_i = 2, b_i = 0.5$. At the same time, the fitness value function change curve and the optimal individual can be obtained, as shown in Figure 2.

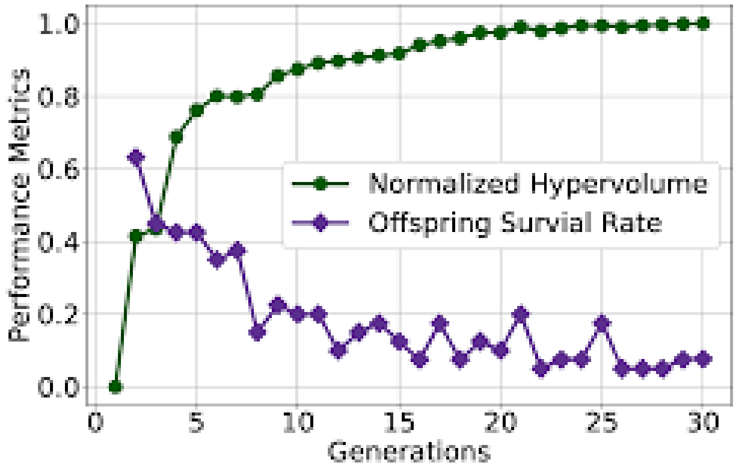


Figure 2. Genetic algorithm operation result graph

It can be seen from the simulation results that the function result obtained by the genetic algorithm is better, and it has certain advantages for solving the multi-variable optimization problem, and the calculation time is short. When the peak-level output ratio $a_i$ and the valley-level output ratio $b_i$ take different values of series 1 to series 10, the peak-level-valley output and the maximum benefit value of each power station calculated by the genetic algorithm are also quite different. Figure 3 is drawn for the convenience of comparison.

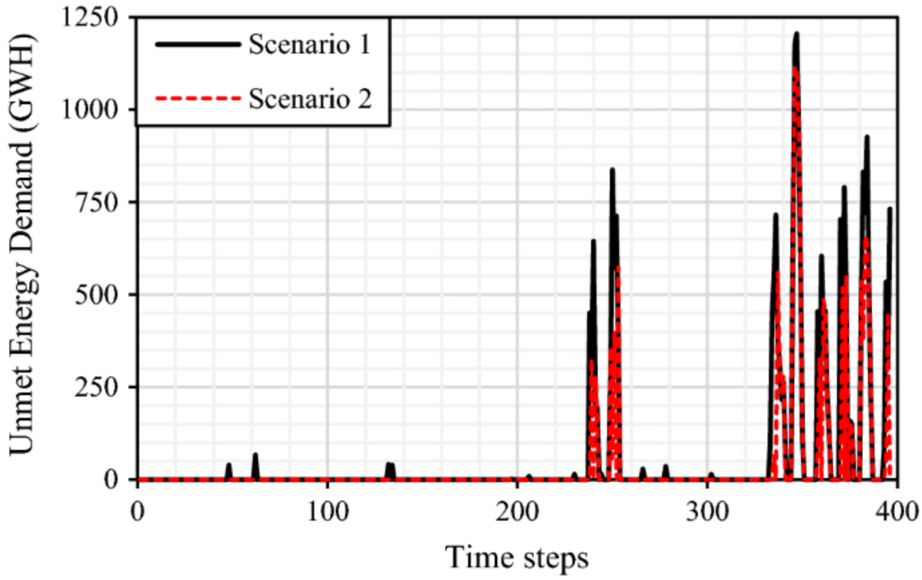


Figure 3. Comparison of the maximum benefit value of different series of cascade hydropower stations

## 6. Conclusion

This article applies the short-term optimal dispatch model of cascade hydropower stations based on time-of-use electricity prices to the A to D cascade hydropower stations. The genetic algorithm and the pattern search method are used to solve the models respectively, and the peak-to-valley output ratio is optimized; finally, the A to D cascade A comparative analysis of time-sharing optimization and general optimization is carried out for hydropower stations, and the rationality of the short-term optimal scheduling model for cascade hydropower stations based on time-of-use electricity prices is obtained, which makes this paper more guiding in the

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actual operation of cascade power stations, and carries out scheduling for decision-makers. Provide a theoretical basis.

## References

[1] Dayan, M. A., Xiangying, X. I. E., Zhixiong, N. A., Wentao, S. H. E. N., & Fanteng, M. E. N. G. Dispatch automation system based low voltage distributed photovoltaic power station connected estimation model. Telecommunications Science, 36(2) (2020) 90-98.

[2] Hosseini, M. M., & Parvania, M. Quantifying impacts of automation on resilience of distribution systems. IET Smart Grid, 3(2) (2020) 144-152.

[3] Kulkarni, V., Sahoo, S. K., Thanikanti, S. B., Velpula, S., & Rathod, D. I. Power systems automation, communication, and information technologies for smart grid: A technical aspects review. Telkomnika, 19(3) (2021) 1017-1029.

[4] Shi, X., Zheng, R., Lin, Z., & Yan, G. Distributed optimization for economic power dispatch with event-triggered communication. Asian Journal of Control, 22(6) (2020) 2412-2421.

[5] Raza, A., Mustafa, A., Rouzbehi, K., Jamil, M., Gilani, S. O., Abbas, G., ... & Shehzad, M. N. Optimal power flow and unified control strategy for multi-terminal HVDC systems. IEEE Access, 7(1) (2019) 92642-92650.

[6] Li, P., Wang, Y., Wang, C., Lu, J., Pan, X., & Blaabjerg, F. Mitigation of voltage sag for DVR to comply with voltage security protocol via elliptical trajectory compensation. IET Power Electronics, 14(5) (2021)1044-1058.