Research on Data Processing Model of Power System Dispatching for Hydropower Grid Connection Using Genetic Algorithm

Qingyuan Liu¹, ², Guojun Ma¹, *
¹Jiangsu University of Science and Technology.Zhenjiang City, Jiangsu Province 212008, China
²State Grid Yancheng Power Supply Company.Yancheng City, Jiangsu Province, 224000, China
*Corresponding author: maguojun@just.edu.cn

Abstract. The output of small hydropower is random and unpredictable. Large-scale access to the power grid increases the complexity and difficulty of power system dispatching decision-making. This paper fully considers the impact of bidding on the grid on the optimal dispatch of cascade hydropower stations, uses the key technology of electrical automation to deeply discuss the time-of-use electricity price theory, and uses genetic algorithms to establish and solve the short-term power generation benefit maximization model of cascade hydropower stations based on the time-of-use electricity price. Simulation analysis shows that the model can effectively improve the adaptability of large and medium-sized hydropower generation plans to small hydropower scenarios, increase the expected peak-shaving benefits of the power grid, and improve the reliability of hydropower plans.

1. Introduction
With the rapid development of my country's hydropower technology, in order to effectively study the short-term power generation benefits of cascade hydropower stations, establish a connection with time-of-use electricity prices, and apply genetic algorithms to analyze the coordinated optimal dispatch of small hydropower grids [1]. Based on research and comprehensive consideration of system operation economy and reliability, a more refined short-term coordinated dispatching model of large and small hydropower is constructed [2]. Not only does it consider the conventional maximum total consumption of hydropower, but also separates energy storage and transmission from hydropower systems [3]. From the economic point of view, the goals of maximizing cascade energy storage and minimizing system network loss are introduced to more comprehensively measure the economics of system operation, and use the probability of system power shortage to evaluate the reliability of the system [4].

2. Grid power generation benefit maximization model

2.1. Optimized scheduling description
The short-term optimal scheduling takes one day (24h) as the scheduling period, and divides a planned day into T time periods, where t is the time sequence number. According to the requirements of the
power system for the guaranteed output of hydropower stations and the goal of power generation companies to pursue maximum benefits, in the known dispatch period, the initial and final water levels of the hydropower stations and the forecasting of the cascade power stations, seek a way to meet the guaranteed output of the power station with a certain guarantee rate And the operation mode of cascade hydropower stations that meets various constraints, maximizes the total power generation benefit value of the cascade during the dispatch period, and uses this as the objective function of the optimal dispatch model [5]. Objective function:

\[ E = \max \left\{ \sum_{i=1}^{n} \sum_{t=1}^{T} F_{it} B_{it} \right\} \]  

(1)

\[ F_{it} = A_{it} Q_{it} H_{it} \Delta T \]  

(2)

Where: \( E \) represents the maximum daily power generation benefit of cascade hydropower stations (yuan); \( n \) represents the total number of power stations of cascade hydropower stations; \( F_{it} \) represents the power generation of i power station during t period (degree); \( B_{it} \) represents the electricity price of i power station during t period (yuan/degree); \( A_{it} \) represents the comprehensive output coefficient of the i power station; \( Q_{it} \) represents the power generation flow of the i power station during the t period (m3/s); \( H_{it} \) 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).

2.2. Constraints

2.2.1. Water balance constraints. In the formula: \( V_{i,t} \), \( V_{i+1,t} \) represents the initial and final storage capacity of the i power station during the t period; \( R_{it} \) represents the average inflow flow of the i power station during the t period; \( Q_{it} \) represents the average power generation flow of the i power station during the t period; \( S_{it} \) represents the average abandonment of the i power station during the t period Water flow.

\[ V_{i,t+1} = V_{i,t} + \left( R_{it} - Q_{it} - S_{it} \right) \Delta T \quad \forall i \in n, t \in T \]  

(3)

2.2.2. Water volume contact constraints. In the formula: \( Q_{i-1,t,-t} \) represents the outgoing flow of the upstream power station, where \( \tau_{i-1,t} \) represents the number of time periods corresponding to the water flow lag from the i-1th power station to the i power station; \( I_{i,\tau} \) represents the time period between the i-1th power station and the i power station the interval inbound flow.

\[ R_{i,t} = Q_{i-1,t,-\tau_{i}} + I_{i,t} \quad \forall i \in n, t \in T \]  

(4)

2.2.3. Water storage capacity constraints. 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.

\[ V_{i,t,\min} \leq V_{i,t} \leq V_{i,t,\max} \quad \forall i \in n, t \in T \]  

(5)
2.2.4. Discharge flow restriction. In the formula: \( Q_{i,\text{min}} \leq Q_i \leq Q_{i,\text{max}} \) respectively represents the upper and lower limits of the discharge flow required during the dispatch period of the \( i \) power station.

\[
Q_{i,\text{min}} \leq Q_i \leq Q_{i,\text{max}} \quad \forall i \in n, t \in T
\]

(6)

2.2.5. 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 after dispatch calculations after the intermediate adjustment is issued [6]. Therefore, the total output of all levels of hydropower stations should be consistent with the daily load curve:

\[
\sum_{j=1}^{n} N_{ij} = N_i \quad \forall i \in n, t \in T
\]

(7)

In the formula: \( N_{ij} \) represents the output of the \( i \) power station during the \( t \) period; \( N_i \) represents the total output of the cascade power station during the \( t \) period.

3. Short-term power generation benefit maximization model based on bidding online

At present, in the actual power production in our country, the operation of cascade hydropower stations mostly follows the daily load diagram assigned to the entire cascade power station by the power system dispatching agency, and then the cascade power stations perform secondary load distribution [7]. In the competitive grid environment, the time-of-use electricity price theory is combined with the short-term power generation benefit maximization model. According to the fact that the load demand at different periods corresponds to different peak, flat and valley electricity prices, the optimal load distribution in the dispatch period (one day) is studied [8]. In order to maximize the net profit of the cascade power station, it has strong practicability [9].

3.1. Optimized scheduling description

The scheduling period of short-term optimal scheduling is 1d, which is divided into 24 periods, that is, 1h is a scheduling unit, and it is divided into three periods of peak, flat and valley at the same time, and different electricity prices are given in different periods [10]. The benefit maximization model of cascade hydropower stations can be divided into peak section benefit, flat section benefit and valley section benefit maximization [11]. As a result, a short-term optimal dispatch model for cascade hydropower stations based on time-of-use electricity prices can be established [12]. Objective function:

\[
E = \max \left\{ \sum_{i=1}^{n} N_{i}' T_i' c_i' + \sum_{i=1}^{n} N_{i}'^p T_p c_i^p + \sum_{i=1}^{n} N_{i}'^v T_v c_i^v \right\}
\]

(8)

In the formula: \( E \) represents the maximum power generation benefit of cascade hydropower stations (yuan); \( n \) represents the total number of power stations; \( N_{i}' \), \( N_{i}'^p \), \( N_{i}'^v \) is the output of the \( i \) power station during peak, flat, and valley periods; \( T_i' \), \( T_p \), \( T_v \) represents the peak, flat and valley period, which is determined by the regional power grid; \( c_i' \), \( c_i^p \), \( c_i^v \) indicate the electricity price of \( i \) power station in peak, flat and valley sections (yuan/kWh).

3.2. Constraints

3.2.1. Peak flat valley time constraints

\[
T_i' + T_p + T_v = 24
\]

(9)
3.2.2. The output constraints of each step. In the formula: $N_{i,min}$ 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; $N_{i,max}$ represents the maximum output of the i power station, which is generally taken as the installed capacity.

\[
\begin{align*}
\min & \leq N_{i,t} \leq \max \\
N_{i,t} &= A Q_{i,t} H_{i,t} \\
\forall i \in n, t \in T
\end{align*}
\] (10)

3.2.3. Peak-to-valley output ratio constraint. 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 as (0.5-1): Between 1.

\[
\frac{N_f^i}{a_i} = \frac{N_p^i}{b_i} \quad \forall i \in n
\] (11)

4. Optimal scheduling model based on genetic algorithm

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 [13]. The calculation process is shown in Figure 1 below. The mathematical model is as follows:

\[
E = \max \left\{ \sum_{i=1}^{d} N_i^p T_i^p c_i^p + \sum_{i=1}^{d} N_i^v T_i^v c_i^v + \sum_{i=1}^{d} N_i^s T_i^s c_i^s \right\}
\] (12)

According to the actual situation of the State Grid, the initial peak-flat-valley period is:
Peak section: 10:00-12:00, 20:00-24:00, a total of 6 hours; flat section: 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 price ratio is: 1.335:1:0.5.
The paper substitutes the known data of the four cascade hydropower stations A, B, C, and D into the constraint conditions to obtain:

1. **Peak flat valley time constraints**

   \[ T^f = 6, \ T^p = 10, \ T^v = 8 \]  \hspace{1cm} (13)

2. **Constraints on the output of each step**

   \[
   \begin{align*}
   N_i &= N_i^f + N_i^p + N_i^v, \quad 489 \leq N_i \leq 1225 \\
   N_i &= N_i^f + N_i^p + N_i^v, \quad 152 \leq N_i \leq 440 \\
   N_i &= N_i^f + N_i^p + N_i^v, \quad 82 \leq N_i \leq 220 \\
   N_i &= N_i^f + N_i^p + N_i^v, \quad 93 \leq N_i \leq 230
   \end{align*}
   \]  \hspace{1cm} (14)

3. **Peak-to-valley output ratio constraint**

   \[ I \leq \frac{N_i^f}{N_i^v} \leq 2, \quad 0.5 \leq \frac{N_i^p}{N_i^v} \leq 1 \]  \hspace{1cm} (15)

4. According to the State Grid, the on-grid power prices 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 [14], 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 [15]. According to calculations, the benefits of cascade power stations during peak, flat and valley periods before optimal dispatching are [16]:

\[
E = 1818.3N_i^f + 2270N_i^p + 908N_i^v + 921.2N_i^f + 1150N_i^p + 460N_i^v + 921.2N_i^f + 1150N_i^p + 460N_i^v + 1922.4N_i^f + 2400N_i^p + 960N_i^v
\]  \hspace{1cm} (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 [8]. 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 in optimized operation at different time periods.

| Plant number | Peak section | Flat section | Tanidan |
|--------------|--------------|--------------|---------|
| 1            | $N_1^f=x(1)$ | $N_1^p=x(2)$ | $N_1^g=x(3)$ |
| 2            | $N_2^f=x(4)$ | $N_2^p=x(5)$ | $N_2^g=x(6)$ |
| 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 paper selects the 9th group of data with the greatest benefit as the final result of genetic algorithm optimization when $a=2, b=0.5$, and 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 [17].

**5. Conclusion**

The paper constructs an overall solution framework for the optimal dispatching model of small hydropower grid-connected power. Transform complex and nested multi-level transmission sections into an equivalent recursive partition structure to realize multi-level transmission section safety control and large and small hydropower abandoned water output calculations; based on the real-time operating status of the system, the use of genetic algorithms can effectively reflect the different loads of the system at different periods of time Lower reliability level; through cascade load splitting and redistribution to
ensure the effectiveness of the initial solution, combined with improved genetic algorithm to achieve model solution.

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