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Original Research

Environment Friendly Hybrid Solar-Hydro Power Distribution Scheduling on Demand Side

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Abstract

Considering the low environmental cost and good social benefits of clean energy power generation, we propose the concept of environmental-friendly model. We also describe power expansion planning model in detail, that helps to incorporate a variety of power generating units, including solar-power, and hydropower, and which appropriately addressed the restrictions of the energy market environment. Taking into account the constraints of cascade hydropower and the uncertainty of solar power, multiple objectives of economic efficiency, load tracking coefficient, and accommodation degree of solar power are formulated. An optimal scheduling model for hybrid solar-hydro power generation system in demand side is established. This model is solved by using an improved genetic algorithm. In various seasons, weather conditions, and time intervals, simulation examples are used to identify the optimal output of the source side and the minimum load transfer volume, as well as the validity and correctness of the suggested method. By means of comparing and analyzing the reliability indices, the impact of solar-hydro power on distribution system is researched and the results show that interconnection of solar power with hydro power can play a certain role in the improvement of power system reliability.

Keywords: hybrid power generation, solar power, delay decision-making, power planning, green energy

Introduction

Solar, wind, hydro, and biomass energy sources are clean, sustainable, safe, and ecologically acceptable alternatives to traditional fossil fuels [1-4]. With the growing intensity of environmental and resource issues, low-cost, robust wind-solar power generation has developed as a comparatively fast-growing new energy power generating technology in the power system. Large power outage will have a great impact on the economy and people's life [5]. However, due to the intermittency and volatility of renewable energy such as wind and solar, it affects the safety of the power supply system and increases the cost of rotating reserve, which brings

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great challenges to the smooth operation of the power grid, resulting in a certain degree of abandonment of wind and hydro [6-7]. Cascade hydropower stations have the advantages of a wide range of power generation regulation and large energy storage capacity [8]. The solar-hydro joint dispatch is carried out on the source side. Based on the reliability and economy of power supply of the grid, the maximum consumption of wind and solar can be achieved [9-11].

At present, many studies have been carried out on hydro and solar complementary system. Literature [12] establishes a mathematical model for maximizing peak flake, and analyzes the output changes before and after water and light complementary in sunny, cloudy and rainy days and its impact on the short-term water dispatching of cascade hydropower stations. Literature [13] established a model of single optimal operation for virtual power plants with hydro-solar to optimize the multiple virtual power plants and joint dispatching of virtual power plants as well as analyzed the economic benefits of this system in the power supply market. From the perspective of classical scene set, literature [14] proposed a collaborative scheduling model of virtual power plant with hydro and solar, considering interruptible load in landmass case and replacement in grid connected environment. In the microgrid environment with distributed energy such as wind-solar-hydro, literature [15] proposed the optimal allocation method of energy storage capacity to ensure the economy of the system. Smart buildings' microgrid wind, hydro, and storage combined power supply system discussed in [16], to adjust the demand according to the dynamic power price of the power grid and reduce the total power charge of the building. The above research focuses on source-side complementary optimization, energy storage configuration, and uncertainty analysis, etc., and did not study source-load optimization scheduling, hydro cascades and solar, or the impact of load side demand response capability on achieving maximum demand consumption, reducing the burden of water and electricity regulation, and improving the stability and reliability. Literature [17] provided a solar energy scheduling algorithm that maximizes solar energy utilization and also proposed a high-efficiency scheduling algorithm for task management and resource scheduling.

Wind and solar power were integrated with hydropower scheduling in [18] to include total power generation, power output stability, and the impact of hydropower on a downstream riverine ecosystem to build a multi-objective optimization model, as well as using the large-scale system decomposition method, a wind, photovoltaic, and hydropower system was broken up into a wind-photovoltaic compensated subsystem and a hydropower system. Optimized utility-scale PV plant size utilizing cost-benefit analysis by combining long- and short-term operational decisions [19]. Multi-objective optimization methods (MOOPs) can be broadly classified into three broad types. It is possible to divide the MOOP into a group of single-objective problems using the first way, which is called the constraint method [20]. It's possible to combine many objectives into a single problem using a set of weights in the second technique [21]. The third is the dynamic weight based evolutionary algorithm, as well as a multi-objective evolutionary algorithm, both of which have been widely used in many industries [22].

However, previous research mainly focuses on energy consumption optimization, task scheduling, service strategy, heat management, and energy storage characteristics, as well as its analysis the internal structure of scheduling according to the demand side rather than the optimal scheduling problem in linkage with the source solar, and hydropower generation systems. In this paper, our method focuses on fellow:

1. The demand-side's energy consumption management is scheduled.
2. Power-side cascading hydropower, solar, and renewable energy power generation systems are summarized.
3. The control center is used to help with the technical side of promoting the use of renewable energy and lowering the cost of high-energy loads.
4. On the load side, the ratio of server load to idle time is the main factor that affects how much energy is used.

Using the characteristics of large energy storage and strong regulation capacity of cascade hydropower, the optimal dispatching model of the linkage between the hydro and solar complementary power generation system and the management on the demand side under multi-objective conditions such as economic benefits, solar consumption and source load matching is established. The optimization model is expressed as an integer linear form for resolving in the algorithm section, and approaches such as binary variables, maximum and minimum values are introduced.

Framework

The basic design of the hydro-solar and management dispatching system as shown in Fig. 1, which includes two power sources: photovoltaics, and cascade hydropower.

Two different types of power generation systems cooperate with each other to meet the daily needs of various types of loads, such as industrial loads on the load side, commercial loads, and residential electricity, and purchase electricity from the grid-side when the source-side power supply is insufficient. The basic architecture of the hydro-solar and management dispatching systems is shown in Fig. 2.

1. Among them, the control center is responsible for managing the industrial load, various data processing, and network requests in the processing zone. It is equipped with a large-scale uninterruptible

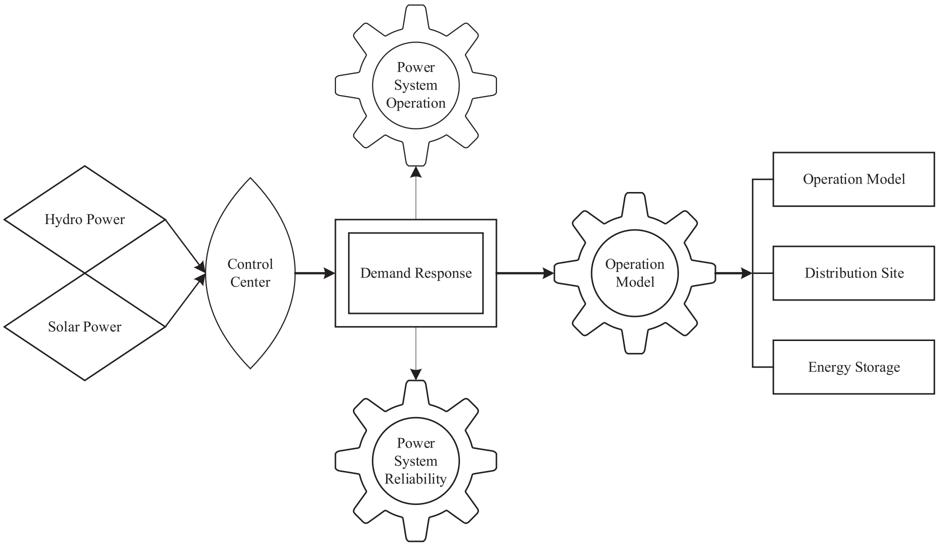

Fig. 1. Power and load-side dispatching system, in which all parts are connected and helpful to understand our given model.

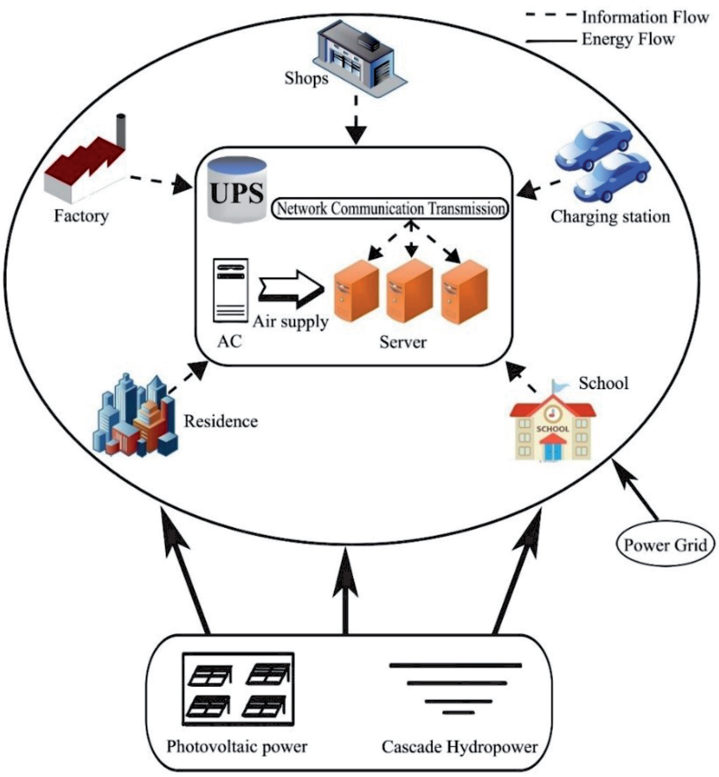

Fig. 2. Our basic framework of scheduling system divided into three main parts, such as load-side, management center, and hydro-solar cascade. Install UPS system to manage cascade process of the power transmission. Control center is a main part of our module, that is useful for power scheduling process.

power system (UPS) to connect with the grid to ensure the power's reliability.

2. The cascade hydropower station must balance the flow of the reservoirs of the hydropower stations, the amount of waste water, the mutual limit of the water head, as well as the regular incoming water, due to its large storage capacity, wide adjustment range of water level, and large energy storage.
3. Photovoltaic power generation can only generate electricity during the daytime. Weather changes affect the level of output. There is a huge difference in output between sunny and rainy days, and output is closely related to the intensity of solar radiation.

As an important infrastructure, the control center needs to be equipped with a high-capacity UPS system to ensure the high reliability of the power distribution.

When the main power input is stable, UPS supplies the main power to the control center after stabilizing the main power, so as to protect the precision equipment from damage and keep the server in a normal working state. At the same time, it charges the locally configured battery. The UPS active power can be defined as follows:

$$P_{UPS,t} = \frac{1}{\eta_{rec,gs}} \cdot \left(E_{on,t} + \frac{P_{DC,t}}{\eta_{inv,1s}} \right) \quad (1)$$

where, $P_{UPS,t}$ is the UPS active power supplying energy to the data center in period t, that is the load demand. $E_{on,t}$ is the active power charged by the battery in UPS during period t when the battery is full ($E_{on,t}$ is equal to 0). $\eta_{rec,gs}$ is the working efficiency of the rectifier and $\eta_{inv,1s}$ is the working efficiency of the inverter. $P_{DC,t}$ is the power consumption of the data center in period t.

Regarding the battery charging process, there are the following constraints:

$$E_{s,t} = (1-\theta) \cdot E_{s,t-1} + E_{on,t} \cdot \lambda_c \quad (2)$$

$$E_s^{min} \leq E_{s,t} \leq E_s^{max} \quad (3)$$

$$E_{on}^{min} \leq E_{on,t} \leq E_{on}^{max} \quad (4)$$

where, $E_{s,t}$ is the amount of electricity stored by the battery during t period, θ is the self-discharge rate of the battery, and λ_c is charging efficiency of storage battery. E_s^{min} and E_s^{max} are the upper and lower limits of battery capacity, respectively. E_{on}^{min} and E_{on}^{max} are the upper and lower limits of battery charging power, respectively.

Most formulas in section 2 refer to the energy consumption of various components of the control center, which can be calculated by giving various parameters. The sum can obtain the energy consumption and UPS load demand, which enter the dual-side joint optimal scheduling of source load as variables.

Methodology

Photovoltaic Power Generation Model

The photovoltaic output of each group is positively correlated with light intensity and temperature [23], which can be described as:

$$P_{pv,j,t} = P_{pv,j}^{m} L_{AC,jt} \left[1 + k_T \left(T_{c,j,t} - T_r \right) \right] / L_{stc} \quad (5)$$

where, $P_{pv,j,t}$ is the electric power of the j^{th} group of photovoltaic cells in period t. $P^m_{pv,j}$ is the maximum electric power of the j^{th} group of photovoltaic cells under the standard test environment, i.e., the light intensity is 1000 W/m^2 and the ambient temperature is 25ºC. $L_{AC,jt}$ represents the light intensity of the j^{th} group of photovoltaic cells in period t, k_T is the power temperature coefficient, $T_{c,j,t}$ is the temperature of photovoltaic cell, and T_r is the reference temperature. L_{stc} is taken as 1000 W/m^2, indicating the light intensity under the standard test environment.

Cascade Hydropower Station Model

The output of cascade hydropower stations is proportional to the head of the reservoir and the water flow consumed by power generation [24], which can be expressed as:

$$P_{hyd,i,t} = A_i Q_{i,t} \quad (6)$$

where, $P_{hyd,i,t}$ are the output of the i^{th} hydropower station in t period. $A_i = g\eta_i H_i$, where, g is the gravitational acceleration, η_i is the power generation efficiency of the hydropower unit of the i^{th} hydropower station, H_i is the net power generation head of the hydropower unit of the i^{th} hydropower station in t period (water head changes little in a day), and A_i can be set as a constant. $Q_{i,t}$ is the corresponding water flow.

Scheduling Method

Load Tracking Coefficient

According to the complementarity index and load tracking coefficient, the matching degree between the power generation at the source-end and the user demand during the joint dispatching of hydro and solar at the source-end and the control center at the load-end is quantified [25]. The holistic acceptability index α^j is defined, which is a combination of all $\alpha_{pv}^j + \alpha_{hyd}^j$ of alternative, with $j = 1, 2, ..., n - 1$ and describes the acceptable level of the alternative in 7th and 8th equations, respectively. The output change rate of source cross wind, water, and light is expressed as:

$$\begin{cases} \alpha_{pv}^j = (P_{pv}^{j+1} - P_{pv}^j)/T, \ \ j = 1,2,\cdots,n-1 \\ \alpha_{hyd}^j = (P_{hyd}^{j+1} - P_{hyd}^j)/T \end{cases} \quad (7)$$

where, P_{pv}^j, and P_{hyd}^j are the output sampling values of hydro, and photovoltaic in the j^{th} period, respectively, T is the period for calculating the power change rate, and N is the total number of sampling points.

The rate of change of source-side power generation is expressed as:

$$\alpha^j = \alpha_{pv}^j + \alpha_{hyd}^j \quad (8)$$

Within the output range of cascade hydropower, the excellent regulation performance of hydropower is used to make the total output at the source side after the complementation of wind and water meet the characteristics of levelling, peak cutting and valley filling, that is:

$$|\alpha^j| \leq B_v \tag{9}$$

$$\left| max\,(P_{pv}^j + P_{hyd}^j) - \frac{1}{n}\sum_{j=1}^{n}(P_{pv}^j + P_{hyd}^j) \right| \leq B_f \tag{10}$$

$$\left| min\,(P_{pv}^j + P_{hyd}^j) - \frac{1}{n}\sum_{j=1}^{n}(P_{pv}^j + P_{hyd}^j) \right| \leq B_g \tag{11}$$

where, B_v, B_f, and B_g are the required change rate of total output curve at source side, the upper limit of peak, and valley value after complementation, respectively. The change rate of electric energy consumption on the load side is expressed as:

$$\beta^j = \frac{P_g^{j+1} - P_g^j}{T}, \quad j = 1,2,\cdots,n-1 \tag{12}$$

where, P_g^j is the sampling value of load demand in period j. The load tracking coefficient I_T is expressed as:

$$I_T = \frac{1}{n-1}\sum_{j=1}^{n-1}\left|\alpha^j - \beta^j\right|, j = 1,.,n-1 \tag{13}$$

The closer I_T is to 0, the more consistent the variation characteristics of multi energy complementary generation power and load power within the considered time scale, and the better the load tracking characteristics on the source side. The min-max standardization method is used to normalize multiple targets [26], i.e.:

$$y_j^b = \frac{y_j^a - y_{jmin}}{y_{jmax} - y_{jmin}} \tag{14}$$

where, y_j^a is the real value of the objective function, and y_j^b is the value obtained by normalization of the objective function. y_{jmax} and y_{jmin} are the maximum and minimum values of the corresponding objective function, respectively. After normalizing the corresponding objective function, the weighting method is used to transform it into a single objective problem.

Including solar output restrictions, upstream and downstream water flow constraints and water stagnation characteristics of cascade hydropower, supply and demand power balance, system backup, and tie line transmission, etc.:

$$P_{grid}^{min} \leq P_{grid,t} \leq P_{grid}^{max} \tag{15}$$

$$\sum_{j=1}^{N_j} P_{pv,j,t} + \sum_{i=1}^{N_i} P_{hyd,i,t} + P_{grid,t} = P_{g,t} \tag{16}$$

where, P_{grid}^{min} and P_{grid}^{max} are the minimum and maximum power at the grid side, respectively, and represent the tie line transmission power constraint. Therefore, equation (16) is the system power balance constraint, and excluding network loss, where, N_k, N_j, and N_i are the number of photovoltaic battery packs, and cascade hydropower stations, respectively.

$$P_{g,t} = P_{UPS,t} + P_{oth,t} \tag{17}$$

$$\sum_{=1}^{N_j} P_{pv,j}^{nom} + \sum_{i=1}^{N_i} P_{hyd,i}^{nom} \geq P_{g,t}(1 + R_t) \tag{18}$$

$$0 \leq P_{pv,j,t} \leq P_{pv,j}^{nom} \tag{19}$$

where, $P_{oth,t}$ is the load demand in the area except the control center. The system reserve capacity constraints such as $P_{pv,j}^{nom}$ and $P_{hyd,i}^{nom}$ represent the maximum allowable output power of photovoltaic battery packs, and cascade hydropower, respectively, and R_t is the system reserve rate. Equation (37) is the photovoltaic cell pack output limits.

$$\sum_{t=1}^{T}\sum_{j=1}^{N_j} P_{pv,j,t} \geq (1 - \beta_m)\sum_{t=1}^{T}\sum_{j=1}^{N_j} P_{pv,k}^{nom} \tag{20}$$

$$V_i^{min} \leq V_{i,t} \leq V_i^{max} \tag{21}$$

$$V_{i,0} = V_i^{begin} \quad ; \quad V_{i,T} = V_i^{end} \tag{22}$$

where, β_m represent the photovoltaic rejection rates. The storage capacity constraint in period t is $V_{i,t}$ where, V_i^{min} and V_i^{max}, respectively, represent the upper and lower limits of the storage capacity of the i^{th} hydropower station. The beginning and end storage $V_{i,0}$ and $V_{i,T}$ respectively represent the storage capacity limits at the initial and end times of dispatching of the i^{th} hydropower station. And V_i^{begin} and V_i^{end} represent the storage capacity control values at the initial and end times of dispatching of the i^{th} hydropower station, respectively.

$$P_{hyd,i}^{min} \leq P_{hyd,i,t} \leq P_{hyd,i}^{max} \tag{23}$$

$$Q_i^{min} \leq Q_{i,t} \leq Q_i^{max} \tag{24}$$

$$I_{i,t} = Q_{i-1,t-\tau} + S_{i-1,t-\tau} + R_{i,t} \tag{25}$$

$$\left|Q_{i,t} - Q_{i,t-1}\right| \leq \Delta Q_i \tag{26}$$

$$V_{i,t} = V_{i,t-1} + \left(I_{i,t} - Q_{i,t} - S_{i,t}\right).\Delta t \tag{27}$$

where, $P_{hyd,i}^{min}$ and $P_{hyd,i}^{max}$ represent the upper and lower limits of the output of the i^{th} hydropower station, respectively. $Q_{i,t}$ represents the discharge flow in period t, and Q_i^{min} and Q_i^{max} are the upper and lower limits of the discharge flow of the i^{th} hydropower station, respectively.

The hydraulic connection constraint of upstream and downstream reservoirs, $I_{i,t}$ and $R_{i,t}$ represent the inflow and interval inflow of the i^{th} hydropower station in period t, respectively. τ represents the water flow delay between power station $i-1$ and power station i. $Q_{i-1,\,t-\tau}$ is the discharge flow and $S_{i-1,\,t-\tau}$ is the waste water of the i^{th} hydropower station in period t. ΔQ_i represents the maximum flow variation allowed and $V_{i,t}$ is the water storage capacity of the i^{th} hydropower station in t period, and Δt represents the period step.

Consider different seasons, temperatures, weather and load conditions to construct several scenarios. Normalize the objective function according to the min-max standardization method, and then use the mixed integer linear programming method in CPLEX to simulate and solve the model in this paper under the MATLAB environment. Using the regulating effect of the cascade hydropower on the power supply side and the demand response capability of the control center on the load side, the changes in the value of the objective function on both sides of the source load before and after in various scenarios are obtained.

Results and Discussion

Results

Considering the strong complementary ability of cascade hydropower to the solar and the management center's flexibility in processing load demand delays, the solar fully absorbed in the calculation example according to the installed capacity proportion of cascade hydropower, and photovoltaic and the power demand level on the load side. The main purpose of this paper is to improve the system economy. The weight coefficients of economic benefit and load tracking coefficient are set as 0.9 and 0.3.

In view of the different influence of water volume from cascade hydropower stations on output levels during rainy and dry seasons, the dual influence of weather and season on photovoltaic power generation, and the energy consumption is different due to the set air-conditioning temperature and whether to participates in demand response. Set up the following 6 scenarios, use CPLEX to perform linear programming simulation in MATLAB environment, and the results obtained are as follows.

Scenario 1: spring, rainy season, sunny day, the cooling temperature is 25ºC, which does not participate in demand response.

Scenario 2: spring, rainy season, sunny day, the cooling temperature is 25ºC, which uses the delay method to process the data load.

Through calculation, in one cycle, scenario 2 transferred a total of 8 loads. It can be seen from Fig. 3 that the overall load demand excluding the control center has little volatility, and the power demand is large from 7:00 to 21:00 o'clock.

The cascade hydropower stations are complementary to the solar power, as shown in Figs 4 and 5. Due to

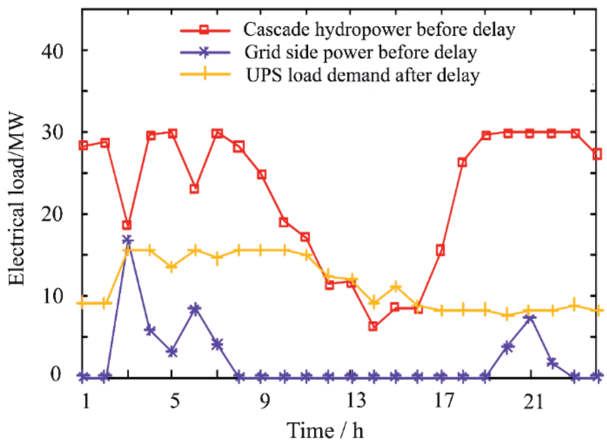

Fig. 4. Scenario 1 output of cascade hydropower, power grid and data center power consumption.

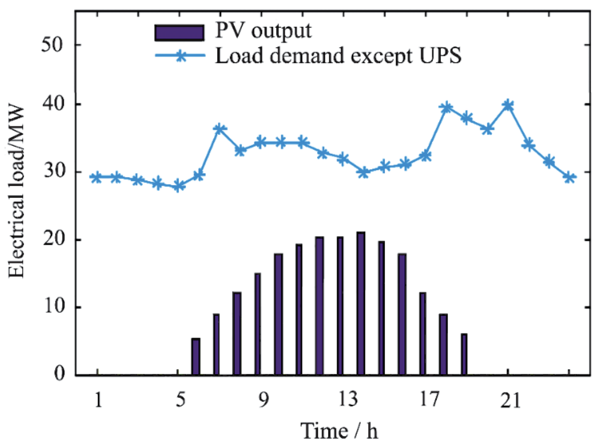

Fig. 3. Scenarios 1 and 2 output of solar, wind and demand of load-side.

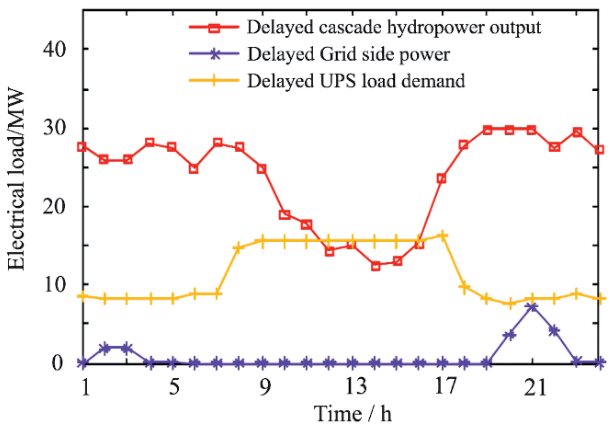

Fig.5. Scenario 2 output of cascade hydropower, power grid and data center power consumption.

the large photovoltaic output during 11:00 to 15:00 o'clock, the cascade hydropower reduces its own power generation, absorbs the sunshine, and uses its own storage capacity advantages to store water to provide greater output for the 18:00 to 24:00 period and reduce the power demand on the main grid.

Comparing Figs 4 and 5, it can be seen that in scenario 1, the control center only considers processing the arriving data load as soon as possible, and the power consumption is concentrated in the period of 3:00 to 11:00 o'clock. Because the photovoltaic output of 3:00 to 6:00 section is 0, the cascade hydropower still cannot meet the regional power demand under the condition of high output, so it is necessary to purchase power from the main power grid. In scenario 2, the control center cooperates with the source side to delay the processing of data load to a certain extent, so that the processing stage is concentrated at 8:00 to 17:00 o'clock, which corresponds to the period of photovoltaic power generation.

Scenario 3: wet season, rainy days during spring, the cooling temperature of the control center is 25ºC, which does not participate in the demand response.

Scenario 4: wet season and rainy days during spring, the cooling temperature of the control center is 25ºC, which uses the delay method to process the data load.

Through calculation, it is found that in one cycle, scenario 4 transfers a total of 5 loads. It can be realised that the output of photovoltaic is 0 in the whole cycle, resulting in a large power supply gap on the source side.

Due to the insufficient power supply at the source side, the power grid side is required to provide power to supplement the system demand. In scenario 3, without delaying the processing time of the data load, the control center concentrates on processing the data load during the period from 1:00 to 10:00 o'clock, and the demand for power is at the peak stage. Scenario 4 cooperates with the system scheduling, runs at full load during the low electricity price period from 1:00 to 7:00 o'clock, and delays the data load to the low electricity price period from 22:00 to 24:00 considering its own server limit.

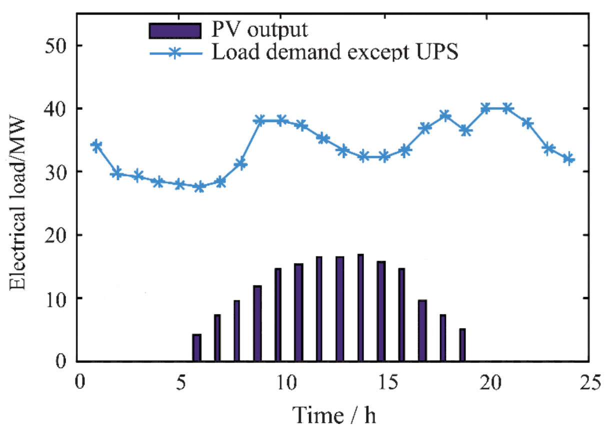

Fig. 6. Scenarios 5 and 6 output of solar and load side demand.

Scenario 5: dry season, and sunny days during winter, the cooling temperature is 28°C, which does not participate in demand response.

Scenario 6: dry, and sunny days in winter season, the cooling temperature is 28ºC, and the load is processed in a delayed method.

Compared with Fig. 2, it can be seen from Fig. 6, that the load demand outside the control center increased significantly in February, and the load decreased slightly at night.

The output of photovoltaic decreases due to the weakening of radiation intensity. Through calculation, it is found that in one cycle, scenario 6 transfers a total of 3 loads. The energy consumption of the control center has decreased to a certain extent due to the improvement of the air conditioning temperature setting as shown in Figs 7 and 8.

Discussion

However, due to the obvious reduction of water volume, the output of cascade hydropower and the

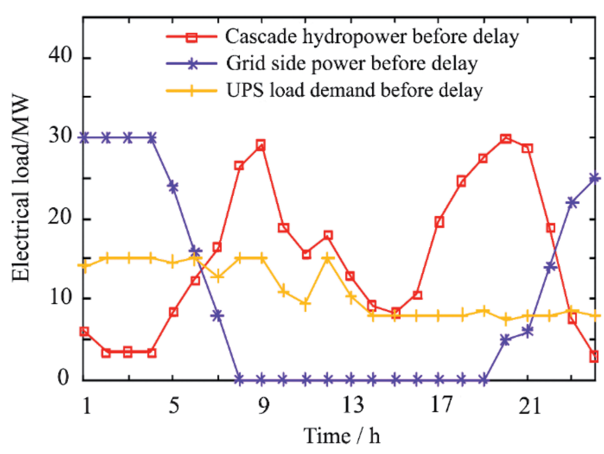

Fig. 7. Scenario 5 output of cascade hydropower, smart grid and data center consumption.

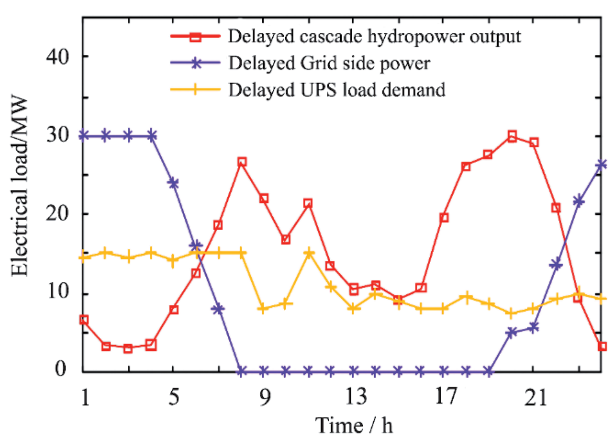

Fig. 8. Scenario 6 output of cascade hydropower, smart grid and data center consumption.

Table 1. Key variables and target values of 6 scenarios.

Sources				Target value		
Scenarios	Cascade hydropower output	UPS load demand	Grid side power	Electricity income/10,000 yuan	Load tracking factor	Abandoned scenery ratio
1	As shown in Fig. 4			85.167	0.0187	0
2	As shown in Fig. 5			86.730	0.0121	0
3				74.740	0.028	0
4				75.595	0.0381	0
5	As shown in Fig. 7			70.104	0.2371	0
6	As shown in Fig. 8			70.340	0.2381	0

regulation capacity on the source side can be ignored. In each scenario, the corresponding relationship between the objective function value and the key variable value (cascade hydropower output, grid-side power, load demand) is shown in Table 1.

It can be seen that due to the use of cascade hydropower to complement the solar power consumption, and the strong demand response capability of the control center, tied with the power exchange of the grid, the full consumption of the photovoltaic in each scenario has been achieved.

From scenario 1 and 2, under the conditions of stable solar output, and sufficient water inflow of cascade hydropower in wet season, the cascade water adjustment capacity and data delay processing mode can be fully utilized to improve the economic benefits of power generation side and achieve better matching between source loads. In scenario 2, the control center uses task delay to cooperate with the regulation of cascade hydropower, so that the output change range of cascade hydropower is significantly smaller than that in scenario 1, and the power exchange with the power grid is reduced. There is a certain demand only in the low-price period at night. Therefore, the economic benefit is greater than that in scenario 1 and the load tracking coefficient is smaller than that in scenario 1.

It can be seen from scenarios 3 and 4 that due to the large fluctuation of solar output, a certain percentage of power needs to be purchased from the power grid side to supplement the system demand. Compared with scenarios 1 and 2, the economic benefits are affected and the load tracking coefficient is also increased. In scenario 4, in order to reduce the system cost, the data center delays tasks at the expense of a certain degree of load tracking. Therefore, the economic benefits, and load tracking coefficient are greater than scenario 3.

From scenario 5 and 6, the output and regulation capacity of cascade hydropower are significantly weakened due to the dry season. Compared with the previous four scenarios, the economic benefits are reduced and the load tracking coefficient is increased. In scenario 6, the control center plays a linkage role with the cascade hydropower at the source side to transfer electricity and improve economic benefits at the cost of a certain degree of load tracking. As a result, the economic benefits and the load tracking coefficient are greater than scenario 5.

A brand-new model for multi-objective optimum scheduling has been proposed here. The suggested model not only takes into account the power generation and power output stability of a hybrid solar-hydro power generation system, but it also takes into account the ecological influence that a hydropower system has on the river downstream. This contributes to an enrichment of the model base for hybrid solar-hydro power generation systems. The improved optimal mode that is suggested in this work and that is also integrated with the dynamic feasible region prevents the destruction of the achievable.

Conclusion

We take into account the system composed of control center, cascade hydropower, and solar, using the synchronized processing of control center and UPS power consumption model. At the same time, energy consumption management of the control center, hydro-cascade and photovoltaic complementation, and the linkage between the source and the load are included. A joint scheduling optimization model of both sides of source load, we proposed a joint dispatching optimization model of multi-energy complementary power generation system of cascade hydro, and solar renewable energy on the demand and power side scheduling system. A mixed integer linear programming algorithm is used, which is useful to calculate and analyses the both side data. In this paper, design case focuses on the impact of different scenarios such as solar, hydro and scheduling system task transfer on the realization of economic benefits. By using our proposed module, the results showed that, with excellent regulation capacity, cascade hydropower plays an important role in improving the performance of the system. The matching degree of economic benefit and source load curve in wet season is obviously better than that in dry season. Using the characteristics of task transfer, the load demand of the scheduling center is matched with the cascade hydropower output and the power exchange of the grid, which can ensure the full consumption of solar, and achieve a better balance between the economic benefits and the source-load curve matching. The more stable photovoltaic output, the more beneficial it is to reduce the adjustment pressure of cascade hydropower and control centers, and improve the economic efficiency of the system. We also focus on the complementation of solar-hydro and task transfer of centralized management centers to achieve optimized operation of source and load ends. Considering task allocation between control center clusters and how other types of loads participate in source-side joint scheduling will become the next research focus.

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Author Contributions

Data curation, AN, YJ, MUS; Formal analysis, AN, MSK, SK, YJ; Funding acquisition, YJ, MUS; Methodology, AN, MSK, SAN; Project administration YJ; Software, FN, IN, Writing – original draft, AN, MUS;

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Availability of Data and Materials

Data supporting reported results can be found in the paper.

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