Research on control strategy of flexible interconnection with multi-source cooperative in various applications

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Abstract

In the face of the high requirements of end-user for power quality and the stable impact of distributed energy resources on the power grid, the flexible interconnection system with multi-source cooperation is proposed, including distributed photovoltaic (PV), hydrogen fuel cell and lithium battery system. This template introduced the research and design of system collaborative control strategy in different working conditions under the premise of high efficiency and reliability. Then, a model of two-zone distribution network system were simulated to verify the effectiveness of strategy, so as to realize the power support of the multi-source collaborative flexible interconnection system to the distribution station area. It improves the power supply reliability of the local power grid, effectively reduces the impact of distributed power on the power grid, and improves the utilization rate of micro power supply.

Keywords

multi source-collaboration, flexible interconnection, distribution network

1. Background

With the promotion and popularization of electrical substitution, the importance of electric energy has been further enhanced in life. At the same time, the demand for power quality and reliability has been increasing at the power distribution network closing to the end-user [1-3]. At present, the scale of distributed energy access in the distribution network is becoming more and more extensive, in the meantime, the amount and utilization rate of electric vehicle charging piles are also gradually rising. The above impacts of source and load has become the development tendency of new power system. Based on the premise of reliable distribution network, how to meet users' requirements for power quality has become the key to the research of new power system.

In view of the current power supply situation of distribution area, combined with the structural characteristics of distribution network, flexible interconnection and mutual sharing between stations have become an effective solution to improve the power quality

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of distribution network [4]. Literature [5] proposed a power optimization cooperative control strategy of flexible interconnection device with energy storage. Wang Chuyang proposed a master-slave control strategy of the flexible DC interconnection system based on the capacity margin of the main station, which optimized the operation mechanism of the main station, and ensured the continuous regulation ability of the DC bus voltage [6]. However, most literatures only focus on the discussion and research of AC grid-connected state of flexible interconnection system, and pay less attention to the technical research under other working conditions such as off-grid, and don't take full advantages of flexible interconnection in distribution network with multi-source access conditions. Therefore, based on the existing technical scheme of flexible interconnection, this paper fully considers multi-source access and multiple application scenarios, then, it carries out modeling simulation and control strategy design under multi-working conditions, finally, a more comprehensive power collaborative optimization is disscussed.

2. System overiew

Flexible interconnection mainly connects two or more transformers together through the control equipment with two-way power flow, which provides power support to each other, and shares mutual capacity [7].

The mainstream topology is that the bidirectional ACDC converters are interconnected by the DC bus. Although the DC side of the system is mostly reserved for the interface of photovoltaic, energy storage and other micro power supplies, no further control strategy is designed. When multiple types of micro power supply are connected to the flexible interconnected system, the increasing schedulable elements lead to more complicated coordinated control. Therefore, it is necessary to consider the optimal control of multi-source system under power balance and voltage stability and seamless switching of working modes.

2.1 Topology Structure

At present, the power supply connected to the distribution network mainly includes distributed photovoltaic, hydrogen fuel cell, lithium battery energy storage system, distributed wind generator system, diesel generator (DG) and other power generations or storage systems. Considering the actual situation, several types of multi-source equipment will be planned and configured according to the application scenario. In this paper, distributed photovoltaic, hydrogen fuel cell and lithium battery energy storage systems are selected to form a multi-source access flexible interconnection system. The specific topology is as follows.

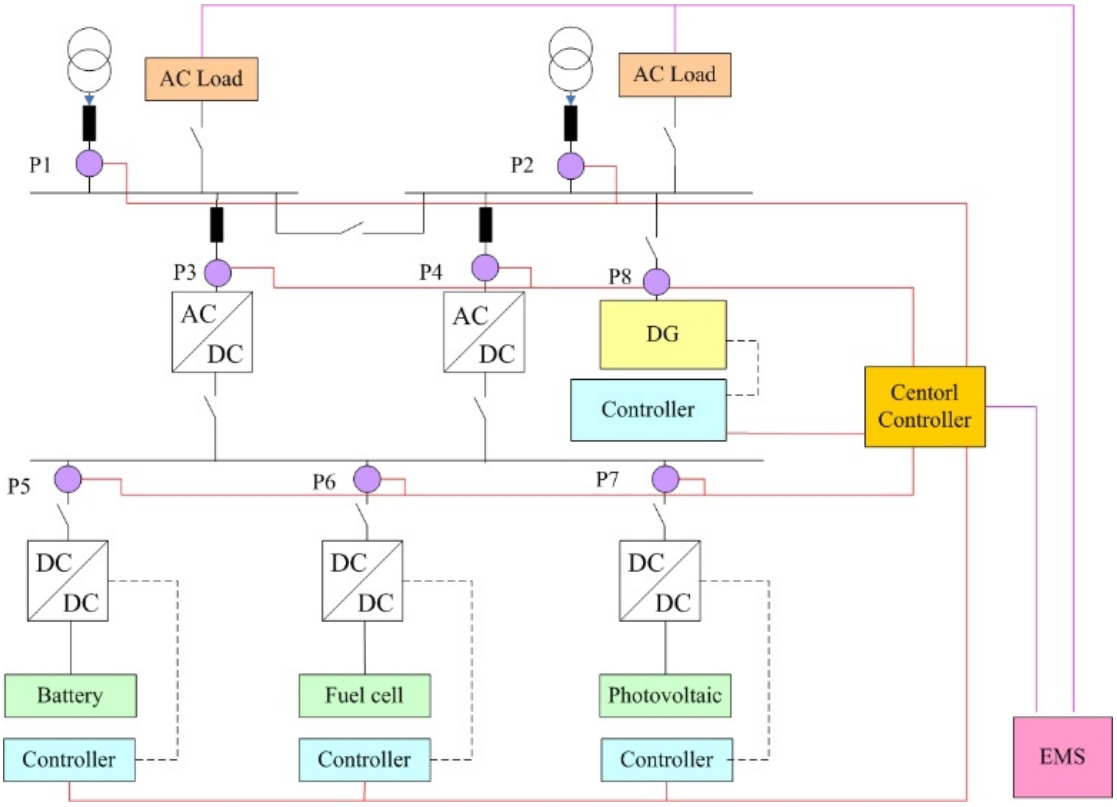


Figure 1: Flexible interconnection system with multiple sources.

2.2 Control Strategy

The general principles of control strategy are described briefly below.

First, when the power supply load is greater than the maximum power that the multi-source flexible interconnection system can provide, it is necessary to consider the load situation comprehensively. According to the load grade standard, the power supply of important load is given priority along with the unimportant load is removed.

Second, aiming at the stability, economy and environmental operation of the system, photovoltaic power generation works in the maximum power point tracking (MPPT) mode to make full use of renewable energy sources. Then, the working mode of lithium battery system and fuel cell are optimized and coordinated

The specific energy management strategy is as follows: In the premise of the stable system, the photovoltaic power generation supplies power to the load firstly. During the peak time of power generation, if the energy of PV is remained, the battery is charged; If the power of PV doesn't meet the load demand, the battery is discharged firstly, the hydrogen energy storage is discharged next. The stable operation of the system is achieved by controlling the working mode of the energy storage converters and AC/DC converters [8-11].

The flexible interconnection system with multi-source can be divided into the following three working conditions according to the interactive connection status with the power grid:

(1) both AC ports are off-grid; (2) one AC port is on-grid, another is off-grid; (3) Both AC ports are on-grid.

3. Simulation Analysis

According to the accessing scale of distributed power sources, a system is modeled including 50kW PV, 75kW lithium battery system, 50kW fuel cell system, two 50kW AC/DC converters and 75kW diesel generator. The maximum power supply capacity of multi-source flexible interconnection system is 100kW. The following simulation model is shown in the following figure, in which the parameters of irradiation intensity are designed according to the 24-hour variation trend under sunny conditions.

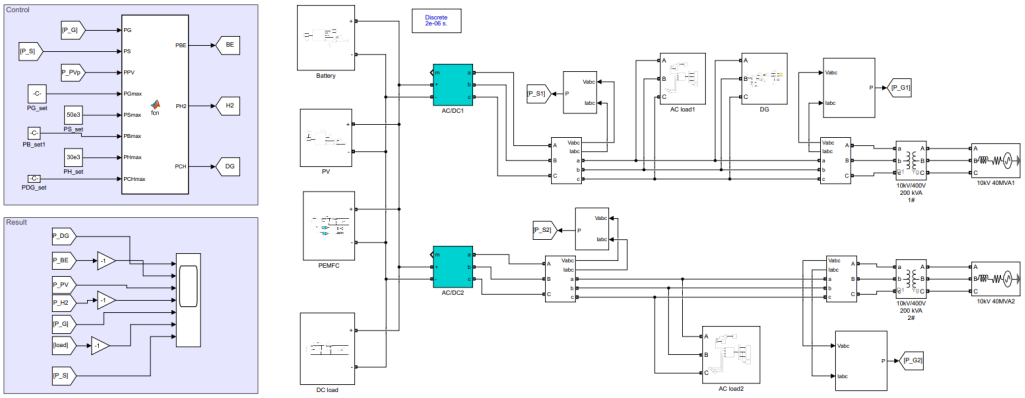


Figure 2: Simulation model.

3.1 Both AC Ports are Off-grid (BPOF)

When the two AC ports of an interconnected system are both off-grid, the AC load status and the predicted load data of the distribution grid must be fully considered. When the load is greater than the maximum power provided by the source of the interconnected system, the power of important load must be provided firstly. At the same time, the contact switch is closed, then the two ACDC converters are connected. Taking into account the cost of energy storage and fuel cell system, direct photovoltaic power supply is given priority during the photovoltaic output period, and energy storage and fuel cell are used to supplement the insufficient photovoltaic output.

It is obvious from the simulation results that the photovoltaic is always in MPPT working mode with the change of irradiation intensity, and the output power is consistent with the change of irradiation intensity. Considering the response speed, the fuel cell is set to constant voltage working mode, and the energy demand of the load is met by adjusting the output power of battery. Before 10:40, the total load is 40kW, which is mainly powered by fuel cell and photovoltaic. Between 10:40 and 13:20, the total load is 70kW, at which time photovoltaic, fuel cell and battery power the load together. After 13:20, the total load increases to 90kW. At this time, the photovoltaic, fuel cell and battery are still used to supply

power to the load, and the power of battery is adjusted to meet the normal energy demand of the electricity load.

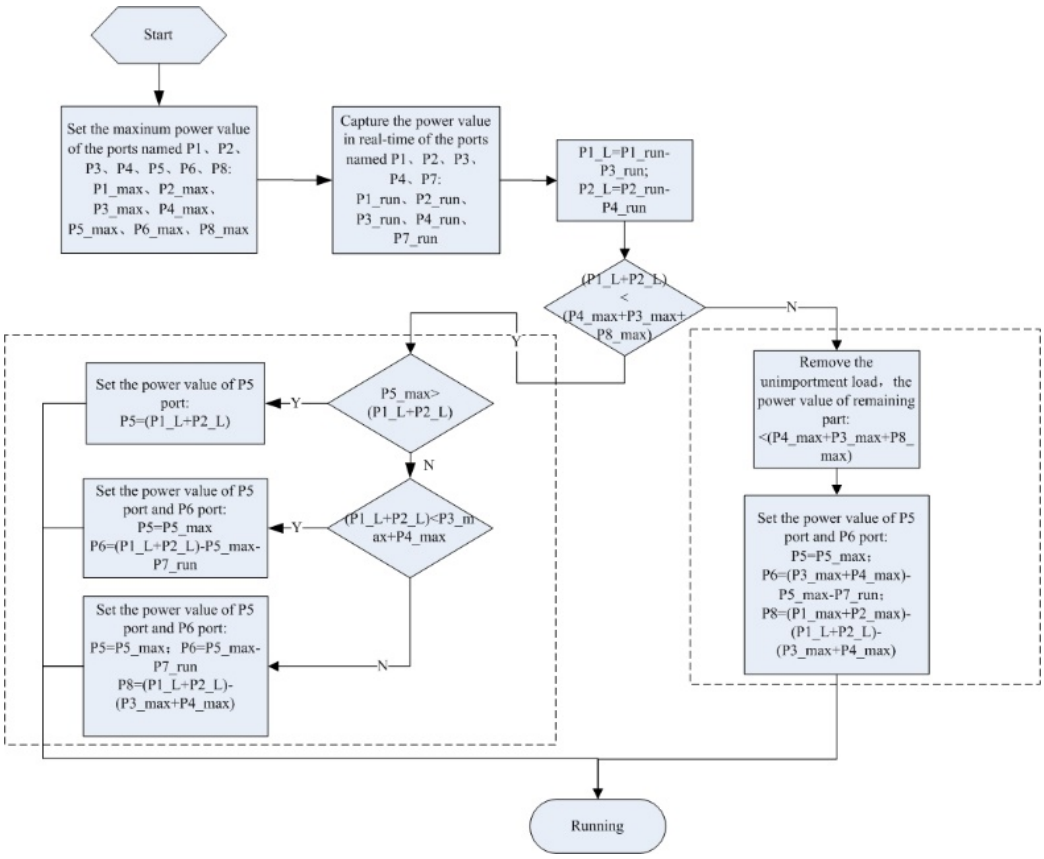
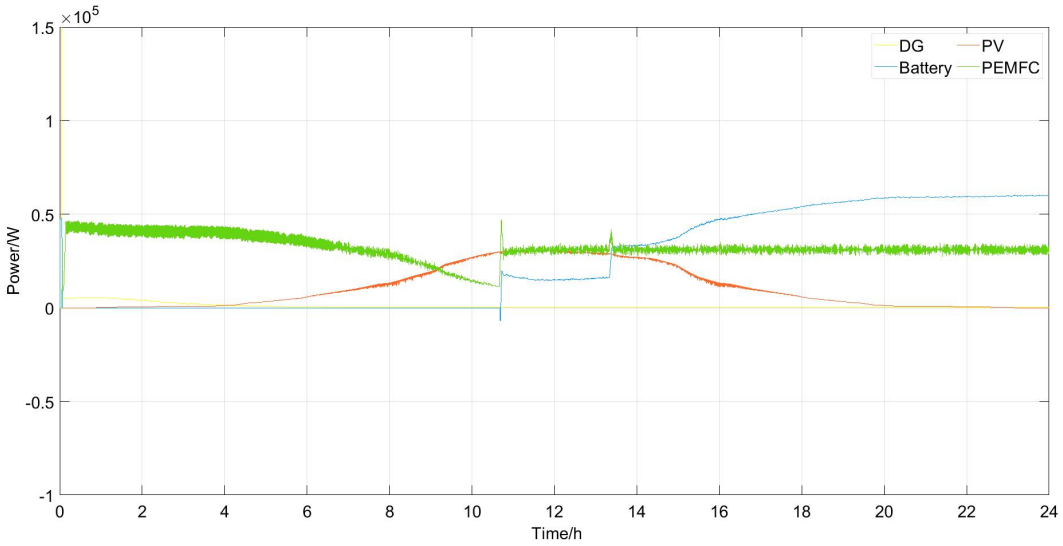
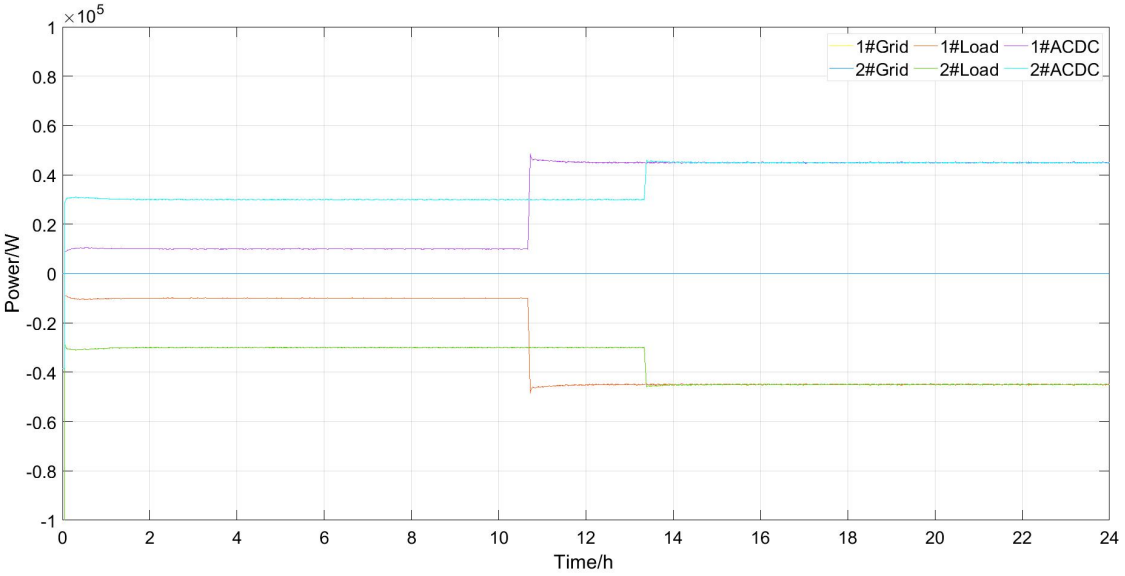


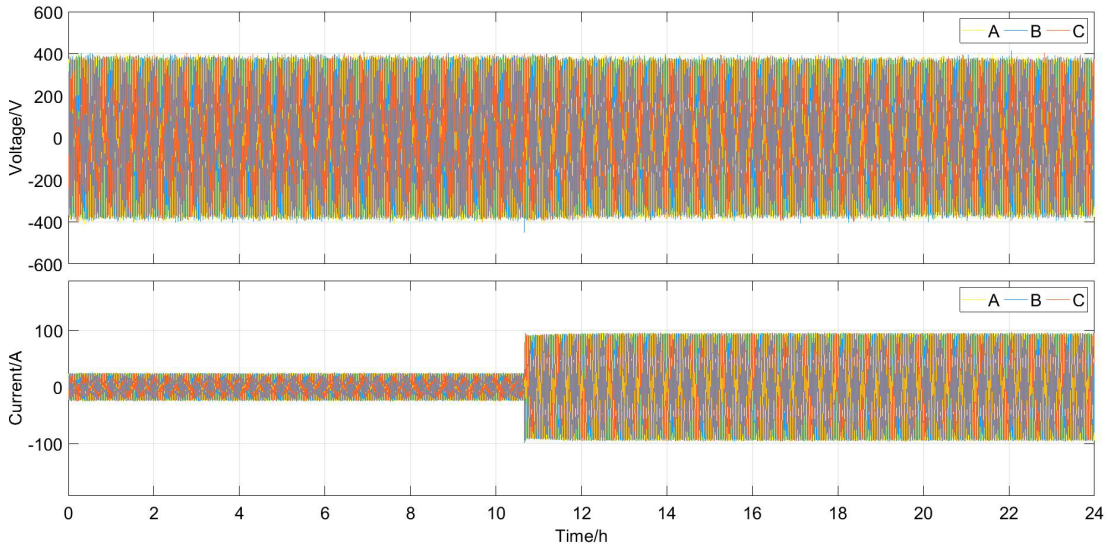
Figure 3: Flow chart of BPOF.



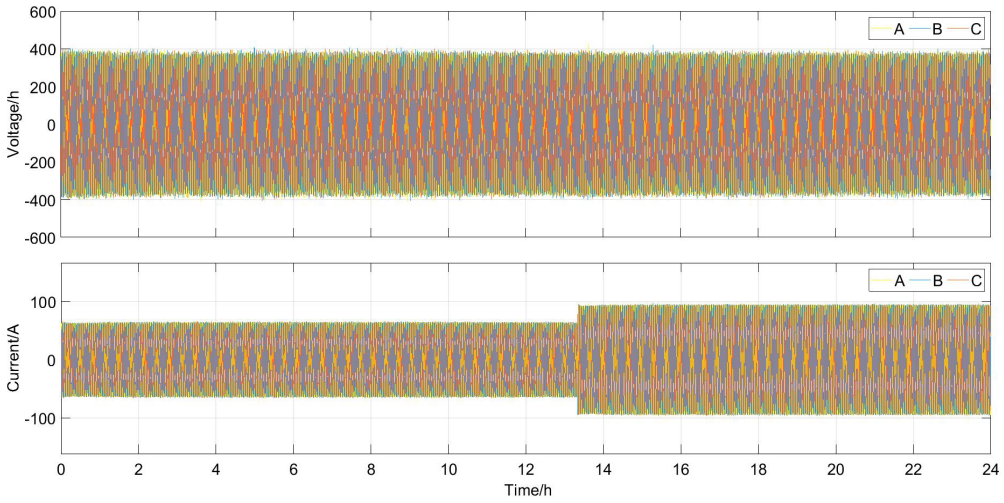
(a) Power of source



(b) Power of grid, load and ACDC



(c) Voltage and current of 1# grid



(d) Voltage and current of 2# grid

Figure 4: Simulation results of BPOF.

3.2 Single AC Port is On-grid (SPON)

In the working condition of SPON, one AC interface is in on-grid, and the other is in off-grid. Both AC ports are connected with flexible interconnection system, so as to realize the uninterrupted power supply of the system.

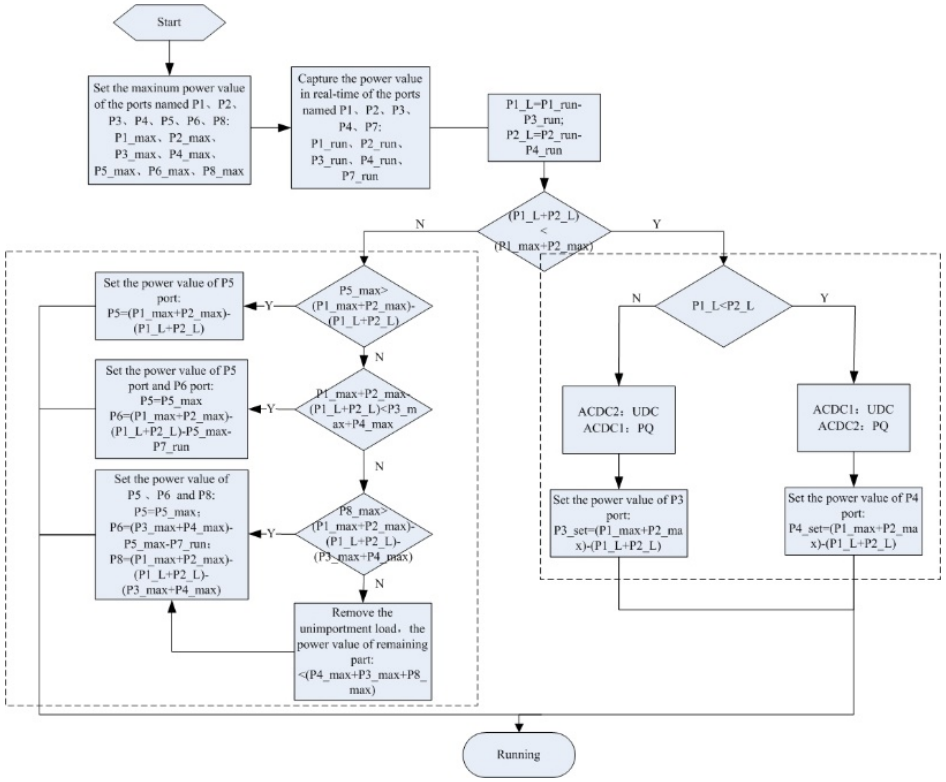
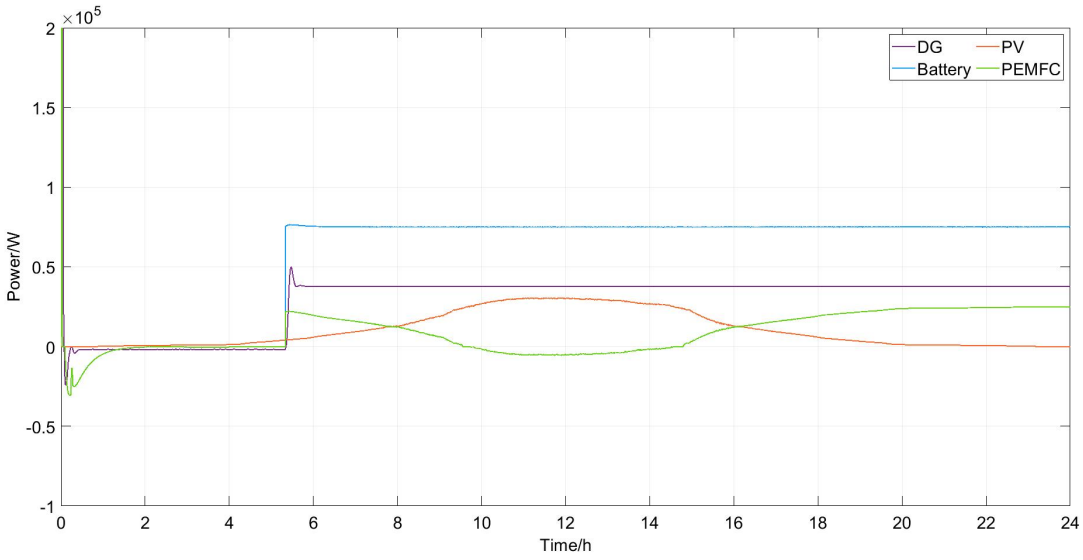
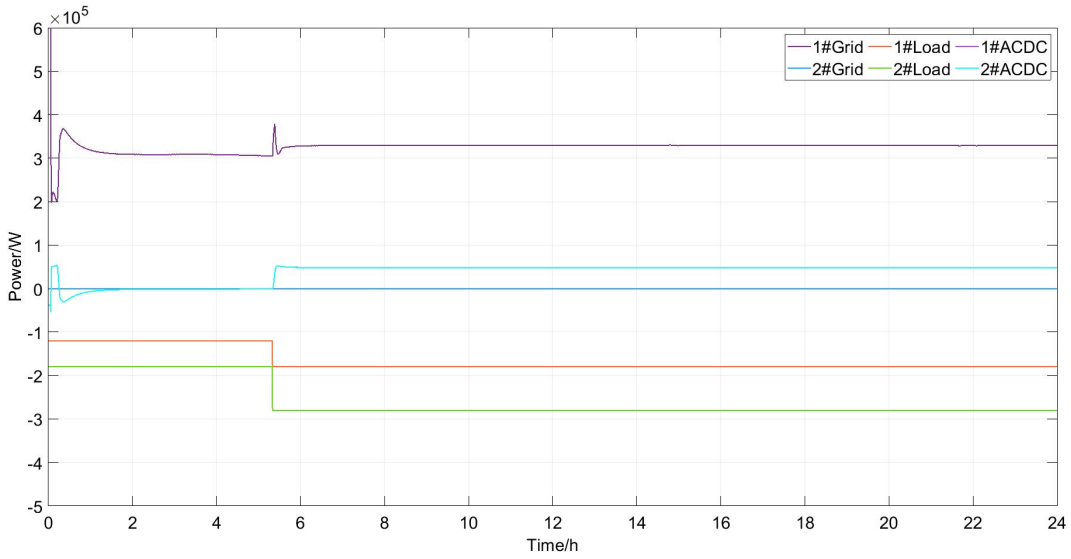


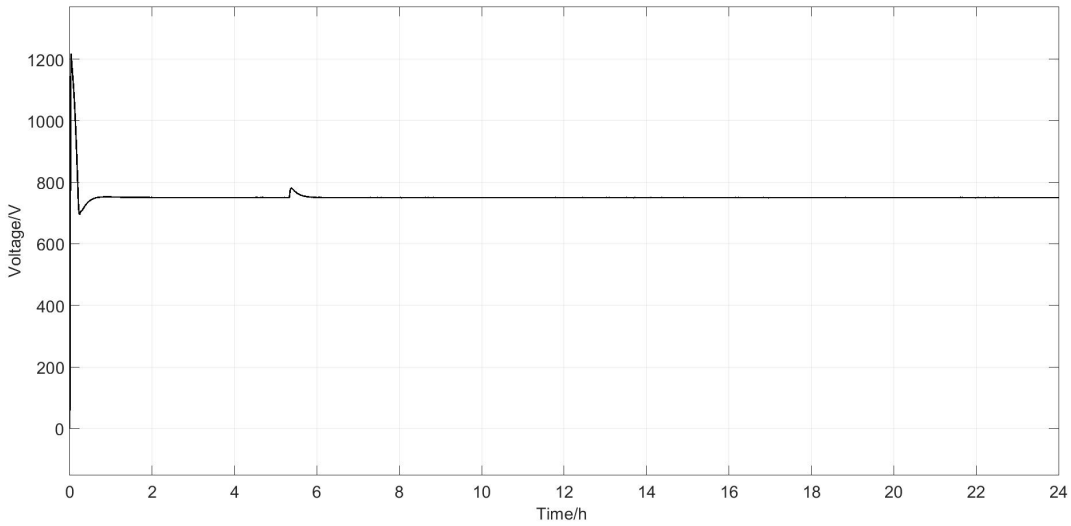
Figure 5: Flow chart of SPON.



(a) Power of source



(b) Power of grid, load and ACDC



(c) Voltage of DC line

Figure 6: Simulation results of SPON.

The simulation results show that when an AC port is off-grid, the system can adjust the output according to different load scenarios to meet the load requirements. At the moment, lithium battery and fuel cell are in constant power control state. Before 5:30, the grid-connected transformer can meet the load demand of the two transformers, and the output of the two ACDC converters are 0. From 5:30 to 14:00, a single on-grid transformer can't meet the load demand, battery and fuel cell are started to supply power, and the output power of fuel cell is reduced during the period of high photovoltaic output, thereby reducing the power supply cost.

3.3 Both AC Ports are On-grid (BPON)

The flexible interconnection system with multi-source is in the grid-connected state and supplies power to two AC ports

1. When the load distribution is uneven between the two transformers, they can be connected through the flexible interconnection system. At the moment, the contact switch is disconnected, and the load balance between the two areas can be achieved through the power flow control on DC bus. Power supply is distributed according to the load. Because of the economical efficiency, battery isn't work in this condition.
2. When the two transformers are in overload state, the contact switch is disconnected. Photovoltaic, energy storage, fuel cell provide power as the emergency power supply to relieve the load pressure of the overload transformer, so that the load ratio of the transformer is kept below 80%.
3. In important scenarios, when the power grid need other power supply prepared, the flexible interconnection system with multi-source is mainly used as backup power, energy storage and fuel cell are in hot standby state. In the event of power cut in grid, the system can supply power to critical loads.

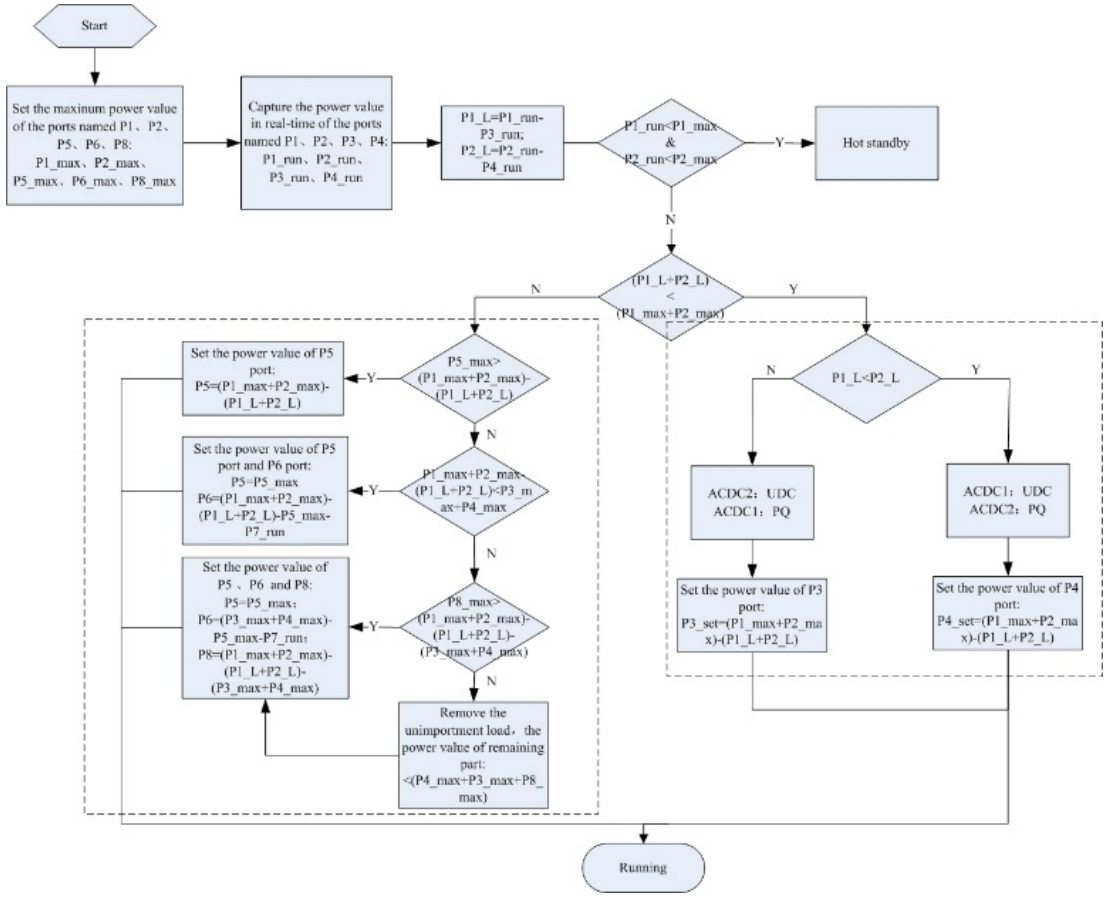
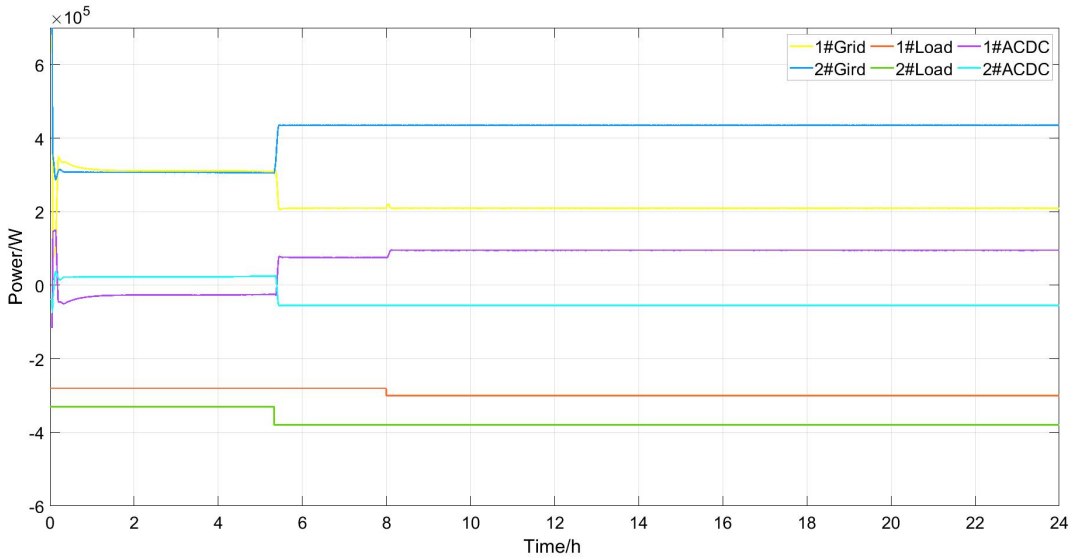
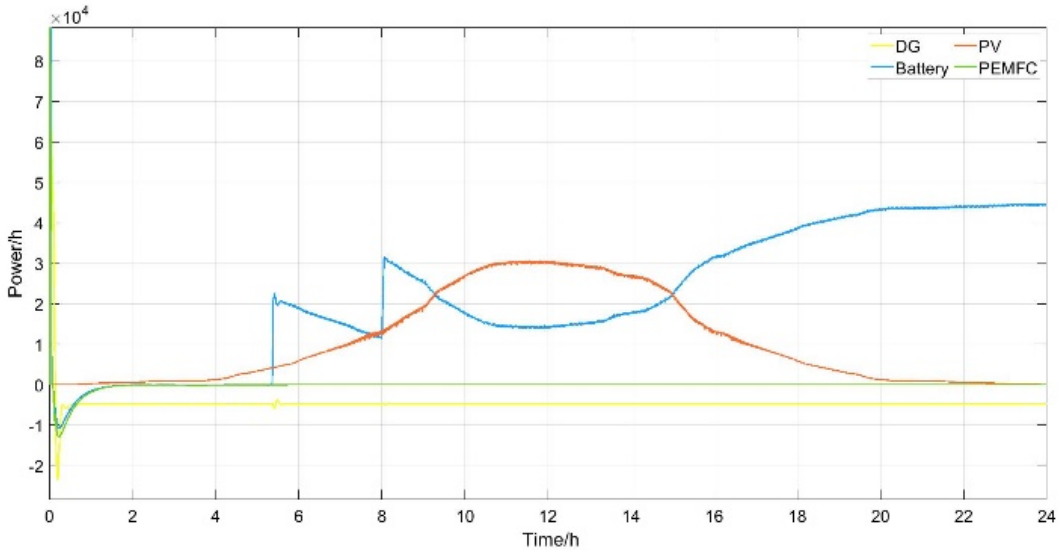


Figure 7: Flow chart of BPON.

It can be seen from the simulation results that the flexible interconnection with multi-source can adjust the power output to meet the load requirements while matching the photovoltaic output power in different load scenarios. At the moment, lithium battery and fuel cell are in constant power control state. Before 5:30, the photovoltaic output is very low, but the load of station 1 exceeds the rated load of transformer by 80%, then part of the overload is transferred to the station 2 through ACDC converters. Between 5:30 and 8:00, the load power increases, If the two transformers are overloaded during continuous operation, the battery should be started firstly for supplementary power supply considering the cost. From 8:00 to 14:00, the photovoltaic output power increases, the power supply of energy storage battery decreases. After 14:00, the photovoltaic output power decreases, and the energy storage battery power continues to rise.



(a) Power of source



(b) Power of grid, load and ACDC

Figure 8: Simulation results of BPON.

4. Summary

Based on the existing flexible interconnection technology scheme of the distribution network, this paper fully considers multiple application scenarios. A hybrid AC-DC power distribution topology of two AC ports with multiple sources was built, next, the working modes and coordinated control strategies of different forms of power supply were optimized in different scenarios, such as photovoltaic, energy storage, fuel cells and diesel generators. Three typical working scenarios of dual AC ports off-grid state, single AC port

off-grid state and dual AC ports on-grid state were selected for modeling and simulation calculation, then the effectiveness and feasibility of the multi-source cooperative flexible interconnection system control strategy were verified.

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