Research on power supply reliability of AC/DC Micro-grid System in "Multi-station Fusion" Project

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Abstract. This paper studied the power supply reliability and structure of the AC/DC micro-grid in the "multi-station fusion" project of smart energy stations. According to study the deep integration of the energy storage unit and the design of the data center, proposed three power supply modes of energy storage unit application to the data center server, and proposed the wiring form of the DC micro-grid. Optimized the configuration and operation mode of the diesel generators and the UPS system. On the basis of ensuring the reliability of the power supply of each system, the construction cost and operation costs were reduced, and the overall energy efficiency of the power system was improved. It provides a reference for the design and operation of "Multi-Station Integration" projects of smart energy stations.

1. Introduction
At this stage, the project of "multi-station integration" of smart energy stations is being carried out in Jiangsu, Henan, Shanghai, Hunan and other provinces. Each project has conducted in-depth research on the structural framework, voltage level, system configuration etc. This paper analyzed the traditional power supply methods and load characteristics of substations, data centers, energy storage stations, charging (replacement) stations, photovoltaic stations, etc., studied the integration and configuration schemes of backup power, DC power and UPS systems in the station, selected the appropriate micro-grid voltage and network topology solutions, proposed the AC-DC micro-grid power supply system structure in the "multi-station fusion" project of smart energy stations. Under the premise of ensuring reliability, the comprehensive energy efficiency of the AC-DC system is improved, the construction and operation costs are reduced. The design and operation of the "multi-station integration" project of smart energy stations will provide reference in the future. This solution has been applied in some pilot project

2. Traditional AC-DC power supply system

2.1. Substation station power system
In substations of 220kV and below, station transformers are generally connected to the low-voltage side of two main transformers, and the capacity of each working transformer is selected according to the load calculated by the whole station. In order to prevent station transformers from quitting operation due to faults, the power supply system of the station is connected by single bus connection. The power load of the station mainly includes transformer cooling device, floating charging device, fire pump, circuit breaker and isolating switch operation and heating, as well as lighting, air conditioning and heating in the substation.
The AC system configuration of the energy storage power station and the charging (changing) power station is similar to the substation.
2.2. AC power supply system of data center
This paper takes B-class data center as an example to illustrate the power supply characteristics of AC power supply system in data center. Class B data centers are usually connected to two power sources and equipped with backup power sources. Two working power supplies are converted into one output to the feeder bus through automatic switch, and the standby power supply is in hot standby state.

The power distribution system of the data center is responsible for providing power supply for air conditioning, fan, lighting and other systems, as well as power supply for various computer loads, servers, emergency lighting and other systems [1].

3. Analysis of AC-DC micro-grid power supply system

3.1. Design principles of AC-DC micro-grids
In order to realize the effective integration of substation, data center, energy storage station, charging (changing) power station and photovoltaic station, smart energy station introduces photovoltaic power supply and energy storage power supply through medium and low voltage AC/DC bus to construct an AC-DC micro-grid system of "source-network-charge-storage".

Smart energy station AC/DC micro network system is composed of on-site and off-site power supply, power supply energy storage system, pv system, station transformer, protection and measurement devices, AC/DC power supply network and so on, provides reliable AC/DC power supply to smart energy station[2][3]. AC-DC micro-grid system, as an important auxiliary infrastructure of smart energy station, is the basis of safe and stable operation of the whole station. The main principles of acdc micro-grid design includes:

(1) Integrate DC and AC load in the station, seek the optimal distribution energy consumption scheme, realize AC-DC load overall balance consumption, and ensure the reliability of system power supply.
(2) Make full use of energy storage transformers, optimize conventional station transformers, integrate UPS power supply, and form AC-DC mutual standby mode through AC-DC micro-grid [4][5].
(3) During peak hours, the energy storage unit supports the whole station load, and the remaining electricity flows into the grid; At the trough, the grid supports the load of the station and charges the energy storage unit. At the same time, the energy storage unit is considered to provide backup power support for the micro grid, improve the power supply reliability of the micro grid.

3.2. Design scheme of AC system
The AC supply system is divided into two parts, 10kV and 400V, and the two parts are connected by two double-split energy-storage and station transformers.

The 10kV power distribution device adopts single-bus sectional connection. The 10kV station transformer are connected from the low-voltage side of the two main transformers of the substation, and another outside 10kV source as the backup power supply.

400V power distribution device adopts single bus section connection, power supply from the low voltage of two double split transformer, meet the requirement of power supply and storage access, and the power supply of auxiliary equipment for substation, data center, energy storage station auxiliary equipment, station communication equipment, protection and control equipment, the electrochemical energy storage system and other load are isolated by isolating transformer.

3.3. Design scheme of DC system
The DC system is divided into three parts: 750V, 220V and 48V. DC 750V is connected by a single bus. After AC/DC conversion, the power is taken from AC 400V bus. After DC/DC transformation, the DC 750V bus provides power to DC load such as data center, DC lighting and charging pile.

DC 220V is connected by a single bus section connection. One power supply is taken from DC 750V bus after DC/DC transformation, and the other power supply is taken from 400V ac bus, providing power supply for 48V communication devices, and the measurement and control devices.

The data center server is powered by DC, with one power supply leading to DC 750V bus and another from 400V AC bus.
3.4. AC-DC micro-grid network topology
See figure 1 for the network topology diagram of AC-DC micro-grid system.

![Network topology of AC / DC microgrid system](image)

This topology diagram contains the AC system and the DC system. The energy storage battery is directly connected to the AC system through the converter; the data center, dc lighting, dc charging pile and photovoltaic system are connected to the dc system.

4. Data center server power supply research

4.1. Power supply mode of the data center server

Class B data centers shall be powered by dual power sources and shall be equipped with backup power sources. When the normal power supply fails, the standby power supply shall undertake all the power load required for the normal operation of the data center.

To enhance power supply reliability of the data center, DC micro network using double supply mode, the important loads adopts the model of "double redundancy" (module redundancy, power supply redundant). Considering that the traditional AC UPS power supply system has the characteristics of high energy consumption, low reliability, difficult maintenance and expansion, and high construction cost, at the same time, the diesel generators in a cold standby state for a long time, and the UPS battery in float charging condition for a long time, need to spend a lot of cost for maintenance every year, so cancel the traditional data center UPS system and the diesel generator power supply mode. In this section, the access type, voltage level and reliability of data center server power supply are deeply analyzed, and the power supply scheme of data center server is proposed.

The data center server equipment is composed of electronic components, always be the DC load, equipment supply module input support ac/dc power, through the dc power supply can reduce the frequency electric energy conversion, improve the energy efficiency and the infrastructure reliability, so the DC power supply is recommended for the energy station, and replace data center UPS battery with storage battery at the same time, Use the remaining power of the storage station to provide emergency power supply, Realize the battery fusion of storage power station and the data center.

4.2. Study on storage access voltage level

This section proposed three modes of the storage unit participate in the power supply of data center server, the storage unit connected directly to 10kV busbar in model 1 (figure 2), the storage unit
connected directly to 400V busbar in model 2, model 1 and 2, the storage unit are standby power as the center of the data, replace traditional diesel generators, but still keep the traditional UPS power supply; Mode 3 connects the energy storage unit directly to 400V bus, cancels the traditional diesel generator and UPS system, and adopts DC micro-grid (figure 3).

![Figure 2 Access mode 1 of the Energy storage unit to data center](image)

This paper firstly obtains the power supply reliability of each link through monte carlo simulation method [6], and then calculates the power supply reliability of different modes.

\[
T(e_i) = \frac{\psi_{e_{max}}(e_i)}{\psi_{e_{max}}} 
\]

(1)

\(T(e_i)\) is the valve level of component \(e_i\), the \(\psi_{e_{max}}\) is the total energy supplied by AC-DC micro-grid, and the \(\psi_{e_{max}}(e_i)\) is the maximum total energy supplied by the system after the failure of component \(e_i\). The reliability of component \(e_i\) is defined as

\[
I_{prob}(e_i) = \frac{1-T(e_i)}{\sum_{j=1}^{M}(1-T(e_j))} 
\]

(2)

\(M\) represents the set of all components.

The failure rate of different components and the input quantity of repair time are shown in the table below.

| Element               | Failure rate/(times/year) | Replacement/repair time /h |
|-----------------------|---------------------------|----------------------------|
| AC circuit breaker    | 0.006                     | 4                          |
| DC circuit breaker    | 0.2999                    | 10                         |
| DC/DC converter       | 0.0237                    | 2.55                       |
| AC transformer        | 0.015                     | 10                         |
| Photovoltaic units    | 0.518                     | 167                        |

According to the calculation, the power supply reliability of the energy storage unit connected to the 10kV bus is 84%, and the power supply reliability of the energy storage unit connected to the 0.4kV bus is 92%. Therefore, it is recommended to use the energy storage unit connected to the 0.4kV bus. In recent years, the data center server load tends to adopt DC power supply mode, mode 3 recommended access data center energy storage unit adopts AC 400V input of DC load, low voltage 750V(220V) DC output form, can guarantee the power supply reliability of the data center, and increasing the efficiency of the power system, reduce diesel generators and UPS battery configuration at the same time, so the model 3 is recommended.
5. Conclusion
This paper studied the traditional power supply mode and load characteristic of transformer substation, data center, energy storage station, charging (exchanging) power stations, developed the AC/DC power supply system structure in the smart energy station "multistation fusion" project. Through the study of the integration of the energy storage unit and the data center in AC/DC micro-grid, put forward the three models of energy storage unit applying to the data center server power supply, optimizing the configuration of the diesel generator and storage time, and the configuration and operation of the UPS battery. On the basis of ensuring the power supply reliability of each system, the construction and operation cost are reduced, and the comprehensive energy efficiency of the power supply system is improved, providing reference for the design and operation of the "multi-station fusion" project of smart energy station.

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