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APPLICATION OF HIGH-VOLTAGE DC POWER SUPPLY IN DATA CENTER COMPUTER ROOM

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Abstract: This article mainly discusses the development background of high-voltage DC power supplies, introduces the origin of high-voltage DC power supply products, the development schools of foreign high-voltage DC power supplies, and the domestic high-voltage DC power supplies of 240V represented by China Telecom and 336V represented by China Mobile. 2 major series in the industry. It also discusses the advantages and disadvantages of high-voltage DC power supplies compared to UPS uninterruptible power supplies in the construction of data center computer rooms, and predicts the future application methods of high-voltage DC power supplies in data center computer rooms. Finally, a data center high-voltage DC power distribution design case is used as a reference for readers to understand high-voltage DC power supplies and their working applications.
Keywords: Electrical engineering; High voltage DC power supply; Data center computer room

1 INTRODUCTION

With the advancement of social science and technology, people's rapidly increasing demand for data has promoted the construction pressure of data center computer rooms in the communication industry. However, the huge data market and the unpredictable data growth trend have also greatly stimulated the communication industry. The Internet industry is determined to invest in the construction of data center computer rooms and put them into action. In the power distribution construction of the data center computer room, the use of the original UPS solution is no longer in line with the company's profit objectives. Traditional UPS power supply has obvious shortcomings such as large initial investment, low later utilization rate, poor reliability, low operating energy efficiency and difficult maintenance. Therefore, as an alternative to UPS, high-voltage direct current power supply HVDC emerged as the times require, and has attracted the attention of the power supply industry and the communication industry.

In this article, the application prospects of high-voltage DC will be fully discussed through four parts: the background of the birth of high-voltage DC power supply, the development branches and advantages and disadvantages of high-voltage DC at home and abroad, the comparison between high-voltage DC power supply and UPS power supply, and data center power distribution design cases. References are provided for readers who have entered the industry or are interested.

2 THE BIRTH BACKGROUND OF HIGH-VOLTAGE DIRECT CURRENT POWER SUPPLY HVDC

The communications industry and most telecommunications design institutes habitually use UPS uninterruptible power supplies as power supply solutions in the power distribution construction of data center IDC rooms. Most server manufacturers in the world also use AC power supplies, but UPS power supplies have always had the following question:

2.1 Reliability is not High

UPS must first rectify AC into DC to charge the backup battery. At the same time, the rectified DC is inverted into AC output. In this double conversion, the fault point is higher, and the backup battery is not directly connected to the load end. As long as the UPS inverter circuit If it fails, the entire UPS system will be unable to output power.

2.2 High Construction Cost

Due to the first reason, when designing UPS power distribution solutions, most users use dual-machine parallel backup, and some users use four-machine backup to ensure the reliability of the UPS. This causes excessive margin and overinvestment problems in UPS. Each UPS requires an independent set of backup batteries, so both equipment investment and construction investment are relatively large.

2.3 Low Operating Energy Efficiency

Since UPS uses a parallel system, if two systems work at the same time, the average load rate is less than 30%. If a four-machine parallel system is used, the load rate of a single machine is even less than 15%. Under this load rate, the efficiency of the entire UPS is extremely low, and it is around 80% for a long time.

2.4 Poor Maintenance Feasibility

When a UPS fails, most of it requires repairs by the manufacturer, and the user or the agency company cannot intervene. Therefore, under the dual pressure of economic pressure and safety pressure, operators have to seek a novel alternative that has a certain technical foundation. It is derived from the 220V DC operating power supply and the electrical performance requirements refer to 48V DC communications. The high-voltage DC communication power supply of power supply has emerged at the historic moment and has become the energy-saving pioneer and promotion driving force for operators.

3 THE DEVELOPMENT PROCESS OF HIGH-VOLTAGE DC TELECOMMUNICATIONS AT HOME AND ABROAD

3.1 Development of Foreign High-Voltage DC Communication Power Supplies

In 1999, at the 21st INTELEC 99 (Copenhagen) conference: France Telecom proposed the high-voltage DC concept for the first time. Subsequently, Japan's NTT Company proposed a high-voltage DC test voltage value of 270V.
In 2003, the 25th INTELEC 03 (Yokohama) Conference: Swedish companies such as POWERBOX, NETPOWER, ERICSSON and other companies proposed the use of 300VDC system power supply.
In 2005, at the 27th INTELEC 05 (Berlin) conference: France Telecom proposed the use of 300-400VDC.
In 2007, at the 29th INTELEC 07 (Rome) conference, the American INTEL company proposed the use of 400VDC power distribution in telecommunications and data centers; Swedish NETPOWER LABS AB and others introduced the experience of running a 9kW HVDC UPS 350VDC for one year.

3.2 Development of Domestic High-Voltage Dc Communication Power Supply

China Telecom started piloting 240V (working voltage 204-288V) high-voltage DC communication power products in Jiangsu Telecom in 2007. And in 2011, group purchasing was launched for the first time. And led the production of the YD/T 2378-2011 "240V Power Supply System for Communications" standard.
China Mobile has launched 336V (working voltage 300V-400V) in 2008, and launched group procurement for the first time in 2013. It is now applying for approval of the 336V standard.
China Telecom adopts the 240V voltage level, mainly to adapt to the UPS power supply transformation of the original 220VAC server that China Telecom has a large inventory. In order to adapt to the original 220VAC AC server power supply, the input voltage specification is set in the range of 204-288VDC. Compatible with the input rectified voltage of 220VAC server power supply.
Rectified voltage formula of 220VAC: VDC = 2VAC (Formula 1)
The input range of global servers is generally 90 ~ 265Vrms. The result of substituting Equation 1 is 127 ~ 374VDC, so the telecommunications 240V specification voltage fully adapts to the working range of the original server power supply.
China Mobile has a small number of original data center computer rooms, so there are relatively few 220VAC servers, so China Mobile does not have the old UPS.
To meet the pressure of transformation, a higher voltage 336VDC high voltage DC power supply can be directly applied.

4. COMPARISON OF VARIOUS PARAMETERS BETWEEN HIGH-VOLTAGE DC COMMUNICATION POWER SUPPLY AND UPS

The advantages of high-voltage DC communication power supply compared to UPS can be reflected in four aspects: reliability, construction cost, operating energy consumption and maintenance safety. Details are as follows.

4.1 Reliability Comparison Between High-Voltage Direct Current Communication Power Supply (HVDC) and UPS

Take 100KVA UPS and 100KW HVDC as examples.

4.1.1 Dual-unit parallel 100KVA UPS reliability

Mobile dual-machine parallel mode uses two 100KVA UPSs to operate in parallel. Assuming that their load rate is 60%, the load rate of a single machine is 30%. Assuming that the single-unit UPS reliability R(t) is 0.99, the reliability calculation formula of the dual-unit parallel system is as follows:

$RN + X(t) = \{1 - [1 - R(t)]^{X+1}\}C_{N+X}^{X}$ (Formula 2)

N+X——Two-machine parallel system, N is redundancy is 1,

The calculation result is:

$R2(t) = \{1 - [1 - 0.99]^{2}\}C_{2}^{2}$

$R2(t) = 0.9999$

4.1.2 Reliability of 100KW HVDC

For a 100KW high-voltage DC communication power supply, it is assumed that the load rate is 60%, and the single-machine reliability R(t) is 0.99.

⑴ If 12KW/20A 240V module is used, the system requires a total of 10 modules (1 redundant module). When the load rate is 60%, that is, 60KW, 5 modules are required, and the remaining 5 modules are redundant modules.

According to Equation 2, the result is: $R10(t) = \{1 - [1 - 0.99]^{6}\}C_{10}^{6}$

$R10(t) = 0.99999999979$

⑵ If a 15KW/37.5A 336V module is used, the system requires a total of 8 modules (1 redundant module). When the load rate is 60%, that is, 60KW

, 4 modules are required, and the remaining 4 modules are redundant modules.

According to Equation 2, the result is: $R8(t) = \{1 - [1 - 0.99]^{5}\}C_{8}^{5}$

$R8(t) = 0.9999999944$

4.1.3 The reliability comparison of the three power supplies is shown in Table 1 .

Table 1 Reliability comparison of three power supplies

Distribution plan	Reliability value R(t)
Dual-machine parallel UPS	0.9999
240V high voltage DC communication power supply	0.99999999979
240V high voltage DC communication power supply	0.9999999944
Reliability comparison (240V)	(1-0.9999)/(1-0.99999999979)=476190 times
Reliability comparison (336V)	(1-0.9999)/(1-0.9999999944)=17857 times

It can be seen that whether it is a 336V high-voltage DC communication power supply or a 240V high-voltage DC communication power supply, its reliability is far higher than that of a dual-machine communication power supply. Parallel UPS power supply.

4.2 Comparison of Energy Consumption Between UPS and High Voltage DC Operation

Also taking a 100KVA UPS and a 100KW high-voltage DC communication power supply as an example, assuming the load rate is 60%, the operating energy consumption between the two can be calculated. See Table 2 below :

Table 2 Comparison of operating energy consumption between UPS and high-voltage DC communication power supply

	Dual-machine parallel UPS	240V power supply	336V power supply
Single machine load ratio	30%	60%	60%
Overall machine efficiency	≤80%	≤95.1%	≤96%
Annual electricity consumption (kWh)	657000	552681	547500
Electricity fee 1.5 yuan/kWh	985500	829021	821250
Annual savings on electricity/ bills		156479	164250

Energy saving rate	/	15.87%	16.67%

As can be seen from the above data, if the power consumption of a 100KW data center computer room is powered by a high-voltage DC communication power supply, the electricity bill saved in one year can be equal to the purchase price of the high-voltage DC communication power supply.

4.3 Comparison of Construction Costs of Dual-Unit Parallel UPS and High-Voltage DC Communication Power Supply

The difference in construction costs between the two is threefold:
(1) For dual-machine parallel UPS, the initial investment is 2 sets of UPS with the same capacity and 2 sets of backup batteries. The initial investment in high-voltage DC communication power supply only requires a power supply system with the same capacity and 2 sets of backup batteries. In terms of system configuration alone, the price of a UPS has been increased.
(2) There is an additional set of UPS in the configuration. In addition, because the UPS uses a 384V backup battery pack, if a 2V battery is used, the number is 192 cells, while the 240V high-voltage DC communication power supply only requires 120 cells under the same circumstances, and the 336V high-voltage DC communication power supply also requires 192 cells. In this case, only 168 sections are needed, and the construction cost of high-voltage DC communication power supply is also less than that of UPS.
(3) Because the daily working efficiency of the UPS is low, excessive power loss will lead to an increase in the power consumption of the air conditioner. Similarly, using Table 2 above as an example, the comparison of air conditioner power consumption is shown in Table 3.

Table 3 Comparison of air conditioner power consumption

	Dual-machine parallel UPS	240V power supply	336V power supply
Single machine load ratio	30%	60%	60%
Annual electricity consumption (kWh)	657000	552681	547500
loss efficiency	≥20%	≥4.9%	≥4%
Power consumption (kWh)	131400	27081	21900
Air conditioner increases power	22.5KW	3	2.5

4.4 Maintenance Comparison Between UPS and High-VOLTAGE DC Communication Power Supply

The UPS circuit is complex and requires maintenance by the manufacturer's professionals in case of failure. The high-voltage DC communication power supply mode is similar to the -48V communication power supply.
The expansion capacity of dual-machine parallel UPS is basically zero, while the high-voltage DC communication power supply adopts a modular design, and the capacity can be expanded at any time as long as there is enough space in the installation rack.

5 DATA CENTER COMPUTER ROOM HIGH-VOLTAGE DC COMMUNICATION POWER DISTRIBUTION DESIGN CASE

Taking a 400m2 data center room as an example, the size of the server cabinet is 1100mm × 600mm. After deducting the operating activity space and power distribution cabinet space, it can accommodate approximately 125 server cabinets with a total capacity of 500KW. Considering the usage margin of 20%, it is 400KW.
Set the rated capacity of the server cabinet to 4KW/unit.
The power calculation formula of computer room air conditioner is as follows:
According to the empirical method "power and area method": QT = Q1 + Q2
QT——Total air conditioning power of the computer room, W;
Q1——Equipment load (=equipment power×0.8), W;
Q2——Environmental load, W (≈0.18KW/m2 × machine room area).
Q1=125×4×0.8×0.8=320KW; (consider 20% margin when using)
Q2=0.18KW/m2 ×400=72KW;
QT=392KW.
Lighting power:

Calculated based on 20W/m2, it is 400×20=8KW.

I

Calculation formula of battery capacity C: C = K [1 + δ(- 25)] Root 1.25 (Formula 2)
I——load current, when the battery is discharged, calculated based on 2V discharge voltage, 240V power supply, I240=400KW/240V=1667A; 336V power supply, I336=400KW/336V=1190A;
T——Discharge time, the data center computer room is 2 hours;
K——discharge coefficient, when the discharge lasts for 2 hours, the value is 0.6;
δ——Temperature coefficient, taken as 0.01;
t——Temperature reference value, taken as 15℃.
Substituting the data into equation 2, we get,
1667 root 2
C240 = 0.55 strands [1 + 0.01 strands (15 - 25)] strands 1.25 ~ 9000Ah
1190 root 2
C336 = 0.55 strands [1 + 0.01 strands (15 - 25)] strands 1.25 ~ 6000Ah
According to the charging current of 0.2C10, the total charging current of the 240V power supply battery is 1800A, which requires 45 40A modules. The total charging current of the 336V power supply is 1200A, which requires 32 37.5A modules.
Therefore, using a 240V high-voltage DC power supply, the total system capacity is 1340KW. If a 20% margin is considered, it is 1675KW. If a 300KW system is used, 6 sets are required (one set does not have full capacity).
Using 240V high-voltage DC power supply, the total system capacity is 1280KW. If a 20% margin is considered, it is 1600KW. If a 300KW system is used, 6 sets are required (one set does not have full capacity).

6 CONCLUSION

This article reviews the development background and development status of high-voltage DC power supplies at home and abroad. It also made a comprehensive comparison with UPS in terms of reliability, operating energy consumption, construction cost and reliability, proving the advantages of high-voltage DC communication power supply. Finally, it briefly introduced high-voltage DC communication through a design case of a data center computer room. How to choose a power supply.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Du Qiu. Development and Application Technology of High Voltage DC Power Supply System in IDC Computer Room. June 2014.
[2] 240V DC Power Supply System for Communications. Place of publication (Beijing): Beijing University of Posts and Telecommunications Press, 2011.