Research on Influence Factor of System Efficiency and Power Loss Factor for DC Power Supply System of Data Center

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Abstract. In order to increase system efficiency and decrease the power loss factor of power supply system of data center, the influence factor should be researched under different conditions. On one hand, system efficiency and power loss factor are compared under different load factors. On the other hand, DC power sources with different voltage level and capacity are implemented into power supply system. Many tables and curves of test results are presented in this paper to help us analyze the influence factor under different conditions of power sources and load factor of data center. Finally, many useful conclusions are drawn and operation suggestion for economic operation of data center is also given in this paper.

Keywords: System Efficiency, Power Loss Factor, DC power supply system

Introduction

In previous years, most data center operators focused on providing enough computing capacity to meet demand primarily, while in recent years, power consumption of data centers has been increased rapidly due to progress in information and telecommunications service, the cost of powering these data centers has gained greater attention[1]. In a typical data centers, less than half of the power is delivered to the IT equipment which includes microprocessors, memory and disk drives. The rest of the power is lost in power conversion, distribution, and cooling [2].

Using a DC micro grid is a possible way for data centers to combine the need for high reliability and the possibility to decrease the losses. With the development and application of DC Microgrid, more and more researches focus on the HVDC power distribution and supply system for some specific load center[3-5]. And DC power supply systems for large data center have proven to be an energy efficient option to conventional AC power supply systems for data centers[6]. DC power supply systems which are shown in Fig. 1 are used in some large data centers, supplying power to IT equipment. The 380V AC steps down from a MV feeder first passes through an uninterruptible power supply (UPS) and step down to 240/336 V DC. Different voltage levels are required for electronic load, so at last a power supply unit (PSU) steps the voltage down to 3.3/5/12V DC again. In a DC data center the AC/DC converter of the UPS is used to supply the DC to the entire facility.
DC system has less power conversion. Therefore, the DC system is theoretically more efficient than the AC system. Moreover, the DC system can expect to save space and simplify the system configuration, because it does not need the transformer required in the AC system.

The Selection of Indicators to Evaluate Energy Efficiency of Power Supply System

Power Usage Effectiveness (PUE) is the recommended metric for characterizing and reporting overall data center infrastructure efficiency according to the Green Grid[7]. PUE is defined by the following formula:

\[
PUE = \frac{\text{Total data center energy consumption or power}}{\text{IT energy consumption or power}}
\]  

The PUE can range from 1.0 to infinity. The optimal PUE value is 1.0 which means 100% efficiency is reached (i.e., all power used by IT equipment only). Currently, there are no comprehensive data sets which show the true spread of the PUE for datacenters. Some preliminary work indicate that many data centers may have a PUE of 3.0 or greater, but with proper design, the PUE value can be decreased to 1.8 ~ 1.6. The Green Grid also considers the development of metrics that provide more granularity for the PUE and DCiE metrics by breaking it down into the following components:

\[
PUE = \frac{1}{DCiE} = \text{Cooling Load Factor (CLF)} + \text{Power Load Factor (PLF)} + 1.0
\]

Where all factors are ratios that are divided by the IT Load and:

• 1.0 represents the normalized IT Load. Effectively this is the IT Load Factor (ILF) but is always 1.0.

• Cooling Load Factor (CLF) is the total power consumed by chillers, cooling towers, computer room air conditioners (CRACs), pumps, etc. divided by the IT Load.

• Power Load Factor (PLF) is the total power dissipated by switch gear, uninterruptible power supplies (UPSs), power distribution units (PDUs), etc. divided by the IT Load.

In this paper, the dc power distribution systems, to be used as an energy conservation technology at data centers, is described. The PLF is suitable to be chosen to compare and evaluate the energy efficiency problem, it can be given as follow equation:
\[
PLF = \frac{Power \ loss \ of \ System}{IT \ equipment \ power \ loss} = \frac{1 - \eta_s}{LF \times \eta_L}
\]  

(3)

In the above formula, the value of \( \eta_s \) is equal to the system efficiency, which is defined as the ratio of output power to input power of UPS. The value of LF is equal to the load factor, the value of \( \eta_L \) is equal to the value of the transmission efficiency of the PDU.

**Test of system efficiency and analysis of power loss factor under different loads**

In this section, some tests will be presented to analyze the influence factor of system efficiency and Power Loss Factor for power supply system.

Because DC system is highly efficient and reliable, China Mobile Communications Group and China Telecom Corp have used the DC system in data centers. There are lots of voltage ranges of HVDC system all over the world, such as 380V system, 350V system, 300V system and 240V system, and 240V HVDC systems and 336V HVDC systems are running on line in China[8]. Several single-module DC power sources with different voltage level and power capacity are applied to substitute for UPS based AC distribution mode for a typical data center of high-tech park with many enterprises. Three kinds of power source modes of DC supply systems are presented to compare efficiency and PLF in this paper according to voltage level and power capacity in the DC side of UPS conversion module, such as 240V/5.8kW, 240V/15kW and 336V/15kW[9].

In the DC power supply system which used the power source of 240V/5.8kW, the transmission efficiency of the PDU is 96%. The efficiency tends to stable when its load factor was more than 50%, and the system efficiency reached to 93.9% when the load factor reached to 60%. The results are shown in Fig.5. We can calculate the value of the PLF according to the measured data and the formula for the system. The results are shown in Fig.6. The results show that the value of PLF decreases when the load factor increasing and it can be 0.08 when its load factor was about 80%. The value of PLF and PUE are lower contrasted with the AC system. Losses are lower in the this system.

![Figure 2. System efficiency of the system using 240V/5.8kW power source.](image-url)
In the DC power supply system which used the power source of 240V/15kW, the transmission efficiency of the PDU is 96%. The efficiency tends to stable when the load factor was more than 30%, and the efficiency reached to 96.37% when the load factor reached to 60%. The results are shown in Fig.7. When the system efficiency is stable, the efficiency is higher than the system using 240V/5.8kW power source. The value of PLF under different load factor is shown in Fig.7. The results show that the value of PLF decreases when the load factor increasing and it can be 0.05 when its load factor was about 80%. The value of PLF and PUE are lower contrasted with the system which used the power source of 240V/5.8kW. Loss are lower in the this system.

In the DC power supply system which used the power source of 336V/15kW, the transmission
efficiency of the PDU is 96%. The efficiency tends to stable when its load factor was more than 30%, and the efficiency reached to 97.39% when the load factor reached to 60%. The results are shown in Fig.7. The results show that the value of PLF decreases when the load factor increasing and it can be 0.035 when its load factor was about 80%. Under the same load factor, the system using 336V/15kW power source has the highest system efficiency and the lowest loss.

![Graph](image1)

Figure 6. System efficiency of the system using 336V/15kW power source.

![Graph](image2)

Figure 7. PLF of the system using 336V/15kW power source.

**Analysis on influence of different power sources**

The higher the voltage level and capacity of the power source, the higher system efficiency it can be achieved at a lower load factor. The system efficiency reaches different value under different sources. The system efficiency reached to the maximum value when the load factor reached to 60%. The highest system efficiency is achieved to 93.9% under the system which used 240V/5.8kW power source. The highest system efficiency can be achieved to 97.39% under the system which used 336V/15kW power source.

The values of PLF are different under different sources. The value of PLF decreases when the load factor increasing. When the load factor reached to 60%, the value of PLF was 0.106 in the system which used 240V/5.8kW power source, the value of PLF was 0.064 in the system which used 240V/15kW power source, the value of PLF was 0.045 in the system which used 336V/15kW power source. The value of PLF decreases when the voltage and capacity increasing.

**Conclusions**

In this paper, the results show that there two factors affecting the system efficiency and PLF
value of DC power supply system for Data Center: load factor and the voltage level and capacity of the power source for DC power supply system.

Load factor can affect the system efficiency of DC power supply system and the PLF value. The statistic results show that the system efficiency increases as the load factor increases when the factor is lower than 40% under different power sources. When the load factor is more than 50%, the system efficiency tends to be stable. And when the factor is more than 70%, the system efficiency decreases, however, the rate of decrease is very small. The value of PLF decreases as the load factor increases.

The voltage level and capacity of power source also has significant effects on the system efficiency of DC power supply system and PLF value. When the voltage level is 240 V, capacity of 15 kW leads to higher power supply system efficiency and lower PLF value with a similar load factor. When the capacity is 15 kW, voltage level of 336 V leads to higher power supply system efficiency and lower PLF value with a similar load factor.

In summary, the operation suggestion of DC power supply system is that try to increase the voltage or rated power of power source and make the load factor higher than 40%. Thus, higher system efficiency and lower PLF value could be obtained so as to get a better PUE value of the data center.

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References


