A Design Scheme for Improving Load Capacity of Large Current Generator

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Abstract. The main technical indicators of high-current output equipment include current amplitude magnitude, current output accuracy, current carrying capacity, current rise time parameters, harmonic output capability and other technical indicators, among which the carrying capacity is an important technical indicator of current output. When the substation on-site equipment is tested, the on-site test cable is long and the load impedance is large. This imposes a high requirement on the carrying capacity of large-current devices. With the connection mode and external load unchanged, the load capacity of high-current devices is increased. The technical requirements and production difficulty of the equipment are greatly increased, and the overall weight and volume of the high-current equipment are also increased, which increases the difficulty of on-site testing of the high-current equipment. This article mainly discusses a test method for improving the carrying capacity of high-current devices. By changing the test method, the load carrying capacity of the device can be improved, and the difficulties in making high-current devices and the difficulty of on-site testing can be reduced.

1. Introduction
The development of power system and equipment testing technology determines that the new large current generator is essential. Load capacity is a very important technical indicator for large current generating equipment [1]. The load capacity has a great influence on the overall design, volume and weight of the large current equipment. The load capacity is proportional to the port voltage, the weight of the equipment and the volume. Based on the convenient and practical requirements, the load capacity is a key indicator for the overall test of the secondary system of substation. This paper optimizes the design of large current generating equipment by changing the output mode of large current equipment [2].

2. Comparison of load capacity of different schemes

2.1. Traditional large current generator scheme
The traditional scheme is as follows:
The traditional large current generator have a negative electrode and a positive electrode the output current is equal to the total output current of the scheme and XL is the self inductance of the line.

2.2. Distributed large current generator scheme

The internal current amplifier of the large current generator is divided into N independent current amplifiers, and the current amplifier 1 is one until the current amplifier N. Wire load current I1, I2... In, load total current I, I1+I2+In=I=n×I1, XLn are line self inductance.

2.3. Test method

Test requirements: Two independent current sources, with synchronous output, same phase, same amplitude, external load line, 2 25mm2, 20 meters long current line as load, current line loop parallel, test line without moving test line, the shape of test loop is not changed.

Because the output value of the experimental current source is small, and the output is quite different from 1000A, the method of increasing frequency is adopted to improve the inductance of the line and increase the intuition of the test.

Traditional scheme simulation test method:
Distributed design scheme simulation test method:

![Diagram of distributed design scheme simulation test method]

**Figure 4.** Distributed scheme simulation test method.

2.4. **Test results**

The test results in the 50Hz frequency environment are as follows:

| Current value (A) | Load A voltage (v) | Load B voltage (v) | Current value (A) | Voltage when load A and load B are in parallel (v) | Voltage difference (v) |
|------------------|--------------------|--------------------|-------------------|--------------------------------------------------|------------------------|
| 5                | 0.057              | 0.057              | 10A               | 0.060                                            | 0.003                  |
| 10               | 0.117              | 0.118              | 20A               | 0.121                                            | 0.003                  |
| 15               | 0.175              | 0.175              | 30A               | 0.182                                            | 0.005                  |
| 20               | 0.235              | 0.236              | 40A               | 0.242                                            | 0.006                  |
| 25               | 0.294              | 0.295              | 50A               | 0.304                                            | 0.009                  |
| 30               | 0.353              | 0.353              | 60A               | 0.365                                            | 0.012                  |
| 35               | 0.413              | 0.414              | 70A               | 0.424                                            | 0.010                  |
| 40               | 0.471              | 0.472              | 80A               | 0.485                                            | 0.013                  |

The test results in the 100Hz frequency environment are as follows:

| Current value (A) | Load A voltage (v) | Load B voltage (v) | Current value (A) | Voltage when load A and load B are in parallel (v) | Voltage difference (v) |
|------------------|--------------------|--------------------|-------------------|--------------------------------------------------|------------------------|
| 5A               | 0.062              | 0.062              | 10A               | 0.067                                            | 0.005                  |
| 10A              | 0.125              | 0.126              | 20A               | 0.135                                            | 0.009                  |
| 15A              | 0.188              | 0.189              | 30A               | 0.204                                            | 0.015                  |
| 20A              | 0.251              | 0.253              | 40A               | 0.272                                            | 0.019                  |
| 25A              | 0.314              | 0.316              | 50A               | 0.340                                            | 0.024                  |
| 30A              | 0.377              | 0.379              | 60A               | 0.409                                            | 0.030                  |
| 35A              | 0.441              | 0.443              | 70A               | 0.477                                            | 0.034                  |
| 40A              | 0.503              | 0.507              | 80A               | 0.547                                            | 0.040                  |

The test results in the 200Hz frequency environment are as follows:
Table 3. The test results in the 200Hz frequency environment.

| Current value (A) | Load A voltage (v) | Load B voltage (v) | Current value (A) | Voltage when load A and load B are in parallel (v) | Voltage difference (v) |
|-------------------|--------------------|--------------------|-------------------|-------------------------------------------------|------------------------|
| 5A                | 0.076              | 0.077              | 10A               | 0.090                                           | 0.013                  |
| 10A               | 0.153              | 0.154              | 20A               | 0.180                                           | 0.026                  |
| 15A               | 0.229              | 0.232              | 30A               | 0.271                                           | 0.039                  |
| 20A               | 0.303              | 0.304              | 40A               | 0.361                                           | 0.057                  |
| 25A               | 0.380              | 0.381              | 50A               | 0.450                                           | 0.069                  |
| 30A               | 0.456              | 0.458              | 60A               | 0.543                                           | 0.085                  |
| 35A               | 0.533              | 0.536              | 70A               | 0.634                                           | 0.098                  |
| 40A               | 0.610              | 0.610              | 80A               | 0.726                                           | 0.116                  |

When the load is separately connected, the voltage drop caused by the inductance of the line is about 10% lower than that of the line inductor when the load is parallel. Moreover, the greater the inductance of the line, the greater the voltage difference is produced by the two test schemes.

It can be seen that when the large current generator is used to output 1000A or even larger current, the power loss of the line can be greatly reduced by the design method proposed in this scheme [3].

3. Detailed design of large current generator

3.1. Design of power supply module

Figure 5. Block diagram of power supply module.

After three-phase 380V rectifier, the transient current of the main power circuit is reduced by soft starting circuit. The power supply voltage is then fed to a large number of high-power DC/DC switching power modules through a large capacity aluminum electrolytic capacitor group. Each group of high-power DC/DC switching power module has the function of busbar voltage detection and over-voltage protection, which is used to control the time sequence of the power supply of a number of high-power DC/DC switching power supplies. To avoid the malfunction of fuses and circuit breakers caused by the high transient impulse current during the startup of high-power DC/DC switching mode power supplies. Each group of high-power DC/DC switching power supply is started in turn [4]. The high-power DC/DC switching power is supplied to the current amplifier separately after starting. Switching power supply has the advantages of high power density, high efficiency, small size and multiple protection functions, which provides very high technical support for the reliability of the device.
3.2. Design of current amplifier module

![Figure 6. Block diagram of current amplifier.](image)

Each transient current output device is connected by a plurality of main power current amplifier units in parallel. Modular design can further reduce costs, reduce design difficulty, reduce maintenance costs and facilitate further upgrading of products in the future [5].

The main power current amplifier is mainly composed of power part and signal control part. After the input of the main power supply, the fluctuation of the busbar voltage is reduced to the minimum to avoid the influence of the fluctuation on the bus voltage to the output precision. And the support capacitor is parallel to the thin film capacitor with high ripple current and low ESR, which provides a fast current response to the transient response, and further reduces the pressure of the output fast transient response to the support capacitor [6]. Then, the inverter H bridge circuit is used to invert the DC current into an AC current output with adjustable amplitude, phase and frequency. The H bridge is composed of high-power semiconductor MOS, and each bridge arm is connected in parallel with a plurality of high-power semiconductor MOS pipes to expand the output power. Because the high power semiconductor MOS tube is a positive temperature coefficient device, that is, with the increase of the temperature of the high-power semiconductor MOS tube itself, the conduction resistance $R_{dson}$ of the high-power semiconductor MOS tube itself also rises. In this way, each bridge arm will form an automatic current sharing effect. Therefore, the high power semiconductor MOS tube of each bridge arm can be used in many direct parallel ways to expand the output power. The driving part of the high-power semiconductor MOS tube needs to be driven separately. The S end of the high-power semiconductor MOS tube needs series resistance to the negative end of the drive circuit. It is used to avoid the current circulation caused by the conduction delay of the high-power semiconductor MOS transistor. The current circulation will affect the driving part of the high-power semiconductor MOS
tube, and even cause the high-power semiconductor MOS tube misleading or False closing to damage the whole main power circuit. The output of the H bridge is square wave with different pulse width. After the multilevel LC filtering, the square wave can form an AC current with a certain ripple current. The ripple current depends entirely on the choice of multistage LC filters. Different types of selection can be used to reduce the cost or increase performance for different requirements. It has considerable flexibility. After multilevel LC filter is filtered, it can output to the output of the whole transient current generator.

4. Conclusion
A design method for improving the output power of current generating equipment is proposed by this optimization scheme. This scheme is suitable for large current generating equipment and suitable for other current generating equipment [7]. When the proportion of inductance of the line is larger, the lower the power loss is. In the substation test, it is very important to reduce the line loss power and improve the output power of the large current equipment.

References
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