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Application and Performance Analysis of Silicon Carbide Power Electronic Devices in Power Systems

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Abstract: As a new wide-band semiconductor material emerging in recent years, Silicon carbide has the advantages of high voltage resistance, high temperature resistance, high power, high breakdown field strength and high thermal conductivity. This paper looks forward to the current status and future development of its application in power system, and its rapid development will bring great influence to the power system. Based on the booming development of silicon carbide materials, it can provide an insight into the possible future development trend of power electronic devices.

Keywords: Silicon Carbide; Power Electronics; AC Transmission; DC Transmission; Solid-State Transformers

1. Current status of silicon carbide power electronics development

As the core of modern power electronic devices, new power electronic devices are one of the extremely active topics in the field of power electronics. New materials to gallium nitride, silicon carbide as the main representative, of which silicon carbide as a wide-band semiconductor materials, because of its excellent physical and electrical properties, has received widespread attention. Silicon carbide material power electronic devices to realize the application of the main: power diodes, silicon carbide MOSFET devices, silicon carbide IGBT, silicon carbide crystal box tube and other power electronic devices.

2. Silicon carbide power electronics in the power system application examples and analysis

Power electronic devices in the power system play a role in the power conversion and control circuits, in order to play to protect the normal operation of power equipment, to play an effective role in energy saving

2.1 DC Transmission

In 2010, China successfully operated the world's first ±800kv/4750A UHV DC transmission project, and the subsequent ±1100kv UHV DC transmission project, which is the world's top in terms of transmission distance, transmission capacity, voltage level, and technical level. The converter valve is mainly composed of crystal box tube, damping capacitor, voltage equalizing capacitor, damping resistor, voltage equalizing resistor, saturation reactor, crystal box tube control unit and other components. The traditional silicon-based SCR converter valve needs to face a large number of components in series and the problem of high conduction loss. With the development of silicon carbide power electronic devices, larger capacity, higher operating temperature and higher power density of the new silicon carbide GT, GTO device research and development, so that the voltage resistance of a single device has been improved, significantly reducing the number of devices required, streamlining the structure of the converter valve, while reducing the conduction loss, for the development of high-voltage DC transmission to create better conditions. At the same time, based on the development of high-voltage DC transmission and the birth of lightweight DC transmission technology will also be with the silicon carbide MOSFET/IGBT performance enhancement, for its further expansion of the application of new opportunities.

2.2 Solid-state transformer

Transformer is the use of the principle of electromagnetic induction to change the alternating current voltage device, in electrical equipment and wireless circuits, commonly used for lifting and lowering the voltage, matching impedance, safety isolation and other roles. Solid-state transformer is a power electronic technology as the core of the power conversion device, its high-frequency transformer on the basis of power electronic conversion technology to integrate, so it is also known as power electronic transformer (PET). Compared with the tradi-

tional transformer, it has the advantages of small size, light weight, etc., and also has the advantages of high power supply quality, automatic current limitation, reactive power compensation ability, easy automatic monitoring and so on. Its application brings many new changes to the power system and helps to solve many problems faced by the current power system. However, high cost, low reliability and other defects are its future to solve the problem of perfection. With the progress of technology, the cost will be gradually reduced, the reliability will also be improved, to replace the traditional transformer has become possible, and has a broader application prospects.

2.3 Flexible AC Transmission

The current direction of alternating current (AC) varies periodically from time to time, and its average current in a cycle is zero. Its difference from direct current is that its direction changes over time, while direct current has no such change in current direction. In the past, the AC power grid basically can only rely on slow, intermittent and imprecise equipment for mechanical control of the grid, greatly limiting the utilization of the line, and can not be effective control of the negative impact of equipment failures, which is very likely to cause major production safety accidents. Thus, a combination of power electronics technology, microprocessing and microelectronics technology, communications technology and control technology and the formation of flexible AC transmission came into being, the birth of this technology to enhance the stability of the AC power grid and reduce the cost of power transmission, thereby improving the quality and efficiency of power transmission.

The proposal and development of flexible AC transmission system (flexible AC transmission system), referred to as FACTS, which utilizes flexible AC transmission technology, has been closely related to the rapid development of power electronics technology. The core components of this system are various FACTS controllers based on power electronics or other stationary devices. Common FACTS include static reactive power compensators, static synchronous compensators, fixed series compensation devices and controllable series compensation devices. These electronic devices can control one or more parameters of the transmission system, which is very effective in solving the problem of the basic uncontrollability of the traditional transmission grid, and also provides a more flexible way of suppressing low-frequency oscillations in the power system.

3. Evaluation of applications

3.1 Application Prospects

Being in the modern society, the use of electricity spreads in every aspect of our life. Similarly, the conversion and use of electric energy and its effective transmission through low-loss methods is the main direction of our future exploration and research. The introduction of new power electronic devices represented by silicon carbide materials provides us with new ways to utilize electric energy. Whether it is in the field of automobiles that are gradually moving into electrification or flexible AC transmission as an emerging technology of AC transmission system or modern solid-state transformers, power electronics will play a pivotal role. Power electronics is an important support technology for the national economy, and an important support technology for modern science and technology. Whether it is for high-tech fields or traditional industries have produced a huge role in promoting. As a specific application of power electronics technology, all kinds of power electronic devices are the core devices of many power systems. Domestic and foreign research on silicon carbide semiconductor material is gradually increasing investment, and many new results have emerged. These new results will boost the new silicon carbide devices in the application and industrialization of further breakthroughs, the research community and industry's enthusiasm and attention to its unabated. It is foreseeable that the new silicon carbide devices will open up new applications in many popular areas of power electronics applications, such as electric vehicles, LED lighting, and so on. In short, the development of silicon carbide power electronics is on the rise.

3.2 Improvement direction

Although, silicon carbide power electronics in the power system application and promotion is in full swing, but the development of it, we should be rational, can not ignore the objective law of things and blindly forward. To realize that although silicon carbide has many ad-

vantages, but it also has a bottleneck to limit its own development. Therefore, how to overcome the bottleneck has become the main direction of improvement. First of all, the price of silicon carbide is still more expensive than silicon-based materials as well as many problems in the manufacturing process, which causes its excellent characteristics are mainly used in high-end applications, which limits its further promotion, so the need to reduce the cost of production of silicon carbide, improve the manufacturing process. Secondly, in the specific application in the power system, can also further optimize the design scheme. For example: the second generation of solid-state transformers based on silicon carbide MOSFET, so that it does not depend on the device or topology in series, it can improve the switching frequency, simplify the system structure; Similarly, the use of IGBT voltage source type converter composed of DC transmission streamline the converter station structure, to solve the reactive capacity to the receiving end of the problem, able to make the lightweight DC transmission as an emerging technology applications bring new opportunities. Under the general trend of energy saving and emission reduction, silicon carbide power electronic devices can make the power system develop in the direction of smarter and more energy-saving.

4. Conclusion

This paper introduces the development and origin of silicon carbide power electronics, and analyzes its specific applications in power systems, such as DC transmission, solid-state transformers, flexible AC transmission and so on. From this, we understand the development of electronic technology and the invention and birth of power electronic devices on the development of science and technology and energy utilization of the major role in promoting. With today's advocacy and promotion of the use of environmentally friendly green energy, power electronic devices and technology will also play an immeasurable role. Any technology is a double-edged sword, we should look at it rationally.

References

[1] QIAN Lighting, ZHANG Junming, SHENG Zheng. Current status and development of power electronic devices and their applications[J]. Chinese Journal of Electrical Engineering.2014.29(34):5149-5151.

[2] Liu Zehong. Innovative practice of ±1100kV ultra-high voltage DC transmission project[J]. Chinese Journal of Electrical Engineering.2020.23(40):7782-7784.

[3] LIU Baolong, CHA Yabing. Solid-state transformer, a key device for future energy interconnection[J]. National Defense Science and Technology.2014.3(35):11-13.

[4] Sheng F, Guo Q, Zhang JM, Qian L. Lighting. Prospect of silicon carbide power electronics in power systems.2012.30(32):1-4.