Application and Prospect of Power Electronics Technology in Smart Grid

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Abstract

Electric energy is advanced energy, it occupies an increasingly important position in industry, agriculture, economy and daily life. Electricity consumption is rising year by year, showing the national economy is becoming more stable, but there are also some problems. Power shortage, low power quality and complex grid structure have become the problems faced by the development of power system. The rise of power electronic technology and its continuous in-depth research provide a possible way to alleviate and solve these problems. This paper firstly summarizes the principles of power electronics technology applied in the development of intelligent field, and then analyzes the examples currently applied in smart grid, such as HVDC, intelligent switch technology, and high frequency technology. Finally, the prospect and possibility of the development of power electronic technology are discussed.

Keywords

Smart Grid; Power Electronics Technology; Application.

1. Introduction

With the continuous progress of science and technology, power electronics technology has become a hot topic in the field of electrical research. It is a new technology of controlling strong current with weak current and a model of controlling high power output with small signal input. For the purpose of studying power transformation and control, power electronics technology is closely related to a variety of disciplines, which are the three major fields of electrical engineering: power, electronics and control. It links these disciplines together organically, which is commonly known in the academic world as an inverted triangle.

The rapid development of power electronic components and power electronic technology has greatly driven the development of power conversion technology. The development of power conversion technology can be roughly divided into three stages ---- The first stage is the application of diode and thyristor and non-controlled or semi-controlled strong wave converter technology; The second stage is mainly the application of self-shutdown devices, such as GTO, BJT, power MOSFET, IGBT, etc. and the general use of PWM control technology; The third stage is characterized by the use of soft switching, power factor correction, harmonic elimination and consideration of electromagnetic compatibility.

The utilization rate of electric energy is gradually improved, the stability of the power grid is continuously improved, and the substation is gradually developing towards the direction of digital intelligence. Remote transmission and sharing can be realized through remote control to promote the efficient allocation of resources. In recent years, these changes have made the cooperation and connection between power electronics technology and smart grid more flexible and reliable. According to the BP Statistical Review of World Energy in 2019, Figure 1 and Figure 2 respectively show the green degree of electric power energy in various countries and the power structure in China. Among them, China's energy greenness is among the upper and middle reaches of the world, and its power structure is also improving year by year, moving toward sustainable development. These data

indicate that China provides fertile ground for the development of power electronics technology, which is why power electronics will play an integral role in the smart grid in the future.

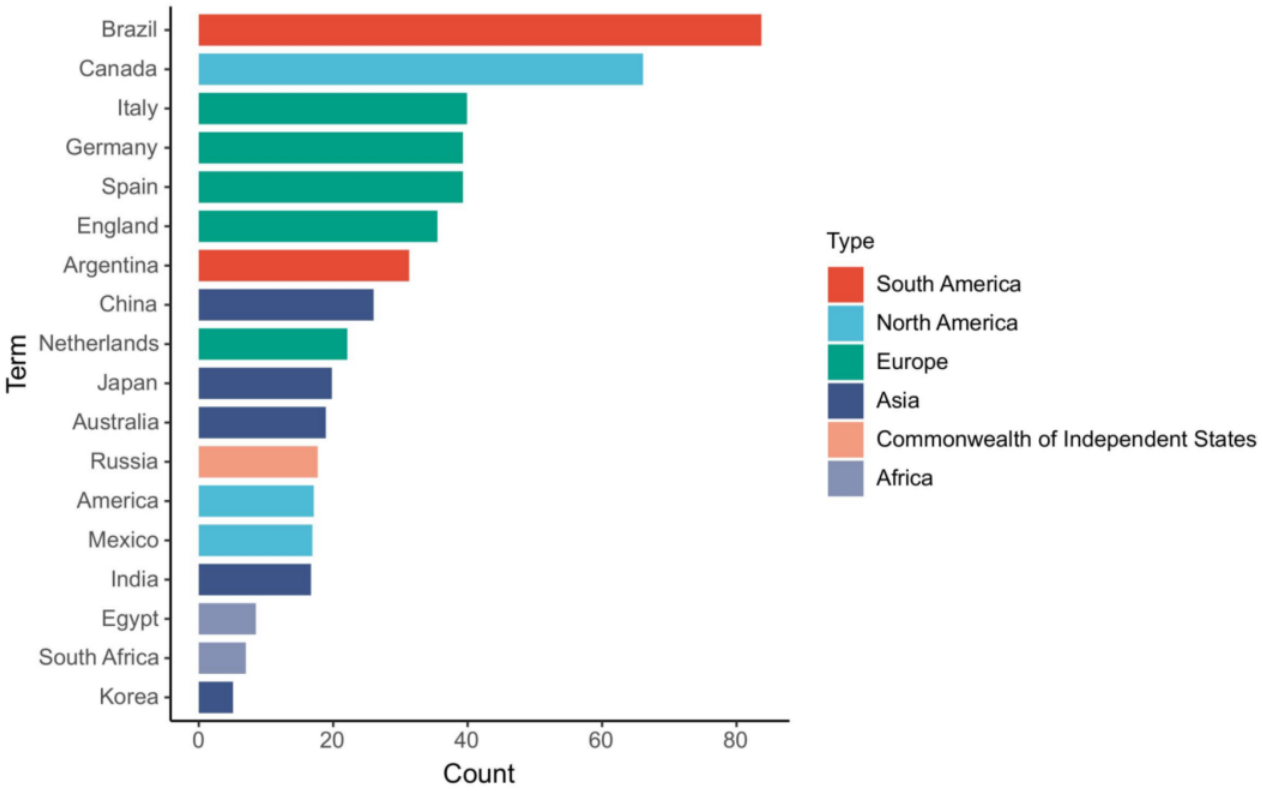

Figure 1. The greenness of electricity sources in some major countries

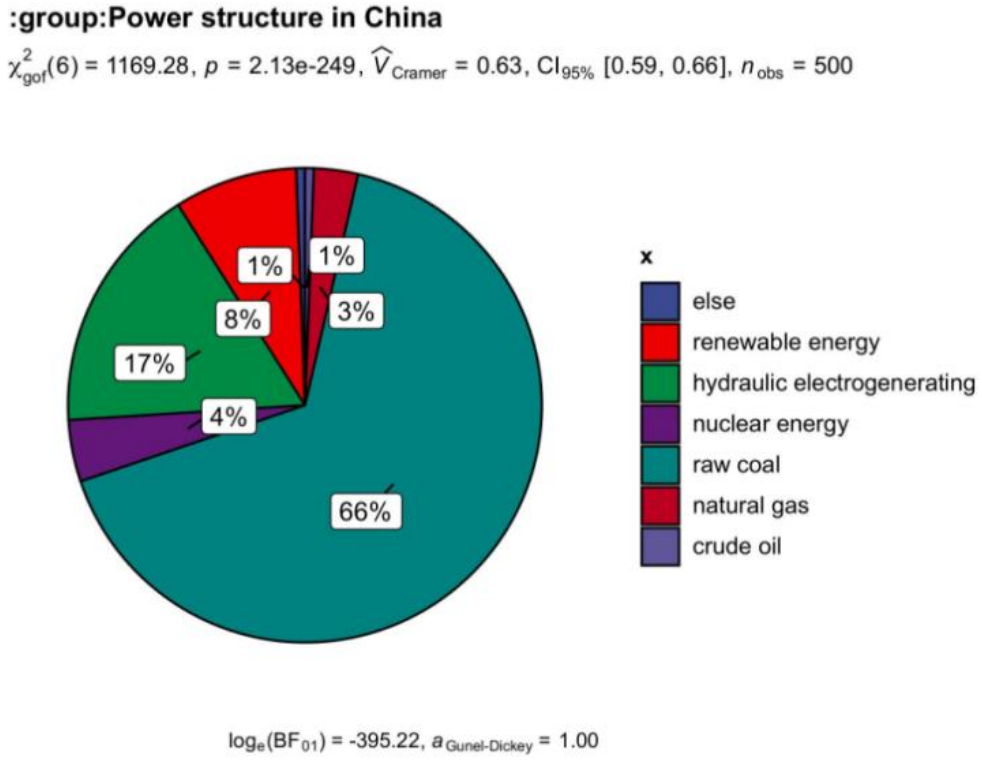

Figure 2. China's power structure in 2018

2. Principles applieed to artificial intelligence

Power electronics have great potential today, thanks to the development of artificial intelligence. Through the implementation of artificial intelligence, the power electronic system is embedded with self-awareness and the system has the ability to adapt, thus can improve the autonomy of the system.

At the same time, the rapid development of data science, including sensor technology, Internet of Things, edge computing, etc., has provided a wide range of data for power electronic systems at different stages of their life.

The methods of artificial intelligence applied to power electronic systems are varied, including expert systems, fuzzy logic, meta-heuristic methods and machine learning. Among them, machine learning is widely known and understood by people. It is designed to automatically discover principles and patterns from collected data or interactions. In the application of power electronics, it can be divided into three different learning modes: supervised learning, unsupervised learning and reinforcement learning.

3. Application of power electronic technology in smart grid

3.1 High Voltage Direct Current Transmission (HVDC)

CHVDC transmission is a technology that converts three-phase alternating current into direct current through the rectifying effect of a converter station, which is transmitted through the transmission line and then inverts the direct current into alternating current through another converter station. In this process, converter, converter transformer, filter, reactive power compensation equipment and other power electronic devices are needed. Compared with traditional AC power transmission, it is more economical to use HVDC power transmission over long or very long distances. It ensures that under a certain power, the current transmitted by the line will not produce a large amount of power loss. More importantly, it improves the reliability of voltage control and makes it easier to communicate effectively between grids. Figure 3 below shows the topology structure of HVDC transmission.

DC circuit breaker, DC power flow controller and fault current limiting device in power electronic devices are always hot topics in the research field. Among them, the hybrid DC transmission engineering circuit breaker and the low loss mechanical DC circuit breaker can not only be directly applied to the HVDC grid, but also provide help for the construction of the smart grid framework.

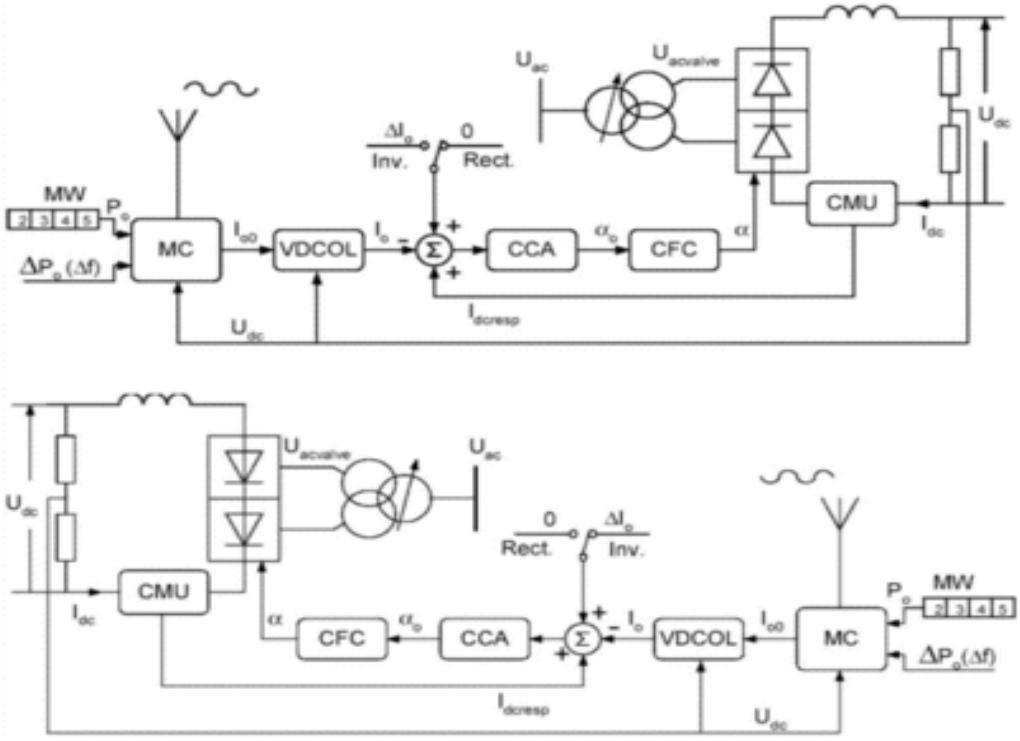

Figure 3. The topology structure of HVDC transmission

3.2 Flexible AC Transmission System (FACTS)

Flexible AC transmission technology is a new technology for flexible and rapid control of AC transmission, which integrates power electronics technology, micro-processing and micro-electronics technology, communication technology and control technology. It can enhance the stability of AC power network and reduce the cost of power transmission. The technology improves transmission quality and efficiency by providing either active or reactive power to the grid.

First of all, it can be fully coordinated with the original transmission mode, and has the advantages of no mechanical wear, small control signal power, high control flexibility. Therefore, it can be adjusted quickly and smoothly, can change the power distribution of the system flexibly and quickly, and improve the stability of the system. Secondly, the transmission capacity of the flexible AC transmission line can be increased to close to the thermal limit of the wire, and the utilization rate of the transmission line can be improved. Third, flexible AC transmission technology can improve the transmission capacity of the link line and reduce the standby capacity of the generator. Finally, the use of flexible AC transmission technology can effectively control the impact of power grid and equipment failures, prevent the expansion of accidents and reduce the impact of system accidents.

Many power electronic devices play a role in this, the most widely used are SVC and SVG.SVC is static dynamic reactive power compensation device, it has TCR and TSC these two types; SVC is an important reactive power compensation device in power system. Figure 4 shows a typical SVC electrical wiring structure. When the pure voltage type nonlinear control is used, the response speed is fast and the adjustment ability is strong. It can transmit or absorb reactive power rapidly according to the variation of reactive power during the parallel system operation, so as to improve the stability of voltage.

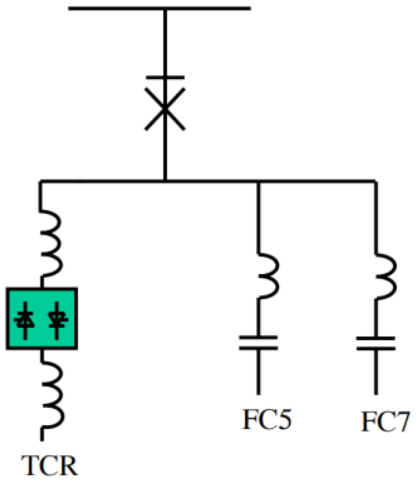

Figure 4. Single-line diagram, directly connected SVC

3.3 Intelligent Switch Technology

Intelligent switch technology is the combination of microcomputer technology and power electronic technology. Its application in the power system can not only improve the service life of the power system equipment, but also improve the stability of the power system and save energy to a certain extent. The significance of intelligent switch lies in the following points: 2. Reduce the impact of machinery on transmission, eliminate the adverse effects in the process of switch action. 2. The switch adopts standard open field bus to connect the switchgear with communication ability, and can carry out data communication with the upper computer, so as to achieve remote control, remote adjustment, telemetry and other functions. 3. Realize the fault judgment and protection of the switch to improve the level of automation.

3.4 High Voltage Frequency Conversion Technology

The technology mainly adopts intelligent control technology and variable speed control technology, which can realize the speed control of high power and high voltage motor. The application of high voltage frequency conversion technology can effectively reduce the degree of electric power consumption and ensure the safety of large motor operation. It can also improve the energy saving effect and power quality, and the energy saving rate can reach about 30%, which can greatly reduce the cost of electric power enterprises.

4. Future development prospest of power electronics

Power electronic technology has been imperceptibly integrated into our lives. Compared with the traditional household appliances we used before, the household appliances with power electronic technology are not only safer and more durable in the materials used, but also lower the cost. LED lamps, for example, have a longer service life than traditional lamps, while low voltage has less effect on voltage, and good color display. In the visible future, the integration of power electronics technology will be higher, but it needs to break through some technical bottlenecks. One is the realization of high-frequency transformers. However, according to the current technical level, transformers are mainly based on low-frequency transformers, especially for high-power transformers. This problem should be solved successfully by continuous research and experiment on the insulated gate bipolar transistors. Second, the power factor regulation in power electronics technology and the use of reactive power compensation device can limit the harmonics in the system to a certain extent, and can judge the actual situation of users to carry out reactive power compensation, so as to ensure the reliability of power quality. But these knowledge and technology are still in the theoretical stage, their practical application will be affected by various unstable factors, and there is still a long way to go before they are put into large-scale use.

5. Conclusion

All in all, only the tip of the iceberg has been revealed so far in terms of the economic and ecological benefits that power electronics can bring. It plays an irreplaceable role in the safe and economical operation of smart power grid and the continuous optimization of its structure.

We should accelerate the pace of research and development in an industry with great potential. In the future, we will make the performance of smart grid more perfect from security, economy, environmental protection and other aspects, so as to realize the take-off of our power industry.

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