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Power Electronic Technology in Smart Grid Prospect

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Abstract*: Electric energy is an extremely complex energy source that has become increasingly important in industry, agriculture, the economy, and daily life. The annual increase in electricity consumption symbolizes more stable economic growth in China, but there are still some problems. Power outages, low power quality, and complex power grid structures are issues that the power grid is facing. The development of power systems, the emergence of power electronics technology, and continuous research on power electronics technology can provide a feasible solution for alleviating and overcoming power problems. This article first summarizes the basic principles of power electronics technology in the construction of intelligent fields and then analyses the current examples of smart grid applications, including high-voltage direct current transmission, high-frequency technology, and intelligent switch technology. Finally, the possibility and potential for the development of power electronics technology were pointed out.

Keywords: Power electronics technology, HVDC, FACTS, AC, DC, Intelligent switch technology.

I. INTRODUCTION

Power electronics technology has become a prominent issue in the realm of electrical study as science and technology improve. It's a novel technique for regulating a strong current with a weak current, as well as a model for controlling high-power output with low signal input. Power electronics technology is intimately tied to several disciplines, which are the three primary departments of electrical engineering: power, electronics, and control, for the aim of investigating power transformation and control. It organically connects various fields, which is referred to as an inverted triangle in the academic world. The fast advancement of power electronic components and technology has had a significant impact on the advancement of power conversion technology. The evolution of power conversion technology may be split broadly into three stages. The first stage involves the use of diode and thyristor technology, as well as non-controlled or semi-controlled strong wave converters; the second stage involves the use of self-shutdown devices such as GTO, BJT, power MOSFET, IGBT, and other self-shutdown devices, as well as the general use of PWM control technology. Soft switching, power factor correction, harmonic reduction, and consideration of electromagnetic compatibility define the third stage. The rate of electric energy usage is steadily improving, the power grid's stability is continually improving, and the substation is gradually evolving in the direction of digital intelligence. Distant control can be used to provide remote transmission and sharing, allowing for more effective resource allocation. These advancements have made the collaboration and link between power electronics technology and smart grid technology more flexible and dependable in recent years. Figures 1 and 2 illustrate the green degree of electric power energy in various nations and the power structure in China, respectively, according to the BP Statistical Review of World Energy in 2019. China's energy greenness is among the world's high and medium echelons, and its power structure is also developing year after year, pointing toward long-term development. These findings suggest that China is a fertile environment for power electronics research, and that power electronics will play an important role in the smart grid in the future.

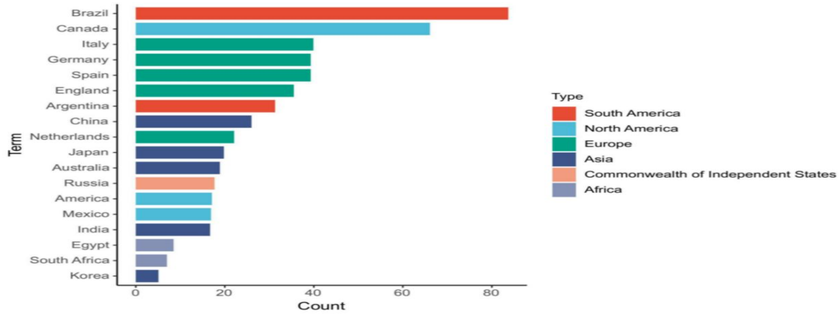

Figure 1. The greenness of electricity sources in some major countries

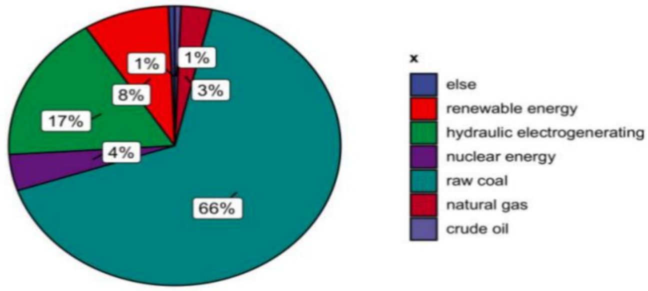

Figure 2. China's power structure in 2019

II. PRINCIPLES APPLIED TO ARTIFICIAL INTELLIGENCE

Thanks to the advancement of artificial intelligence, power electronics now offer a lot of promises. The power electronic system is infused with self-awareness and has the potential to adapt as a result of artificial intelligence deployment, which can increase the system's autonomy. Simultaneously, advances in data science, like sensor technology, the Internet of Things, and edge computing, have supplied a wealth of data for power electronic systems at various phases of their lives. Expert systems, fuzzy logic, meta-heuristic approaches, and machine learning are some of the artificial intelligence methods used in power electronic systems. People are familiar with and understand machine learning, which is one of them. It's built to find principles and patterns in gathered data or interactions automatically. There are three main learning modes in the use of power electronics:

1) Supervised learning
2) Unsupervised learning
3) Reinforcement learning

III. APPLICATION OF POWER ELECTRONIC TECHNOLOGY IN SMART GRID

A. High Voltage Direct Current Transmission (HVDC)

HVDC transmission is a technology that uses the rectifying effect of a converter station to convert three-phase alternating current into direct current, which is then transmitted through the transmission line, and then inverts the direct current into alternating current through another converter station. This procedure necessitates the use of a converter, converter transformer, filter, reactive power compensation equipment, and other power electronic gear. Using HVDC power transmission across long or extremely long distances is more cost-effective than using regular AC power transmission;

1) It guarantees that, at a given power level, the current transferred by the line does not result in significant power loss.
2) it increases the resiliency of voltage management and makes efficient communication across grids simpler.

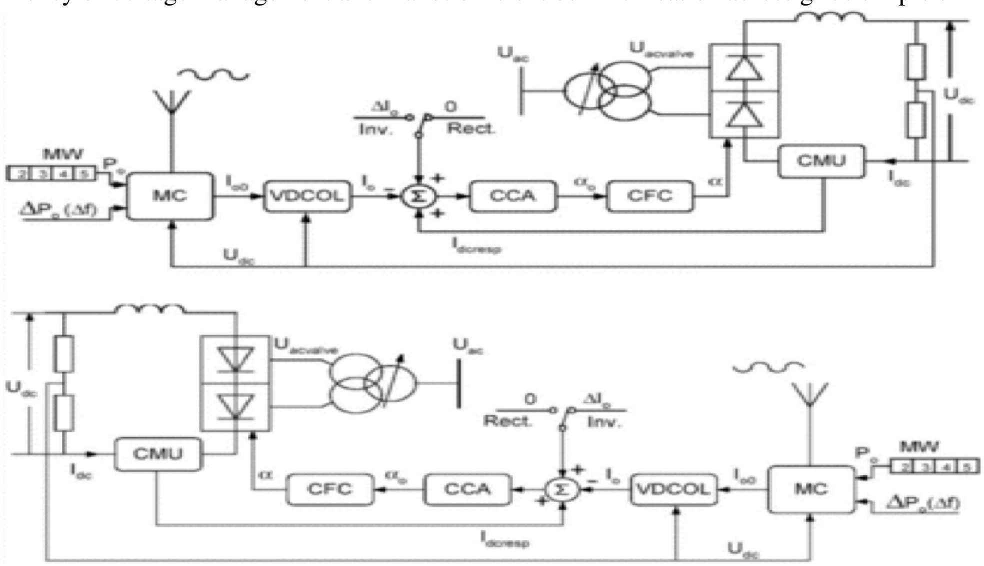

Figure 3. The topology structure of HVDC transmission

Figure 3 above shows the topology structure of HVDC transmission. DC circuit breakers, DC power flow controllers, and fault current limiting devices in power electronic devices are always hot topics in the research field(ZHANG Bin, 2019). 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.

B. Flexible AC Transmission System (FACTS)

Flexible AC transmission technology combines power electronics, micro processing, and microelectronics, communication, and control technology to provide flexible and quick control of AC transmission. It can improve the AC power network's stability and lower the cost of power transmission. By delivering either active or reactive power to the grid, the technique enhances transmission quality and efficiency. First and foremost, it is fully compatible with the original transmission method, and it has the advantages of no mechanical wear, low control signal power, and great control flexibility. As a result, it can be modified fast and smoothly, modify the system's power distribution flexibly and rapidly, and increase the system's stability. Second, the flexible AC transmission line's transmission capacity can be enhanced to near the wire's thermal limit, and the transmission line's utilization rate can be improved. Third, flexible AC transmission technology may increase the link line's transmission capacity while decreasing the generator's standby capacity. Finally, flexible AC transmission technology can effectively regulate the impact of the power grid and equipment failures, preventing the spread of accidents and reducing the severity of system accidents. SVC and SVG, two of the most often utilized power electrical devices, play a part in this. SVC stands for static dynamic reactive power compensation device, and it comes in two varieties: TCR and TSC. SVC is a critical reactive power compensation device in power systems. The electrical wiring configuration of a typical SVC is shown in Fig.4.

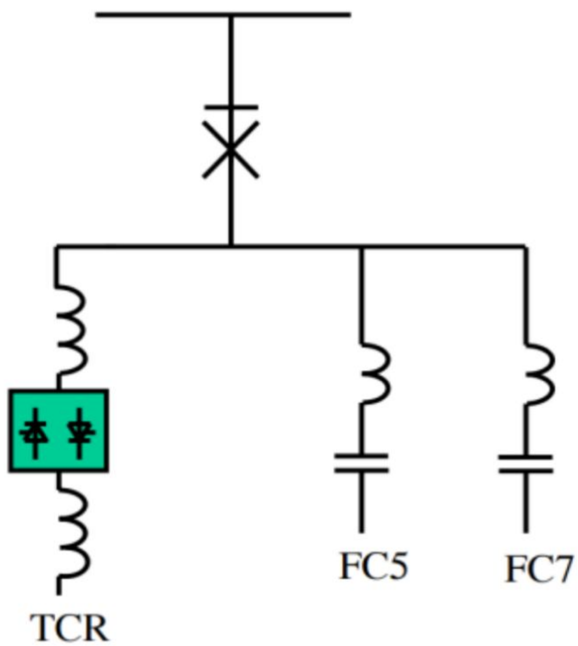

Figure 4. Single-line diagram, directly connected to SVC

C. Intelligent Switch Technology

Intelligent switch technology combines microcomputers and power electronic technology(Y. Zhao and F. Tian, 2013). 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:

1) Reduce the impact of machinery on transmission, and eliminate the adverse effects in the process of switch action.
2) The switch adopts a standard open field bus to connect the switchgear with communication ability and can carry out data communication with the upper computer, 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.

D. High Voltage Frequency Conversion Technology

Intelligent control technology and variable speed control technology are mostly used in the technology, which can regulate the speed of high-power, high-voltage motors. The use of high voltage frequency converter technology may significantly cut electric power consumption while also ensuring the safety of big motor operations(W. A. Cronje, 2005). It can also increase energy efficiency and power quality, with an energy savings rate of up to 30%, significantly lowering the cost of electric power companies.

IV. FUTURE DEVELOPMENT PROSPECTS OF POWER ELECTRONICS

Power electrical technology has been inextricably woven into our daily life. Household appliances using power electronic technology are not only safer and more durable in the materials used than traditional household appliances, but they are also less expensive. LED lighting, for example, has a longer service life than conventional lamps, and low voltage means less voltage fluctuation and better color display. Power electronics technology will be more integrated soon, but several technological hurdles must be overcome before. The fabrication of high-frequency transformers is one example. Transformers, on the other hand, are mostly based on low-frequency transformers, especially high-power transformers, according to current technical levels(CHEN K, 2019).

Continuous study and experiments on insulated gate bipolar transistors should be effective in solving this challenge. Secondly, in power electronics technology, power factor control and the use of reactive power compensation devices can restrict harmonics in the system to a certain extent and can assess the real situation of users to carry out reactive power compensation, ensuring power quality dependability. However, this knowledge and technology are still in the theoretical stage, and their practical implementation will be influenced by a variety of uncontrollable events. There is still a long way to go before they are widely used.

V. CONCLUSIONS

In terms of power electronics' economic and environmental benefits, just the tip of the iceberg has been disclosed thus far. It is critical to the safe and efficient operation of the smart power grid and the ongoing structural optimization. In an industry with enormous potential, we should speed up the pace of research and development. We will improve the performance of smart grids in the future in terms of security, economics, environmental protection, and other factors to achieve the take-off of our power sector.

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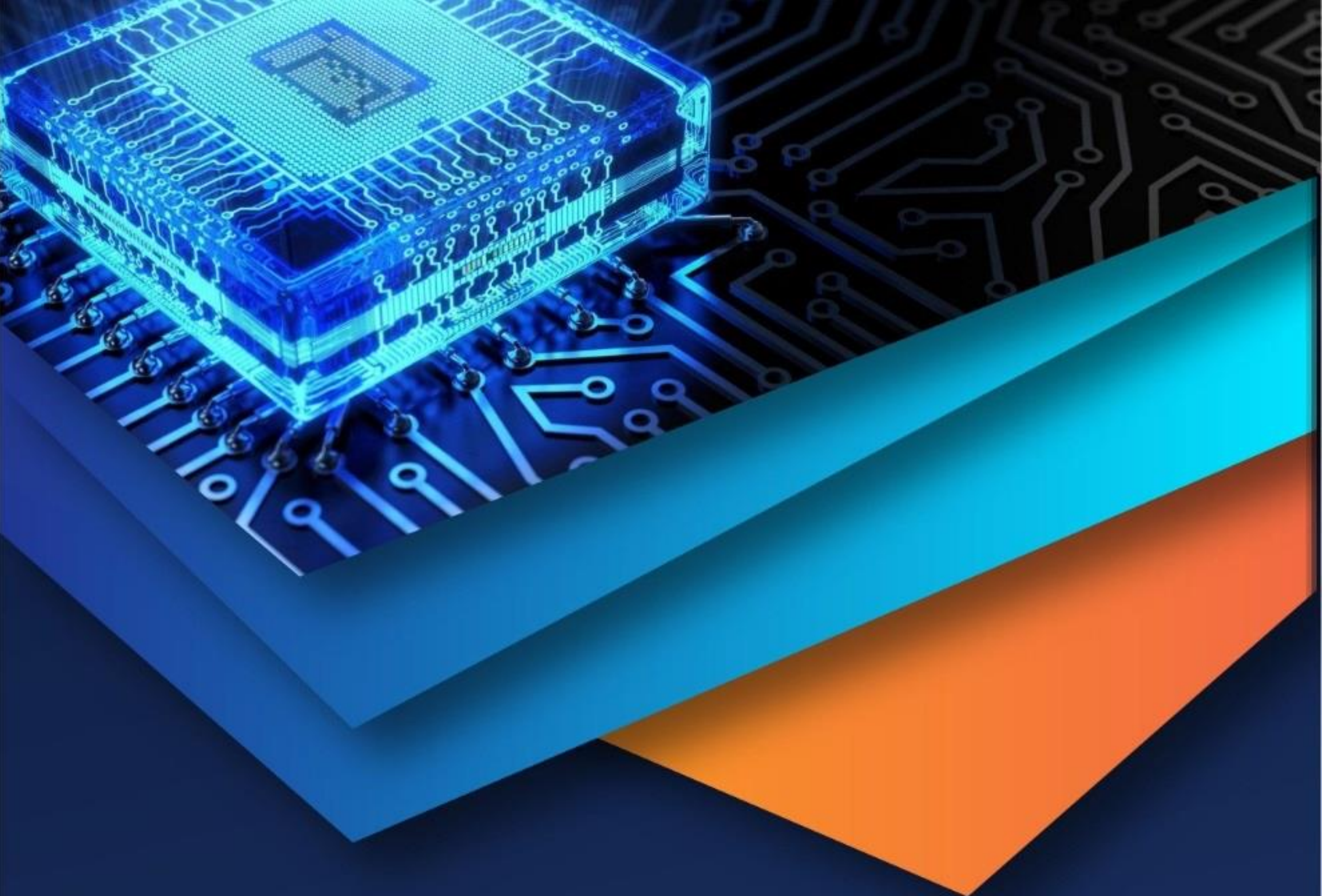

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