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## Applications of advanced power electronic technology in smart grid

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### ABSTRACT

Smart grid is currently developing towards informatization and automation, and introduction of power electronic technology will provide necessary guaranty for the normal operation of smart grid. This research firstly presented an overview of smart grid, then it introduced the features of smart grid as well as research contents and development direction of power electronic technology. Meanwhile, it also described the roles of power electronic technology in smart grid and discussed the applications of power electronic technology in smart grid. Through the introduction of this research, the important roles of power electronic technology in smart grid could be perceived; however, power electronic technology still has some deficiencies, which need to be further improved.

### KEYWORDS

Smart grid; Power electronic technology; Development direction; Application.

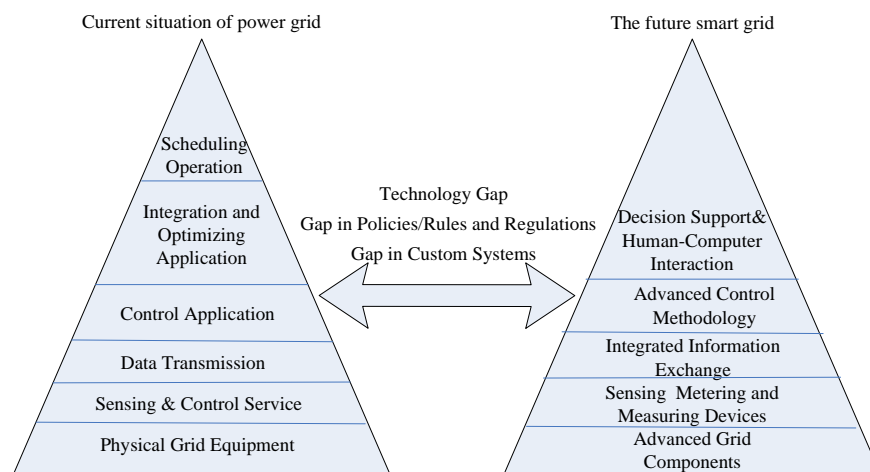


## INTRODUCTION

With the development of the society as well as the improvement of technology and informatization level, environmental problems become increasingly prominent, and rational utilization and protection of resources become more important; as a result, development of grid in China is confronted with great challenges. In order to make better use of resources, China gives great impetus to the development of smart grid, the major task of power industry is to constantly learn and update advanced science and technology so as to continuously enhance the construction of smart grid. Electric Power Research Institute in America firstly proposed the noun of smart grid, which is their blueprint for the grid structure of next generation. Smart grid connects every part of the power company, conducts the data collection automatically, and makes comprehensive analysis on the operation management of the company by means of advanced network technology and intelligence technology so as to optimize the operation management and power supply service<sup>[1-2]</sup>. Power electronic technology is a newly rising electronic technology, which is mainly applied in electric power<sup>[3]</sup>; it is a kind of technology that converts and controls the power by utilizing the power electronic device<sup>[4]</sup>. The introduction of power electronic technology into smart grid is the irresistible trend for the development of science<sup>[5]</sup>. Continuously developing the power electronic technology, enhancing the application of power electronic technology in smart grid and guaranteeing the rational utilization of resources in China become our major tasks<sup>[6]</sup>. Starting from the concept of smart grid and power electronic technology, this research studied the roles of power electronic technology in the construction of smart grid, and analyzed applications of power electronic technology in smart grid as well as the corresponding application cases.

## OVERVIEW OF SMART GRID

The concept of smart grid is characterized by flexibility. Due to the different national condition, geographical environments, economic developments as well as scientific and technological levels of different countries in the world, the definitions and strategic focuses for smart grid are different too. In 1999, scholars from Tsinghua University proposed the idea of digital power system, which opens up the road of exploration for smart grid; in 2009, China firstly proposed the development goal for smart grid; besides, State Grid brought the idea of independent innovation into the construction of smart grid, and established the smart grid which took ultra-high voltage grid as the main frame, and which was based on coordinated development of grids of different levels<sup>[7]</sup>. Compared with traditional grid, smart grid is more compact in structure, and it is additionally equipped with a series of auxiliary components as well as real-time response platform, which make the smart grid more flexible and reliable. As is shown in Figure 1, based on the construction of grid in some city in Canada, Canadian expert in power system Scott J. Anders created comparison diagram between current grid and future smart grid<sup>[8]</sup>, which means that the supporting technology of smart grid still needs to be improved.



**Figure 1 : Comparison diagram between current grid and future smart grid**

According to the current research on smart grid and the concept of smart grid, it is concluded that smart grid has seven features as follows:

(1)Self-healing nature. It means that smart grid can isolate the defective component or recover the function of this component without human intervention so as to guarantee the normal power supply.

(2)Safety. It means that smart grid can resist the interference from some external factors so as to guarantee the safety of personnel, equipment and grid.

(3)Interactivity. It means that smart grid will be additionally equipped with auxiliary components, which will help the adaptive interaction between power consumer and power grid so as to further discover the role of power consumer in the power grid.

(4)Economy. It means that smart grid can integrate and optimize the assets and equipments currently owned by the power grid, and give full play to their roles so as to achieve the purpose of reducing investments and operating costs.

(5)Excellent quality and high efficiency. It means that power consumers can make rational utilization of the power and learn about the power consumptions in time.

(6)Environmental protection. It means that smart grid is applied to the utilization of different resources and supports the utilization of renewable energies such as wind energy, solar energy and geothermal energy.

(7)High marketing promotion. It means that information technology applied by smart grid have been greatly improved on the base of original power network so as to attract more investors and consumers, which achieves the purpose of pushing smart grid towards the direction of marketization.

## RESEARCH CONTENTS AND DEVELOPMENT DIRECTION OF POWER ELECTRONIC TECHNOLOGY

Advanced power electronic technology is the key element for smart grid, and intelligentization of power electronic technology is the development direction for the future. Considering the fundamental development of the grid in China, various power electronic technologies will be widely used; the constant innovation and development of power electronic technology will make sure that the power can be fully utilized. The development of monitoring, communication, control and protection technology will turn the power flow control over wide range into reality.

### Research contents of power electronic technology

Research contents of power electronic technology can be divided into three parts: power semiconductor, integral control of power electronic circuit, main circuit of electronic converter.

(1)Power semiconductor: Power semiconductor, also known as power electronic device, belongs to high-power electronic operation device, and is applied in the conversion and control of electric energy. Besides, it can be divided into semi-controlled device, full-controlled device and uncontrollable device. Semi-controlled device is used above the bearing capability of voltage and current capacity and accounts for a big proportion in general devices; full-controlled device can be divided into two types, which are current-driven device and voltage-driven device; uncontrollable device includes uncontrollable power diode. With simple working theory and uncomplicated structure, it has quite high reliability.

(2)Integral control of power electronic circuit: Power electronic circuit takes the industrial electricity as control object. Its purpose is to reduce the energy loss during the application of the industrial electricity. Power electronic circuit is the high-power device which converts and controls the energy by utilizing the power semiconductor.

(3) Main circuit of electronic converter: Its core is power semiconductor. In order to realize the conversion and control of the electric energy, main circuit of the electronic converter adopts different circuit topologies and operates different control methods. Proper components should be selected according to different environments so as to realize the utilization of components by high frequency, high power and low energy loss during conversion.

### Development direction of advanced power electronic technology

Power electronic technology includes direct current transmission technology, flexible alternating current transmission technology, electric power quality control technology and energy conversion technology. Direct current transmission technology has currently gone through great changes. Generally speaking, development of direct current transmission has close connection with alternating current transmission; however, in recent years, due to the heavy use of direct current transmission projects, the issues such as the safety, controllability, reliability of direct current transmission become inevitable problems that must be solved in mainstream transmission technology. Therefore, introduction of many new technologies into DC transmission technology is the new direction for the development of future transmission technology. Flexible alternating current transmission technology increases the controllability of voltage, current and power in power system by adopting electronic power devices in power system so as to increase the capacity of power transmission. Since FACTS technology was brought up in 1980s, power electronic technology has been widely used in alternating current. With the development of modern technology as well as the improvement of power system, development of electric power quality control technology becomes particularly important due to the fact that quality of power is directly related to profits of power supply companies, power consumers and device manufacturers. However, current research on the electric power quality control technology is still at the starting stage; as a result, there are still many issues for the scholars to study and explore. Energy conversion technology is a quite important technology in power electronic technology. Any form of distributed generation must deal with the interface energy conversion between distributed power and power grid, consumers as well as energy storage systems. Besides, rational utilization of renewable energies such as wind energy and solar energy has become a hot topic for the research of the global energy conversion technology. The routes for current development and future development direction of advanced power electronic technology are displayed in TABLE 1 as follows.

**TABLE 1 : Current development and future development direction of advanced power electronic technology**

<b>Power Electronic Technology</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
direct current transmission technology	Break through key technical problems for regular direct current transmission; realize the project demonstration for flexible current transmission; propose the idea of new direct current transmission. Realize the project demonstration for the typical devices such as thyristor controlled series	Realize the proprietary intellectual property rights for the core device of direct current grid connection and extra-high voltage direct current transmission; flexible current transmission system gets mature and nationally popularized, and new direct current transmission enters testing stage	Establish the direct current transmission system based on smart grid, which plays a leading role in the field of direct current transmission technology
flexible alternating current transmission technology	compensation and controllable reactor in extra-high voltage grid; Complete the formulation of technical standards for custom power products; complete the research on key technology for the intelligentization of the existing FACTS device.	Realize extensive use of FACT device in smart grid; realize the upgrade of FACTS technology and the intelligentization of its applications.	Realize the modularization, unitization, and intelligentization and establish the integral theoretical system
electric power quality control technology	Complete the research on optimal configuration of custom power technology in distribution grid; finish the project demonstration for custom power industrial zone.	Settle the key technical problems of smart distribution grid, realize the intelligentization of new distribution grid; realize the standard guidance and restraint mechanism for custom power product; spread the usage the custom power industrial zone on a national scale	Complete the standard quality ranking system for custom power product; implement custom power technology on a large scale.
energy conversion technology	Finish the project demonstration for pumped storage starting dynamo; finish the research on key technology for large scale wind power integration by utilizing power electronic technology.	Realize large scale quick adjustable energy conversion in energy storage system; realize efficient and safe grid-connected operation in gigawatt-level wind power plant and standard production of core devices.	Form standard,configurable module for general energy conversion; spread and apply large scale power winter integration technology in the system.

**ROLES OF POWER ELECTRONIC TECHNOLOGY IN THE CONSTRUCTION OF SMART GRID**

With the development of society, science and technology have experienced dramatic changes, and power system in China has been constantly improved; with the development of electronic technology, electricity has become the indispensable part in our life, and social demands for electricity grow bigger and bigger; therefore, role of power electronic technology in smart grid has become more and more important.

(1)Application of power electronic technology in smart grid can play the role of security for devices, which means that it can guarantee the safety and reliability of the device. Accompanied by the development of science and technology, power electronic technology is developing rapidly. However, there are still many problems that need to be solved in the system, and therefore improvement of the system becomes the direction of development. As for smart grid, the primary issue during its operation is to guarantee the safety; however, there are certain loopholes and defects in many power framework of the existing power companies; besides, natural disaster will definitely cause damages to the safe operation of power grid. In order to solve the above problems, power companies need to constantly update and improve the power electronic technology so as to guarantee the safe and stable operation of smart grid.

(2)Application of power electronic technology in smart grid can continuously improve the quality of electric power and solve the problem of growing social demands for electricity. With the social development and the popularity of electronic products, people can not live without electricity. Therefore, people's demands for electricity will grow bigger and bigger, and requirements for the quality of electricity will get higher and higher. Lack of power supply and substandard quality of electric

power will seriously affect people's life, which leads to serious economic loss. This requires the power companies to continuously update devices and learn new technology so as to improve the efficiency of smart grid and optimize the quality of electric power. This reflects the important role of power electronic technology in the construction and safe operation of smart grid.

(3) Application of power electronic technology in smart grid can effectively promote the utilization of renewable energies such as wind energy, solar energy. With the excessive exploitation and utilization of non-renewable energies, supply of non-renewable energies can not satisfy people's needs any more. Renewable energies such as wind energy and solar energy become the objects of extensive utilization and exploitation. China has advantageous conditions for developing wind energy. With vast area and changeable meteorological condition, the wind energy stored in China is immeasurable; according to relevant data, till 2020, electricity produced by wind energy in China will reach up to 10 trillion to 15 trillion voltage; solar energy comes from the energy released from the constant nuclear fusion reaction inside the sun; as for the utilization of solar energy, people develop the products converted from solar energy mainly by the direct transmission of photo-thermal energy, photoelectricity and photochemistry, such as generating the photovoltaic power by utilizing the solar power, storing the solar energy by using the monocrystalline silicon battery, and obtaining the hydrothermal energy by using the solar energy. According to relevant data, till 2020, the electricity generated by utilizing the solar energy can reach up to 1 trillion.

### APPLICATIONS OF POWER ELECTRONIC TECHNOLOGY IN SMART GRID

Application of power electronic technology in smart grid includes power transmission and distribution, power source, new energy and distributed generation. Power electronic technology plays an important role in smart grid; therefore, application of power electronic technology in smart grid must be enhanced so as to improve the operation efficiency of smart grid. The power electronic technologies applied to solve the problems faced by smart grid are displayed in TABLE 2

**TABLE 2 : Applications of power electronic technology in smart grid**

<b>Problems in Power System</b>	<b>Solutions</b>
discontinuity and volatility of renewable energy	STATCOM and SMES technology for integrating stored energy
voltage fluctuation with load change	SSSC, SVC, TCSC, STATCOM, UPFC, CSR
low voltage caused by faults	SSSC, SVC, STATCOM, TCPAR, CSR
overload of transmission line and transformer	SSSC, TCSC, TCPAR, UPFC
adjustment of power flow	SSSC, UPFC, TCSC, TCPAR
load distribution after the occurrence of faults	TCPAR, UPFC, SSSC, TCSC, STATCOM, CSC
restrictions on the excess of fault current	SCCL, UPFC, SSSC, TCSC
resonance of subsynchronous turbine or generator shaft	SSSC, TCSC
loose mesh network with transient stability	SSSC, TCSC, UPFC, TCPAR, HVDC
remote power oscillation generator and radial line	SVC, STATCOM, SSSC, TCSC, UPFC, TCPAR
loose mesh network controlled by voltage after accident	SSSC, SVC, STATCOM, UPFC
regional connection, voltage stability of closed or loose mesh network	SVC, STATCOM, UPFC, TCPAR, MCSR, CCSR
power quality control	DSTATCOM, DVR, UPQC, PET
distribution passage for power supply	distributed generation connected with PET, integrated energy storage and converter

### APPLICATION CASES OF KEY POWER ELECTRONIC TECHNOLOGY IN PROJECT

#### Engineering applications of shunt compensation

As the latest stainless steel factory with integrated production, Lianzhong Stainless Steel Corporation is committed to become the leading stainless steel manufacturing company in the world. Lianzhong Stainless Steel Corporation appointed C-EPRI Science & Technology CO., Ltd to conduct the research on the key technology of reactive-load compensation device (also known as SVC device) and bring it into successful operation; as the SVC device with the largest installed capacity in China, it can effectively solve the problems of decreasing power quality caused by pulsating load of the equipment, which guarantees safe power supply and safe operation of project in the company.

TABLE 3 displays the main technical parameters of SVC device applied to Lianzhong Stainless Steel Corporation.

**TABLE 3 : Main technical parameters of SVC device applied to lianzhong company**

Main Parameters	Reference Value
Rated Capacity/Mvar	180
Rated Voltage/kV	35
Rated Frequency/Hz	50
Rated Current/A	2969
Trigger Mode	-
Range of Working Voltage/pu	0.9-1.1
Installed Capacity of Filter/Mvar	300
Capacity of Fundamental Wave	180

**Engineering application of series compensation**

Yi-Feng 500 kV TCSC project is a national scientific research program approved by National Development and Reform Commission. This project is developed and designed by C-EPRI Science& Technology CO.,Ltd ; through research and development, rated power for Yi-Feng 500 kV TCSC project has been promoted from 1,460,000kW to 2,500,000kW; furthermore, all the devices of this project are independently designed, developed and assembled by China. TABLE 4 demonstrates the main parameters of Yi-Feng 500 kV TCSC project.

**TABLE 4 : Main parameters of yi-feng 500 kV TCSC project**

Main Parameters	Reference Value
Rated Capacity /Mvar	500
Rated Voltage /kV	50
Rated Frequency /Hz	2330
Rated Current /A	544.3 (FSC) , 114.48 (TCSC)
Engineering Mode	MOV+GAP+Thristor
Change of Rated Capacity (MJ/three phase)	137.39 (FSC) ,114.48 (TCSC)
compensation degree	30%(FSC)+15%(TSCS)
electric capacity set/pu	2.25 (FSC) ,2.35 (TCSC)

**Engineering applications of conventional power technology**

Power load of some large airline company in Beijing had suffered from the transient power quality problems caused by voltage drop and short-term power interruption for a few times. According to the situation of this company, C-EPRI Science& Technology CO.,Ltd installed two conventional power devices: SSTS and DVR; introduction of these two devices perfectly settled the problems of power quality in this company. TABLE 5 shows the main parameters of 10kV DVR device introduced by this company.

**TABLE 5 : Main parameters of 10kV DVR device**

Major Parameters	Reference Value
Rated Capacity /Mvar	10
Rated Voltage /kV	300
Rated Frequency /Hz	50
Range of Compensating Voltage/pu	0.1-0.5
Response Time of Compensation /ms	< 5
Compensation Time/s	1

**CONCLUSIONS**

The construction of smart grid has positive social benefits and economic benefits for China; besides, it is helpful for the protection of non-renewable resources and reduction of environmental pollution. Electric power is the foundation for national development; therefore, it is important to enhance the application of power electronic technology in smart grid of China, which plays an important role in the development of power industry as well as the development of whole society. With the

development of advanced power electronic technology, power industry in China will present a good developing trend. However, there are still many different problems existing in the construction of smart grid in China, which needs professional scholar to improve the research on power electronic technology, and introduce or develop new power electronic technology so as to guarantee the fully effective operation of smart grid in China.

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