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Study on the role and application of advanced power electronics in the construction of smart grid

Ning Yao

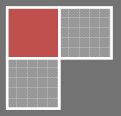
School of electrical Engineering & Mechano-Electronic Engineering, Xuchang University, Xuchang, Henan 461000, (CHINA)

ABSTRACT

To construct smart grid, it is essential to utilize advanced technologies in a way that these technologies may ensure the effectiveness of the construction. In term of the development of China's power system, there have been continuous breakthroughs in advanced power electronics. Informatization, digitization and integration have become the dominant theme in construction of the current power system. Viewing from the international trend, however, with the rapid progress of times, a nation's comprehensive strength is manifested by its power system, and almost every country is conducting extensive researches on the development and application of advanced power electronics. The construction of smart grid in our country has its own characteristics, and the paper will focus its study and exposition on this regard. First, we will probe into the definition of smart grid with Chinese characteristics and the energy storage technique, so as to display the advanced nature of our power Electronics. Second, we will explore the battery energy storage system (BESS) and its application from an all-covered viewpoint. Last, a beneficial study will be made on the establishment of the model of BESS. Thus, convincing as the paper's study approach is, it will contribute to the theory and practice of our country's smart grid building.

KEYWORDS

Smart grid; Power electronics; Significance; Applied research.



PREFACE

From the point of social progress, the level of a nation's power system is one of the major limitations to its development. Many countries have made intellectualization the main direction in building of their intelligent power system. The paper will focus on the study of the smart grid with Chinese characteristics, the BESS and its application and the model of BESS. By promoting the application of advanced power electronics in the designation and perfection of the smart grid in our country, it will also accelerate our construction of an intelligent, digitalized and informationalized power system.

SMART GRID WITH CHINESE CHARACTERISTICS

Definition of smart grid

Consulting through the contemporary documents, we could not find a clear definition of smart grid, and there is not much consensus between different definitions. Relevant definitions could be concluded after searching through international documents as following:

One aspect of smart grid is, that by opening up its electrical system, it builds an information sharing platform. With the help of intelligent techniques and high-tech terminals, it connects customers together and then with power companies. Thereby it improves its acquisition and processing of electric power data, which enable it to do the dual-directional regulation of the power system[1]. The power system then gets an effective remote control over other consumption systems, which leads to an impressive improvement of the battery's storage capacity, and to the diversification of the application of the BESS. In the mean time, with an interactive development model of the data shared by power grids formed, these data could now be coalesced in effect. This provides a valid ground for the evolution of the power system's managerial method and its function model. The grid system's service capacity is also improved, it gets more reliable and stable when functioning, which also ensures the overall utilization efficiency[2].

Smart grid is a highly automatized power system. Monitoring every single consumer node in real time, it can regulate those nodes between the power stations and consumer points, with such efficiency that the electric information interacts without delay. The optimal utilization of those interactive functions demands a large number of distributed intelligent devices, which may only response to the data from the grid with adequate self-control units.

The essential features of smart grid itself could be demonstrated in three aspects. The first aspect, which is an vital factor in the construction of the grid, is that the sensors in the system is qualified to monitor the generation, transmission, distribution and the supply process of power. The second aspect lays in the efficient gathering, processing and analyzing of the data from the grid network. The last aspect is the optimized utilization of those data, with the aim to better the management and function of the grid for a stabilized operation.

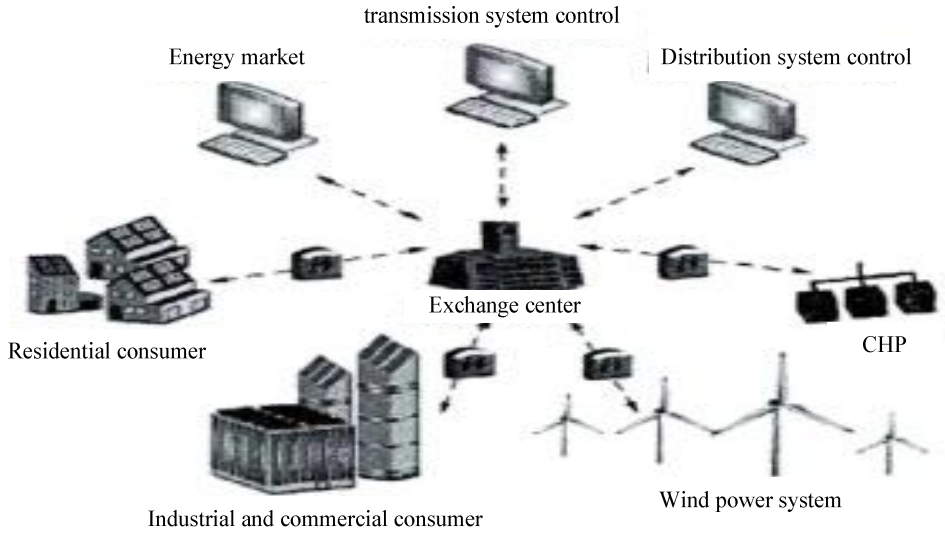


Figure 1 : Illustration of the function of smart grid

Smart grid with Chinese characteristics

The definition of the smart grids in our country, however, is featured by the fact that they are based on a frame of the construction of ultra-high voltage grid (UHV grid). Thus lays the foundation for our smart grid with the coordinated development of grid frameworks of various levels. It is the efficient use of the up-to-date electronic communication technology that made today's smart grid truly informationlized, intelligent and visualized. The network information

technology should play a key role in the construction of the world-leading grid that is informationlized and the digitized. This, being the dominating theme in the grid construction in our country, possesses certain Chinese characteristics. The construction could be divided into three major phases[3].

Early in this century, as the experimental programmes of smart grids were carried out, experience of the management and relevant technical norms were collected. All these have built a firm foundation for the construction of smart grid. From the experimental programmes, some concrete analyses of concrete problems were done and that provided valuable knowledge for the later expansion of the grid.

During the period of 2010 to 2015, a general popularization of smart grid will be on the way. Focus will be the construction the UHV grid, the perfection of its power transmission and distribution, and to get breakthroughs in the core techniques of the grid. Also achieved in this period should be the service system of smart grid, to exert the values of its construction.

By 2020, with the realization of a moderately prosperous society, a completed smart grid system would also have been established, so would be the scientific criteria for the construction of the grid. In the mean time, the R&D of relevant high-tech devices should constantly progress, so the grid will be able to meet any issue and develop in accordance with the scientific and technological development of the time. With this last developmental phase of smart grid achieved, it marks that we have entered a new time for the development of smart grid.

Application of energy storage technology in the smart grid construction

With the rapid growth of world economy, there is a fast rising demand for electricity. By 2013, China has become the second largest consumer of electricity in the world. A long-term perspective requires a scientific composition of the power system for our further develop. It is the main direction for the future power systems to become smart grids. From this point of view, the world is at a same starting line. If China could be prompt in this regard, we would play a leading role in the power system's evolution, and take the high ground in the world's social and economical development.

Having been developing in the past decades, China's power system faces yet another turning point in the new century. This means now the dominant factors is the investment to the power system and the scientific development of its infrastructures, which is also the breaching point for our power system to make qualitative change from quantitative ones[4]. The level of the system's scientific development is mainly reflected in the correspondence of high-tech products, and the combination of information technology and digital network, will lead to its standardized construction. It is only on such basis can our power system industry be improved, and then enter a new developmental phase.

TABLE 1 : Comparison between the functions of traditional power grid and smart grid

Function	Traditional grid	Smart Grid
Communication	None or unidirectional	Bi-directional
Exchange with users	Few	Many
Meter	mechanical	Digital
Operation and management	Manual collation	Remote monitoring
Power Providing	centralized	Distributed generation; Power storage system
Current control	Limited	Common
Reliability	Apt to malfunction and failure	Adaptive protection and isolating
Power supply recover	Manual	Self-recovering
Network topology	Radial	Network

The key point of the smart grid construction is to satisfy the domestic power demand. It is estimated that, up to 2020, the capacity of our wind power generation will reach 30GW, and photovoltaic power generation, 1GW. With the increasing investment in the power system, the renewable energy generation has become the main direction in the future and is of strategic significance. Both being green and renewable powers, the wind and the solar energy, because of their inborn features, can provide significant persistence to the power system. Moreover, with their relatively smaller ratio of grid-connected capacity and gross grid capacity, they lack the ability to impose strong impact to the grid. Furthermore, what little impact may exist could be eliminated with stable distribution techniques of power plus the perfection of the transmission system. In order to improve the renewable energy generation, during its development, it should be regarded as a pressing issue to adopt efficient power storage devices and to design new power distribution facilities for the stability of the grid[5]. Currently, from their fruitful work, our researchers have been making breakthroughs in area of power storage system with equal capacity to the new system. This lays solid ground for renewable energy generation's efficiency, quality and reliability. Figure 2 shows the application history of power storage technology in China's power system.

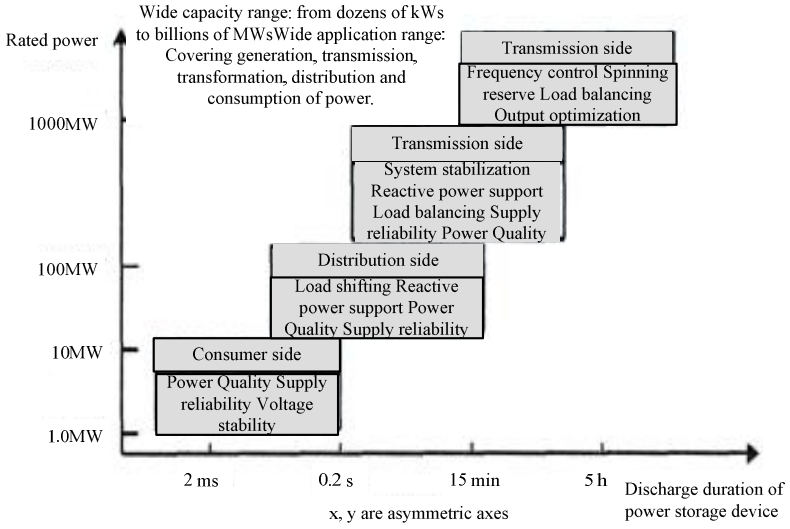


Figure 2 : Application history of power storage technology in China's power system

BESS AND ITS APPLICATION

The research and development of the BESS has become an important part in the construction of smart grid. The popularization of the technique relies largely on the research of its cost, security and etc to optimize its potential. The same goes for the research on its performance and efficiency of energy conversion to uncover its feasibility and applicability.

To realize its diverse application, also should be considered is the reality of our power consumption combined with current grid construction, and the power storage technique adopted for the construction. To make the power storage equipment more applicable, conducive analysis should be done to the capacity, service life and the continuous discharge duration of the battery, so is the research on high-power energy storage technology. TABLE 2 shows dynamic responsive characteristics of the major power storage methods.

TABLE 2 : Dynamic responsive characteristics of the major power storage methods

Storage method	Output power （KW）	Discharge duration	Response time	Cycle life(ten thousand times)
Flywheel	0~0.25	1ms~15min	1ms~20ms	2
SMES	0.01~10	1ms~8s	1ms~5ms	10
Super capacitor	0~0.1	1ms~1h	1ms~20ms	5
Lead acid battery	0~50	Several seconds to hours	>20ms	1.2
VRB	0.03~3	Several seconds~10h	20ms~Several seconds	1.2
sodium-sulfur battery	0.05~8	Several seconds to hours	20ms~Several seconds	0.25

MODELS OF BESS

Basic principle model based on ideal voltage source and equivalent internal resistance

Based largely on its primary model, the building of this model starts from inspecting the influence it receives under the state of charge, and been improved on the basis of the over-voltage condition, its Thevenin equivalent model was established[6]. In the construction of this model, through processing and analyzing massive data, it optimizes the visualization and the specification of the model's work, which is based on the battery's change of state during the power generation with the data as its basic constant[7].

Giglioli four-phase model、 spice model

These are the improved equivalent circuit models of the nonlinear variations during the charging and discharging. These dynamic models, with complicated parameters to process the variations, are apt at the simulation with high accuracy requirements. The BESS is mainly composed by the battery set, converters and charge and discharge control devices, as

shown in Figure 3. The R in the figure means the equivalent resistance connected with converters and lost in the internal lines. L is the equivalent inductance of the converter's circuit, and C is the smoothing capacitance at the direct current side. The alternating current system and the battery set exchange energy through the converter. The process: control device gives signal to the switches in the converter to modify their state, so that the converter can act as the rectifier or the inverter. The system will charge the batteries when it is the rectifier. With the inverter, the batteries discharge to feed the system. This is how energy flows between the system and the battery set.

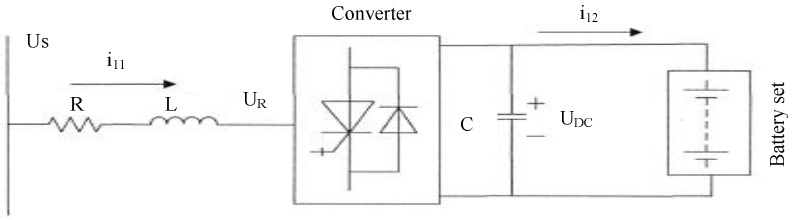


Figure 3 : Structure diagram of the model of BESS

APPLICATION OF THE BESS IN WIND POWER

Being the major project of China's renewable energy in the future, with the recent year's policy support and technical breakthrough, wind power has been rapidly developing. Induction generator not only works perfectly in the grid-connected, but is also easy to product, control, and start functioning. Its rotor is also of high mechanical strength. As a result, many wind power plants adopt such generator in grid-connected power generation. Figure 4 illustrates the most common system of variable speed constant frequency wind power induction generator.

One feature of induction generator in the power system is that, while it outlets active power, it requires reactive power from the system. Because of that, the generator system may suffer transient voltage instability from the disturbance. This brings many obstacles to large-scale application of grid-connected wind power generation.

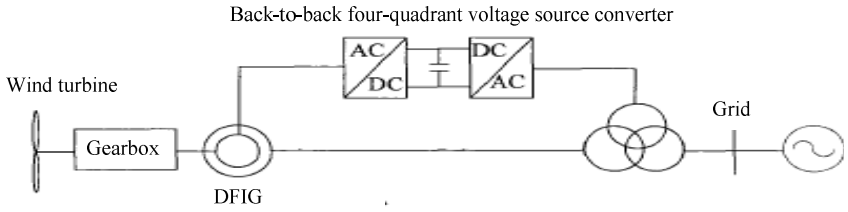


Figure 4 : Diagram of variable speed constant frequency wind power induction generator

BESS has obvious advantages in terms of capacity, service life, production cost and technical maturity. For wind power generation, it could, on the one hand, by adjusting the device's active power, operate electric power load, making the inaccessible units accessible to the system. On the other hand, it can also provide the system with frequency control and rapid power response.

CONCLUSION

We have discussed the role and application of advanced power electronics in the construction of smart grid. The study started with the construction of smart grid in our country, explaining the development and application of advanced power electronics, then reflected on the model construction that underlines the foundation for the grid. May this paper contribute to later studies on this field, and pose a progressive influence on the future development of our country's construction of smart grid.

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REFERENCES

[1] Daliang Yang, Ziguang Lu, Naishan Hang; Experiment reform and construction of the practice innovation platform for power electronics technology, Experimental Technology and Management, **30(8)**, 171-174 **(2013)**.

[2] Liangyu Su, Wu Wang, Yu Ge; Expanding innovative thinking with simulation teaching for Power Electronics, Experimental Technology and Management, **(1)**, 170-173 **(2013)**.

[3] Guangfu Tang, Zhiyuan He; A review of 2012 CIGRE-Latest developments on HVDC and power electronics, Automation of Electric Power Systems, **36(24)**, 1-3 **(2012)**.

[4] Jun Rong, Junhua Wan; Application of computer simulation technology in difficulty of classroom teaching of Power Electronic Technology, Experimental Technology and Management, **29(8)**, 103-105 **(2012)**.

[5] Hong Yu; Application of power electronic technology in power systems, Coal Technology, **31(10)**, 40-41 **(2012)**.

[6] Qingmin Lv; The several research focus on power electronic technology, Power Electronics, **45(5)**, 106-107 **(2011)**.

[7] Chunyan Zang, Zhenjiang Pei, Ruifeng Gou; Smart and modern power electronics, Power Electronics, **(13)**, 50-53 **(2010)**.