BeiDou Navigation Satellite System III Application in The Power Industry

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Abstract. As an important lifeline industry of the national economy, electric power has great demand for navigation and positioning, short message communication and timing of the BeiDou system. With the BeiDou III put into operation, the BeiDou system will be more widely used and deepened in power. This paper first introduces the main application of BeiDou system in China's power system, and then introduces the construction situation and various performance indicators of BeiDou III in detail. From the three aspects of precise positioning, short message communication and timing function, the performance index of BeiDou III and its specific application in power system are expounded. In addition, the future application and development of BeiDou system in energy industry are prospected.

1. Introduction

With the reform and development of power system, the dependence of navigation and positioning system in power system has increased greatly. Navigation and positioning system is widely used in power grid, power enterprise marketing and power construction. China BeiDou Satellite Navigation System (BDS) is a self-developed and innovative satellite navigation system. It is the third mature satellite navigation system after the US Global Positioning System (GPS) and Russian Glonas Satellite Navigation System (GLONASS). Before the BeiDou satellite system provided services, China's power industry has basically formed a dependence on the US GPS and Russian GLONASS satellite navigation systems. It involves information about almost all outdoor operations and equipment assets of power grid companies, such as mobile industry mobile operations, line inspections, and GIS data collection. The BeiDou system is developing rapidly, the technology is becoming more mature, and the safety is obviously better than GPS. It is of great significance to ensure the safety and reliability of the power grid operation control and the safe and stable operation of the power system. The popularization and application of BeiDou satellite navigation system in power industry can greatly improve the reliability of future national energy construction.

Since 2010, State Grid Corporation of China has vigorously promoted the application and exploration of BeiDou in the power industry. The content covers BeiDou's timing, frequency, positioning and short messages, and has formed a variety of BeiDou power application solutions. These solutions have also been widely used in power grid production and management. BeiDou satellite navigation system has three functions: positioning, short message communication and timing. It can determine the geographic latitude and longitude and altitude of the user at any time and any place within the service area and provides two-way short message communication and precise timing service.

In terms of timing, State Grid Corporation of China released two synchronization specifications in 2009 and 2013 respectively. With the development of power system automation, dispatching
automation, substation lightning location, power angle measurement unit, traveling wave ranging and other devices put forward more stringent requirements on time accuracy. In the field of power grid control, more than 800 sets of dispatching automation master stations have received the BeiDou timing signal. In terms of positioning, the high-precision positioning function plays an important role in the transmission line tower deformation monitoring and distribution terminal fault location. In addition to the above several scenes, the high-precision positioning function has also been applied in the fields of power engineering surveying and mapping, power intelligent inspection, charging pile management, and geological disaster monitoring.

In terms of short message communication, the BeiDou short message is a unique function different from other satellite navigation systems. With the wide coverage of BeiDou system, it can be used as a powerful complement to the existing optical fiber network and wireless public network, or as an emergency means of communication, to solve the problem of data acquisition and transmission in non-signal areas. The application of BeiDou short message in the fields of power information collection, emergency communication assurance and distribution terminal monitoring enlarge the communication coverage and improves the fine management level of power grid equipment by provincial and municipal power companies.

With the operation of BeiDou system III, BeiDou Satellite Navigation System has covered most of the world, and its integrated positioning service capability is partially better than GPS system; moreover, it has higher security than GPS system, and also has differential functions such as short message data communication (BeiDou RD function). Therefore, the use of BeiDou satellite navigation system to provide services for the power industry will be one of the development directions of the future power grid.

2. BeiDou Navigation Satellite System III

BeiDou is a global satellite navigation system built and operated independently by China and compatible with other satellite navigation systems in the world. The development strategy of the BeiDou Navigation Satellite System (BDS) is divided into three steps. Since the start of development in the 1990s, the construction of BeiDou I, BeiDou II and BeiDou III has been implemented according to the “three-step” strategy. With the completion of the construction of BeiDou III basic system, global services were provided on December 27, 2018.

2.1. The basic service performance of BeiDou system III

Compared with BeiDou II, the satellite BeiDou system III network covers the whole world. The system has been improved in load, inter-satellite link and laser communication. In addition, satellite search and rescue function and global position reporting function have been added. Compared with other satellite navigation systems, B1C and B2a signals with better performance and compatibility are added, and satellite-based enhancement services are provided in accordance with international standards. At the same time, a higher performance cesium atomic clock and a hydrogen atomic clock are configured. The stability of the cesium atomic clock is on the order of E-14, and the stability of the hydrogen atom is on the order of E-15. Detailed information of BeiDou III is shown in Table 1. The new technology has greatly improved the performance of BeiDou system III[1]. The performance of BeiDou basic services is evaluated by global testing (Table 2). The positioning accuracy has been improved by 1-2 times on the basis of the BeiDou II, and the satellite design life has been increased to 10-12 years. The communication function of short message is retained.
Table 1. BeiDou system III business technical indicators description.

| Service type               | Signal frequency point | Satellite                                      |
|----------------------------|------------------------|------------------------------------------------|
| RNSS Public Authorization  | B1I,B3I,B1C,B2a,B2b    | 3 Geosynchronous Orbit (GEO)                   |
|                            | B1A,B3Q,B3A            | +3 Tilted Geosynchronous Orbit (IGSO) + 24 Medium Earth Orbit (MEO) |
| SBAS Public Authorization  | B1C,B2a                | 3GEO                                           |
| Regional short message communication service | L (Inbound), S (Outbound) | 3GEO                                           |
| Global short message communication service | L (Uplink), B2B (Downlink) | 14MEO                                          |
| International Search and Rescue Service (SAR) uplink | Uplink: 406MHz Downlink: 1544-1545 MHz | 6MEO                                           |
| Precise positioning correction information transmission | B2b                   | 3GEO                                           |

Table 2. BeiDou system III service performance.

| System Service Area | positioning accuracy | Speed measurement accuracy | Timing accuracy | System service availability |
|---------------------|----------------------|----------------------------|----------------|----------------------------|
| Global              | Horizontal 10m, (95% confidence) | 0.2m/s (95% confidence) | 20ns (95% confidence); | Better than 95% |

2.2. Navigation Service

Navigation positioning is the basic service provided by the satellite navigation system. The navigation service of the BeiDou system can be divided into basic navigation services, differential navigation services and precise positioning services.

2.2.1. Basic navigation services. The basic navigation services are divided into two modes: satellite radiodetermination service (RDSS) and satellite radio navigation service (RNSS). The positioning accuracy of RDSS is generally about 100m, which will be increased to 20m in areas with calibration stations.

2.2.2. Differential navigation service. Differential navigation service is a precision enhancement service based on basic navigation service. It is mainly based on the modification error of the ground difference station to improve the accuracy. Differential service can be divided into local difference and wide-area difference. BeiDou Global System provides satellite-based enhanced navigation services for authorized RNSS users, with positioning accuracy up to meter level.

2.2.3. Precision positioning service. Precision positioning service is an application for measuring users. Precision positioning can be divided into precise single point positioning, relative positioning and differential positioning. BeiDou precision single point positioning accuracy: 2-4 cm horizontal, 5-6 cm elevation.BeiDou and GPS combination will improve the convergence time.

2.3. Short message communication service

Short message communication services in China and its surrounding areas have increased service capacity by 10 times, reduced the transmitter power to 1/10 of the original, with a single
communication capacity of 1000 Chinese characters (14000 bits), and a global short message communication service with a single communication capacity of 40 Chinese characters (560 bits).

2.4. BeiDou Timing Service

The time benchmark of BeiDou system is BDT of BeiDou time. BDT uses SI seconds as the basic unit to accumulate continuously without leap seconds. The starting epoch is UTC 00h00min00s on January 1, 2006, and counts in weeks and seconds in weeks. BDT establishes contact with international UTC through UTC (NTSC). The deviation between BDT and UTC is within 100 ns (modulus 1 second). The conversion between BeiDou and UTC and other navigation systems is shown in Table 3.

Table 3. The conversion between BeiDou and GPS navigation systems .

| Parameter name                       | GPS                        | BDS                        |
|--------------------------------------|----------------------------|----------------------------|
| semimajor axis of ellipsoid          | 6 378 137.0 m              | 6 378 137.0 m              |
| Oblateness of Earth                  | 1/298.257 223 563          | 1/298.257 222 101          |
| constant of earth gravitation        | 398 600 5 × 10^8 m^3/s^2   | 3 986 004.418 × 10^8 m^3/s^2 |
| the rotation angular velocity of the earth | 7 292 115 × 10^{-11} rad/s | 7 292 115 × 10^{-11} rad/s |

3. Application of BeiDou in Power System

At present, the application of BeiDou system in China's electric power industry has covered all aspects of power generation, transmission, substation, distribution and power consumption. It has further strengthened the construction of China's power natural resources management system and power safety emergency management system, effectively guaranteed the safe and stable operation of electric power, and greatly enhanced the level of space-time intellectualization of energy in China.

3.1. Application of high precision positioning in electric power

The emergency communication command system constructed by State Grid Corporation adopts BeiDou satellite navigation system, and all emergency communication vehicles are equipped with BeiDou positioning terminal. The company has built a unified vehicle management platform, covering the company's production and official vehicles. A monitoring, assessment and early warning system of transmission line geological hazards based on BeiDou has been built to effectively enhance the ability of transmission line to resist natural disasters and actively respond to the threat of geological hazards caused by rainstorms and floods to transmission lines[2]. The State Grid is actively promoting the pilot application of UAV and robot patrol inspection, and actively promoting the directional application of charging stations, charging piles and distribution network equipment.

3.2. BeiDou timing service system in smart grid

The high-precision timing system based on the BeiDou system has broad application prospects in the process of smart grid construction[3]. In particular, the current BeiDou timing system has received strong support from the state and has achieved unprecedented development. With the development of power system automation, dispatching automation, substation lightning positioning, power angle measuring unit, traveling wave ranging and other devices put more stringent requirements on time accuracy(Table 4). The operation of the BeiDou III has effectively promoted the development of the power system.

In the field of power grid control, 90% of dispatching master automation systems and 20% of substations (less than 66KV substations are seldom equipped with time synchronization systems) have received BeiDou timing signals. Both the newly built and reformed automation system of dispatching master station and the time synchronization device of substation receive BeiDou timing signal. BeiDou timing signal is applied 100% in the field of information management. Three safe, stable and reliable first-level time source nodes have been built, which are mainly based on BeiDou signal and supplemented by GPS signal and traceable to a unified standard time.
Table 4. Power system time synchronization requirements.

| Business type                                      | Time synchronization accuracy/s |
|---------------------------------------------------|--------------------------------|
| Fault Location Device for Line Traveling Wave     | $1 \times 10^{-6}$            |
| Lightning Location System                         | $1 \times 10^{-6}$            |
| Power angle measuring system                      | $4 \times 10^{-5}$            |
| Fault Recording System                            | $1 \times 10^{-3}$            |
| Time sequence recording device                    | $1 \times 10^{-3}$            |
| Microcomputer Protective Device                   | $1 \times 10^{-3}$            |

3.3. Application of BeiDou short message in electric power

BeiDou short message is a unique function of BeiDou system which is different from other satellite navigation systems. With the advantage of BeiDou system that has wide coverage and is not limited by geographical location, BeiDou short message can be used as a powerful supplement to existing optical fiber network and wireless public network, or as an emergency means of communication, to solve the problem of data acquisition and transmission in non-signal areas[3-5].

At present, the BeiDou short message power information collection device has been put into use in areas not covered by the public communication network of power companies. In terms of distribution network terminal detection, the State Grid is currently carrying out the demonstration application of the intelligent construction of the BeiDou satellite system supporting distribution network to realize the fault location and repair of the uncovered area of the communication public network. For emergency communication, the BeiDou short message terminal has been installed in emergency communication vehicles, and the BeiDou system is used to locate the vehicle position and send back.

4. Conclusions

The safe production and operation management of power grid are closely related to time and space. It needs high precision location service provided by BeiDou system, short message communication service without public network coverage area and time and frequency service functions necessary for power grid operation[6]. BeiDou system is used in the field of electric power, which solves the problem of collecting electric power information in areas without communication signal coverage in some provinces and cities, effectively solves the problem that natural disasters may lead to the paralysis of public network communication, reduces the failure rate of power supply and makes the operation of power grid safer, improves the service efficiency of power grid system, shortens the emergency response time after accidents, and improves the management level. It reduces the cost of power supply.

Grid security is a top priority for power grid companies in terms of national economic security and national defense security. As a global satellite navigation system, BeiDou system can provide basic technical support such as navigation and positioning, precise timing and short message communication services for the construction of smart grid, ubiquitous power Internet of Things and energy Internet. It is an effective supporting means for the development of China’s energy strategy. With the promotion of BeiDou technology, BeiDou system will support the digitalization and intelligence of the energy Internet, and promote the development of energy from two-dimensional to three-dimensional multi-source time and space intelligent management, thus promoting the development of the energy industry.

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