A High Precision Time Synchronization Method for Smart Grid based on Beidou Satellite System

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Abstract. With the rapid development of power grid and the large-scale application of automation equipment in power station, the requirement of high precision time synchronization for power system production and control is rapid growth. The accuracy of time synchronization for power system is an important basis to guarantee power network operation control and fault analysis, and a fundamental guarantee to improve power network accident analysis and stability control. In order to ensure that the automatic device receives accurate time synchronization signal, time monitoring and application schemes of different technical routes are studied in this paper. It is proposed that the precise monitoring based on the direct measurement of Beidou can realize high precision time monitoring and synchronization, better guarantee the accuracy of time synchronization between power equipment, ensure the precision of phase measurement, line fault location and time sequence recording of power system, and provide technical support for the stable and reliable operation of power system.

1. Introduction
Modern power network control technology is closely related to time. Time is the trigger condition for many automatic control [1]. Therefore, only the acquisition of high-precision time information can guarantee the accurate and safe operation of power network control equipment. The small-time delay error in power grid operation may cause the data collected to be out of sync, affect the data analysis and application, endanger the safety production, and cause the immeasurable economic loss. Smart grid will produce a large amount of data information. In order to ensure the accuracy of information and improve the use value of information, information needs to be attached with time stamp. Only accurate measurement of time can guarantee that the data is based on the same exact time. Energy generating units, large regional power grid interconnection, ultra-high voltage power transmission, smart power grid development direction [2]. The development of power grid puts forward high demand for time synchronization of power grid. In the future, the popularization and application of digital power technology, such as the online prediction system of grid preventive control (OPS), the wide-area measurement system (WAMS), and the wide-area monitoring and analysis protection control system (WARMAP), etc., will require more urgent time synchronization and require more time synchronization. Time has become the fourth basic element of power grid after voltage, current and power, especially the smart grid currently under construction. Time has become the core element of process control.

The maintenance of time synchronization system is mainly based on offline inspection, testing and...
judging whether the time synchronization between the source time synchronization device and the timing device meets the requirements of time synchronization. This synchronization technology can only achieve the accuracy at the time of being checked, and cannot ensure the long-term stability and reliability of synchronization of the timing equipment. In the case of production accident, it is difficult to accurately locate the fault point due to the lack of reference time signal [3-4].

The time synchronization device accepts the external BD(Beidou)/GPS/active time reference signal and outputs the time information and time synchronization signal according to the required time accuracy and transmission mode. The timing synchronization system is mainly used to synchronize and calibrate the time of other supporting systems in the network. By introducing the time synchronization system, the time reference information can be transmitted to each management monitoring device accurately, and the time accuracy of the timing device can be controlled and calibrated, and to ensure that the production automation device and the marketing business system receive the accurate time synchronization signal and implement the unified supervision of the whole network time.

2. Time synchronization system

2.1. Reception of time

2.1.1. GPS satellite timing. GPS global positioning system (GPS) is the earliest system that can time the satellite. It is managed and operated by the US government. The constellation of GPS is made up of 24 satellites. It is located over the earth's surface at 20200 km, with an operating cycle of 12 hours. The satellites are uniformly distributed on six orbits, with an orbital inclination of 55 degrees. More than four GPS satellites can be observed anywhere in the world at any time. GPS time is based on the United States naval observatory's coordinated UTC (USNO), whose time origin is defined at 0000 UTC (USNO) on 6 January 1980. At present, the GPS system can achieve 100ns timing accuracy.

2.1.2. GLONASS satellite timing. Global navigation satellite system (GLONASS) is a second-generation military navigation system independently developed and controlled by the ministry of defense of the Soviet Union (now Russia). The GLONASS constellation consists of 27 working and 3 backup stars, so the GLONASS constellation consists of 30 satellites. The 27 stars are evenly distributed in three nearly circular orbit planes, which are separated by 120 degrees, each of which has 8 satellites, 45 degrees apart from the satellites in the plane, with an orbital altitude of 23,600 kilometers. The operation cycle is 11 hours and 15 minutes, and the orbit inclination is 64.8 degrees.

2.1.3. Beidou satellite navigation system. Beidou satellite navigation system is a global satellite navigation system independently controlled by China. It consists of 8 GEO satellites (including 4 IGSO satellites) and 24 MEO satellites. The main functions of the system are positioning, speed measurement, single and two-way timing, short message communication. Positioning accuracy is better than 10 meters, speed measurement accuracy is better than 0.2 meters per second, timing accuracy is better than 50ns, and short message communication is 120 Chinese characters per time. The time base of Beidou satellite navigation system is BDT. BDT adopts international system of units (SI) seconds as the basic unit continuous accumulation.

2.2. Time synchronization device

The time synchronization device mainly consists of receiving unit, clock unit and output unit, as shown in figure 1.

![Figure 1. The basic composition of time synchronization device](image)

The receiving unit of the master clock and the slave clock takes the received wireless or wired time reference signal as the external time reference. The receiving unit of the main clock is composed of antenna, feeder, low noise amplifier (optional), lightning protector and receiver.

The clock unit receives wireless time reference signals (such as BDS, GPS), wired time reference
signals and thermal standby time signals, and simultaneously monitors the operation state of each time reference signal and clock difference with local clock. The time deviation between local clock and external time source is calculated by using multi-source decision mechanism. The clock unit has the functions of time source clock difference measurement, time difference adjustment, multi-source judgment and punctuality.

The output unit outputs various time synchronization signals and time asking signals, status signals and alarm signals, as well as time, status and alarm information.

2.3. Time synchronization of business requirements

The protection equipment, automation equipment and measurement and control equipment of various automation systems, power plants and substations need time synchronization, and the time accuracy of various business systems is shown in table 1.

| Equipment or systems for power systems | Time synchronization accuracy |
|---------------------------------------|-----------------------------|
| Automation system                     | better than 1s               |
| Line traveling wave fault location device | better than 1us             |
| Synchronous phasor measuring device   |                             |
| Measure and control device, intelligent terminal, protection measure and control integrated device | better than 1ms             |
| Equipment online status detection device or automatic recorder | better than 1ms             |
| Electrical energy acquisition device  | better than 1s               |

3. Time monitoring technique

3.1. Four ways to time synchronization system

1) The GPS module and Beidou receiving module are built in the time synchronization device, and the time information is acquired by the GPS system and Beidou system for synchronization.
2) Code mode. For example, IRIG-B code encodes the reference time signal of the clock source and transmits it to each timing device through a special transmission medium. This method has high time accuracy in the case of short line delay [5].
3) Network timing. There are mainly Network Time Protocol (NTP) and Simple Network Time Protocol (SNTP), which transmit the Time information of clock source to each subsystem in the form of Ethernet packet and calibrate the Time by clock. In this way, the matching between system and equipment is completed through the network, which has good networking flexibility [6-7].
4) IEEE1588 protocol. The network time synchronization protocol, which mainly operates in Ethernet, calculates the network delay of transmission medium by timestamp the data packet in the physical layer of Ethernet protocol, thus eliminating the uncertain delay of response time synchronization message and improving the synchronization accuracy of time [8-9].

3.2. Beidou time server technical route

The latest third-generation Beidou satellite receiver is equipped on Beidou time server to obtain the precise UTC time and frequency from the Beidou satellite timing system, and the oscillator (the oscillator can adopt crystal clock, rubidium clock, etc.) are tamed by the precise time-frequency signal, and then output the stable NTP or PTP network timing protocol. The output signal of the Beidou receiver communicates with the central processor and other circuits through the bus, and the central processor controls and processes the system through the FPGA. The core processor needs filtering algorithm to prevent a large number of messages in the network from blocking the timing port of NTP or PTP. The principle diagram of timing is shown in figure 2.
4. Conclusion

By introducing time synchronization monitoring and management system, can accurately monitoring device would transmit the time reference information to the management, implementation of each pair device working condition, time, accuracy and time deviation control and calibration, etc. To ensure production automation equipment and marketing terminal receives the precise time synchronization signal, the entire network time synchronization state implementation of unified regulation.

The Beidou time server is applied in the power system to the control center, power plant and substation computer control system and computer information system, which provides guarantee for the unified time of power network. Because the satellite antenna is exposed to the outside, the satellite signal is very weak and vulnerable to interference and deception, although the redundant configuration of the dual-Beidou satellite receiver and receiving antenna can avoid single point of failure, and the belt cannot effectively avoid the security risks caused by interference spoofing. By adopting the ground network time synchronization method, the security risks brought by interference and deception can be effectively avoided. The NTP network time synchronization network can meet the millisecond application requirements of the grid information system, and the PTP network time synchronization can meet the microsecond application requirements of the grid production scheduling and control system.

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