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# The Multi-source Synchronization System of Power System

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***Abstract***

*Since the power system frequency and time synchronization network are networking alone, which brings a lot of system synchronization, reliability and security issues, this article will merge frequency synchronization network and time synchronization network into one to set up the synchronization system of power grid. In this paper, we present a new generation of power synchronization network program with BDS and GPS timing as the cure. Meanwhile, it presents a three-level power system synchronized demonstration network which is consist of provincial power grid, municipal power grid and substations. And Iin the end, we conduct some research on related technologies of this program.*

***Keywords:*** *system frequency network, time synchronization network, three-level power system synchronized demonstration network*



## 1. Introduction

The proposed program aims to change the status of localized satellite navigation technology in China, solve the existing SDH network communication delay jitter, and improve the performance of network time synchronization protocol. Moreover, in the management system of China's electric power system, power communication and scheduling automation business are under different management departments, this may cause many issues such as management authority and the division of responsibility. These problems make China's electric power dispatching automation system to rely on the U.S. GPS timing as a major way. The implementation of this program can contribute to the integration of power system automation and communication system synchronization network as well as the establishment of the whole network synchronization monitoring and management system. Besides, it may also promote the sustainable development of BDS (BDS Navigation Satellite System) in the power industry [1].

## 2. Digital Clock Synchronization Technology

Digital clock synchronization system is a physical network which is composed of node clock devices and timing link. It distributes timing signal (signal including frequency or time) to all NEs of various business networks with the time synchronization technology to achieve various service network synchronization. Digital clock synchronization system is divided into frequency and time synchronization: (1) Frequency Synchronization Principle: After the external input signal is processed, the system will output the internal clock signal to the clock unit. Then, the signal will be locked by PLL of clock unit and synthesized into the preferences of various types of clocks. At last, it will be assigned to the output unit. Clock board can simultaneously receive and lock satellite timing signals. (2) Time Synchronization Principle: After obtaining the standard time from the time source satellite, the system will send the time information to the various devices that require time synchronization through the time allocated link of Inter-office or intra-office.

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## 3. Power System Time Synchronization Requirements

Today, the power system is getting more and more calls for the real-time and reliability of information in business such as production run, schedule management and administrative communications, which has also put forward higher requirements on the power communication network synchronization [2-4].

(1) Power Communication System Digital Frequency Synchronization Network: Electricity digital synchronization system is an important part of power communication network. It can accurately transmit the synchronization information from the reference clock to each node in the synchronization network, thereby regulating the network clock to establish and maintain synchronization, and satisfying the requirements of transmission and switching performance when deliver business information in communication network. It is the key to ensure the performance critical network timing.

(2) Power Dispatching Automation System Time Synchronization requirements: With the development of power systems, demand of dispatching automation of power system to the standard for time accuracy is increasingly high, dispatching automation requires time synchronization between master terminal and remote terminal (RTU). Currently, software or hardware time setting can't meet the demand, so the satellite timing functions in power system applications is becoming increasingly important and popular.

(3) Power Communication Network Security Encryption Synchronization Requirements: In the electric power communication network, with the expansion of the network, the network system security has become increasingly important, the kind of security measures is increasing, such as password protection, encryption, electronic authentication and so on, and many security measures also need time synchronization signals.

## 4. The Status of Power System Synchronization

### 4.1. The Component of Power System Time Synchronization Network

Power system time synchronization network consists of time synchronization systems of all scheduling mechanism and substations (power plants) at all levels. At present, the chief mode of domestic power dispatching automation system clock synchronization is "intra-station local clock + GPS". The master scheduling and substation set GPS independently. The equipments of plant/station receive local cable time reference signal through comunication network. Because of the short distance, the delay error can be ignored. Different plants/stations can only depend on GPS and there is no terrestrial communication network to transmit synchronization signals as a backup. Due to the design differences, different clock may have some bias, and the reliability of independent single clock is not easy to guarantee. In addition, different manufacturers may provide different GPS technology and configure, meanwhile, it's not easy to meet the needs of time synchronization of different automated systems [5]. The component of power system time synchronization network is shown in Figure 1.

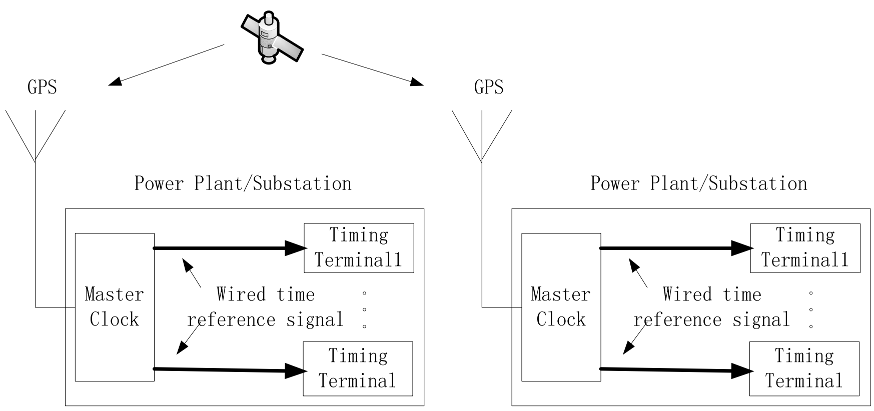


Figure 1. The Component of Power System Time Synchronization Network

### 4.2. The Component of Power System Frequency Synchronization Network

Currently, the Synchronous Digital Hierarchy (SDH) transmission network has become the main way for the power system to transmit information [6]. Dedicated power communication network is different from public communication network. The particularity of the power industry decides that the electric power communication must have high reliability, in which, clock synchronization problem is the most important. Power digital synchronization system can transmit the synchronization information accurately from the reference clock to all nodes in synchronization network. In this way, it can adjust the clock in the network to establish and maintain the synchronization. The system can meet the demand of performance while transmitting and switching information in the communication network. And it's the key to maintain the performance of network timing [7].

The process of information transmission is the same as the frequency synchronization principle that is described in part 2. The component of power system frequency synchronization network is shown in Figure 2.

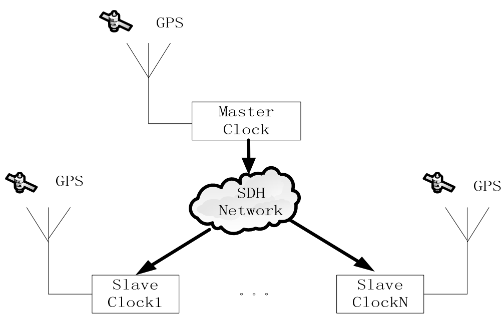


Figure 2. The Component of Power System Frequency Synchronization Network

## 5. Two Networks Unifying Multi-source Timing System

The production safety of power industry is related to the security of national energy and economy. China's electric power dispatching automation system relies on the U.S. GPS as the way of timing. It may lead to major safety accident if the GPS signal is turned off or under adjustment. As the development of China's BDS satellite system, a single GPS clock source must be replaced and transformed [8-10].

This part presents a three-level power system synchronized demonstration network which consists provincial power grid, municipal power grid and substations. It merges frequency synchronization network and time synchronization network into one to set up the synchronization system of power grid. The system of three-level time synchronization is shown in Figure 3.

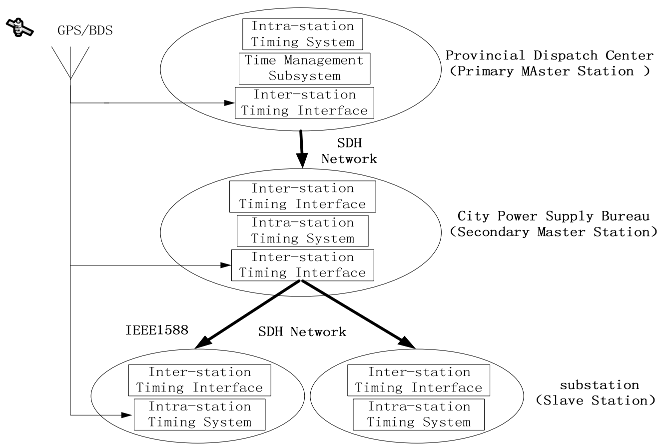


Figure 3. The System of Three-level Time Synchronization

The time synchronization system of both master and slave station can flexibly build various types of time synchronization system, such as basic, master-slave, host-backup and so on. Each time setting node of both master and slave clock can offer time setting singles to terminals through time setting plug-in. Each master clock of time setting node is equipped with “GPS+ BDS” dual-mode timing receiver to achieve GPS and BDS timing function. In addition, the master clock time synchronization via circumscribed wide area time synchronization interface device to achieve its time synchronization with its upper and lower nodes, and nodes transmit synchronization signal through the SDH network. Nodes use the ping-pang time setting system to eliminate the impact of distance between them under the IEEE-1588 protocol [11-12].

In this scheme, three questions need to be mainly solved:

(1) Implementation of IEEE-1588 time setting on E1 interface: Adjacent nodes use SDH equipment for date communication, and the interface with SDH equipment is E1. In order to achieve the inter-station time synchronization on interface E1, it uses IEEE-1588 time setting technology. IEEE-1588 is a combination of hardware and software for time setting technology. Its high accuracy needs to be guaranteed by hardware which can provide high-precision packet sending and receiving timestamp. However, since the IEEE-1588 protocol is not customized for the SDH network, there’s no ready-made product that can be used to implement the IEEE-1588 time setting on E1 interface. Therefore, this scenario uses the "FPGA E1 interface chip" program to achieve IEEE-1588 time setting on E1 interface. It uses FPGA to achieve the data sending and receiving control on E1 interface, and the sending and receiving timestamp insertion which is defined in one-step of IEEE-1588 [13].

(2) SDH network latency and jitter control technology:

In this scenario, the adjacent two nodes use IEEE-1588 protocol to achieve inter-stations time synchronization. So to use the IEEE-1588 protocol to achieve inter-station synchronization, we must develop a special equipment to achieve IEEE-1588 time setting on E1 interface. In addition, it should calculate the transmission delay of IEEE-1588 packet on E1 interface and jitter the filtering of SDH network to ensure a high precision of time synchronization between stations.

Inter-station equipment can only be connected through SDH network in the power system. Although SDH network is synchronous digital hierarchy and its own link delay is more stable, but by the disturb of signal noise, frequency synchronization, error codes, slip code, link palindrome and link switching, the link delay still has a certain extent of jitter and wander. Jitter can be classified into the following specific categories: jitter caused by sliding damage, pulse stuffing jitter and pointer adjustment jitter.

In order to solve the jitter of link delay in SDH network, this scenario uses the IEEE-1588 protocol to achieve time setting between stations. One way, we use the ping-pang time setting of IEEE-1588 protocol specific to estimate the current link delay; On the other hand, we add a filter in IEEE-1588 protocol to process the link delay. Estimated link delay will be fed into the filter, the output will be used to estimate the state of random delay jitter of SDH network, then, the delay caused by the SDH equipment will be eliminated, and the stability of the output will be ensured. In addition, in the processing of IEEE-1588 protocol, it will analyze the jitter of delay to determine whether there is code slip, pointer adjustment, pulse stuffing and other incidents in SDH equipments. When those abnormal events occur, it will cause the link delay in large areas, and the original state of filter will be unable to match. At this time, it is necessary to re-estimate the value of link delay, and recalculate the link delay.

(3) Multi-source timing and dynamic switching technology:

Since the system is a multi-source timing system that is based on GPS, BDS and ground time setting reference. Each timing node will measure the difference of time and frequency between local time and reference source. The timing node will calculate the stability of the reference source through the frequency standard of atomic clock, and choose the best reference source.

When the input stability of the reference source is better, it will use PPS second atomic clocks that are generated from reference source to tame atomic clocks within the node, and in this way, it will improve the precision of atomic clocks. Tameness principle is the use of better stability characteristics of atomic clocks to monitor and evaluate the precision of input pulse. After establishing the atomic clock error model, it will select and correct the tameness time constant. When the optimal clock source changes, it will modify the error with the mode of slowly adjusting.

## 6. Conclusion

By the proposed power system synchronization network, the limitation of technology and management system has been broken down. It will change the status of localized satellite navigation technology in China, solve the existing SDH network communication delay jitter, and improve the performance of network time synchronization protocol. Besides, it merges frequency synchronization network and time synchronization network into one to set up the synchronization system of power grid. With the “Atomic Clock + BDS + GPS" multi-source timing mode and dynamic switching, the reliability of the power system synchronization will be greatly improved.

## References


[1] WANG Yang, ZHAO Hong-bo, LIU Chun-mei, CHEN Zhe, TENG Ling, LU Li-feng. Applications of BDS Satellite Synchronization System in the Power System. *Telecommunication for electric power system.* 2011; 32(1); 54-57.

[2] SONG Guang-qian, FU Guo. Overview of synchronization network used in electric power system. *Telecommunication for electric power system.* 2005; 26(3); 57-59.

[3] Yang Mengjuan, Zhang Daonong, Huang Xirui. A study on technology of power time syschronization system. *Advanced Power System Automation and Protection(APAP).* 2011; 10(3); 2272-2277.

[4] Aweya J, Al Sindi N. Role of Time Synchronization in Power System Automation and Smart Grids. *Industrial Technology (ICIT).* 2013; 3: 1392-1397 .

[5] Electric power industry standard of the people's Republic of China. DL/T 1100.1-2009

[6] GUO Wei. Optimization of Synchronous Digital Hierachy Transmission Network of Power Network. *Distribution & Utilization*. 2010; 27(4).

[7] WEI Wei, LI Yang, CHEN Fang. Time Synchronization System in Power Backbone Communication Network Based on IEEE 1588 Protocol. *Telecommunication for electric power system*. 2011; 32(1); 10-15

[8] Chen Jiongcong, Zhang Daojie, Gao Xinhua. Research of beidou system in electric power system time service. *China International Conference on Electricity Distribution (CICED)*. 2008; 10; 1-5.

[9] Chen Canhui, Zhang Xiaolin. Simulation Analysis of Positioning Performance of BeiDou-2 and Integrated BeiDou-2/GPS. *Communications and Mobile Computing (CMC)*. 2010; 4(2); 505-509.

[10] Jeehyeon Baek, Seungsoo Yoo, Sun Yong Kim. Jamming Effect Analysis of Two Chinese GNSS BeiDou-II Civil Signals. *International Journal of Electrical and Computer Engineering (IJECE*). 2012; 2(6); 840-845.

[11] Bin Zhao, Jie Ji, Min Zhang, Peng Zhai. Reseach of Time Synchronization Algorithm Based on IEEE1588 in Electric Power System. *International Conference on Control Engineering and Communication Technology (ICCECT)*. 2012; 10; 1006-1009.

[12] Yi Liu, Haiying Yang. Precise Clock Synchronization Algorithm for Distributed Control Systems. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(7); 3826-3833.

[13] Mingzhu Qi, Xiaoli Wang, Zhiqiang Yang. Design and implementation of IEEE1588 time synchronization messages timestamping based on FPGA. *Electric Utility Deregulation and Restructuring and Power Technologies (DRPT)*. 2011; 7; 1566-1570.