Research on An Improved Cluster Average Clock Synchronization Method Based on ACATS Algorithm

Shunjiang Wang[1], Lina Cao[1], Xuming Lv[1], Di Cui[1] and Ming Gao[2*]

[1]State Grid Liaoning Electric Power Supply Co., Ltd., Shenyang, Liaoning, 110006, China

[2]Graguate Department, Shenyang Institute of Engineering, Shenyang, Liaoning, 110136, China

[*]Corresponding author's e-mail: 945687573@qq.com

Abstract. At present, the real-time data of electric power measurement are not the same cross-section data, which have a large error and affect the analysis effect of various advanced application software. When the power grid fails, such analysis results may cause decision-making errors, thus threatening the safe and stable operation of the power grid. The ACATS algorithm is adopted in the invention, taking into consideration the phase offset, frequency drift and random delay in the process of information transmission. Inspired by the algorithm, the monitoring idea is used to improve the local average clock synchronization method of the nodes in the cluster in the algorithm, reducing the number of information exchanges required in the same step process of the nodes in the cluster, and taking into account the phase offset, frequency drift, and The random delay in the process of information transmission is of great significance to the practical network.

1. Introduction

1.1 Research background and significance

Time is the most important physical quantity and the basic form of matter. Physical quantity measurement units mostly need unit of time as a benchmark to set up, which is closely linked with the amount of time, especially in some such as space rocket launch test, high-speed digital communications, the land and sea measurement, satellite positioning, the plane takes off, earthquake prediction, etc., the timing and punctual accuracy reached high-precision standard microseconds or even dozens of nanoseconds. At the same time, with the rapid development of modern social science and technology, time synchronization technology has been widely used in our daily life, and plays an indispensable role in the fields of transportation, communication and power. In the field of communication, the concept of "synchronization" refers to frequency. Synchronization, that is, the clock frequency synchronization and phase synchronization of each node of the network, and its error should comply with relevant standards. So far, in the field of communication, the problem of frequency and phase synchronization has been well solved. But the measurement accuracy and resolution of time synchronization technology still need to be improved[1].

In recent years, the new generation of quantum frequency standard technology has developed rapidly, and the optical clock theory and technology have made continuous breakthroughs, which will affect the qualitative leap of time frequency technology[2]. It is of great practical significance to carry out the research on high-precision time synchronization comparative processing technology, not only to improve the existing time scale and its application ability in China, but also to explore the new type of time frequency measurement in the future. Therefore, a new method is urgently needed to improve the accuracy of time synchronization technology and promote the development of time and frequency in the field of measurement and control.

1.2 development status

As we all know, GPS technology can cover the whole world, providing people with extremely accurate location, speed, time and other information 24 hours a day. At present, GPS technology is a global resource sharing, widely used in navigation and positioning, timing and other related areas[3].In the power system of our country, GPS technology is mainly applied in the substation. Through the network, RS232 and RS485, some devices are directly connected with the front machine, a remote device network, serial port, etc[4].

The protocols that transmit time in computer Internet mainly include time protocol, day time protocol, network time protocol and precision time protocol. In addition, there is a simple network time protocol for the client only. The time server on the network continuously monitors the timing requirements using the above protocol on a different port and sends the corresponding format of time codes to the client. In rfc-1305, the network structure, data format, server authentication, weighting and filtering algorithm of NTP are specified comprehensively. NTP technology can be used in local networks and wide area networks. The accuracy is usually only milliseconds or seconds. Network time protocol is widely used in foreign countries to provide time synchronization services. After 20 years of development, hundreds of first-class time servers have been distributed in the United States, the United Kingdom and other countries, among which the performance of the national institute of standard technology of the United States is the best. In addition, there are tens of thousands of secondary servers distributed around the world[5].

2. Construction of time synchronization system in substation automation system

2.1 Substation synchronous clock system

In view of the current substation synchronous clock system, if the substation is 500KV,when the substation synchronous clock is used, redundant configuration is required, and two independent main clocks and one set of clock expansion units need to be set in the whole station. In addition, a set of master clock needs to be set up separately in the relay room of 200Kv[6]. The main function of the master clock is to receive the time signal of GPS, and input the master clock signal of another indoor dispatch and GPS event signal as the standard time source, so as to complete the indoor device timing[7].

2.2 Timing modes of substation automation system

The substation automation system can also be called the plant station system. Since the substation can be divided into station layer equipment and bay level equipment, the substation automation system timing method can be carried out around the station layer equipment and the bay level equipment[8]. For the station layer time, because the structure of the station layer network is very similar to the Ethernet structure of the master station system, the three kinds of time matching can be mainly selected in the way of server time matching, master control unit time matching and network protocol time matching. Secondly, when the interval layer measurement and control network are Ethernet, if the interval side equipment and the station layer equipment are in the same network, station control equipment can be used[9].

3. Time synchronization technique

3.1 Time synchronization theory
Substation time synchronization means keeping the clocks of substation equipment in sync with a standard clock source, thus keeping the clocks of substation equipment in sync. With the development of substation automation, time synchronization technology of power system develops gradually[10]. Power grid is a network with strong real time and relevance. Ensuring the time synchronization system of collaborative and unified work of each node of power system plays an increasingly important role in maintaining the security and stability operation of the power grid. Time synchronization technology becomes particularly important after the comprehensive digitalization of secondary substation system.

3.2 Substations are mainly timed

3.2.1 Pulse pair. When the clock signal is updated, a second pulse or minute pulse signal is sent to the device through the coaxial cable. Use the precise edge (rising or falling edge) of the pulse as a marker of timing. Each device corrects its own clock time to a uniform base time by receiving a pulse signal.

3.2.2 Serial time message. The time data is encapsulated in the agreed message format and sent to the device through the asynchronous serial communication interface. After receiving the message, the device passes it out. Use the parsed data to modify the time of its internal clock. The advantage of serial port message pair is abundant data and strong stability. The disadvantages are low timing accuracy, short transmission distance and message format that needs to be agreed upon in advance.

3.2.3 IRIG B code. Irig-b is a clock code designed for clock signal transmission. Irig-b code rate is 100PPS. Frame rate is 1 frame/s, and a frame period includes l00 code elements. Each bit length is 10ms.Disadvantages of irig-b code:

- 1) the communication of irig-b code needs to send the pulse signal continuously, which occupies the whole communication channel. B code requires high stability of communication device, which requires independent interface and cable.
- 2) irig-b time correction algorithm does not include time correction process error. Timing accuracy is completely dependent on the hardware device and the network state. At present, the timing accuracy of irig-b code cannot meet the microsecond synchronization accuracy stipulated by IEC61850 standard.

3.3 Timing technique
1). To build an improved average cluster clock synchronization method, the ACATS algorithm is applied to a relatively simple sensor composed of three nodes in the network for example, a transmitter for three nodes broadcast a synchronous beacon, assumes that the nodes to estimate their relative phase offset, the time synchronization process as shown in figure 1, :The transmitter broadcasts a synchronous beacon to three nodes Vi, Vj and Vk. Each node records the local time of receiving the beacon ti,tj and tk: node Vi sends a packet to node Vj, which contains ti information. When node Vj receives the packet, node Vk also listens to the packet. Then, node Vj sends a packet to node Vk, which contains tj information. When node Vk receives the packet, node Vi also listens for the packet. Then, node Vk sends a packet to node Vi, which contains tk message. When node Vi receives the packet, node Vj also listens for the packet. At this time, the three nodes all know the time information ti,tj and tk, and then calculate the average time avg=(ti+tj+tk)/3 respectively, and update their local time.

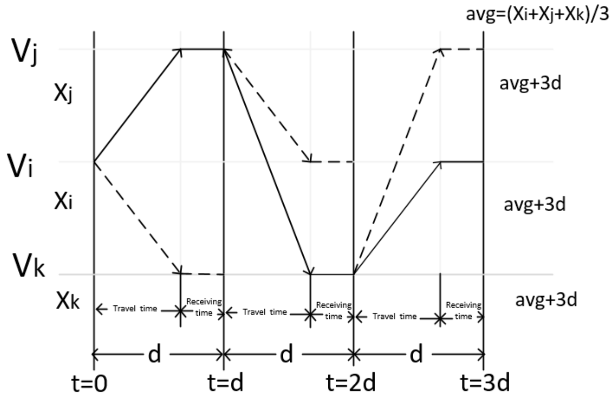

Fig 1 Basic framework of wireless sensor networks

2) Assuming that the nodes experience the same time between sending and receiving information, it is a fixed value, set as d, as showed in figure 2. The transmitter in the cluster broadcasts a member of all clusters. Synchronous beacons, which record the local time at which the beacon is received. One of the nodes sends a packet with its own record value to one of its neighbors. When the neighbor node receives the packet, the other nodes in the cluster also listen.When the packet arrives, the secondary neighbor node sends a packet containing its own record value to one of its neighbors (excluding its parent node). When its neighbor node receives the packet, the other nodes in the cluster also listened to this packet and looped it down until all the nodes in the cluster knew the time value recorded by each other and stopped the sending of the packet, Then all the nodes in the family calculated the average of the recorded values and updated their own local time.

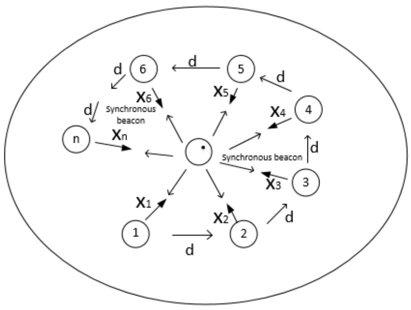

Fig 2 The concrete synchronization process of cluster average

$$\forall \mathrm{i} \in \mathrm{n}: \ \mathrm{avg} = \frac{1}{\mathrm{n}} \cdot \sum_{i=1}^{n} (x_i + nd) = \frac{1}{\mathrm{n}} \cdot \sum_{i=1}^{n} x_i + \mathrm{nd} \tag{1}$$

- n: number of nodes in the cluster,
- Xi: local time recorded when node vi receives synchronous beacon
- d: fixed time delay,
- avg: calculated average value of recorded values of all nodes, namely the value when members of the family are synchronized,

3) by cluster average global average clock synchronization, assumes that the wireless sensor network (WSN) with N nodes, can be divided into M a cluster, set up the first L Ci with ni a node, a cluster when a clan in the transmitter is busy to cluster members radio beacon, members in the cluster is in the working state of receiving information, i.e., no redundant channel to respond to other signals.

4). Cluster average clock synchronization algorithm is considering phase offset, frequency drift and random time delay. The wireless sensor network is divided into several clusters M of cross interconnection, and the switching signal s(K) open each family in turn. When the nodes in the cluster

Ci $V_1^{'} \sim V_{ni}^{'}$ receive the synchronous beacon broadcast by the transmitter, record their respective local time $x_1^{'}$ (k-1) ~ $x_{ni}^{'}$ (k-1), and then send their respective record values $x_1^{'}$ (k-1) ~ $x_{ni}^{'}$ (k-1) and frequency $w_1^{'}$ (k-1) ~ $w_{ni}^{'}$ (k-1) to their neighbor nodes in turn., L=1…M.At this time, all nodes in the cluster know each other's record values $x_1^{'}$ (k-1) ~ $x_{ni}^{'}$ (k-1), and frequency $w_1^{'}$ (k-1) ~ $w_{ni}^{'}$ (k-1), and then calculate the average of record time $\text{avg} = \frac{1}{n_i}\sum_{i=1}^{n_i} x_1^{'}(k-1) + sum\_\bar{d}(k-1)$ and frequency respectively $w = \frac{1}{n_i}\sum_{i=1}^{ni} w_1^{'}(k-1)$ .Each node updates its local time and clock frequency as $x_1^{'}(k) = x_2^{'}(k) = \cdots = \frac{1}{n_i}\sum_{i=1}^{n_i} x_1^{'}(k-1) + sum\_\bar{d}(k-1)$ and $w_1^{'}(k) = w_2^{'}(k) = \cdots = w_{ni}^{'}(k) = \frac{1}{n_i}\sum_{i=1}^{ni} w_1^{'}(k-1)$ respectively.

4. The experimental simulation

ACATS algorithm is in CATS algorithm on the basis of the average nodes within the cluster clock synchronization method for improvement, while CATS algorithm is inspired by classical algorithm of RBS, and that at this point, we will be on the three algorithms in figure 3 and 4 as shown in the simulation experiment on the network, and comparison analysis, including CATS and ACATS algorithm simulation are within clusters transmitter radio beacon on the basis of a synchronization.

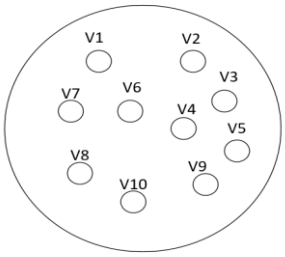

Fig 3 Simple single cluster network

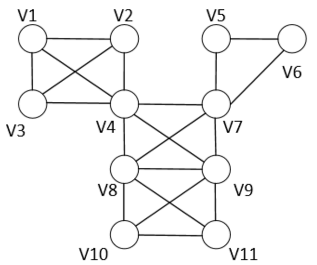

Fig 4 A network graph that divides cluster structures

4.1 Packet transfer delay uncertainty

The simulation results are shown in FIG. 5 and 6. FIG. 5 shows the comparison of synchronization errors in each algorithm when the single-cluster network achieves synchronization. Figure 6 shows the comparison of synchronization errors in each algorithm when the multi-cluster network achieves synchronization. It can be seen that RBS have an obvious phenomenon of increasing synchronization error, which increases with the increase of the number of levels. Synchronization accuracy of ACATS and CATS is the same. However, the information exchange times of each algorithm shown in table 2 indicate that ACATS and CATS algorithm save energy and reduce energy consumption significantly compared with RBS algorithm, while ACATS algorithm also USES less information exchange than CATS algorithm, which is improved in saving energy consumption.

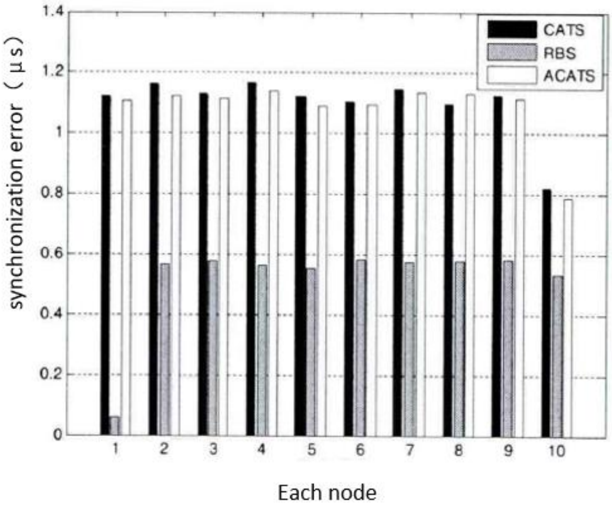

Fig. 5 Comparison of synchronization errors between two algorithms in single cluster networks

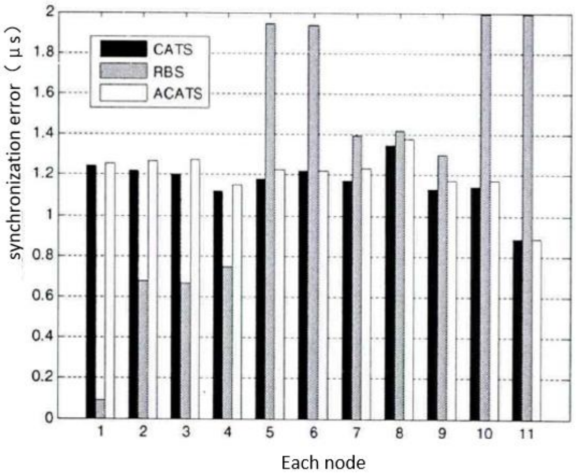

Fig. 6 Comparison of synchronization errors between two algorithms in multi-cluster networks

Table 1. mean synchronization error of each node

Synchronization error(unit: μs)	RBS	CATS	ACATS
Fig.3 Simple single cluster network	0.51764	1.01017	1.0847
Fig.4 A network graph that divides cluster structures	1.2866	1.1689	1.2013

Table 2. The statistics of information exchange times of each algorithm under two kinds of network

Synchronization error(unit: μs)	RBS	CATS	ACATS
Fig.3 Simple single cluster network	1890	18	10
Fig.4 A network graph that divides cluster structures	3528	1012	642

It can be seen from figure 3, 4, table 1 and table 2 that after comparative analysis of the three algorithms, ACATS and CATS are significantly better than RBS in energy consumption, saving energy, while ACATS is also improved compared with CATS. In terms of synchronization accuracy, ACATS and CATS are equivalent. When synchronizing multi-cluster networks, the synchronization error of ACATS and CATS is slightly smaller than that of RBS.

The advantages of CATS in algorithm and ACATS algorithm are also included. For example, by applying the broadcasting characteristics of wireless channels, phase and frequency compensation can be completed in the case of low time and space complexity. At the same time, communication overhead and synchronization error are relatively low. It greatly improves the scalability of the network and can be applied to large-scale network. Compared with CATS algorithm, one is the average synchronization within the cluster, which reduces the number of information exchange required when nodes within the cluster reach the average clock state. Second, ACATS algorithm considers the random delay, estimates the clock synchronization error, and considers the characteristics and factors of the most practical network.

5. Conclusion

The improved cluster average clock synchronization method solves the problem of insufficient time synchronization accuracy of substation. Using ACATS algorithm, record the time information of each node, consider phase offset, frequency drift and random time delay, obtain the average value and update its local. Time, keeping the clock in sync, ensuring that the time synchronization system of each node of the power system cooperates and works in unison to maintain the safe and stable operation of the grid.

Acknowledgments

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