## Preferential Subject 2

# Time in Protection Applications – Time sources and distribution Methods
# Special Report

Dr. Yubo Yuan
(CHINA)

## Summary

The CIGRE Study Committee B5 – Protection and Automation - covers within its scope principles, design, application and management of power system protection, substation control, automation, monitoring and recording including associated internal and external communications, substation metering systems and interfaces for remote control and monitoring.
This paper is the special report for Preferential Subject No. 2 “Time in Protection Applications – Time sources and distribution Methods "of the CIGRE SC B5 2018 Session in Tromso (NO).

## Keywords

Time Synchronization, PACS, IEC61850, PTP (Precision Time Protocol).

## 1. Introduction

The Preferential Subject No.2 of the CIGRE SC B5 2019 Session in Tromso (NO) is entitled "Time in Protection Applications – Time sources and distribution Methods ", associated with the following subitems:

- Sources and distribution of time references in PACS and Wide Area Systems and the related accuracy
- Engineering of time synchronization and time reference distribution for IEC 61850 process bus based protection and control applications
- Commissioning and testing of time reference sources and distribution means
- Expected behavior of PACS functions in case of loss and recovery of time synchronization

A total of 19 papers with authors from 9 different countries have been received for this Preferential Subject. These papers can be divided into 5 groups, some papers covering more than one subject:

1. Time Synchronization Methods (7 papers, cf. §2) (206, 210, 211, 213, 215, 216, 217)
2. Application and Evaluation of PTP (5 papers, cf. §3) (201, 202, 203, 214, 218)

3. Experience feedback, Pilot projects and Demonstrators (5 papers, cf. §4) (205, 207,209, 212, 219)
4. Testing and Associated Test Platforms (2 papers, cf. §5) (204, 208))

## 2. Time Synchronization Methods

**Paper 206** from USA introduces the role of time synchronization in IEC 61850 in power system protection and control. It describes the principles and applications of time in IEC 61850 in detail, including time expression in IEC 61850 model and GOOSE model, related requirements, time expression in IEC 61850 model, time expression in GOOSE model, time expression of sampling communication, transmission time definition, time protocols, time synchronization source, etc.

**Paper 210** from Austria indicates that two-sided measurement requires accurate time synchronization for precise fault location. For that, synchronization methods are available which require verification to ensure the desired accuracy. This paper investigates the practical application and possible pitfalls of the following methods: Fiber Optical cable, GNSS, PTP, advanced time synchronization over Ethernet-based networks.

**Paper 211** from Austria compares and discusses available time synchronization solutions such as PPS, IRIG-B and PTP in digital substations with process bus. In the paper, the PTP method is introduced in detail, practical challenges for the verification of the time synchronization are discussed and possibilities for verification of the accuracy and the correctness of the synchronized clocks are also presented.

**Paper 213** from Norway introduces time synchronization requirements in power systems. It also demonstrates a typical time synchronization setting method in IEC 61850 digital substations. The prospect of establishing a high-precision PTP-WR link to the external mean value through fiber-optic networking is presented.

Relay protection time synchronization is estimated based on IEC 61850-9-2 using analog value data in **paper 215** from Russia. In this paper, relay protection behavior is studied in cases of time synchronization lost and resynchronization by relay protection, AMU and SAMU devices. The authors propose measures to eliminate possible protection failure in different situations. The report discusses various data sets from one source, taking into account the requirements of various relay protection functions that can use these data sets, including modes when AMU and SAMU sources lose synchronization.

**Paper 216** from Russia describes a method which utilizes the auxiliary power network in the station as the reference signal to realize the unified calculation of the phase angle deviation within the whole station. From the essence of the phase angle calculation, the "natural synchronization" is proposed, which is highly innovative.

**Paper 217** from Russia states that the wavelet transform could detect the start point of disturbance in each instrument transformer and be used for time synchronization. It has been trying to calculate the deviation when the SC fault occurs.

**Question 2.1**: For the relay protection system in the station, is the unified time signal like GPS essential to time synchronization? Do we have alternative approaches?

**Question 2.2**: What is the effect of losing time synchronization on protection schemes within or between substations?)

## 3. Application and Evaluation of PTP

One of the significant benefits of PTP includes automatic path length compensation, support for redundant time sources and the cabling efficiency of a shared network. **Paper 218** from Brazil defines PTP as the preferred synchronization method, regarding 1PPS as an alternative for legacy applications. The PTP differs from other network synchronization protocols (such as SNTP) by the accuracy achieved due to the Master / Slave relationship. Several papers cover the application, test method of PTP in digital substations. PTP provides an effective way to eliminate the clock error of each device in the distributed network system and the transmission delay of each device data in the network. PTP has been applied to multiple substations and has on-site operation experience, but the subsequent promotion also needs to consider the cost of equipment upgrade, which is the biggest problem that restricts its application in the station.

**Paper 201** from China first introduces several applications of IEEE 1588 in the smart substation. The main functions of IEEE 1588 are to provide accurate SOE (Sequence of Event) time scales for the intelligent terminal, to provide accurate event recording time for the protection test device, and to realize synchronous sampling of current/voltage data for merge unit. Then, a test method for IEEE 1588 timing function in smart substations is introduced, and the test data are given through the practical project.

**Paper 202** from United Kingdom introduces the time synchronization performance of primary clock and slave clock and presents the recovery ability from loss of synchronism. Besides, the deviation test and the shake performance are also presented.

**Paper 203** from USA describes the challenges of a PTPv2 implementation in a PRP network, and presents the tests and results if using these protocols in a real case scenario. It says PTP implementation in PRP networks is still an obscure path. It is not an easy since it involves deep architecture changes, standard interpretation and internal definitions in a scenario where there are few implementations available for testing and comparing. It states 'more refined definitions and different types of implementation are still important'.

**Paper 214** from Chile has developed testing and analysis of time synchronization for Multi-Vendor IEC 61850 process bus based protection and control applications, and developed complete scheme for this test consist of Merging units and digital relays from ABB, SIEMENS, EFACEC and GE with interfaces to interoperate using IEC 61850-9-2 process bus and IEC 61850-8-1 station bus.

**Paper 218** from Brazil evaluates the PTP performance of the Process Bus with several scenarios of Ethernet network loading. Six scenarios were set up to check PTP performance on the process bus up to 10 Mus connected in the network. The paper introduces that the traffic interferes with the PTP sync mechanism.

**Question 2.3**: What's the pros and cons of IEEE 1588 compared with IRIG-B?

**Question 2.4**: What's the best interval of the synchronization frame for IEEE 1588 that suits the PAC applications and hardly affects the network traffic? And how will the interval affect the packet loss and synchronization?

## 4. Testing and associated Test Platforms

The process level has been introduced to a digital substation, which makes all kinds of information shareable, provides the foundation of advanced application analysis, and makes substation more intelligent. At the same time, it also puts forward higher requirements for time synchronization, for example in the case of process level networking, the logic of protection and control devices rely heavily on time clock synchronization.

With the wide application of the merging unit (MU), conventional real-time analog data sampling in measuring device is seldom used in smart substation Consequently, a new network sampling method based on fiber-optic network transmission is widely applied, analog data are acquired by remote measure modules and MUs and converted into SV messages. In this method, a massive amount of fibers are reduced, all data sharing in the substation is realized, and the arrangement is very simple, but it requires high accuracy of the station synchronization system signal. Compared to point-to-point sampling method, reliability of the network sampling method can’t be ensured.

**Paper 204** from China analyzed the network sampling data synchronization technology based on electrical reference vector, as well as the influence of the clock synchronization system abnormity on the sampling, measurement calculation and synchronism function of the measuring device.

**Paper 208** from China introduced the overall scheme of time synchronization and time synchronization monitoring of intelligent substation in China, also with the time synchronization accuracy test method, which can effectively improve the reliability of the substation protection and control system.

**Question 2.5**: How to judge the sampling data between different IEDs is out of synchronization? And how to perform data compensation processing?

**Question 2.6**: How to perform time synchronization monitoring test?

## 5. Experience feedback, Pilot projects and Demonstrators Synchronization

This chapter introduces the diverse pilot time synchronization installation in the view of engineering application dispersed over the world. According to its characteristics, the synchronization is divided into pulse/coding synchronization, PTP network synchronization and wide area time synchronization in IEC 61850 substation and PACs. Pulse/coding synchronization is widely used in conventional substations. PTP synchronization is specified in pilot project due to the modification cost. Wide area time synchronization is implemented in the Dispatching Center. These demonstration projects have taken an important step and are valuable experiences in time synchronization.

**Paper 205** from Brazil introduces the solutions of time synchronization for PAC systems in the Brazilian electric power system, especially in IEC 61850 applications. It compares the principal time synchronization methods including IRIG-B, 1PPS, SNTP and PTP. The solutions adopted in practical PAC systems in Brazil and the structure for acceptance tests are presented as well.

**Paper 207** from China introduces the application of time synchronization in digital substations in China. This paper describes China’s practice in satellite time synchronization system and process bus network in detail. Besides, the scheme of selection between the masters and the strategy of the time synchronization system during power-up and satellite tracking, adjustment mechanism during abnormal situations such as the hold over difference between the masters, and the recovery from disconnection with satellites are discussed in the paper.

**Paper 209** from Norway introduces the novel practice of time synchronization in the Statnett R&D project’s intelligent station, which combines a variety of methods including PTP, PRP and BMCA to guarantee the reliability and security simultaneously. This paper provides valuable insights for the engineering practice. The reliability and security of time synchronization signals with economical investments should be considered.

**Paper 212** from Japan introduces a sampling synchronization method and a PTP method adopted for Protection and Control Systems (PACS) in Japan. Furthermore, several application examples are provided to prove the effects of aforesaid methods which meet the application requirements well of several typical PACS mentioned in the paper.

**Paper 219** from Brazil shows the availability and reliability of converging telecommunications systems that succeeded in Brazil. It demonstrates an overview of the Unified Synchronism Network, operated by the telecommunications company, modern and appropriate to the needs of Operational Technology (OT) and Information Technology (IT). The main challenges and Benefits for the implementation of this new Unified Synchronism Network have also be presented.

**Question 2.7**: What are the accuracy requirements of different applications, such as protection, SOE, traveling wave fault location and WAMS? How can we balance the reliability with the economy?

**Question 2.8**: How to guarantee the security of the time synchronization system of a specific county? Using the unified time signal obtained from the satellite or build a unified clock on earth, which will be better?

## 6. Conclusion

The stable operation of the secondary system heavily depends on the accurate measurement of time. The failure in time synchronization of PACS can result in protection tripping time not corresponding to the sampling time. Furthermore, it might affect the numerical and logical actions of the device, and leading to the mis-operation or operation-refusing of circuit breakers. Therefore, failure in time synchronization might cause great difficulty to fault clearance, and even endanger the operation of the power system.

The industry concern is attached to "Time in Protection Applications – Time sources and distribution Methods" and proven for Preferential Subject 2 with 19 received papers. The awareness that IEC 61850 conformance alone is not sufficient to obtain interoperability, interchangeability or maintainability when PACS is growing. Additional specifications and requirements are needed for this, and the outline of what these specifications should contain, how they should be organized and what might be their format is emerging. Several of the received papers contribute to this discussion, and the proposals include time in PACS, Precision Timing Protocol files or standardization of the architecture, of IEC 61850 models and of the functional description.

The experience feedback of time synchronization has put forward several items which need more attention and which will, without doubts, be important in the years to come. These items include time synchronization and smart substation. There are already time synchronization projects in cooperation with telecom operators in Brazil. The numerous contributions discussing qualification, test platforms, maintenance and staff training are an indication for this evolution. Several very concrete projects of test platforms and demonstrator PTP have been presented in the papers received.

Finally, there is now substantial experience feedback of time synchronization in IEC 61850, including some pilot projects featuring process bus and using Sampled Values. One important conclusion here is that network is the trend of future time synchronization. This concerns both tools and procedures and may also impact utility organizations.

The work related to defining a future substation concept must adopt a realistic approach, to balance between cautiously considering existing technical requirements and courageously adopting novel technologies”. This conclusion globally holds for all the subjects covered by the papers of PS2.