Design and Its Application of Power Time Synchronization Management System Based on TMU and IEC61850 Protocol

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Abstract. By deploying the TMU device at stations and power plants, the time synchronization measurement of the station clock device and secondary device are performed. The automatic discovery of the device status and the real-time upload of the time difference data are realized based on the IEC61850 protocol. The time synchronization network configuration, alarm and performance data are unified maintained, managed and monitored, to enhance the plant station time synchronization precision control ability, which has a good operability, scalability and compatibility.

1. Introduction
With the rapid expansion of the scale of the power grid and the rapid development of various technologies, the requirements for the time synchronization of secondary equipment are also getting higher and higher. The regulatory agencies at all levels need to fully understand the operation of the secondary equipment, Analyze the situation of the secondary equipment time synchronization status professional work carried out by the subordinate regulation and control institution thoroughly and in-depth[1] in order to better guide the daily work. At present, the following problems exist in the construction and operation of the time synchronization system: On the one hand, there are many types of clock devices in the power grid and there is a lack of a unified time synchronization management method [2]. On the other hand, there is no time synchronization of integrated management system [3], lack of efficient operation and maintenance methods, effective closed-loop management [4] and monitoring the timing status of various clock devices.

Although smart grid dispatching control system has some time monitoring ability [5], it cannot be accurate to the millisecond level and cannot forecast the trend of time deviation in advance. It is an inevitable choice to study the precise time synchronization monitoring method and build an independent time management system outside the dispatching control system to realize the real-time information collection and delivery to the plant information [6-10]. In addition, the issue of standardizing interfaces, enhancing comprehensive access capabilities, and resolving differences in software architecture and system interfaces that result in inconsistent management protocols and mutual incompatibilities is also an important aspect that has often been overlooked.

This article describes how to deploy TMU equipment at the plant site to measure the time synchronization between the clock equipment in the station and the secondary equipment to be granted
time. The automatic discovery of equipment status and the real-time upload of the time difference data based on the IEC61850 / MMS protocol can be realized. Realize time synchronization network configuration, unified maintenance of alarm and performance data, integrated management and real-time monitoring to improve the time synchronization accuracy control ability of the plant station. The achieved system has good operability, scalability and compatibility, and has well the economic and social benefits.

2. Time Synchronization Management Needs

According to the status quo of substation time synchronization and the different requirements of substations on time synchronization, the scheme is especially suitable for plant stations that require extremely time synchronization or plant stations which are important hubs of the grid. For such sites, it is necessary to monitor the running status of the time synchronization system in three aspects: the status monitoring of the timing device to ensure the running status of the timing device is normal; the timing accuracy of the timing device ensures that the timing accuracy of the timing device is normal; Condition monitoring, to ensure that the device is synchronized when the state was normal. Specifically include the following three types of monitoring content:

a) Time monitoring of equipment status. The clock device (timing device) is located in the safety zone I. The clock device shall have the status self-test function, and send information of its antenna status, module status and number of stars found to IEC61850 protocol to the equipment status monitoring substation I area). The equipment status monitoring sub-station will send the monitoring information to the equipment status monitoring master (time synchronization module).

b) Timing accuracy monitoring equipment. Deploy a station-side TMU unit at the substation, which is in Safety Zone I. All timing devices in the station include a master clock, a backup clock and an extended clock, and each timing device gives a station a timing signal of a station-side TMU device. After receiving all the timing signals, the station-side TMU device uses the timing signal of the master clock as a reference, Timestamps of other timing devices in the station and the master clock are measured and the result of the measurement is called station time difference. The station-side TMU device sends the station time difference information to the equipment status monitoring substation by using the IEC61850 protocol through the local area network in the station. On the other hand, the station-side TMU device sends the timing signal of the master clock of the station to the dispatching end TMU through PTP over E1, and the dispatching end TMU device restores the time signal and compares it with the dispatching center master clock time to measure the difference Value, call it wide area time difference. The dispatching end TMU sends the wide area time difference to the equipment condition monitoring master (time synchronization module).

c) Status monitoring of equipment when granted. Dispatching and substation automation systems of various types of devices or systems to be time-tested, the application-layer functions of online monitoring of time synchronization status shall be implemented according to the requirements in the following table.
3. Time Synchronization Measurement

Time Synchronization Measurement Device (TMU): A monitoring device based on the synchronization pulse monitoring device to realize the sampling pulse of the sampling unit [11], which is used to monitor the sampling synchronization pulse in real time and send the monitoring data and its own status to the substation via MMS Station control layer network time monitoring equipment.

In this solution, as Figure 1, one clock device with status self-test and one TMU device with station-side status (all located in the control area) are configured. Meanwhile, the device self-test status of the
equipment is modified as shown in FIG. 1. Time synchronization management messages are mainly four categories:

The first category is the status monitoring of the timing device, including the self-test status information of the timing device, which interacts directly with the device status monitoring sub-station via the station device / spacer network through the clock device as shown in ①.

The second type is the monitoring of the time difference in the station, mainly using the station-side TMU device to receive the timing of all the time-keeping devices in the station, and then calculating the time difference between other clocks in the station and the main clock. Directly with the equipment status monitoring sub-station interaction, as shown in the ② class information shown.

The third category is the monitoring of wide-area time difference. The station-side TMU is mainly used to send the time signal of the master clock of the station to the dispatching end TMU through the PTP over E1. The dispatching end TMU measures the wide-area time difference and sends it to the master station system. As shown in Figure 1, the flow of station-side information should be encrypted between the station-side TMU and the E1 interface of the communication.

The fourth category is the monitoring of the time-honored equipment, including the self-test information packet of the time-honored equipment and the test of the synchronized status of the time-tested equipment and the equipment status monitoring substation through the "ping-pong principle". As shown in the figure 1 information, when the device being granted in the control zone interacts directly with the device status monitoring substation through the station control / bay level network, the device to be granted in the non-controlled zone interacts with the device status monitoring substation through the transverse interconnection firewall, The figure only to control and security in the sample.

The above four types of information, of which the first category for the timing device monitoring, the second and third categories for the accuracy of timing equipment monitoring, the third category for the status of equipment being granted time monitoring, the formation of three from the time-to-end Time-end closed-loop monitoring, from the time synchronization status to the accuracy of the time synchronization of the three-dimensional monitoring, built into the most complete time synchronization management model.

4. Time Synchronization Management System Design

4.1. System Overall Structure

Combined with the demand analysis, the system structure shown in Figure 2, generally speaking, from bottom to top is divided into three layers, including: application layer, platform layer, and acquisition layer.

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4.2. Longitudinal Data Acquisition interface

System and TMU, monitoring sub-station communication between the industries should adopt IEC IEC 61850-MMS specific communication protocol.

a) Based on IEC61850 client / server communication mode to achieve integrated data transmission, communication mapping protocol in accordance with IEC61850 Part 8-1.

b) Intelligent remote machine as a gateway, acting as a proxy to communicate with the main station. From a functional realization perspective, all information is transparently transmitted, and the master accesses all IED data through the intelligent tele control module.

c) The intelligent remote machine provides the publish subscription LD for organizing all the data sets and the report control blocks. Each scheduling master accesses the LD data set and operates the report control block of the LD to obtain the data. For different data needs, should be able to achieve different data transmission priority. The TMU device shall be modelled in this functional object in accordance with the data models, services and modelling methods defined in IEC 61850 Part 7, data relating to the same functional object, and data attributes, including some functional extensions of the functional object; Multiple, functionally relevant or system-wide data should be modeled on a common logical node or logical device.
| Property          | Type   | Semantics                      |
|-------------------|--------|--------------------------------|
| Mod               | INC    | mode                           |
| Beh               | INS    | behavior                       |
| Health            | INS    | health status                  |
| NamPlt            | LPL    | Logical node nameplate         |
| TmudRef1Alarm     | SPS    | 1st reference signal status    |
| TmudRefnAlarm     | SPS    | N th reference signal state    |
| TmudRef1Type      | INS    | No. 1 reference signal type    |
| TmudRefnType      | INS    | N th reference signal type     |
| TmudCont1Alarm    | SPS    | 1st reference signal transition detection state |
| TmudContnAlarm    | SPS    | N th reference signal hopping detection status |
| TmudChannelAlarm  | SPS    | E1 link status                 |
| TmudBoa1Alarm     | SPS    | The first card state           |
| TmudBoanAlarm     | SPS    | The n th board status          |
| TmudBoa1Type      | INS    | The first card type            |
| TmudBoanType      | INS    | The n th board type            |

The device logical device is instantiated under the name "TMUD" and contains at least the status monitoring logical node SMUD (shown in Table I).

And the data telemetry logical node MMUD (shown in Table II) as following, in which files are to provide device model, manufacturer, software version and other information.

| Property            | Type   | Semantics                                              |
|---------------------|--------|--------------------------------------------------------|
| Mod                 | INC    | mode                                                   |
| Beh                 | INS    | behavior                                               |
| Health              | INS    | health status                                          |
| NamPlt              | LPL    | Logical node nameplate                                 |
| TmudTssm1DiffSec    | INS    | The first device to be tested station within seconds    |
| TmudTssm1DiffNs     | INS    | The first device to be tested within the station nanosecond time difference |
| TmudTssmmDiffSec    | INS    | The n-th unit under test station time difference of seconds |
| TmudTssmnDiffNs     | INS    | The n-th device to be tested has a station time difference of nanoseconds |
| TmudSubs1DiffSec    | INS    | The first substation wide-area time difference seconds  |
| TmudSubs1DiffNs     | INS    | The first substation wide-area time difference nanosecond |
| TmudSubsnDiffSec    | INS    | The nth substation wide-area time difference seconds    |
| TmudSubsnDiffNs     | INS    | The n-th substation's wide-area time difference nanosecond |

4.3. Horizontal System Integration Interface

Time synchronization integrated management system to Web service way to achieve with the data center, the main station OMS system and secondary equipment condition monitoring system interface.

One of the main interface with the data center to achieve data exchange service interface and application service interface. Interface with the master station OMS system to obtain from the OMS system station time synchronization equipment, accounting information and defect data, and the time synchronization integrated management system to determine the time synchronization device fault information pushed to the OMS system defect processing module for unification deal with. The interface with the secondary equipment condition monitoring system will push the status information of the time synchronization devices at each plant to the secondary equipment condition monitoring system for unified equipment status evaluation and status maintenance.
Interface format unified form of XML, the specific provisions are as follows:

```xml
<?xml version = "1.0" encoding = "gb2312"?>
<info>
  <CorporationCode> Region Code </CorporationCode>
  <! - Incoming indicator names can be one or more ->
  <api name = "indicator name 1"> value 1 </api>
  <api name = "indicator name n"> value 1 </api>
</info>
```

System for each business system to develop a complete set of Web Service interface standards, the business system in accordance with the standards for development. To achieve any of a business system, only by modifying the configuration file, you can quickly access the system, to achieve loosely coupled interactive integration.

4.4. Mechanism and Process

The TMU equipment is deployed at the plant site to measure time synchronization between the clock equipment in the station and the secondary equipment to be granted time, and the automatic detection of the equipment state and the real-time upload of the time difference data based on the IEC61850 / MMS protocol, The deployment of the master station to achieve time synchronization network configuration, alarm and performance data unified maintenance, integrated management and real-time monitoring to improve plant time synchronization accuracy control capabilities, based on the method of the application system has good operability, Scalability and compatibility.

The key process of the present invention is shown in Figure 3, the specific steps are:

a) A TMU and IEC61850 protocol based grid time synchronization integrated monitoring and management method is characterized by comprising the following steps:

b) Acquisition and measurement: Deploy the TMU time synchronization measuring device at the site of the plant, the clock equipment in the access station and the secondary equipment to be time-synchronized for measurement;

c) Data upload: At the station end through the IEC61850 / MMS protocol, the equipment status data will be collected and the time difference data will be uploaded to the master station in real time;

d) Monitoring Management: At the dispatching end of the master station, the data synchronization and conversion can realize the unified maintenance, integrated management and real-time monitoring of time synchronization network configuration, alarm and performance data.
5. System Application

5.1. System Key Indicators
   a) The status monitoring of timing equipment ensures that the running status of timing equipment is normal; the synchronization monitoring accuracy of the equipment when it is granted is better than 10ms.
   b) The timing accuracy of timing equipment ensures the timing accuracy of timing equipment is normal; the time difference monitoring accuracy of timing equipment is better than 1μs, and the monitoring accuracy of wide-area time difference is better than 10μs.
   c) The status monitoring of the device when it is granted ensures that the synchronization status of the device is normal.

5.2. Application Examples
The system has been tested in WebLogic container for 5 months, the data is collected correctly, the system is stable and the functional effect is outstanding. The typical application is as shown in Figure 4 below:
Figure 4. Time Synchronization Topology and Time Difference Monitoring Examples

Conclusion
On the basis of this, the key index system of time synchronization system, the index algorithm and the auto-discovery technology of hidden trouble points are studied. Based on the Hadoop big data platform, the time synchronization network and equipment are modeled, and the fault tree analysis algorithm is studied to form In line with the clock synchronization service fault location, to achieve the trend of deviation time deviation becomes larger, or when the timing fails to communicate the network channel,
the device automatically detects the status of the point of failure to further improve the accuracy of time synchronization.

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