Research on Key Parameters of Intelligent Substation Merging Unit Test

Yang LIU* and Qiang-chao XU
Guangdong Power Grid Corporation Dispatch Center, Guangzhou Power Supply Bureau, Guangzhou, China, 510620
*Corresponding author

Keywords: Merging unit, Synchronization, Data precision, Time delay, Scheme design.

Abstract. Merging unit is an important part of the intelligent substation, whose performance is directly related to the safe and reliable operation of the substation intelligent. Therefore, it is needed to test the key parameters before the merging unit is installed to ensure that the merging unit can meet the requirements of the safe and stable operation of the intelligent substation. Aiming at some of the key considered issues in merging unit design, this paper proposed merging unit test performance parameters that should be paid attention to: the AC sampling time synchronization parameters, the switch time synchronization parameters, the output data precision parameters, the time delay parameters. Then this paper puts forward specific scheme design for these problems, which provide more references for the future merging unit testing.

Introduction

With the development of the smart grid, more and more intelligent substations are being popularized and applied. The main difference between intelligent substation and traditional substation lies in the transformation of data communication level. The key point of intervention is the introduction of the merging unit. The merging unit in intelligent substation, as an important process equipment layer, process layer for intelligent electronic devices (intelligent electronics, devices, IED) and the bridge of IED data transmission interval, which allows different IED have the data sharing function. The network delay characteristics, synchronous sampling characteristics and data output characteristics of merging unit will directly affect the correct operation of substation secondary devices. It plays a very important role in the safe and reliable operation of intelligent substation. The recent occurrence of that the data transmission through the merging unit to the differential protection device data is not synchronized, resulting in differential protection malfunction of the accident, shows the importance of the characteristics of the merging unit for intelligent substation. Consequently it is necessary to carry out the field test on the key parameters of the merging unit before the merging unit is applied to the intelligent substation. Forasmuch, this paper presents a test scheme for output data synchronization parameters, precision parameters and delay parameters of the merging unit based on the actual operation of the field.

This paper first analyses the characteristics of the intelligent substation merging unit. Based on that we analyzed the necessities of the synchronization test, precision test and time delay test of the merging unit. Then respectively, we put forward the synchronous test of AC sampling value, the measurement of the switching value, the output data accuracy test, test scheme using GPS time scale information that has received sent package and that using closed loop information for transmission of delay parameters. It provides specific reference for the future test of the intelligent substation merging unit.

Characteristics of Intelligent Substation Merging Unit

With the development of intelligent substation, as the key products of the process layer, the application of the merging unit is expanding, and the research on it is much further. The definition of the merging unit was originally proposed in IEC60044-7/8: It is a physical unit used to combine the time correlation of the current or voltage data from the secondary converter of the electronic
transformation. It is usually connected to an interval voltage and current transformer data, and after
A certain process, output to the process layer network or spacer smart devices obeying specified
format. Also, draw from the subsequent release of 61850-9-1/IEC 2, the communication mode of
the merging unit is further defined. In the current new intelligent substation, most of the merging
units produced by the manufacturers approve the IEC61850-9-2 standard.

The information sharing in intelligent substation is different from that between the compartments in
traditional substation realized by cable interconnection. The information sharing of intelligent
substation is based on the optical fiber Ethernet, and merging unit is the key equipment, which
provides raw data for protection devices, measurement and control devices, measuring devices and
other standard equipments. In the light of the literature material and the field operation experience,
the following questions need to be considered in the design of the merging unit.

a) High requirement to the reliability and real-time of data communication. The data collected by
the secondary voltage transformer and current transformer of the transformer substation and are
transmitted to the relevant protection device via the merging unit is as an important criterion for its
action. The operation instructions given by the substation layer must be transmitted to the relevant
action device through the merging unit. The length of time and reliability of the data processing in
the merging unit will affect the correctness and timeliness about the action of both the protection
device and the action device, which will influence the safe and reliable operation of the substation.
Therefore, it is necessary to draw on higher requirements for the real-time performance of the
merging unit and the anti-interference ability of the data.

b) Large data transmission flow. The merging unit needs to deal with the voltage and current
signals of the secondary devices. All of these signals are periodic. It is the high real-time
requirement of the system that the interface of the merging unit needs large flow for
communication.

c) Ability to handle multiple tasks at the same time. Since different manufacturers have different
IED standards, its data transmission format won’t be the same. The merge unit needs to normalize
the transmitted data in accordance with the IEC 61850 standard and to distinguish the distortion of
the sampling signal. This requires the merging unit be able to handle these tasks at the same time.

d) High requirement for communication speed. Serial communication is generally adopted in the
data interface of the merging unit. This will have a higher requirement to the communication speed.

The merging unit is the ‘living water source’ of the secondary device data. The quality of the
product is directly related to the reliability and stability of the whole intelligent digital substation.
So it is necessary to carry out further research on it. For the above mentioned problems in intelligent
substation merging unit, this paper propose some significant performance parameters during the test
of combined substation: AC sampling value time synchronization parameter, switching time
synchronization parameter, output data precision parameter and time delay parameter. Then we
design corresponding test plans for these parameters.

Merging Unit Performance Test Scheme Design

The overall framework of the performance test of the merging unit is shown in Figure 1. The test
system can set physical input or message input to build basic test environment according to
different testing purposes. Test system obtains some of the key merging unit performance
parameters via the analysis of the input and output. The following section respectively introduce the
test scheme design of the synchronization parameter, time delay parameter and precision parameter
of the merging unit.

![Figure 1. Block diagram of merging unit performance test.](image-url)
Synchronization Test
During the synchronous acquisition and summary of three-phase voltage and current output signal of the merging unit, it output to secondary protection control unit in accordance with a certain data format. Data transmission in this process may be subject to delay and interference, causing the non-synchronization of the data received by the secondary protection control unit, affecting the normal operation of the secondary protection control unit, bringing security risks to the substation operation. Forasmuch, it is necessary to test the synchronization of the merging unit output data.

**Synchronous Parameter Test of AC Sampling Value.** The AC sampling value time synchronization parameter test scheme is shown in Figure 2. The GPS clock signals are respectively connected to a high precision oscilloscope and a merging unit to provide clock pulse signals. The microcomputer is connected to the output terminal of the merging unit. Then input the same AC source signal to the oscilloscope and the merging unit. In order to avoid the delay of the merging unit is the cycle of the AC source signal, the signal cycle of the given signal is much larger than that of the merging unit. Merging unit select rising edge triggered mode. Then, the data collected by the merging unit is read by the microcomputer and obtain angle $\beta$ of its zero crossing point of the waveform rising edge relative to the rising edge of the clock signal. At this point the oscilloscope also calculates angle $\alpha$ of the zero crossing point of the waveform rising edge relative to that of the clock signal. Then the AC sampling value time synchronization angle error of the merging unit is:

$$\theta_{\text{sampling value}} = \alpha - \beta$$

![Figure 2. The AC sampling value time synchronization parameter test scheme of merging unit.](image)

Switching Time Synchronization Parameter Test. Merging unit switch time synchronization parameters test scheme is shown in Figure 3. The whole scheme is similar with the merging unit AC sample value synchronization parameters testing, and just that the input signal is changed from AC source to switch quantity. The merging unit is still using the rising edge triggered mode. Switch quantity select to move at the whole minute moment and record it as $T_0$. During the test, read the switching signal collected by the merging unit. When detect switch quantity change, record it as $T_2'$,
and $T_2$ is obtained by subtracting $T_0$ from $T_2'$. In the same way, read the scale of the switch quantity change and departure signal scale of the GPS clock rising edge in the display value of the oscilloscope. Do the subtraction and convert it as time, recording as $T_1$. Therefore, the switching time synchronization error of the merging unit will be:

$$T_{\text{switch signal}} = T_2 - T_1$$ \hfill (2)

**Research on Output Data Delay Test**

As different manufacturers have different IED standards, the output of the data format will not be the same. In order to achieve the data sharing between different IED, the merging unit needs to process the data. In addition, the merging unit takes time to collect the data and send the unified format data. These are the reasons for the delay. Due to the delay in each of the signal transmission and different signals might experience different transmission link, the difference presents as the fault phase error between each phase, which will bring serious consequences to the secondary protection control unit and these are why the test of delay is necessary.

**Test Scheme for Delay Parameter of Merging Unit.** There are two schemes for the delay parameter test of the merging unit. Let's break them down in the following sections.

a) **Merging unit delay test scheme based on closed loop mode**

The merging unit delay test scheme that use closed loop is shown in Figure 4. In this scheme, the merging unit, the microcomputer and the relay protection device are connected in series. Optical fiber Ethernet is adopted between the merging unit and the relay protection device to simulate the scene of the actual application. In this test, the computer sends out a fault signal of the real scene simulation—the moment recorded as $T_1$. This signal is then transmitted to the secondary protection unit via the data conversion of the merging unit. The secondary protection unit act and put out a node. Then feedback this signal to computer and record this moment as $T_2$. The prior inspected intrinsic action time of the secondary protection unit is recorded as $T_g$. Then the transmission delay of the merging unit to the secondary protection device is obtained as:

$$T_{\text{transmit}} = T_2 - T_1 - T_g$$ \hfill (3)

![Figure 4. merging unit delay test scheme based on closed loop mode.](image)

b) **Using GPS time scale information that has received sent packets**

The merging unit delay parameter test plan that use GPS time scale information is shown in Figure 5. In this scheme, one merging unit is used as the sending end, and the other one is used as the receiving end. Apply same GPS clock signal to two merging units to provide accurate time synchronization. When testing, data is sent by merging unit 1 at whole second timing, the moment recorded as $T_1$. The microcomputer reads the data moments received by the merging unit 2, recorded as $T_2$. Then we can get the data transmission delay between the two merging units:

$$T_{\text{transmit}} = T_2 - T_1$$ \hfill (4)
Output Data Precision Test

The sampled data is output by a certain data format after the consolidation of the merging unit. This will inevitably have error. Whether the accuracy of the data message is satisfied with the requirement of the two protection control unit or not directly affects the normal operation of the two protection control unit. This is the reason why the precision test should be carried out.

Merging Unit Precision Parameters Test Scheme. The output data precision test scheme of the merging unit is shown in Figure 6. Use accurate value of an AC source as the input signal of the merging unit and send it to the computer via merging unit processing. The microcomputer reads the signal, compare it with the exact value of the AC source. Since the relative error rate can be obtained, the sampling data error parameters of the merging unit can be obtained.

Conclusion

This paper analyzes some specific features of the Intelligent substation merging unit. Based on this, some key parameters which need to be tested in the combined unit test are proposed: the synchronization parameter of the merging unit, the precision parameter of the output data, the time delay parameter. Accordingly, test schemes are proposed to provide more references for the key parameters of the future substation.

Acknowledgement

This work is financially supported by The science and Technology Projects from China Southern Power Grid Company Limited (K-GZM2014-120).

References


