Study Committee B5

Protection and Automation

Paper ID_10220

The Development of Merging Unit based on Process Bus for Electronic Transformer in the Digital Substation

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Motivation

- The digital substation automation system is operated as the digital substation with station bus only in South Korea. In the case of such the system, the large number of copper wires are used to transmit electrical signal such as measurement, monitoring and control signal from the GIS in the field to the IED inside the substation. The cable installation cost are high, and it causes serious problem that the IED malfunctions because external noise or surge signals are transmitted to the inside of the substation through the cable.
- The conventional power transformer installed in the GIS is based on a coil wound around an iron core. This method has the problems that the weight is heavy, the sufficient installation space is required, and CT saturates under high fault current conditions is saturated.

Method/Approach

- The Korea Electric Power Corporation (KEPCO) is planning to change the full digital substation as shown in Figure 1. In order to change to the full digital substation operating system, it is necessary to apply the Merging Unit (MU) and the electronic transformer.
- This paper proposes the Merging Unit (MU) can be linked with the electronic transformers such as the Low Power Instrument Transformer (LPIT) using the rogowski coil. The MU receives the measurement and monitoring information of transmission and substation facilities in the field as analog signals and converts them into digital signals. The converted digital signal is transmitted to the protection IED inside the substation based on the IEC 61850 protocol through the process bus network. In addition, The MU receives the control signal of the protection IED based on the IEC 61850 and controls the transmission and substation facilities.

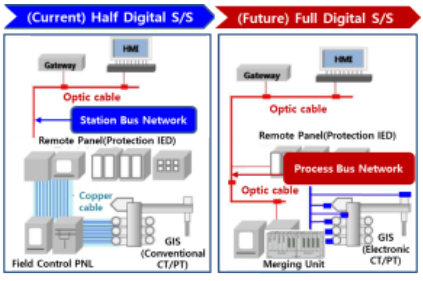

Figure 1. The digital substation plan in South Korea

Objects of investigation

a. The system configuration of the MU

- The developed MU is composed of the modules with various functions as shown Figure 2 and in Table 1.
- The AIU module can be divided into A and B Types, and A Type is the module that can be linked with the conventional transformer with the iron core. The AIU-B module is a module that can be linked with LPIT. In the case of current and voltage measurement data, the packets in the form of IEC 61850 sampled value are transmitted to the protection IED.
- The DIU module inputs operation status information of the field facilities through the photocoupler. The input signals are converted into a digital signal and transmitted to the station bus network through the IEC 61850 MMS message. The DOU module can control the facilities by receiving the IEC 61850 goose message transmitted from the protection IED and operating the relay contact through PLC logic.
- The CIU module is connected to the process bus network supports the high-availability seamless redundancy and the parallel redundancy protocol function. The MCU module provides the precise time synchronization such as IEEE1588.

Figure 2. The MU for process bus of digital substation

Table 1. The functional modules for the MU

Fnactinal Modules		Main Fnaction	Specification
AIU	A-type	Connect the CT/VT	Channel : 8ch (Current and Voltage each 4ch) Input Range : 1~5A, 0~250V
	B-type	Connect the LPIT	Channel : 9ch (Current 6ch, Voltage 3ch) Input Range : 0~7V
DIU		Monitor the status	26ch/module
DOU		Control the relay contact	16ch/module
CIU		Connect process and station bus network	HSR/PRP Network Switch (SV, Goose, MMS) Port : 100M/1G Optical Ethernet 4ch
MCU		Time synchronization Supply the control power	IEEE1588v2, PPS, IRIG-B, SNTP AC 220V±20%, DC 125V±20%, 50/60Hz
EXU		Connect extension I/O unit	Expanded up to DI 128 status and DO 96 contacts
Operation S/W		Remote access to the MU	Firmware update, Change the setting value Edit PLC logic and IEC 61850 configuration

Study Committee B5

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Paper ID_10220

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continued

Experimental setup & test results

a. The Performance Test of the MU

- The measurement precision test is performed by linking the LPIT and MU. The test configuration and method are shown in Figure 3. We use the current and voltage signals output through the same power supply, and compared the analog signals output through the standard CT/PT (accuracy: ±0.1%) with the digitally converted values through the LPIT and MU. The measurement error for the current and voltage magnitude is confirmed through the signal analyzer such as a signal analyzer as shown in Figure 4. In Figure 4, the red line is the analog signal from the standard CT/PT, and the green line is the digital signal output from the MU. As shown in Table 2, the precision test results showed that the measurement accuracy is within ±0.2% in the low level range and within ±0.05% in the middle/high level range of the current and voltage. Finally, we is confirmed that the measurement accuracy satisfies class 0.2 when the LPIT and MU are connected.

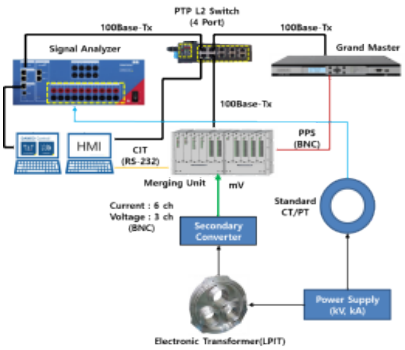

Figure 3. The configuration of the measurement precision test

Table 2. The result of measurement accuracy test

Current measurement accuracy					
Input range	Standard CT measurement	MU measurement	Measurement accuracy (%)	Reference accuracy (%)	
Low	34.8A	34.854A	-0.2%	within ±0.75%	
Middle	324.2A	324.29A	-0.034%	within ±0.2%	
High	633A	632.99A	-0.011%	within ±0.2%	
Voltage measurement accuracy					
Input range	Standard VT measurement	MU measurement	Measurement accuracy (%)	Reference accuracy (%)	
Low	2.31kV	2.3058kV	+0.194%	within ±1%	
Middle	9.69kV	9.6972kV	+0.028%	within ±0.2%	
High	19.91kV	19.911kV	-0.002%	within ±0.2%	

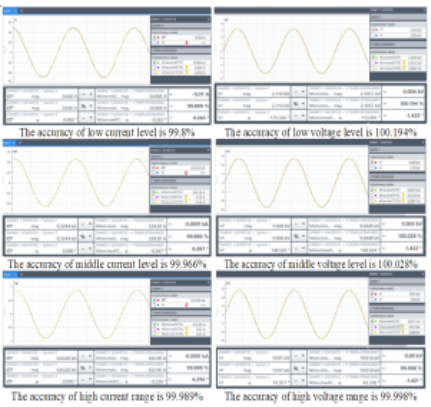

Figure 4. The accuracy of the current and voltage signal

b. IEC 61850 Communication Conformance Test

- IEC 61850 communication test conducted SV packet transmission test for IEC 61850 9-2 LE and transmission and reception test for MMS and Goose message defined in IEC 61850 8-1. The SV packet is tested according to the UCAIUG 30900601 test procedure. Since the SV packet is information used as a source for the protection function of the IED, very high reliability is required. Thus, the test contents for communication services check the performance of packet loss, packet delay, and change the quality bit in positive and negative conditions. The packet loss test is divided into 80 sample/cycle for protection and 256 sample/cycle for measurement, and repeats 10 times to check whether one or more packets are lost by checking the number of packets transmitted for 1 minute. The test for MMS and Goose message defined in IEC 61850 8-1 is performed according to the test procedure of the UCAIUG 10075662.
- Finally, we met all the mandatory and additional conditional tests and obtained IEC 61850 certificate for SV and MMS and GOOSE issued by UCA.

c. Environment Conformance Test

- As for the environmental test of MU, according to the IEC 61850-3 test procedure, the total of 37 test issues such as EMC/EMI are tested as shown in Figure 5 and Table 3.

Figure 5. The environmental test of MU (EMC/EMI)

Study Committee B5
Protection and Automation
Paper ID_10220

The Development of Merging Unit based on Process Bus for Electronic Transformer in the Digital Substation

continued

Table 3. The environment test conditions for MU

Num	Test Issues		Reference	Test Level	Test Condition
1	General Terms and Definitions		IEC 60297-3-101	-	Dimensions of structure
2	Clearances and creepage distances		IEC 60255-27	-	Impulse voltage : ±10 Source Impedance : 2 Ω, 100MΩ
3	Protective bonding resistance		IEC 60255-27	-	12V rms AC or 12VDC, 60s, 0.1Ω
4	Single-fault condition		IEC 60255-27	-	Voltage : 55 Vrms or 140 V dc Current : 3.5mArms, 5mApeak, 15mAdc
5	Burden for DC power supply		-	Maximum of 5 test	Watt measurement
6	Burden for AC power supply		-	Maximum of 5 test	VA measurement
7	Burden for binary input		-	Maximum of 5 test	Input current measurement
8	Mains Frequency Voltage		IEC 61000-4-16	Level 4	30V cont. 300V 1s
9	Power Frequency Withstand Voltage		IEC 60255-27	2kV, 1min	less than 10mA
10	Impulse-Voltage Withstand Test		IEC 60255-27	L-E: 5kV, S-E: 1kV	1.2/50 μs, 1s, 2m
11	Electrostatic Discharge		IEC 61000-4-2	Level 3	Contact: 6kV, Air: 8kV
12	RadiatedRadio-Frequency Electromagnetic Field		IEC 61000-4-3	Level 3	10V/m, 80~3,000Mhz
13	Fast Transient Burst		IEC 61000-4-4	Level 4	4kV
14	Surge		IEC 61000-4-5	L-G: 4kV, L-L : 2kV	1.2/50us
15	Conducted Disturbances (induced by radio-frequency fields)		IEC 61000-4-6	Level 3	10V
16	Power FrequencyMagnetic Filed		IEC 61000-4-8	Level 5	100A/m continuous, 1,000A/m 1s
17	Voltage Dips (ac power)		IEC 61000-4-11	-	30% for 1period, 60% for 50periods
18	Voltage Dips (dc power)		IEC 61000-4-29	-	30% for 0.1s, 60% for 0.1s
19	Voltage Interruptions (ac power)		IEC 61000-4-11	-	100% for 5period, 100% for 50periods
20	Voltage Interruptions (dc power)		IEC 61000-4-29	-	100% for 0.05s
21	Voltage Ripple on dc Power Supply		IEC 61000-4-17	Level 3	10% of rated DC value
22	Damped Oscillatory Wave		IEC 61000-4-18	Level 3	Common: 2.5kV, Differential: 1.0kV Voltage Oscillation Frequency: 1Mhz
23	Conducted Emission		CISPR 22	0.15~30Mhz	QP: 87~97dB, AV : 84~74dB
24	Radiated Emission		CISPR 22	30~6,000MHz	AV: 60dB, Peak 80dB(3m)
25	Enclosure Test	Protection	IEC 60529	IP	Enclosure protection Degrees
26		IP rating	IEC 60529	IP	Enclosure protection Degrees
27	Climatic Environmental Test	Cold Operation	IEC 60068-2-1	Operation	-25°C~25°C, 16h
28		Cold Storage	IEC 60068-2-1	Storage	-40°C~25°C, 16h
29		Dry Heat Storage	IEC 60068-2-2	Operation	25°C~70°C, 16h
30		Change of Temperature	IEC 60068-2-2	Storage	25°C~70°C, 16h
31		Cold Operation	IEC 60068-2-14	Operation	-25°C~70°C (5Cycle)
32		DampHeat Steady State	IEC 60068-2-78	Storage	25°C~70°C, 93±3%(10days)
33		Damp Heat cyclic	IEC 60068-2-30	Operation	-25°C~70°C (6 of 24h Cycle) lower : 85%, 25±3%, upper : 93±3%
34		Fire hazard	IEC 60695-11-10	Class V-1	-
35	Mechanical Performance	Vibration	IEC 60068-21-1	Class 1	-
36		Shock & Bump	IEC 60068-21-2	Class 1	-
37		Siesmic	IEC 60068-21-3	Class 1	-

d. IEC 61850 Communication Compatibility Test

- In order to perform communication compatibility tests between various MU and IED devices, The HSR and PRP network systems are configured as shown in Figure 6. In order to build a reliable network system for the process bus, we tested by configuring a hybrid network in which HSR and PRP is combined.
- The communication compatibility test for IEC 61850 9-2 SV between various MUs and IED devices was performed. We set the icd files of various MUs as shown in Table 4 and performed communication compatibility tests between MUs and IEDs according to the IEC 61850 version.
- As the result of the communication compatibility test as shown in Table 5, it is confirmed that the IEC 61850 version and the padding bit for the SV packet affect the communication compatibility as shown in Fig. 7. The padding bit is a dummy bit and is used to improve the processing speed by creating packet information in the form of a multiple of 4.

Figure 6. IEC 61850 Communication Compatibility Test

Table 4. The MU icd file setting value

MU Device	svID	APPID	confRev	Dst. MAC	Version
KDN	X0000MU00#MU0101	16381	1	01:0C:CD:04:80:01	Ed 2.1
DANEO	X0000MU00#MU0102	16382	1	01:0C:CD:04:80:02	Ed 2.0
S-Vender	X0000MU00#MU0103	16383	1	01:0C:CD:04:80:03	Ed 2.0
A-Vender	X0000MU00#MU0104	16384	1	01:0C:CD:04:80:04	Ed 1.0

Table 5. The test result of communication compatibility

IED Device	Ed 1.0 with Pad	Ed 1.0 without Pad	Ed 2.1 with Pad	Ed 2.1 without Pad
S-Vender	not interoperable	Interoperable	not interoperable	Interoperable
A-Vender	not interoperable	not interoperable	Interoperable	Interoperable

Figure 7. SV Packets by the padding bit

Conclusion

- In this paper, we describe the development of a MU that can be linked with the electronic transformer and configure the process bus of the full digital substation. The MU can be composed of modules with various functions.
- We verified the performance of the developed device by performing measurement accuracy test, environmental test and IEC 61850 communication test. As a result of the measurement accuracy test, we confirmed that the measurement accuracy satisfies class 0.2. In addition, we confirmed that both the environmental test and the communication test satisfies the IEC 61850 standard. In order to perform communication compatibility tests, we configure the process bus network system and confirm that the IEC 61850 version and the padding bit affect the communication compatibility.
- The developed MU is planned to be used a pilot operation at the full digital substation demonstration site in South Korea.