The Interoperability of the New Direct Transfer Trip (DTT) Technique with Carrier Signal Protection Scheme (PTT and DEF) and SCADA System between two Utilities in Thailand

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Abstract

This research paper presents the case study of the concept and implementation for special protection scheme called Direct Transfer Trip (DTT) technique with Carrier Signal Protection Scheme (Permissive Transfer Trip (PTT) and Directional Earth Fault Transfer Trip (DEF)) to enhance the power system stability when connected the small power producer (SPP) to the system. The case study here will talk about the scenario in natural gas type SPP named ABCD. This SPP itself has a very unique manner that is ABCD usually earn its revenue from selling the electricity to Provincial Electricity Authority (PEA) via 115kV substation of Electricity Generating Authority of Thailand (EGAT). Both EGAT and PEA play some part in controlling how ABCD will generate and transfer the electricity through their own properties. The recent status of the protection scheme in this SPP is that there are only distance and directional relays connected at both EGAT's bus and ABCD ends without any interconnection. The tripping commands on both ends rely on these two and the operator. In the meantime, ABCD would like to increase its generation capacity from 92 MW to 119 MW. It is then required to meet EGAT's new protection scheme requirement with DTT technique and carrier signal protection scheme (PTT and DEF). PEA also now asks to have access to monitor and control the status of such protection scheme via PEA's supervisory control and data acquisition (SCADA) system. This paper thoroughly elaborates the concept design and how to execute the implementation of the existing protection system and devices to meet both EGAT and PEA requirements. Two teleprotection cabinets were added at both ends (EGAT's bus and ABCD's bus) in order to complete the interconnection between the two via PEA's fiber optics network. These two teleprotection cabinets play a significant role to fulfill EGAT's DTT function with carrier signal protection scheme (PTT and DEF) requirement. The in depth details of how to reconfiguration the existing system with this newly design scheme will be explained. Another requirement to link up with PEA's SCADA system was done by adding another cabinet comprised of the gateway protocol converter (between PEA's DNP3 protocol and internal ABCD's IEC-61850 protocol), remote terminal unit (RTU) and Ethernet switch at the ABCD's end. The previously mentioned PEA's fiber optic network has been used here via multiplexer (MUX). In order to validate that the newly-improved protection scheme is able to work properly, both factory acceptance test (FAT) and the commissioning test (after implementation) are mandatory. This paper also explains the steps and process on how to do FAT and commissioning test. The test results and analysis are also presented here in this paper. The concept design, the implementation results and the test results from this particular case study can be used as a very good example for the similar circumstance in Thailand.

1. INTRODUCTION

In Thailand, the electrical power system has been managed by three state utilities i.e., the Electricity Generating Authority of Thailand (EGAT), the Metropolitan Electricity Authority (MEA), and the Provincial Electricity Authority (PEA). EGAT is responsible for operating the generation and the transmission systems, while MEA and PEA are responsible for distribution system in metropolitan and other local areas, respectively. According to the Power Development Plan (PDP 2012) during the year 2012-2025, Thailand government plans to purchase more electrical power from the private sector i.e., Independent Power Producer (IPP), Small Power Producer (SPP) and Very Small Power Producer (VSPP) to enhance the stability and reliability of Thailand's electrical power system [Chai Chompoo-inwai et al, 2009]. EGAT is responsible for purchasing electrical power from IPP and SPP, while PEA is responsible for purchasing electrical power from SPP and VSPP, whereas MEA is responsible for purchasing electrical power from SPP only. Each utility has its own requirements and regulations about the electricity purchasing policy. One of the key and common requirement is the teleprotection scheme of high voltage transmission line between the main power source (EGAT, MEA and PEA) and the private sector power plant when synchronizing. Almost all private sector in Thailand is able to connect to only

one Utility while the SPP power plant can connect and sell the electricity to both EGAT and PEA. Such an SPP must update its teleprotection scheme to comply with all connected grid network requirements and regulations.

Nowadays, PEA's regulation for interconnection to PEA grid has two main requirements which are (1) PEA requires the IPP/SPP contractor to install at least the simplest Direct Transfer Trip (DTT) teleprotection scheme for monitoring any of the circuit breaker status connected to PEA substation via PEA's fiber-optic cable [Chow Chompoo-inwai, et al., 2014] and (2) the SPP contractor must meet up with the requirement to link up with PEA's Supervisory Control and Data Acquisition (SCADA) system. It should be noted here that PEA's SCADA system is now operating over DNP3 protocol.

EGAT, on the other hand, has set its own new regulation for interconnection to any of EGAT grid. The IPP/SPP contractors must install or update their teleprotection schemes according to EGAT's new regulation which requires at least the following capabilities:

  • Direct Transfer Trip scheme (DTT)
  • Permissive Transfer Trip scheme (PTT)
  • Directional Earth Fault Transfer Trip scheme (DEF)

EGAT also require the IPP/SPP contractor to link up with EGAT's SCADA system for remote control and monitoring the main equipment status in IPP/SPP power plant over IEC-60870-5-103 protocol.

This paper mainly focuses on a very interesting case study here. The scenario is that there is one natural-gas type SPP power plant namely "ABCD". This SPP has a very unique and interesting manner. ABCD usually earns its revenue from selling the electricity to PEA via 115 kV EGAT's substation; however, this action has been done over PEA's transmission line. A very simple existing teleprotection scheme as shown in Fig.1 has been used for years, more details in the next section.

An issue now starts when ABCD want to increase its generation capacity from 92 MW to 119 MW. It is then a must to meet EGAT's new teleprotection scheme requirements for DTT with carrier signal protection scheme (PTT and DEF). PEA also now asks to have access to monitor and control the real-time status of such a protection scheme via PEA's SCADA system. As a result, this research paper presents the solution for this case study in terms of the design concept and implementation including the commissioning test results. This special protection scheme is then called Direct Transfer Trip (DTT) technique with Carrier Signal Protection Scheme (PTT and DEF) and SCADA system for monitoring & control (communicated by IEC61850 and DNP3 protocol) between "ABCD" and two utilities.

2. EXISTING CONNECTION AND TELEPROTECTION SCHEME BETWEEN ABCD POWER PLANT AND TWO UTILITIES

ABCD is the petrochemical industrial company located in the eastern part of Thailand. ABCD has been selling the electricity to PEA via EGAT substation since 2001. The existing connection scheme between ABCD power plant and two utilities is illustrated in Figure 1.

The overall system consists of seven units of natural gas type generators (G1-G7) which has a total generation capacity of 92MW. ABCD connects to EGAT's 115kV substation namely RAYONG1 (EGAT RY1) and then connects to PEA substation also namely RAYONG1 (PEA RY1) via PEA's transmission line. The currently used protection scheme for this scenario is that there are only two relays: distance relay (21) and directional relay (67) connected at EGAT's infinite bus and ABCD ends without any teleprotection scheme.
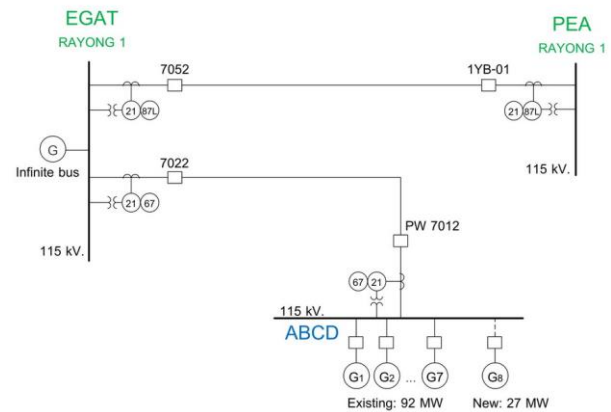

Fig. 1 Existing connection scheme between ABCD and two utilities

3. PROPOSED DIRECT TRANSFER TRIP (DTT) TECHNIQUE WITH CARRIER SIGNAL PROTECTION SCHEME (PTT AND DEF)

A DTT Technique with Carrier Signal Protection Scheme (PTT and DEF) is sending/receiving signals of the teleprotection between EGAT substation and ABCD power plant, to disconnect a circuit breaker at both ends. Because faults occur in transmission lines between both substations, to clear fault instantaneous, regardless of the time delay from relay protection [Emil Bartosiewicz et al., 2013]. The scheme of teleprotection according to EGAT's requirement is illustrated in Figure 2.

The signaling scheme of DTT, PTT and DEF relies on digital teleprotection for sending/receiving signals via fiber-optic cables to Multiplexer (FOM). Then, FOM will convert signals from E1-G703 terminal to fiber-optic cables for interconnection of both substations.
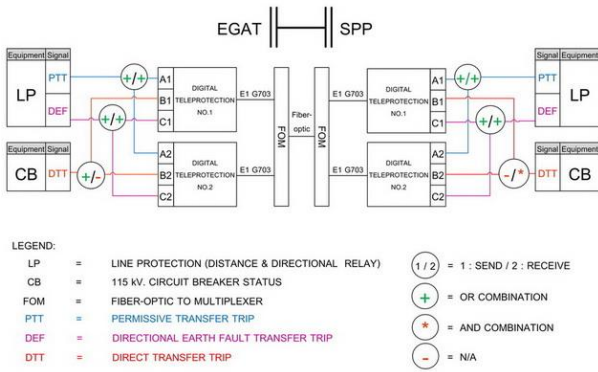
Fig. 2 Teleprotection scheme according to EGAT's requirement

DTT signaling scheme relies on the status "open" of a circuit breaker at EGAT RY1, to send DTT signal (Key) for disconnecting a circuit breaker at SPP instantaneous, to prevent SPP into islanding mode [Chow Chompoo-inwai et al, 2014]. The scheme of disconnect a circuit breaker at SPP must be depending on logic of EGAT's requirement. Therefore, two digital teleprotection units at SPP must receive exactly the same DTT signal (AND logic) to prevent the wrong trip from device's failure.

In general, PTT signaling scheme relies on pilot tripping scheme of the distance relay. In this case, the Permissive Over-Reaching Transfer Trip (POTT) is used. POTT reads either over-reaching zone 2 or initially-extended zone 1 to generate tripping signal (Key) for remote relay. Complete tripping signal will then be generated by distance relays after the fulfillment of two criteria:

- Local picking up either by over-reaching zone 2 or initially extended zone 1.
- Receiving remote tripping signal from another substation [Emil Bartosiewicz et al., 2013].

Both ends at EGAT and ABCD are able to send/receive the tripping signals mutually, which in fact, the digital teleprotection scheme needs only one PTT signal (OR signal logic).

DEF signaling scheme also applies similar methodology as PTT signaling scheme. The key difference is that DEF signaling scheme relies on pilot tripping scheme of the directional overcurrent relay (67) instead. And the picking up signal in directional earth fault overcurrent has been used to generate tripping signal (Key) to remote relay. Tripping signal will be generating after the fulfillment of two same criteria as of the PTT scheme. Both EGAT and SPP (ABCD) are also able to mutually send/receive the tripping signal as in PTT scheme.

The single line diagram of DTT Technique with Carrier Signal Protection Scheme (PTT and DEF) is illustrated in Figure 3. In order to get such a protection scheme to work, two extra teleprotection cabinets must be installed at both ends (EGAT substation and ABCD power plant). The communication between two ends has been done via PEA fiber optics network. Each of the teleprotection cabinet comprises of two key components:

- Two digital teleprotection units (redundancy) for sending/receiving the DTT, PTT and DEF signal between two substations. The command logic of signals can be configured as AND/OR as required (in this paper the ISKRA DZ-9 teleprotection application is used) [DZ9 Teleprotection Application Description]

- A Fiber-optic to Multiplexer (FOM) for converting signal from digital teleprotection (E1-G703 terminal) to fiber-optic cable between both substations (in this paper, HUAHUAN-H9MO fiber-optic transmission equipment is used) [H9MO-LMN4E1-SDH User's Manual for Fiber-Optic Transmission Equipment, 2007].
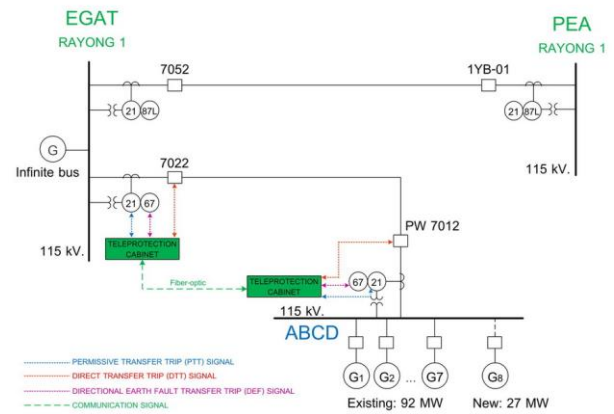

Fig. 3 Single line diagram of a DTT Technique with Carrier Signal Protection Scheme (PTT and DEF)

The digital teleprotection unit receives DTT signal from a circuit breaker; when circuit breaker 7022 at EGAT substation is in the "Open" status, the DTT signal from EGAT will be sent to the digital teleprotection at ABCD power plant via FOM. Two digital teleprotection units at ABCD power plant need to receive the same DTT signal before sending a trip signal to circuit breaker PW7012 at ABCD power plant. Keep in mind that ABCD will not send out DTT signal to trip the circuit breaker at EGAT substation.

In contrary, for the PTT and DEF teleprotection scheme, both EGAT and ABCD are able to sending/receiving the tripping signals between the two to trip the circuit breakers in both ends. The existing PTT signaling scheme is now using the POTT scheme, while the DEF is using the signal from directional earth fault overcurrent to generate the tripping signal to both ends of the teleprotection units. The MICOM-P437 distance protection device is currently used in EGAT substation now [MICOM-P437 Technical Manual, 2011]. ABB-REL670 transmission line distance protection device is

now utilized in ABCD power plant [Line distance protection, REL670, Reference Manual, 2010]. In additional to the tripping signals, all other alarming signals and communication statuses must be sent to both EGAT and ABCD Distributed Control System (DCS) in real-time mode. Such a scheme of teleprotection and communication between EGAT-RY1 and ABCD power plant is illustrated in Figure 4.
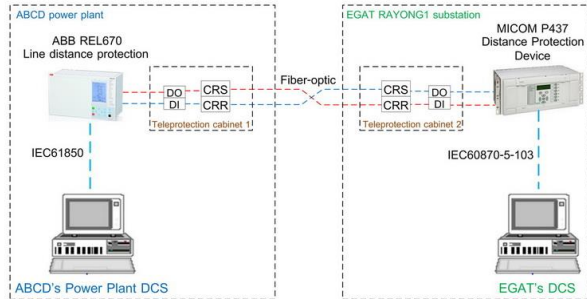

Fig. 4 Scheme of teleprotection & communication between EGAT-RY1 substation and ABCD power plant

4. SCADA SYSTEM FOR MONITORING AND CONTROL OF ABCD POWER PLANT USING IEC61850 PROTOCOL

As mentioned before, ABCD is selling the electricity via PEA's transmission line system. In order to complete the interconnection, ABCD must also comply with PEA's new SCADA regulations for interconnection to PEA grid so that PEA will be able to monitor and control real-time parameters i.e., power flow, energy relevant parameters and having access to other equipment in ABCD power plant. PEA also asks to have access to monitor real-time statuses of the teleprotection scheme between EGAT-RY1 substation and ABCD substation via PEA SCADA Control Center. PEA would allow all of the transmission parameters over any protocol but it must have some kind of gateways for converting those parameters into PEA DNP3 protocol. PEA parameters requirements are called Input/Output points list (I/O points list). The PEA I/O standard points list consists of at least: (1) Status Input 49 items, (2) Analog Input 16 items and (3) Control Output 4 items as shown in Table 1 to Table 3, respectively.

ABCD power plant is currently using IEC-61850 protocol to communicate between Intelligent Electronic Device (IED) i.e., relay protection, power meter and etc. [Christoph Brunner, 2008]. Therefore, the I/O points list will be sent out to Remote Terminal Unit (RTU) to link up with PEA's SCADA system over IEC-61850 protocol using copper wires.

Table 1 Status Input points list of PEA's requirement.

ITEM	POINT NAME	STATE				Connection type at ABCD	
		0	1	2	3	Connection	Type
1	01YB-01 Closed/Open Status	Undefine	Closed	Open	Fault	IEC61850	SOE
2	01YS-01 Closed/Open Status	Undefine	Closed	Open	Fault	IEC61850	DI
3	01YS-02 Closed/Open Status	Undefine	Closed	Open	Fault	IEC61850	DI
4	01YS-03 Closed/Open Status	Undefine	Closed	Open	Fault	No Equipment	-
5	01YG-01 Closed/Open Status	Undefine	Closed	Open	Fault	IEC61850	DI
6	01YB-01 Control Set on	Undefine	Local	Remote	Fault	Copper wires	DI
7	01YS-01 Control Set on	Undefine	Local	Remote	Fault	Copper wires	DI
8	Sync. Switch Selection	Undefine	Auto	Manual	Fault	No Equipment	-
9	50 BF Relay Status	Undefine	On	Off	Fault	Not use function	-
10	01YS-02 Control Set on	Undefine	Local	Remote	Fault	No Equipment	-
11	DTT Inter-Trip Cut Off Status	Undefine	On	Off	Fault	Copper wires	DI
12	Distance Relay Phase A	Normal	Trip	-	-	IEC61850	SOE
13	Distance Relay Phase B	Normal	Trip	-	-	IEC61850	SOE
14	Distance Relay Phase C	Normal	Trip	-	-	IEC61850	SOE
15	Distance Relay Earth Fault	Normal	Trip	-	-	IEC61850	SOE
16	Distance Relay Trip	Normal	Trip	-	-	IEC61850	SOE
17	Distance Relay Zone 1	Normal	Trip	-	-	IEC61850	SOE
18	Distance Relay Zone 2	Normal	Trip	-	-	IEC61850	SOE
19	Distance Relay Zone 3	Normal	Trip	-	-	IEC61850	SOE
20	Distance Relay Switch on fualt	Normal	Trip	-	-	IEC61850	SOE
21	Distance Relay DC Supply	Normal	Fail	-	-	Copper wires	DI
22	Distance Relay VT Supply	Normal	Fail	-	-	IEC61850	DI
23	Directional Overcurrent Phase A	Normal	Trip	-	-	IEC61850	SOE
24	Directional Overcurrent Phase B	Normal	Trip	-	-	IEC61850	SOE
25	Directional Overcurrent Phase C	Normal	Trip	-	-	IEC61850	SOE
26	Directional Earth Fault	Normal	Trip	-	-	IEC61850	SOE
27	Directional Relay DC Supply	Normal	Fail	-	-	Copper wires	DI
28	Time Delayed (CB Fail)	Normal	Trip	-	-	Not use function	-
29	Teleprotection (DTT)	Normal	Trip	-	-	IEC61850	SOE
30	Line Aided Trip (PTT)	Normal	Trip	-	-	IEC61850	SOE
31	Auto Reclosing Operated	Normal	Operated	-	-	Not use function	-
32	Auto Reclosing lockout	Normal	Lockout	-	-	Not use function	-
33	DC Supply Control Circuit	Normal	Fail	-	-	Copper wires	DI
34	AC Supply Control Circuit	Normal	Fail	-	-	Copper wires	DI
35	Gas low pressure warning	Normal	Alarm	-	-	Not Support	-
36	Gas low pressure lockout	Normal	Lockout	-	-	Not Support	-
37	Trip Cct. Supervision 1	Normal	Fail	-	-	Copper wires	DI
38	Trip Cct. Supervision 2	Normal	Fail	-	-	No Equipment	-
39	Spring Charge	Normal	Fail	-	-	Not Support	-
40	Transformer Differential Relay	Normal	Trip	-	-	No Equipment	-
41	Synchornizing Check	Normal	Operated	-	-	No Equipment	-
42	Sync. Relay MCB Trip	Normal	Alarm	-	-	No Equipment	-
43	Under/Over Frequency Step1	Normal	Alarm	-	-	Not use function	-
44	Under/Over Frequency Step2	Normal	Trip	-	-	Not use function	-
45	Under/Over Voltage Step1	Normal	Alarm	-	-	Not use function	-
46	Under/Over Voltage Step2	Normal	Trip	-	-	Not use function	-
47	Under/Over Instance	Normal	Trip	-	-	Not use function	-
48	Under/Over Frequency Relay	Undefine	On	Off	Fault	Not use function	-
49	Sync. Switch Selection	Normal	Off	-	-	No Equipment	-

Table 2 Analog Input points list of PEA's requirement

ITEM	POINT NAME	UNIT	SCALE		Connection type at ABCD	
			ACTUAL DATA	RAW DATA	Connection	Type
1	Current Phase A	A	0..1200	0..32767	Copper wires	AI
2	Current Phase B	A	0..1200	0..32767	Copper wires	AI
3	Current Phase C	A	0..1200	0..32767	Copper wires	AI
4	Voltage Phase A-B	kV	0..150	0..32767	Copper wires	AI
5	Voltage Phase B-C	kV	0..150	0..32767	Copper wires	AI
6	Voltage Phase C-A	kV	0..150	0..32767	Copper wires	AI
7	Frequency	Hz	0..60	0..32767	Copper wires	AI
8	Active Power	MW	+/- 0..155.88	+/-0..32767	Copper wires	AI
9	Reactive Power	MVAR	+/- 0..155.88	+/-0..32767	Copper wires	AI
10	Power Factor	%	+/-0..100	+/-0..32767	Copper wires	AI
11	THD Current Harmonic Phase A	%	0..100	0..32767	Copper wires	AI
12	THD Current Harmonic Phase B	%	0..100	0..32767	Copper wires	AI
13	THD Current Harmonic Phase C	%	0..100	0..32767	Copper wires	AI
14	THD Voltage Harmonic Phase A-B	%	0..100	0..32767	Copper wires	AI
15	THD Voltage Harmonic Phase B-C	%	0..100	0..32767	Copper wires	AI
16	THD Voltage Harmonic Phase C-A	%	0..100	0..32767	Copper wires	AI

Table 3 Control Output points list of PEA's requirement

ITEM	POINT NAME	STATE		Connection type at ABCD	
		0	1	Connection	Type
1	01YB-01 CB Close/Open Command	Close	Open	IEC61850	SBO
2	01YB-01 Close Bypass Sync. Command	Close	-	IEC61850	SBO
3	01YS-01 DS Close/Open Command	Close	Open	IEC61850	SBO
4	01YS-02 DS Close/Open Command	Close	Open	IEC61850	SBO

The single line diagram of ABCD SCADA system and PEA's SCADA Control Center is illustrated in Figure 5. To implement this SCADA scheme, the RTU cabinet

must be installed at ABCD power plant, to link up with PEA's SCADA Control Center via the existing PEA's fiber-optic network over Synchronous Digital Hierarchy (SDH) multiplexer (MUX) at PEA-RY1 substation. Each of the RTU cabinet consists of:

• An Ethernet switch to communicate between IED (REL670) and RTU (this paper uses HIRSCHMANN RSPL-20 Rail Switch Power Lite) [Reference Manual Rail Switch Power Lite (RSPL), 2008].

• A Remote Terminal Unit (RTU) for collecting parameters in ABCD power plant and sending out to gateway. A gateway protocol converter will do the conversion two different protocols between PEA DNP3 protocol and the internal ABCD IEC-61850.
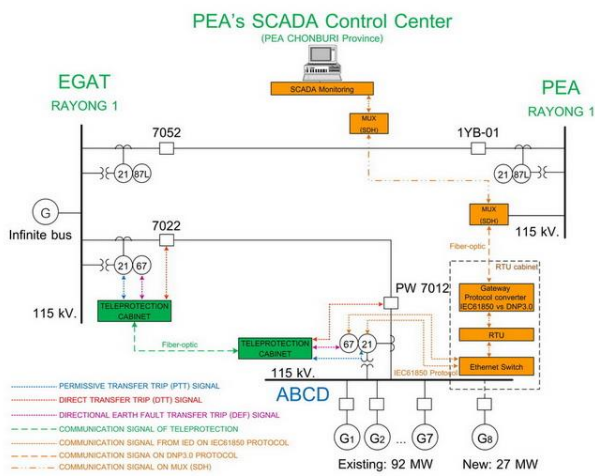

Fig. 5 Single line diagram of SCADA system between ABCD power plant & PEA's SCADA Control Center.

For the implementation of this scenario in this paper, the universal device which is able to work as either in RTU mode or Gateway protocol converter mode has been applied (REMSDAQ Callisto^{nx} Utility Controller), [CaSE NX User Manual, 2014].

5. FACTORY ACCEPTANCE TEST AND COMMISSIONING TEST

In order to validate that the newly-improved protection scheme is able to operate properly, both the factory acceptance test (FAT Test) and the commissioning test (after installation) are mandatory. The FAT test procedures utilize the hardware test tools and also the special simulation software. The commissioning test was done under the special condition that needs all three parties to operate the teleprotection scheme and SCADA system simultaneously. In fact, the teleprotection scheme is mainly tested by EGAT and the SCADA system is mainly tested by PEA.

Figure 6 illustrates system configuration for the FAT test of teleprotection cabinets. This was done by simulating

the connection between two teleprotection cabinets at both ends (EGAT and ABCD) then connecting with actual devices in the simulation. The PTT and DEF signals are simulated by relay protection of each side. The injected voltage and current to the relay was created by a test tool (OMICRON CMC-356 Universal Relay Test Set and Commissioning Tool is used for this purpose), [CMC-356 Reference Manual]. The DTT signal is simulated by copper wires via Digital Input/Output (DI/DO) of teleprotection cabinets. Finally, the operating time of all signals are measured by this test tool.
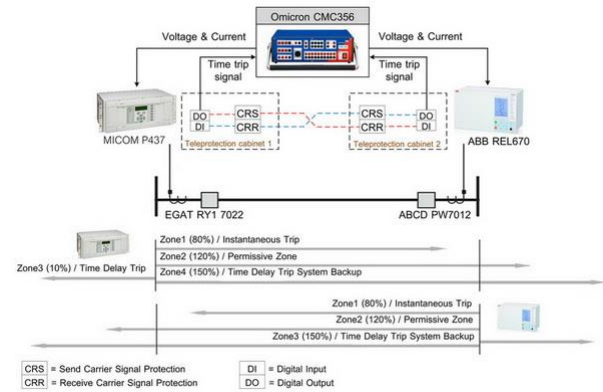

Fig. 6 System configuration of the teleprotection cabinets FAT test

The tested results for both FAT test and commissioning test of the teleprotection functions i.e., DTT, PTT and DEF comparing to the existing (traditional) protection scheme are shown in Table 4 to Table 6, respectively.

Table 4 illustrates the test results of the proposed DTT carrier signal protection scheme when a fault occurred and it caused EGAT circuit breaker 7022 to operate and in the "Open" status. It was found that the circuit breaker at ABCD (PW7012) tripped simultaneously right after the circuit breaker 7022 at EGAT opened. The existing line protection system, on the other hand, needs to wait for a time delay which depends on the protection function setting of ABCD.

Table 5 and Table 6 present the test results of the new teleprotection functions (PTT and DEF Carrier Signal Protection). It is clear to be seen that the new teleprotection schemes with PTT and DEF have a much shorter operating time than the currently-used protection. This is mainly because the existing protection system needs to wait for a time delay which depends on the parameters setting of a relay protection, while the new teleprotection functions can be operated instantaneously. It is very clear here that the DTT with PTT and DEF Carrier Signal Protection scheme gives the system more stable and reliable.

Table 4 Test results of a DTT carrier signal protection scheme

Fault Function	Status of circuit breaker at ABCD (PW7012) (open/ not open)	
	Traditional Protection (line protection)	DTT Carrier Signal Protection
EGAT's circuit breaker (7022) "open", when a fault occur.	A circuit breaker is not trip (remain status)	A circuit breaker is trip (open status)
Remark	waiting time delay from protection function,	-

Table 5 Test results of a PTT carrier signal protection scheme

Sub-station	Fault Function	Operating time (ms)			
		Traditional Protection (Distance Protection)		PTT Carrier Signal Protection in POTT scheme (Distance & PTT carrier)	
		Setting parameter	A/F	Setting parameter	A/F
ABCD	Distance relay zone 1	< 40.0	31.6	< 40.0	32.7
	Distance relay zone 2	300.0	319.0	< 40.0	32.6
	Distance relay zone 3	600.0	618.0	600.0	621.0
	Distance relay zone 4	-	-	-	-
EGAT	Distance relay zone 1	< 40.0	28.9	< 40.0	28.4
	Distance relay zone 2	300.0	322.1	< 40.0	29.5
	Distance relay zone 3	600.0	620.4	600.0	621.1
	Distance relay zone 4	600.0	626.5	600.0	623.3

Table 6 Test results of a DEF carrier signal protection scheme

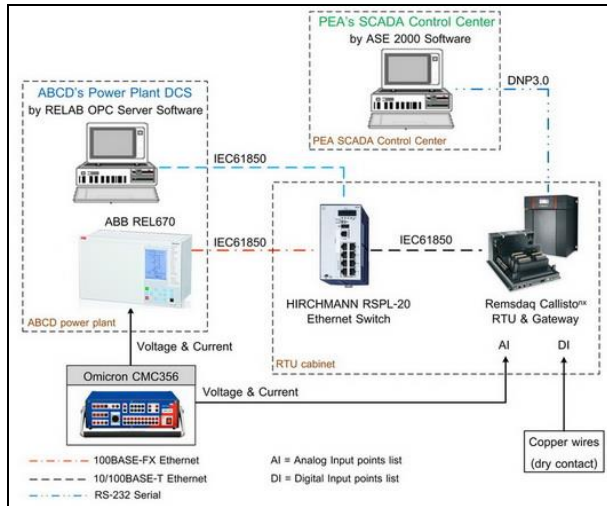| Sub-station	Fault Function	Operating time (ms)			
		Traditional Protection (Directional Earth Fault Protection)		DEF Carrier Signal Protection (Directional Earth Fault & DEF carrier)	
		Setting parameter	A/F	Setting parameter	A/F
ABCD	Directional Earth Fault	600.0	619.8	< 40	19.4
EGAT	Directional Earth Fault	600.0	620.4	< 40	20.1

Fig. 7 System configuration of RTU cabinet for FAT test

Figure 7 illustrates system configuration of RTU cabinet FAT test. The FAT test of the RTU cabinet was done by simulating the connection between a RTU cabinet and two ends (ABCD plant and PEA's SCADA Control Center). Both are connected with real devices in the simulation process. All IEC-61850 point lists are simulated by relay protection at ABCD power plant, which inject voltage and current to the relay by a test tool (OMICRON CMC-356). All the analog point lists

(AI) are simulated by a test tool directly, while the Digital Input point lists (DI) are simulated by the copper wires (dry contact). In the FAT test, ABCD's DCS was simulated by "RELAB OPC SERVER" software, to monitor I/O point lists over IEC-61850 protocol, while PEA's SCADA Control Center was simulated by "ASE2000" software, to monitor I/O point lists via RTU and Gateway over PEA-DNP3 protocol. However, the commissioning test was done at the actual locations for both ABCD's DCS and PEA's SCADA Control Center.

The test results for both FAT test and commissioning test of the newly-installed SCADA system including Status Inputs, Control Outputs and Analog Inputs points list are shown in Table 7 to Table 9, respectively.

Table 7 Test results of the Status Input points of SCADA system.

ITEM	POINT NAME	STATE				Monitoring at location (Pass/Fail)	
		0	1	2	3	ABCD's DCS	PEA's SCADA Control Center
1	01YB-01 Closed/Open Status	Undefine	Closed	Open	Fault	Pass	Pass
2	01YS-01 Closed/Open Status	Undefine	Closed	Open	Fault	Pass	Pass
3	01YS-02 Closed/Open Status	Undefine	Closed	Open	Fault	Pass	Pass
5	01YG-01 Closed/Open Status	Undefine	Closed	Open	Fault	Pass	Pass
6	01YB-01 Control Set on	Undefine	Local	Remote	Fault	Pass	Pass
7	01YS-01 Control Set on	Undefine	Local	Remote	Fault	Pass	Pass
11	DTT Inter-Trip Cut Off Status	Undefine	On	Off	Fault	Pass	Pass
12	Distance Relay Phase A	Normal	Trip	-	-	Pass	Pass
13	Distance Relay Phase B	Normal	Trip	-	-	Pass	Pass
14	Distance Relay Phase C	Normal	Trip	-	-	Pass	Pass
15	Distance Relay Earth Fault	Normal	Trip	-	-	Pass	Pass
16	Distance Relay Trip	Normal	Trip	-	-	Pass	Pass
17	Distance Relay Zone 1	Normal	Trip	-	-	Pass	Pass
18	Distance Relay Zone 2	Normal	Trip	-	-	Pass	Pass
19	Distance Relay Zone 3	Normal	Trip	-	-	Pass	Pass
20	Distance Relay Switch on fualt	Normal	Trip	-	-	Pass	Pass
21	Distance Relay DC Supply	Normal	Fail	-	-	Pass	Pass
22	Distance Relay VT Supply	Normal	Fail	-	-	Pass	Pass
23	Directional Overcurrent Phase A	Normal	Trip	-	-	Pass	Pass
24	Directional Overcurrent Phase B	Normal	Trip	-	-	Pass	Pass
25	Directional Overcurrent Phase C	Normal	Trip	-	-	Pass	Pass
26	Directional Earth Fault	Normal	Trip	-	-	Pass	Pass
27	Directional Relay DC Supply	Normal	Fail	-	-	Pass	Pass
29	Teleprotection (DTT)	Normal	Trip	-	-	Pass	Pass
30	Line Aided Trip (PTT)	Normal	Trip	-	-	Pass	Pass
33	DC Supply Control Circuit	Normal	Fail	-	-	Pass	Pass
34	AC Supply Control Circuit	Normal	Fail	-	-	Pass	Pass
37	Trip Cct. Supervision 1	Normal	Fail	-	-	Pass	Pass

Table 8 Test results of the Control Output points of SCADA system.

ITEM	POINT NAME	STATE		Monitoring at location (Pass/Fail)	
		0	1	ABCD's DCS	PEA's SCADA Control Center
1	01YB-01 CB Close/Open Command	Close	Open	Pass	Pass
2	01YB-01 Close Bypass Sync. Command	Close	-	Pass	Pass
3	01YS-01 DS Close/Open Command	Close	Open	Pass	Pass
4	01YS-02 DS Close/Open Command	Close	Open	Pass	Pass

Table 9 Test results of the Analog Input points of SCADA system.

ITEM	POINT NAME	UNIT	SCALE		Monitoring at location (Pass/Fail)	
			ACTUAL DATA	RAW DATA	ABCD's DCS	PEA's SCADA Control Center
1	Current Phase A	A	0..1200	0..32767	Pass	Pass
2	Current Phase B	A	0..1200	0..32767	Pass	Pass
3	Current Phase C	A	0..1200	0..32767	Pass	Pass
4	Voltage Phase A-B	kV	0..150	0..32767	Pass	Pass
5	Voltage Phase B-C	kV	0..150	0..32767	Pass	Pass
6	Voltage Phase C-A	kV	0..150	0..32767	Pass	Pass
7	Frequency	Hz	0..60	0..32767	Pass	Pass
8	Active Power	MW	+/- 0..155.88	+/-0.32767	Pass	Pass
9	Reactive Power	MVAR	+/- 0..155.88	+/-0.32767	Pass	Pass
10	Power Factor	%	+/- 0..100	+/-0.32767	Pass	Pass
11	THD Current Harmonic Phase A	%	0..100	0..32767	Pass	Pass
12	THD Current Harmonic Phase B	%	0..100	0..32767	Pass	Pass
13	THD Current Harmonic Phase C	%	0..100	0..32767	Pass	Pass
14	THD Voltage Harmonic Phase A-B	%	0..100	0..32767	Pass	Pass
15	THD Voltage Harmonic Phase B-C	%	0..100	0..32767	Pass	Pass
16	THD Voltage Harmonic Phase C-A	%	0..100	0..32767	Pass	Pass

Finally, Figure 8, 9 and 10 presents the actual work process for on-site implementation for the new teleprotection scheme and the SCADA system, including all the new extra RTU cabinets.

Fig. 8 (Left) FAT test of the Teleprotection cabinets and (Right) FAT test of an RTU cabinet

Fig. 9 (Left) Teleprotection cabinet installed at ABCD and (Right) Teleprotection cabinet installed at EGAT-RY1 substation

Fig. 10 RTU cabinet installed at ABCD Power Plant

6. CONCLUSIONS

The proposed DTT teleprotection scheme with carrier signals (PTT and DEF) has now been in operation in ABCD power plant for around six months already. The SCADA system of ABCD power plant is also in operation and already linked up with both EGAT's and PEA's SCADA system and it is now working properly and smoothly. The proposed system has been insured the stability and reliability throughout the process of tentative FAT test and commissioning test. The proposed teleprotection scheme with SCADA system is able to resolve the aforementioned issue of a very unique manner interconnection problem. This particularly case study shall be used as a very good example for the future to come and similar circumstance in Thailand.

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