International Journal of Engineering & Technology, 7 (2.12) (2018) 329-332

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research Paper

IOT based modeling of closed transition transfer switch in IEC 61850

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Abstract

Background/Objectives: The power demand of utility electrical power has stimulated the use of distributed energy for peak shaving. Distributed energy resources need to be monitored and controlled like Internet of Things.
Methods/Statistical analysis: Distributed Energy Resources (DERs) are small scale electric energy system like Micro Turbine, Photovoltaic, Wind power, Small Generator and widely spread in Korea. For utilizing electrical device with Internet of Things, we need integrated system and adapt International Electrical Code like IEC 61850.
Findings: To connect DERs with uninterrupted grid system, it required Closed Transition Transfer Switch (CTTS). Existing International Electrical Code presented some distributed energy resource by IEC 61850-7-420. However, the switch like CTTS is not presented. So, we described modeling of CTTS in IEC 61850 and verified monitoring data with TCP/IP**.**
Improvements/Applications: The proposed modeling of CTTS not only combines the DERs with grid system but also conjugates smart grid system with IOT Technology.

Keywords: *IoT; Closed Transition Transfer Switch; IEC 61850; Smart Grid; Uninterrupted System*

1. Introduction

Recently, peak power demand has been renewed to the maximum and backup power has dropped to a critical level, aggravating power supply-demand situation such as rolling blackouts[1]. To solve the problems the usage of Distributed Energy Resource (DER) which are connected with grid[2]. DER is a small power system like Micro Turbine, Photovoltaic, Wind power system, small generator. Each of DERs has own standard by manufactures. Integration of DERs such as wind, energy storage, and DR to existing electrical networks can help companies eliminate the investment cost related to transmission line expansion and establishment of new conventional power plants[3]. To accommodate toe DERs into the existing system, it is required in uninterrupted connection technology like Closed Transition Transfer Switch (CTTS). Existing connection system of Automatic Transfer Switch (ATS) makes interruption because the system has single switch. In order to solve the problem, CTTS is composed two switches for each power source. The advantages are that DERs can be operated without interrupting power to loads and power can be retransferred to the utility after a failure without interrupting power to loads. The system will be connected with various DERs and required a flexible and reliable communication protocol for control and monitor functions of CTTS. Micro gird system has many power source and needs integrated standardization for Internet of Things. IEC 61850 is standard communication of power system and integrated devices of different types into the system. IEC 61850-7-420 is committed to the principle of standards to support the various DERs[4]. However, interconnection for DERs with switch has not been presented. So, this paper describes the configuration and function of CTTS for mapping to IEC 61850 and considers existing logical nodes and uses new logical nodes (LNs).

1.1. Technical background

The CTTS consists of two switches for the grid and generator as shown in Figure 1.

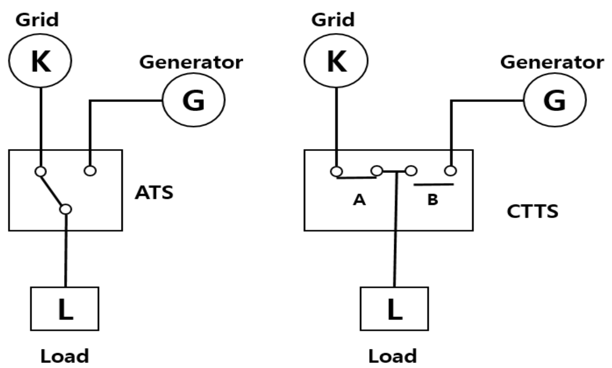


Fig. 1: Diagram of ATS & CTTS.

If synchronization conditions with grid power is satisfied after generator is activated, it is transferred to the generator power after parallel operation within 100ms[5]. The CTTS synchronization conditions are designed as stated in Table 1.

Table 1: Synchronization Condition & Parallel Operation Times

Category	Conditions
Voltage Phase Difference	<10°
Frequency Difference	<1Hz
Voltage Difference	<5%
Parallel Operation Times	<100ms

CTTS is generally utilized for interconnected reciprocating engine system like emergency generator in Smart grid system. According to the Korea Electrical Safety Corporation's statistics dated June 2013, the country had 69,986 emergency generator with a total capacity of 21GW, which is equivalent to the capacity of approximately 20 nuclear power generating unit. According to Table 2 below, operating hours vary depending on the ratio of investment cost. Despite the support (3 years, 100%), if an emergency generator is operated for more than 70.9 hours per years, it is more efficient than Demand Resource Market operating costs. If business models beneficial to customers are developed and grid-connection technology is secured, it would be a very effective demand resources [6].

Table 2: Emergency Generator Required Operating Hours Equal to the Operating Cost of the DRM

Investment Support Ratio	Compulsory Participation Commitment Period for Demand Management		
	3 year	5 year	10 year
50%	35.4 h/year	22.5 h/year	13.0 h/year
70%	49.6 h/year	31.6 h/year	18.2 h/year
100%	70.9 h/year	45.1 h/year	26.1 h/year

Therefore some of emergency generator utilized as demand resources, they might significantly decrease peak power. For utilizing emergency generator, the system must be uninterrupted status. So, it required Closed Transition Transfer Switch and International Standardization for making Smart grid system based on IoT technology

1.2. Proposed modelling of CTTS

The proposed modeling of CTTS described International Electrotechnical Commission Standards. The international standard IEC 61850 has been recognized as a globally accepted solution enabling integration of heterogeneous devices and applications in the power system automation domain[7]. So we will describe CTTS with IEC 61850 standards using existing Logical Nodes and new Logical Nodes.

1.3. Organization of the paper

Section 2 define mapping CTTS data classes and attributes. Section 3and Section 4 are the hardware & software implementation detail. Section 5 compare between CTTS Modbus data and Mapping data in IEC 61850. Section 6 concludes the paper.

2. CTTS mapping to IEC 61850

IEC 61850 allow to user can use the modeling method and Common Data Classes (CDC) in IEC 61850-7-1. The description of each logical nodes is Figure 2 as follows

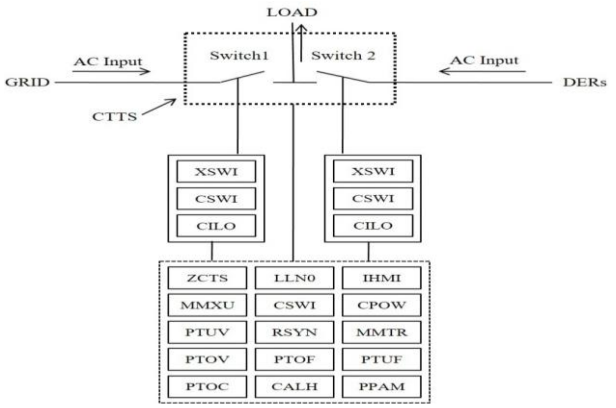


Fig. 2: CTTS Mapping to IEC 61850.

1) ZCTS is the logical node (LN) defines the characteristics of the closed switch in CTTS. There is new logical node ZCTS, which is inherited from logical node class, Z, denotes to the LN group for further equipment. C is meaning of Closed and TS is Transfer Switch.
2) LLN0 logical node device for CTTS that includes common information for logical device.
3) MMXU & MMTR are Grid and DERs values at CTTS
4) PTUV (Under Voltage), PTOV (Over Voltage), PTOF(Over Frequency), PTUF(Under Frequency), PTOC(Over Current), PPAM(Phase Angle) are protection logical nodes.
5) CPOW is the point-on –wave breaker controller LN provides all functionality to close or open a circuit breaker at a certain instant of time.
6) CSWI is the switch control LN handles all switchgear operations from the operators and from related automatics.
7) IHMI is front panel operator interface at bay level to be used for configuration, i.e. local control
8) RSYN is a synchronizing function that produces a release for a closing command of circuit breaker between two circuits whose voltages are within prescribed limits of magnitude, phase angle, and frequency.

Table 3 shows the new proposed LN to characterize a closed transition transfer switch. The letter "T" is Transient data object. The status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state. The column specified with M/O/C defines whether data objects are mandatory (M) or optional (O) or conditional (C) for the instantiation of a specific logical node[4].

Table3: Ctts Zcts Class

ZCTS class				
Data object name	Common data class	Explanation	T	M/O/C
Measured values				
DERtyp	ING	Type of DER Unit		M
OpTmh	INS	Operation time		M
AutoManCtl	SPC	Automatic or Manual Mode		M
FltAck	SPC	Acknowledge fault clearing		O
GnSync	SPS	Generator is synchronized		O
AVR	MV	Automatic Voltage Regulator		O
GnCtl	DPC	Starts or stops the generator		O
HzRtg	ASG	Nominal frequency		O
VRtg	ASG	Voltage level rating		O
ARtg	ASG	Current rating under nominal voltage		O

3. Hardware implementation

CTTS internal interconnection used CAN communication and output data used RS 485 connection. And the data type of CTTS output is Modbus serial communication protocol. Modbus enables communication among many devices connected to the same network. To convert Modus data to IEC 61850, we installed gateway. The IEC 61850 gateway has ARM Cortex M5 Series 500Mhz CPU, 512MB Ram, 512MB, Flash memory. It supported IEC 61840 Group 1 MMS protocol and RS 485 based 2 Channel communication (Half Duplex Mode). Main VPN has Quad Core CPU, 4GB memory, dual redundant power supply system. It supported standard IPSec Protocol, IKE V1, V2, IKE Diffie-Helman Group 1,2,5,14,15,16,17,18, Bandwidth-based load-balancing. Figure 3 displays the hardware implementation.

Fig. 3: Hardware Implementation.

4. Software implementation

Modeling of CTTS started to make a modeling Markup language based on XML considering Intelligent Electrical Devices characteristic and attributes. This modeling define IEC 61850 Class and FC details. We use the SCL Forge software and verified standard compliance.

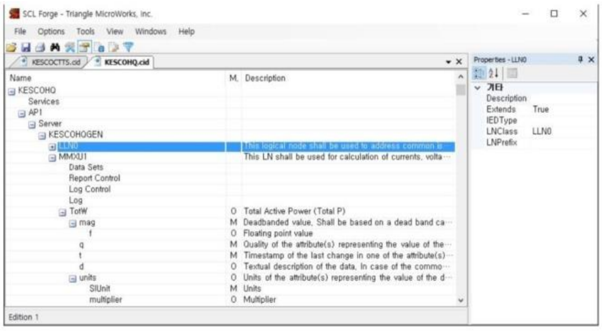


Fig. 4: IED Modeling of SCL Tool (SCL Forge).

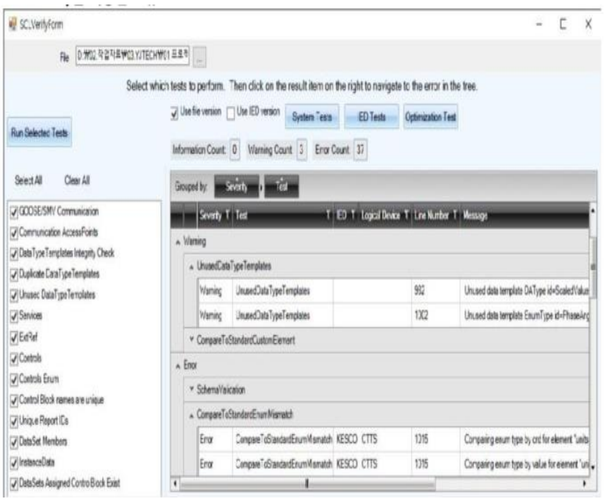


Fig. 5: SCL Verify Error Check.

Figure 6 is Modbus data of Closed Transition Transfer Switch connected by generator and Figure 7 converts to IEC 61850 data format from Modbus data.

40220	10645	Mains V	V	Unsigned	2	0	0	8277*	Mains values	Generator Data
40221	9628	Mains V L1-L2	V	Unsigned	2	0	0	9673*	Mains values	
40222	9629	Mains V L2-L3	V	Unsigned	2	0	0	9673*	Mains values	
40223	9630	Mains V L3-L1	V	Unsigned	2	0	0	9673*	Mains values	
40224	8210	Mains freq	Hz	Unsigned	2	1	400	700	Mains values	
40226	8198	Mains curr L1	A	Unsigned	2	0	0	8275*	Mains values	
40227	8199	Mains curr L2	A	Unsigned	2	0	0	8275*	Mains values	
40228	8200	Mains curr L3	A	Unsigned	2	0	0	8275*	Mains values	
40229	8204	Mains PF		Integer	1	2	-100	100	Mains values	
40230	8395	Mains Ld char		Char	1	-	-	-	Mains values	
40232	8202	MainsImport	kW	Integer	2	0	0	8276*	Mains values	
40234	8524	MP L1	kW	Integer	2	0	0	8276*	Mains values	
40235	8525	MP L2	kW	Integer	2	0	0	8276*	Mains values	
40236	8526	MP L3	kW	Integer	2	0	0	8276*	Mains values	
40237	8203	Mains Q	kVAr	Integer	2	0	-32768	32767	Mains values	
40239	8527	MQ L1	kVAr	Integer	2	0	-32768	32767	Mains values	
40240	8528	MQ L2	kVAr	Integer	2	0	-32768	32767	Mains values	
40241	8529	MQ L3	kVAr	Integer	2	0	-32768	32767	Mains values	
40242	8565	Mains A	kVA	Integer	2	0	-32768	32767	Mains values	
40243	8530	MA L1	kVA	Integer	2	0	-32768	32767	Mains values	
40244	8531	MA L2	kVA	Integer	2	0	-32768	32767	Mains values	
40245	8532	MA L3	kVA	Integer	2	0	-32768	32767	Mains values	
40246	8533	MPf L1		Integer	1	2	-100	100	Mains values	
40247	8534	MPf L2		Integer	1	2	-100	100	Mains values	
40248	8535	MPf L3		Integer	1	2	-100	100	Mains values	
40249	10548	Mains V unbal	%	Unsigned	2	0	0	200	Mains values	
40250	10550	Mains I unbal	%	Unsigned	2	0	0	200	Mains values	
40251	8445	WiringCheck		Unsigned	2	0	0	65535	Invisible	
40253	8626	M Ld char L1		Char	1	-	-	-	Mains values	
40254	8627	M Ld char L2		Char	1	-	-	-	Mains values	
40255	8628	M Ld char L3		Char	1	-	-	-	Mains values	
40256	8195	Bus V L1-N	V	Unsigned	2	0	0	9888*	Bus values	Grid Data
40257	8196	Bus V L2-N	V	Unsigned	2	0	0	9888*	Bus values	
40258	8197	Bus V L3-N	V	Unsigned	2	0	0	9888*	Bus values	
40259	10666	Bus V	V	Unsigned	2	0	0	9888*	Bus values	
40260	9631	Bus V L1-L2	V	Unsigned	2	0	0	9907*	Bus values	
40261	9632	Bus V L2-L3	V	Unsigned	2	0	0	9907*	Bus values	
40262	9633	Bus V L3-L1	V	Unsigned	2	0	0	9907*	Bus values	
40263	8208	I Aux	A	Unsigned	2	0	0	8566*	Bus values	
40264	8211	Bus freq	Hz	Unsigned	2	1	400	700	Bus values	

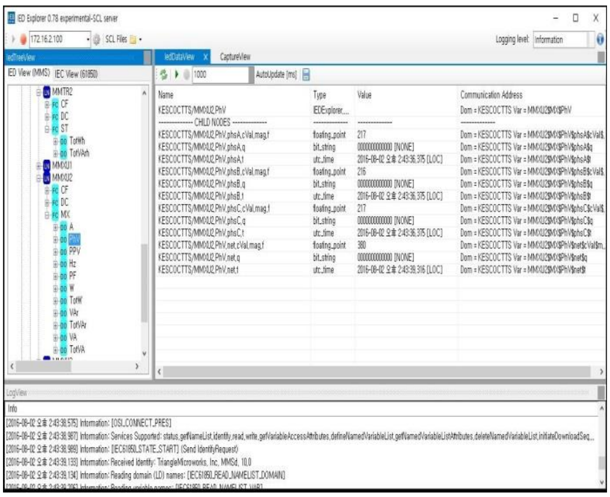
Fig. 6: Modbus Address of CTTS.

Type		Variation	Dimension	Data Type	Modbus Address	Modbus Description	IEC61850 data location
CTTS	Generator	genAphaseVoltage	V	float	40217	GEN_VOLT_R_RMS	KESCOCTTS/MMXU1MXPhV$phsA$cValmagf
		genBphaseVoltage	V	float	40218	GEN_VOLT_S_RMS	KESCOCTTS/MMXU1MXPhV$phsB$cValmagf
		genCphaseVoltage	V	float	40219	GeN_VOLT_T_RMS	KESCOCTTS/MMXU1MXPhV$phsC$cValmagf
		genVoltage	V	float	40220	GEN_NOMIN_VOLT	KESCOCTTS/MMXU1MXPhVnetcValmagf
		genVoltage12	V	float	40221	GEN_VOLT_RS_PH_PH	KESCOCTTS/MMXU1MXPPV$phsAB$cValmagf
		genVoltage23	V	float	40222	GEN_VOLT_ST_PH_PH	KESCOCTTS/MMXU1MXPPV$phsBC$cValmagf
		genVolatage31	V	float	40223	GEN_VOLT_TR_PH_PH	KESCOCTTS/MMXU1MXPPV$phsCA$cValmagf
		genFrequency	Hz	float	40224	GEN_FREQ_R	KESCOCTTS/MMXU1MXHzmagf
		genAphaseCurrent	A	float	40226	GEN_CRNT_R_RMS_A	KESCOCTTS/MMXU1MXA$phsA$cValmagf
		genBphaseCurrent	A	float	40227	GEN_CRNT_S_RMS_A	KESCOCTTS/MMXU1MXA$phsB$cValmagf
		genCphaseCurrent	A	float	40228	GEN_CRNT_T_RMS_A	KESCOCTTS/MMXU1MXA$phsC$cValmagf
		genAphasePowerFactor	-	float	40246	EN__PF_R_POWER_FACTO	KESCOCTTS/MMXU1MXPF$phsA$cValmagf
		genBphasePowerFactor	-	float	40247	EN__PF_S_POWER_FACTO	KESCOCTTS/MMXU1MXPF$phsB$cValmagf
		genCphasePowerFactor	-	float	40248	EN__PF_T_POWER_FACTO	KESCOCTTS/MMXU1MXPF$phsC$cValmagf
		genActivePower	kW	float	40232	GEN_TOTAL_W	KESCOCTTS/MMXU1MXTotWmagf
		genAphaseActivePower	kW	float	40234	GEN_POWER_R_W	KESCOCTTS/MMXU1MXW$phsA$cValmagf
		genBphaseActivePower	kW	float	40235	GEN_POWER_S_W	KESCOCTTS/MMXU1MXW$phsB$cValmagf
		genCphaseActivePower	kW	float	40236	GEN_POWER_T_W	KESCOCTTS/MMXU1MXW$phsC$cValmagf
		genReactivePower	kVAr	float	40237	GEN_TOTAL_VAR	KESCOCTTS/MMXU1MXTotVArmagf
		genAphaseReactivePower	kVAr	float	40239	GEN_POWER_R_VAR	KESCOCTTS/MMXU1MXVAr$phsA$cValmagf
		genBphaseReactivePower	kVAr	float	40240	GEN_POWER_S_VAR	KESCOCTTS/MMXU1MXVAr$phsB$cValmagf
		genCphaseReactivePower	kVAr	float	40241	GEN_POWER_T_VAR	KESCOCTTS/MMXU1MXVAr$phsC$cValmagf
		genApparentPower	kVA	float	40242	GEN_TOTAL_VA	KESCOCTTS/MMXU1MXTotVAmagf
		genAphaseApparentPower	kVA	float	40244	GEN_POWER_R_VA	KESCOCTTS/MMXU1MXVA$phsA$cValmagf
		genBphaseApparentPower	kVA	float	40245	GEN_POWER_S_VA	KESCOCTTS/MMXU1MXVA$phsB$cValmagf
		genCphaseApparentPower	kVA	float	40246	GEN_POWER_T_VA	KESCOCTTS/MMXU1MXVA$phsC$cValmagf
	Grid	mainAphaseVoltage	V	float	40256	MAIN_VOLT_R_RMS	KESCOCTTS/MMXU2MXPhV$phsA$cValmagf
		mainBphaseVoltage	V	float	40257	MAIN_VOLT_S_RMS	KESCOCTTS/MMXU2MXPhV$phsB$cValmagf
		mainCphaseVoltage	V	float	40258	MAIN_VOLT_T_RMS	KESCOCTTS/MMXU2MXPhV$phsC$cValmagf
		mainVoltage	V	float	40259	MAIN_NOMIN_VOLT	KESCOCTTS/MMXU2MXPhVnetcValmagf
		mainVoltage12	V	float	40260	MAIN_VOLT_RS_PH_PH	KESCOCTTS/MMXU2MXPPV$phsAB$cValmagf
		mainVoltage23	V	float	40261	MAIN_VOLT_ST_PH_PH	KESCOCTTS/MMXU2MXPPV$phsBC$cValmagf
		mainVoltage31	V	float	40262	MAIN_VOLT_TR_PH_PH	KESCOCTTS/MMXU2MXPPV$phsCA$cValmagf
		mainFrequency	Hz	float	40264	MAIN_FREQ_R	KESCOCTTS/MMXU2MXHzmagf
		mainAphaseCurrent	A	float	40265	MAIN_CRNT_R_RMS_A	KESCOCTTS/MMXU2MXA$phsA$cValmagf
		mainBphaseCurrent	A	float	40266	MAIN_CRNT_S_RMS_A	KESCOCTTS/MMXU2MXA$phsB$cValmagf

Fig. 7: IEC 61850 Data.

5. Results

Figure 8 represents accurately convert an existing communication protocol (Modbus) and IEC 61850. The Grid Phase to Voltage show 217V (Phase A), 216V (Phase B), 217V (Phase C) and Voltage to Voltage is 380V. And The Grid Frequency is 59.9Hz.



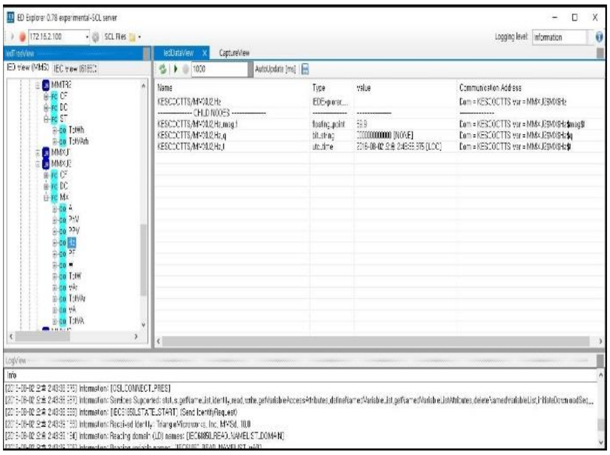


Fig. 8: Testing Result.

6. Conclusion

This paper proposed mapping CTTS to IEC 61850 for using IoT Technology. First we defined the CTTS data classes and attributes. We used new logical node like ZCTS because there is not defined switch system in IEC 61850 standard. The CTTS system support output data in RS485 and the data type is Modbus data. So, we convert to the IEC 61850 standard data type from Modbus data. And then the comparison data has same result with onsite and remote site. Therefore, the proposed scheme can be applied to remote system like IoT.

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