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Research Paper

Design and modeling uninterrupted power system with IEC 61850-7-420

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Abstract

Background/Objectives: Micro-grid is new electrical networks with Distributed Energy Resources(DERs) like photovoltaic, energy storage, small generator. IEC 61850 is international standard of integrated power system with various DERs.
Methods/Statistical analysis: Many researches are being conducted about modeling Distributed Energy Resource and designing system operation and protection method. So, we need integrated system modeling with IEC 61850-7-420 and design uninterrupted system with Photovoltaic, Energy Storage System, Generator.
Findings: To operate DERs with uninterrupted system, it required electrical facility like Closed Transition Transfer Switch (CTTS). CTTS performs an uninterrupted switching operation between two power sources. International Electrical Code 61850-7-420 described some DERs model and LNs (logical nodes) and data classes. This logical nodes and data classes are effective in modeling DERs. So, this paper describes uninterrupted system for mapped IEC 61850 and considers LNs in existence and new logical nodes.
Improvements/Applications: The proposed uninterrupted systems combined the DERs with IEC 61850 and the systems are applicable to Micro-grid system

Keywords: *Micro-Grid; Uninterrupted System; IEC 61850; Closed Transition Transfer Switch; ESS*

1. Introduction

Electricity generation increase 4.1% each year, from 332,413GWh in 2005 to 477,592GWh in 2014[1]. The increased concern for the environmental impacts of centralized generation, distributed generation like micro-grid system favorably occurs from renewable sources. Distributed Energy Resources (DERs) are Photovoltaic, Wind power, small generator. Recently, To solve the renewable energy unstability (Frequency, Active Power), Energy Storage System (ESS) is introduced in the micro-grid system. Most DER and micro-grid research has focused on system operation, economic analysis and system protection[2-6]. The micro-grid has very dynamic behavior because DERs or loads connection and disconnection are very frequent. So, Micro-grid is important to maintain stable power supply without interruption and needs integrated operating system for system's control. IEC 61850 is international standard about integrated distributed automation system. . International Electrical Code 61850-7-420 defines LNs(logical nodes) and data classes for DERs and help in modeling DER system effecitively[7-8]. This paper present uninterrupted power system model with IEC 61850-7-420 and experiment on uninterrupted system with diesel generator, energy storage system.

2. Modeling uninterrupted power system

The uninterrupted power supply system consists of generator, ESS, Photovoltaic and Closed Transition Transfer Switch (CTTS) as shown in Figure 1.

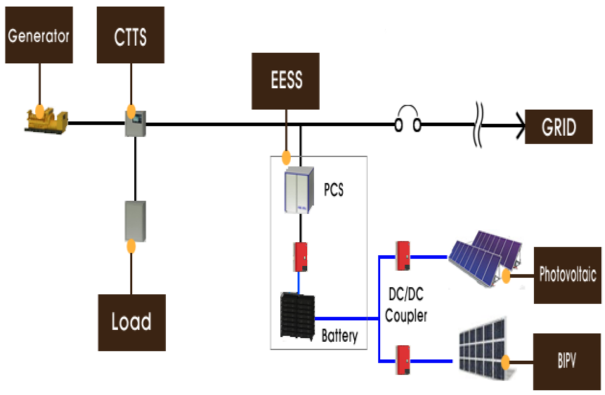

Fig. 1. Diagram of Uninterrupted Power Supply System.

If grid fault occurs in the power system, the system detects accident of grid and discharge battery. While the load was supplied by energy storage system, CTTS send the signal to diesel generator. When the generator has normal voltage, CTTS check the synchronization condition between generator and ESS. If synchronization condition satisfied, it is transferred to the generator power and supply power to load. After grid fault disappear, CTTS check the synchronization condition between Grid and generator. The switch transfers to the Grid system and supply electrical power to load. Photovoltaic charge the ESS battery or supply power to load. This process maintains stable power supply system without regard to the system's state.

2.1. Modeling DERs with IEC 61850-7-420

1) IEC 61850-7-420 is constituted to the standards to support the various DERs[9]. This standard defines the IEC 61850 information models to be used in the exchange of information and communication with DERs, which composed dispersed generation devices and dispersed storage devices, including synchronous generator, photovoltaic, wind power system, energy storage. This paper used a existing model of DERs given blow.
2) Synchronous Diesel Generator(CTTS)
3) ESS(PCS)
4) Photovoltaic(Inverter)

The common LNs in distributed resource measurements could include
CSWI: Switch between generator and inverter (see IEC 61850-7-4.
MMXU: Output electrical measurement (see IEC 61850-7-4)
ZBAT: Remote monitoring and control of critical auxiliary battery system function and states
MENV: Emissions characteristics, including coolant air or water intake, outlet exhaust air, manifold, engine, turbine, oil lubrication, after-cooler, etc
MTEMP: Temperature measurements
Most distributed resources support RS-485 or TCP modbus data and convert to IEC 61850 standards.

No	Dimension	Type	Modbus Address	Modbus Description	IEC61850 Mapping Data
1		int	40005	Operation Status	KESCOCTTS/LLN0STLoc$stVal
2		int	40008	MODE	KESCOCTTS/LLN0STMod$stVal
3	A	float	40041	GEN_CRNT_R_RMS_A	KESCOCTTS/MMXU1MXA$phsA$cValmagf
4	A	float	40042	GEN_CRNT_S_RMS_A	KESCOCTTS/MMXU1MXA$phsB$cValmagf
5	A	float	40043	GEN_CRNT_T_RMS_A	KESCOCTTS/MMXU1MXA$phsC$cValmagf
6	V	float	40045	GEN_VOLT_R_RMS	KESCOCTTS/MMXU1MXPhV$phsA$cValmagf
7	V	float	40046	GEN_VOLT_S_RMS	KESCOCTTS/MMXU1MXPhV$phsB$cValmagf
8	V	float	40047	GeN_VOLT_T_RMS	KESCOCTTS/MMXU1MXPhV$phsC$cValmagf
9	V	float	40049	GEN_VOLT_RS_PH_PH	KESCOCTTS/MMXU1MXPPV$phsAB$cValmagf
10	V	float	40050	GEN_VOLT_ST_PH_PH	KESCOCTTS/MMXU1MXPPV$phsBC$cValmagf
11	V	float	40051	GEN_VOLT_TR_PH_PH	KESCOCTTS/MMXU1MXPPV$phsCA$cValmagf
12	Hz	float	40052	GEN_FREQ_R	KESCOCTTS/MMXU1MXHzmagf
13	-	float	40053	GEN__PF_R_POWER_FACTOR	KESCOCTTS/MMXU1MXPF$phsA$cValmagf
14	-	float	40054	GEN__PF_S_POWER_FACTOR	KESCOCTTS/MMXU1MXPF$phsB$cValmagf
15	-	float	40055	GEN__PF_T_POWER_FACTOR	KESCOCTTS/MMXU1MXPF$phsC$cValmagf
16	kW	float	40057	GEN_POWER_R_W	KESCOCTTS/MMXU1MXW$phsA$cValmagf
17	kW	float	40059	GEN_POWER_S_W	KESCOCTTS/MMXU1MXW$phsB$cValmagf
18	kW	float	40061	GEN_POWER_T_W	KESCOCTTS/MMXU1MXW$phsC$cValmagf
19	kW	float	40063	GEN_TOTAL_W	KESCOCTTS/MMXU1MXTotWmagf
20	kVAr	float	40065	GEN_POWER_R_VAR	KESCOCTTS/MMXU1MXVAr$phsA$cValmagf
21	kVAr	float	40067	GEN_POWER_S_VAR	KESCOCTTS/MMXU1MXVAr$phsB$cValmagf
22	kVAr	float	40068	GEN_POWER_T_VAR	KESCOCTTS/MMXU1MXVAr$phsC$cValmagf
23	kVAr	float	40071	GEN_TOTAL_VAR	KESCOCTTS/MMXU1MXTotVArmagf
24	kVA	float	40073	GEN_POWER_R_VA	KESCOCTTS/MMXU1MXVA$phsA$cValmagf
25	kVA	float	40075	GEN_POWER_S_VA	KESCOCTTS/MMXU1MXVA$phsB$cValmagf
26	kVA	float	40077	GEN_POWER_T_VA	KESCOCTTS/MMXU1MXVA$phsC$cValmagf
27	kVA	float	40079	GEN_TOTAL_VA	KESCOCTTS/MMXU1MXTotVAmagf
28	A	float	40141	MAIN_CRNT_R_RMS_A	KESCOCTTS/MMXU2MXA$phsA$cValmagf
29	A	float	40142	MAIN_CRNT_S_RMS_A	KESCOCTTS/MMXU2MXA$phsB$cValmagf
30	A	float	40143	MAIN_CRNT_T_RMS_A	KESCOCTTS/MMXU2MXA$phsC$cValmagf
31	V	float	40145	MAIN_VOLT_R_RMS	KESCOCTTS/MMXU2MXPhV$phsA$cValmagf
32	V	float	40146	MAIN_VOLT_S_RMS	KESCOCTTS/MMXU2MXPhV$phsB$cValmagf
33	V	float	40147	MAIN_VOLT_T_RMS	KESCOCTTS/MMXU2MXPhV$phsC$cValmagf
34	V	float	40149	MAIN_VOLT_RS_PH_PH	KESCOCTTS/MMXU2MXPPV$phsAB$cValmagf
35	V	float	40150	MAIN_VOLT_ST_PH_PH	KESCOCTTS/MMXU2MXPPV$phsBC$cValmagf
36	V	float	40151	MAIN_VOLT_TR_PH_PH	KESCOCTTS/MMXU2MXPPV$phsCA$cValmagf
37	Hz	float	40152	MAIN_FREQ_R	KESCOCTTS/MMXU2MXHzmagf
38	-	float	40153	MAIN_PF_R_POWER_FACTOR	KESCOCTTS/MMXU2MXPF$phsA$cValmagf

Fig. 2: Mapping IEC 61850 for CTTS (Generator).

No	Dimension	Type	Modbus Address	Modbus Description	IEC61850 Mapping Data
1		int	40001	PCS STATUS	KESCOPCS/LLN0$Health$stVal
2		int	40002	C/D STATUS	KESCOPCS/LLN0STMod$stVal
3		int	4003	Remote Mode	KESCOPCS/LLN0STMod2$stVal
4		int	40004	OP MODE	KESCOPCS/LLN0STMod3$stVal
5		int	40007	FAULT INFORMATION 1	KESCOPCS/LLN0$Fault1$stVal
6		int	40008	FAULT INFORMATION 2	KESCOPCS/LLN0$Fault2$stVal
7		int	40009	FAULT INFORMATION 3	KESCOPCS/LLN0$Fault3$stVal
8		int	40010	FAULT INFORMATION 4	KESCOPCS/LLN0$Fault4$stVal
9		int	40011	FAULT INFORMATION 4	KESCOPCS/LLN0$Fault5$stVal
10	℃	float	40012	PCS_IGBT_TEMP1	KESCOPCS/MTMP1MXTmpmagf
11	℃	float	40013	PCS_IGBT_TEMP2	KESCOPCS/MTMP2MXTmpmagf
12	℃	float	40014	PCS_IGBT_TEMP3	KESCOPCS/MTMP3MXTmpmagf
13	℃	float	40015	PCS_IGBT_TEMP4	KESCOPCS/MTMP4MXTmpmagf
14	℃	float	40016	AC FILTER 1 TEMP	KESCOPCS/MTMP5MXTmpmagf
15	℃	float	40017	AC FILTER 2 TEMP	KESCOPCS/MTMP6MXTmpmagf
16	℃	float	40018	AC FILTER 3 TEMP	KESCOPCS/MTMP7MXTmpmagf
17	℃	float	40019	AC FILTER 4 TEMP	KESCOPCS/MTMP8MXTmpmagf
18	V	float	40020	AC line to line voltage Vrs	KESCOPCS/MMXU1MXphV$phsA$cValmagf
19	V	float	40021	AC line to line voltage Vst	KESCOPCS/MMXU1MXphV$phsB$cValmagf
20	V	float	40022	AC line to line voltage Vtr	KESCOPCS/MMXU1MXphV$phsC$cValmagf
21	A	float	40023	AC current R-phase	KESCOPCS/MMXU1MXA$phsA$cValmagf
22	A	float	40024	AC current S-phase	KESCOPCS/MMXU1MXA$phsB$cValmagf
23	A	float	40025	AC current T-phase	KESCOPCS/MMXU1MXA$phsC$cValmagf
24	Hz	float	40026	AC frequency	KESCOPCS/MMXU1MXHzmagf
25	kW	float	40027	AC Actve Power	KESCOPCS/MMXU1MXTotWmagf
26	Kvar	float	40028	AC Reactive Power	KESCOPCS/MMXU1MXTotVArmagf
27	0.01	float	40029	AC Power Factor	KESCOPCS/MMXU1MXtotPF$mang$f
28	kWh	int	40030	Today discharge energy	KESCOPCS/MNTR1STTotWh$actVal
29	kWh	int	40031	Today charge energy	KESCOPCS/MNTR2STTotWh$actVal
30	kWh	int	40032	Total Dis-chagrge Energy	KESCOPCS/MNTR3STTotWh$actVal
31			40033		
32	kWh	int	40034	Total Dis-chagrge Energy	KESCOPCS/MNTR4STTotWh$actVal
33			40035		
34	V	float	40036	DC-link voltage	KESCOPCS/MMXU2MXphVnetcValmagf
35	V	float	40037	Battery side voltage	KESCOPCS/MMXU3MXphVnetcValmagf
36	A	float	40038	Battery side current	KESCOPCS/MMXU3MXAnetcValmagf
37	kW	float	40039	Battery side power	KESCOPCS/MMXU3MXTotWmagf
38	%	float	40041	Battery SOC	KESCOPCS/MENV1MXSOCmagf
39		int	40050	STS STATUS	KESCOTRSTS/LLN0$Health$stVal

Fig. 3: Mapping IEC 61850 for PCS (ESS).

No	Dimension	Type	Modbus Address	Modbus Description	IEC61850 Mapping Data
1		int	40024	SYS_STS	KESCOIVT1/LLN0STLoc$stVal
2		int	40032	RUNTM_TOT	KESCOIVT1/LLN0STOpTmh$stVal
3	V	float	40034	PV	KESCOIVT1/MMXU1MXPhVnetcValmagf
4	V	float	40036	DCV	KESCOIVT1/MMXU1MXPhV$PhsA$cValmagf
5	A	float	40038	PA	KESCOIVT1/MMXU1MXAnetcValmagf
6	W	float	40040	PW	KESCOIVT1/MMXU1MXW$net#cVal$mag$f
7	V	float	40042	IV	KESCOIVT1/MMXU2MXPhVnetcValmagf
8	A	float	40044	IA	KESCOIVT1/MMXU2MXAnetcValmagf
9	W	float	40046	IW	KESCOIVT1/MMXU2MXWnetcValmagf
10	VA	float	40048	VA	KESCOIVT1/MMXU1MXTotVAmagf
11	%	float	40050	PF	KESCOIVT1/MMXU1MXTotPFmagf
12	Hz	float	40052	Hz	KESCOIVT1/MMXU1MXHzmagf
14	V	float	40058	V1	KESCOIVT1/MMXU3MXPhV$phsA$cValmagf
15	V	float	40060	V2	KESCOIVT1/MMXU3MXPhV$phsB$cValmagf
16	V	float	40062	V3	KESCOIVT1/MMXU3MXPhV$phsA$cValmagf
17	A	float	40064	A1	KESCOIVT1/MMXU3MXA$phsA$cValmagf
18		float	40066	A2	KESCOIVT1/MMXU3MXA$phsB$cValmagf
19		float	40068	A3	KESCOIVT1/MMXU3MXA$phsC$cValmagf
20	W	float	40070	W1	KESCOIVT1/MMXU3MXW$phsA$cValmagf
21	W	float	40072	W2	KESCOIVT1/MMXU3MXW$phsB$cValmagf
22	W	float	40074	W3	KESCOIVT1/MMXU3MXW$phsC$cValmagf
23	VA	float	40076	VA1	KESCOIVT1/MMXU3MXVA$phsA$cValmagf
24	VA	float	40078	VA2	KESCOIVT1/MMXU3MXVA$phsB$cValmagf
25	VA	float	40080	VA3	KESCOIVT1/MMXU3MXVA$phsC$cValmagf
26	%	float	40082	PF1	KESCOIVT1/MMXU3MXPF$phsA$cValmagf
27	%	float	40084	PF2	KESCOIVT1/MMXU3MXPF$phsB$cValmagf
28	%	float	40086	PF3	KESCOIVT1/MMXU3MXPF$phsC$cValmagf
29	V	float	40088	MPP	KESCOIVT1/MMXU3MXPhVnetcValmagf
30		float	40090	TEMP	KESCOIVT1/MTEMP1MXTmpmagf
31	Wh	float	40094	KWH_TOT	KESCOIVT1/MNTR1STTotWh$actVal
32	Wh	float	40100	KWH_QUART	KESCOIVT1/MNTR2STTotWh$actVal
33	Wh	float	40104	KWH_HOUR	KESCOIVT1/MNTR3STTotWh$actVal
34	Wh	float	40108	KWH_DAY	KESCOIVT1/MNTR4STTotWh$actVal
35	Wh	float	40112	KWH_MON	KESCOIVT1/MNTR5STTotWh$actVal
36	Wh	float	40116	KWH_YEAR	KESCOIVT1/MNTR6STTotWh$actVal
37		int	40024	SYS_STS	KESCOIVT2/LLN0STLoc$stVal
38		int	40032	RUNTM_TOT	KESCOIVT2/LLN0STOpTmh$stVal
39	V	float	40034	PV	KESCOIVT2/MMXU1MXPhVnetcValmagf

Fig. 4: Mapping IEC 61850 for Inverter (Photovoltaic).

2.1.1. Hardware implements

Diesel generator, ESS and photovoltaic specifications are as follows.

Table 1: Hardware Specifications

	Diesel generator	ESS	Photovoltaic
Capacity	300kW	250kW 125kWh(2C-rate)	125kW
Phase	3Φ	3Φ	3Φ
Frequency	60	60	60
Voltage	380/220VAC	380/220VAC 750VDC	380VAC 300VDC

IEC 61850 gateways have ARM Cortex CPU (500Mhz), RAM(512MB), Flash memory(512MB). It communicated 2 channel Half Duplex Mode based on RS 485 and MMS protocol with IEC 61850 Group 1. The Ethernet modem router support TCP/IP protocol and connect network with data server

2.1.2. Software implements

SCL Forge software convert Modbus to IEC 61850 and modeling Markup language based on XML. The program make CID modeling file and install CID to the Gateway. Each DERs define fixed IP and check the data by Hammer program(Triangle Microworks Inc).

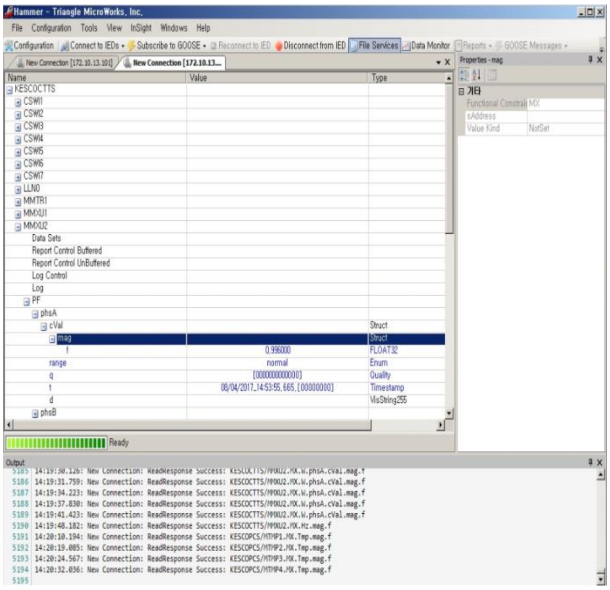

Fig. 5: Result of IED Data by Hammer Program.

3. Experiment of uninterrupted power system

The CTTS consists of two switches for the resources (e. g. Grid, diesel generator, ESS) and transfers uninterrupted state which matches synchronization condition. The CTTS synchronization condition are designed as stated in Table 2[10].

Table 2: Synchronization Condition & Parallel Operation Times

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

To verify uninterrupted power system, this paper followed scenario given blow.

1) Grid fault
2) ESS discharge
3) Operating Diesel generator
4) Closed Transition Transfer between ESS and Diesel generator
5) Grid fault recover
6) Closed Transition Transfer between Diesel generator and Grid
7) Stopped Diesel generator

Figure 6 represents experiment of uninterrupted power system. During all the proceedings scenario, the load remained uninterrupted. Figure 7 is closed transition transfer condition of two resources (diesel generator, ESS).

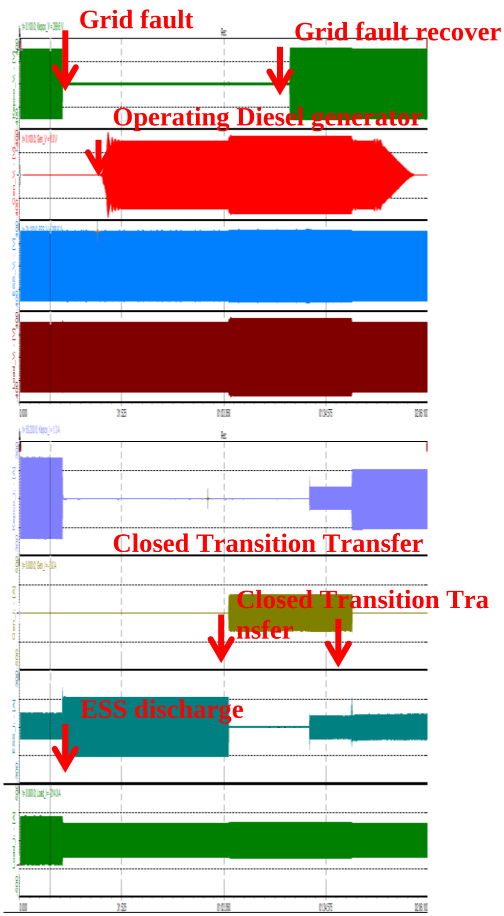

Fig. 6: Result of Experiment Uninterrupted Power System.

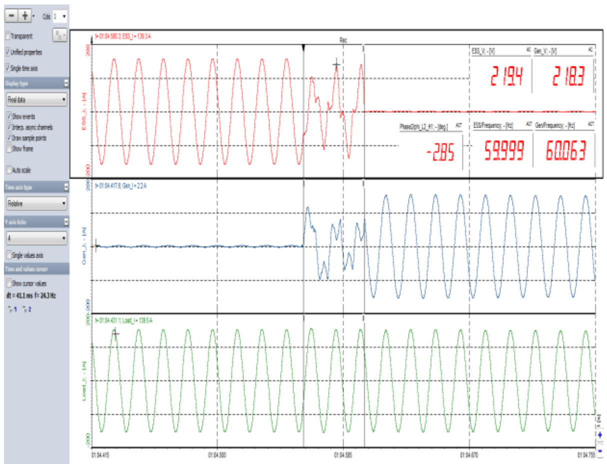

Fig. 7: Result of Synchronization Condition.

ESS voltage is 219.4V and Generator voltage is 218.3V. The difference between two voltage is 1.1V (0.5%), ESS frequency is 59.999Hz and Generator frequency is 60.063Hz. The difference between two frequency is 0.064Hz. The phase of two resources is -2.85° and parallel operating time is 41.1ms. All synchronization conditions of experiment were satisfied with UL 1008 synchronization condition.

4. Conclusion

This paper design and modeling uninterrupted power system with IEC 61850. To modeling DERs, we used IEC 61850-7-420 modeling data and convert modbus to IEC 61850 standard form using SCL Forge program. Data was received with Gateway and we constitute integrated micro-grid system operation. To verify uninterrupted operating system, we experiment system process and synchronization condition of closed transition transfer switch. The result of synchronization condition was satisfied with UL 1008 standard. So, this system can adopt integrated mico-grid system and maintain uninterrupted power supply regardless grid state.

Acknowledgment

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References

[1] Korea Power Exchange, The 7th Basic Power Supply Plan in 2015~2029 (http://www.kpx.or.kr/www/contents.do?key=92) , 2015
[2] A. Dimeas & Hatziargyriou, Operation of a Multiagent System for Microgrid Control. IEEE Transactions on Power Systems, Vol.20, No.3, 2005.
[3] A.K. Basu, T.K.Panigrahi, S.Chowdhury, S.P. Chowdhury, N. Chakraborty, A. Sinha, Y.H. Song, Key energy management issues of setting market clearing price (MCP) in micro-grid scenario, Proceedings of the 42nd International Universities Power Engineering Conference, 2007
[4] H.A. Gil & G. Joos, Models for quantifying the economic benefits of distributed generation, IEEE Transactions on Power Systems, Vol. 23, No. 2, 2008
[5] F.D. Kanellos & N.D. Hatziargyriou, Control of variable speed wind turbines in islanded mode of operation, IEEE Transactions on Energy Conversion, Vol. 23, No. 2, 2008
[6] R.A. Walling, R. Saint, R.C. Dugan, J. Burke, L.A. Kojovic, Summary of distributed resources impact on power delivery systems, IEEE Transactions on Power Delivery, Vol. 23, No. 3, 2008
[7] I. T. WG17, Introduction to IEC 61850-7-420: Distributed energy resources (DER) object modeling, White Paper, Ver. 2, 2009
[8] Taha Selim Ustun, Cagil Ozansoy, and Aladin Zayegh, Modeling of a Centralized Microgrid Protection System and Distributed Energy Resources According to IEC 61850-7-420, IEEE Transactions in Power Systems, Vol. 27, No. 3, 2012
[9] Salvatore Cavalieri, AlessioRegalbuto, Mapping IEC 61850 SCl to IPC UA for Smart Grid Application, IEEE, 2015
[10] UL, UL 1008 : Transfer Switch Equipment (https://standardscatalog.ul.com/standards/en/standard_1008_8) , 201