A PROTECTION COORDINATION ESTIMATION OF DISTRIBUTION NETWORK FOR SMART DISTRIBUTION MANAGEMENT SYSTEM

Cheol-Min Chu
KEPCO-South Korea
cmchu79@kepco.co.kr

Yun-Sang Yun
KEPCO-South Korea
drk9034@kepco.co.kr

Seong-Chul Kwon
KEPCO-South Korea
mindall@kepco.co.kr

Il-Keun Song
KEPCO-South Korea
songilk@kepco.co.kr

ABSTRACT

The smart grid offers new opportunities to improve the efficiency of operating and controlling distribution systems through the accurate information of the real-time situation of the network. And also, it is possible to automatically protect the network by using the communication infrastructure. The Korean Smart Distribution Management System (KSDMS) project launched at 2009 to achieve advanced distribution operation for potential smart grid systems in Korea. The KSDMS allows the optimization for operating and controlling the network, whose circumstance is hourly changed by the energy supply(depending on Distributed Generator(DG)) and consumption(depending on Load), by using the various analysis and control software. And also, in KSDMS, the energy security is highly considered by using the protection estimation method which automatically changes the setting value of protection coordination under the circumstance. In this paper, an adoptive algorithm for change and estimation of the protection coordination setting is proposed, and the protection coordination scheme designed in KSDMS is briefly introduced.

INTRODUCTION

The Protection Coordination applied in KSDMS is categorized into communication coordination and over-current protection coordination for field equipment. And also, the adoptive method to reset the protection coordination of two ways, called to Protection Coordination Estimation (PCE), is designed and developed in KSDMS. The purpose of PCE is to automatically change the information which is necessary for protection coordination, such the coordination with OCR installed substation, type of TC curve, operating sequence in typical protection method, in various changeable circumstance of the distribution network. In KSDMS, the PCE estimates the setting value for two way of protection coordination above mentioned.

In KSDMS, the applied two methods for protection coordination are briefly introduced. One of the methods is the communication protection coordination, based on IEC 61850, which is main protection scheme. The other is over current protection coordination which is typically applied for the protection in distribution network and operated as a backup scheme in KSDMS. In order to appropriately use the protection methods depend on the circumstance of the network, the network case is assumed that as following below.

① Case of Communication protection
→Radial Network with & without DG
→Closed Loop Network with & without DG
② Case of over-current protection
→Radial Network with and without DG

The communication method is based on IEC 61850. According to the multicast as a characteristic of IEC 61850, each IED(intelligent electric device) has an MAC address information on the other IEDs, which is the object to communicate with the IED, and select the IEDs' data for performance of protection coordination without hitch. The data format is based on Goose Massage designed in the standard, and the data which is described in next chapter is additionally designed for protection algorithm. The over-current protection algorithm is not a difference with typical way. However, the way is modified to apply some concepts, because there is no way to handle the continually changed circumstance of the network. Two protection methods designed in KSDMS is purposed to reliably and perfectly conduct the protection function, so the PCE proposed in this paper is explained and verified with test model.

PROTECTION COORDINATION

As mentioned in Intro., there are two methods for protection coordination. One is the main protection to be designed and used to the communication, and another is backup protection, which is for the case that the communication infrastructure isn't installed or malfunctioned, to be designed with the over-current protection.

Communication Protection Coordination

In the communication protection based on IEC 61850, the data for the protection and algorithm are designed. The difference with typical protection method is to successively carry out the protection and transfer from fault section using not only protection equipment but also automatic switch. The data for the protection is designed as following below.

Table. 1 Data format for communication protection

no.	title	mean
1	PRF (Protector Forward Fault)	detect the fault by protection equip. on forward direction
2	PFF (Protector Reverse Fault)	detect the fault by protection equip. on reverse direction
3	SRF (Switch Forward Fault)	detect the fault by switch on forward direction
4	SFF (Switch Reverse Fault)	detect the fault by switch on reverse direction
5	DTO (Direct Transfer Open)	Depending on the terms, the detected switch transmit the signal to directly open the pair of switch
6	TF(Trip Fail)	Case that trip is failed
7	Type of Equipment	The Protection equipment type

Including these data, we also design the protection time count for the reliability of data and operation of equipment. Each count has a default time, and it can be changed on the case that the delay time of OCR installed in main circuit breaker is changed. If the network is changed with connection of main transformer

Using the above data, the case study is performed to verify the algorithm of communication protection method, as following below figure.

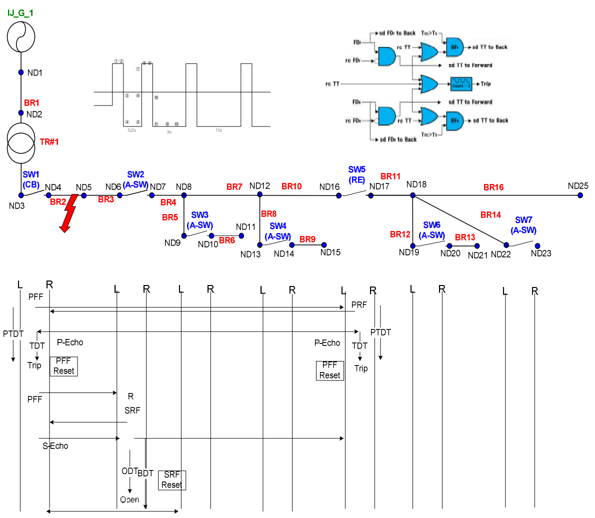


Fig. 1 Case study for the communication method

There are so many result of case study. According to those results, the protection equipment needs IP address information on communication objects which are installed in both side of the nearest equipment among the all of the equipment. As a result, the protection equipment has communication objects as following table.

Table. 2 Result of communication objects in case study

FIED	L(Left)	R(Right)
G1		R1
R1	G1	R2, R3, G2
G2	R1	G3
G3	G2	R2, G4
G4	G3, R2	G5
G5	G4	G7
R2	R1, R3, G3, G4	G6
G6	R2	
G7	G5	G8
G8	G7	G9
G9	G8	R3
R3	R1, R2, G9	G10
G10	R3	

The data, such a count and address, for communication protection should be reset, when the network is changed . For generating the resetting data, the algorithm flow is described in Figure.2.

Over-Current Protection Coordination

The reset information on over-current protection coordination is operating time depending on the fault current and operating sequence. Even though there is little difference between utilities depending on their own protection coordination sachem, the above data should be changed in every time to change the structure of the network. However, the network considered in KSDNS is various radial system include of the loop network. So it is possible to exceed the limit term demanded to keep the coordination time delay between two protection equipment. Therefore, the over current protection coordination proposed in this paper should consider the reset condition to generate the data.

1) When considering several protection equipment(more than limits), the protection equipment which make minimum outage section in case of occurrence of fault is selected and same the protection data with forward/ backward protection equipment
2) For protection coordination in loop distribution system, each protection equipment has bi-directional set-data, and decides which directional set-data(forward/backward) is applied in accordance with a network information.

Considering two terms of over-current protection coordination, the coordination time delay is generated and maintained in accordance with protection scheme in utility and the equipment characteristic. For generating the resetting data, the algorithm flow is described in Figure.2.

DESIGNG OF PCE

In order to perform adaptive protection coordination in each methods, the PCE generates the reset data automatically. In KSDMS to consider a changeable network condition in real-time, various information are generated for understanding on the condition to operator, even data required by the programme such a Power flow, PCE. etc.[2]

Algorithm for PCE

The algorithm of PCE for adaptive estimation on protect ion coordination is following below figure.

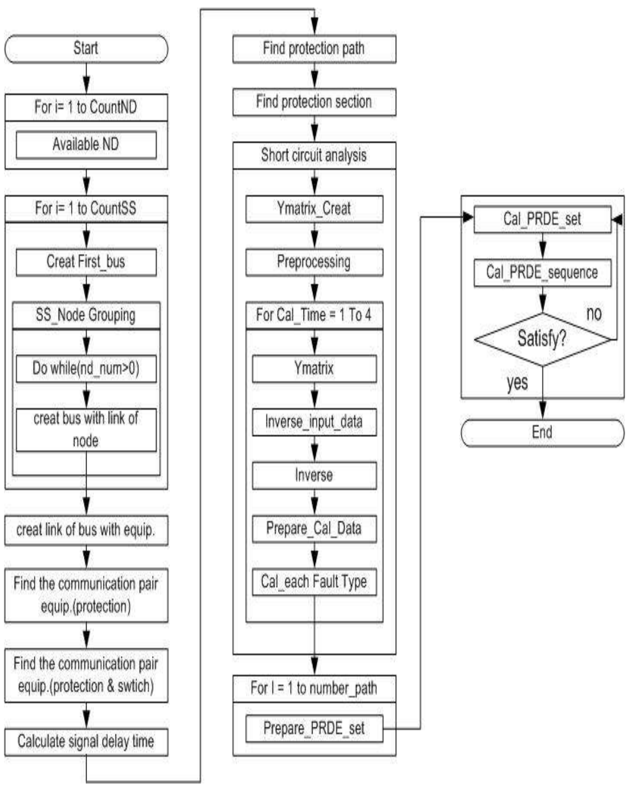


Fig. 2 Algorithm of PCE

In this flow, first of all, data generated in the various analysis and control software (network connectivity processor, state estimation, load flow analysis, etc.) is acquired. Depending on network condition based on the topology, the communication objects pairing with the each protection equipment installed IED selected. And, the protection time Count is generated in accordance to protection time delay on main circuit breaker. Finally, we could get the information required for PCE as following below.

-Set of direction data for directional relay in open and closed loop system
-Set of IP(or MAC) address data on communication objects(IED) and information required ICD file
-Set of data on Protection Time Count
-Set of data required for communication protection algorithm considering the communication condition

For over-current protection coordination, the coordination path consisted of the protection equipment (such a breaker, recloser, etc) is generated. After that, minimum equipment set of path is generated to consider the section load charged by protection equipment in the path. Next, depending on the minimum set of path, the sequence and the protection delay time using TC-curve is generated in accordance to protection scheme of utility. At that time, the fault analysis is done as a inter-operating module in PCE.
According to above flow, the algorithm of PCE is realized, and the result is generated as following below figure.

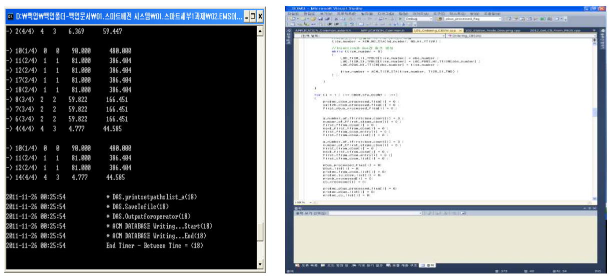


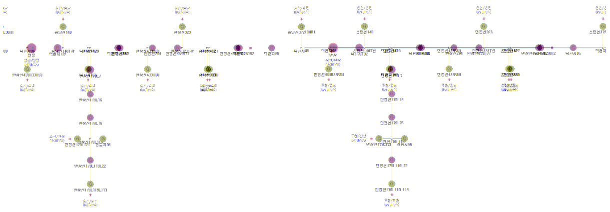
Fig. 3 Realization of PCE

Data Structure

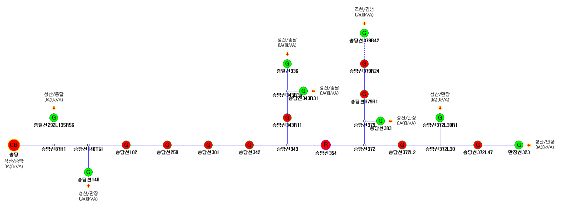
For carrying out PCE, topology data and measurement data whose structure was introduced in ref.[1] are required.

Case study

In order to verifying the algorithm of PCE, two feeders operated by Korea Electric Power Corporation(KEPCO) in Jeju-island are selected as test model. The way of verification is to compare between the result of PCE and real data of protection coordination. The part of communication protection is verified by hand-calculation. The test feeder is connected with normal-open-point, so it is possible to verify the various case of distribution network, even if there are no DG.



(a) Manjang-distribution line



(b) Songdang-distribution line

Fig. 4 Test system in Jeju

Result

The result of case study is following table.3. The result is similar to the existing data which mean the PCE is possible to generate the data for protection coordination. However, even if the result is similar, it dose not mean the method is directly applied in the real field. The reason is that the structure of the selected test model might be easy to solve. Before applying the algorithm, we would be various test models.

CONCLUSION

This paper introduces the protection coordination methods and adaptive estimation of the coordination designed in KSDMS. There are successful results on the case study described above chapter. However, it is not enough to apply in real system due to various circumstance of distribution network. Especially, in the part of over-current protection coordination, the way that is more efficient method to consider the use of existing infrastructure in case of the closed loop network is necessary. And also, the communication protection coordination method should be developed to consider the general purpose. After the development, we have a plan to verify the protection algorithm and the way of estimation through the field test.

REFERENCES

[1] C.M.Chu, 2011,"Design of application common model for network analysis in smart distribution management system", *CIRED*, paper #224.

[2] S.Y.Yun, 2011,"Development of Smart Distribution Management System for Predictive Operation of Power Distribution Systems ", *CIRED*, paper #221.

[3] J.See,W.Carr, 2009,"Real time distribution analysis for electric utilities", *IEEE Rural Electric Power Conf.*, B5-1-B5-8

[4] J. See, W. Carr, S. E. Collier, 2009, "Real time distribution analysis for electric utilities," in *IEEE Rural Electric Power Conf.*, pp.B5-1-B5-8.

[5] Sukumar M. Brahma, 2004, "Development of Adaptive Protection Schme for Distribution Systems With High Penetration of Distributed Generation" in *IEEE Transaction on power delivery*. Vol19, No. 1.

[6] Ioannis S. Baxevanos, 2004, "Implementing Multi-agent systems technology for power distribution network control and protection managment" in *IEEE Transaction on power delivery*. Vol22, No. 1.

Table. 3 Result of communication objects

prde_no	Leve r-1g	Leve r-3g	Over-current				Communication			Exist			
			Tap1g	Tap3g	Curve	Seq.	Left	Right	count	Tap1ga	Tap3ga	Curve	Seq.
33	0.8	0.7	0.75	4	6	0	0	36, 42	20	0.75	4	6	0
36	0	0	32.4	218.127	1	1	33	38	30	32.4	218.127	1	1
38	0	0	9.076	84.711	2	2	36	42	30	15.127	54.457	2	2
42	0	0	5.255	49.045	4	3	33,38	47,62	20	5.255	49.044	4	3
47	0	0	4.299	40.127	2	2	42	88	30	4.299	40.127	2	2
88	0	0	81	432	1	4	47	62	30	75.923	337.541	1	4
62	0	0	72.9	256.52	1	5	88, 42	64	20	44.55	324.317	1	5
64	0	0	3.583	33.438	2	6	62	71	30	3.583	33.439	2	6
71	0	0	5.971	55.731	4	3	64	69	30	5.971	55.731	4	3
69	0	0	65.672	134.615	2	2	71	85	30	13.933	55.731	2	6
85	0	0	81	432	1	4	69	79, 58	30	44.55	324.317	1	5
79	0	0	81	432	1	4	58, 85	57	30	44.55	256.52	1	5
58	0	0	81	432	1	4	79	0	30	75.923	337.541	1	4
57	0	0	81	432	1	4	79	60	30	75.923	337.541	1	4
60	0.8	0.7	0.75	4	6	0	57	0	30	0.75	4	6	0