UNDERGROUND LOW VOLTAGE LOOP SYSTEM OF KEPCO

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ABSTRACT

KEPCO has adopted radial system at low voltage distribution. Recently KEPCO began to have the problems. As low voltage customer's limit was changed from 499 kW to 999 kW, the uses of large capacity transformer are increased. Installation space of TR & CB are insufficient at downtown area. Utility rate of transformer is low. When transformer is replaced, LV system experiences interruption. So we developed the underground low voltage loop system. KEPCO's LV loop system is consisted of HV CB, TR, LV loop IED, LV CB, operation system (server).
To develop the low voltage loop system, we simulated the load flow and fault analysis by EMTDC program, made a simulator for lab test, developed the protection coordination and established test bed at 22.9kV network. And field test was done.

INTRODUCTION

DAS(Distribution Automation System) monitors HV distribution system, and control the equipment of system for protection and maintenance.

But LV radial distribution system does not monitor and control for fault of the transformer or low voltage system. So low voltage distribution customers experience interruption when the fault occurs at transformer or low voltage distribution line. And the space required to install the power equipment is insufficient at downtown area.

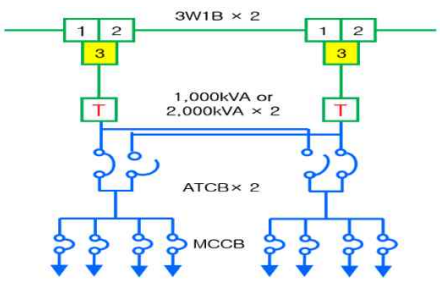


Figure 1. Compact Distribution Station

So we developed the compact distribution station such as in Figure 1, It is a low voltage open loop system. It is consisted of 2 or 3 units of the transformer, ATCB(Auto Transfer Circuit Breaker), and MCCB at the same place. When fault occurs at one transformer, compact distribution station separates the faulty transformer, and connect low voltage side by ATCB. At compact distribution station is constrained to install only 2 or 3 transformers and it must be installed same place. But low voltage loop system could install more than 3 transformers for parallel operation at different place.

UNDERGROUND LOW VOLTAGE LOOP SYSTEM'S CONFIGURATION

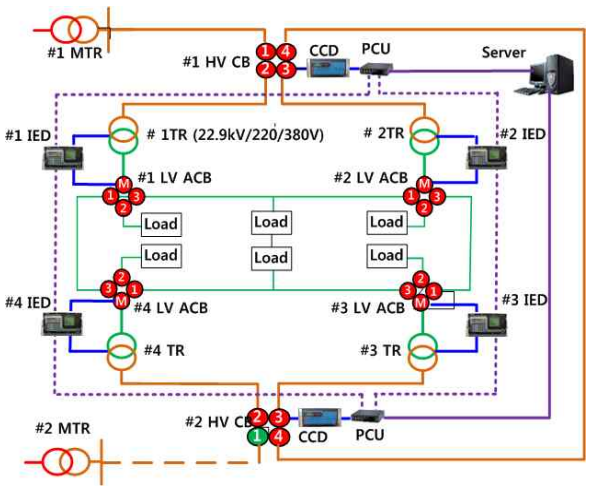


Figure 2. Underground low voltage loop system

Figure 2 shows the underground low voltage loop system. LV loop system is consistd of HV CB, transformer, IED, ACB, and operation system(server) with one or two distribution lines.

HV CB

HV CB is used to connect or disconnect with high voltage side distribution line. CCD(Closed loop Control Device) controls HV CB by communication with IED. And PCU(Protection Communication Unit) is used to send and receive the data between CCD and LV IED.

Transformer

At low voltage radial distribution system, transformer connection uses Y-Y, but low voltage loop system adopts Δ-Y, because the harmonic frequency zero-sequence current in the secondary lines supplied by transformer do not flow in the primary lines and it primary system does not see load unbalances and ground faults in the secondary system. The %Z of LV radial system's

transformer is 4.5%. It designed to 7% for low voltage loop system, because the fault current is increased as network impedance is reduced by loop system. And loop system could not install the current limit fuse for transformer's fault or Bay-O-Net fuse for low voltage side protection. over load by using HV CB, IED, and ACB(Air Circuit Breaker).

Low voltage loop IED

IED(Figure 3) monitors low voltage loop system and controls HV CB and ACB with communication between CCD, operating system, other IED, and operating system.

Figure 3. Low voltage loop IED

IED is used for monitoring about low voltage loop system. It monitors voltage, current, and angle, and status of HV CB and ACBs.
IED is used for protection coordination of low voltage loop system also. Functions of IED are overcurrent relay, over/under voltage relay, reverse power flow relay, the percentage differential relay and etc.

Operating system(Server)

Operating system manage the low voltage loop system. It's functions are bellows.

- · remotely configure for IED's setting and control.
- · build the DB of loop system's measured data manage
- · manage the operating and maintenance history of loop equipment
- · data exchange between other external systems

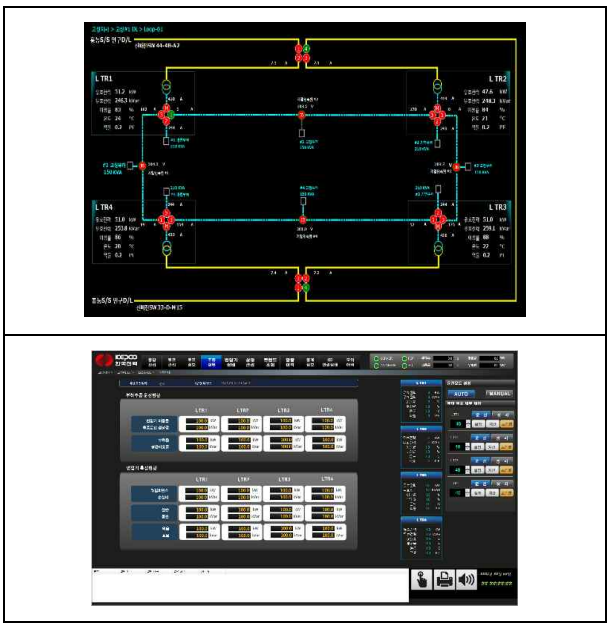


Figure 4. Screen shot of the operating system's monitor

Figure 4 is the screen shot of the operating system's monitor. It implements the status and measured data of low voltage loop system to monitor for operator, and operator can control the loop equipment on site.

LOW VOLTAGE LOOP SIMULATOR

Before the field test of loop system for IED and operating system. We tested them with simulator. It can simulate the function of circuit breaker, distribution line, transformer, RLC load.

Figure 5 is the low voltage loop simulator that can simulates two transformers parallel operation.

Figure 5. Low voltage loop simulator

We tested protection coordination for the various contingency of the loop system, and the communication between IED and operating system. Figure 6 and Figure7 are the result of the test.

순서	No/Seq	발생시각	고장...	동전...	고장발...	A상전류	B상전류	C상전류	N상전류
1	1-1	2015/06/02 17:11:18.163	자동	정	__CN	10A	10A	255A	255A
2	2-1	2015/06/02 17:08:44.783	자동	정	__CN	10A	10A	259A	258A

Figure 6. Fault history at ACB

순서	발생시각	Port	종류	Data
160	2015/06/02 17:13:28.141	L	송신	00
161	2015/06/02 17:11:18.231	L	송신	80
162	2015/06/02 17:11:18.221	L	송신	00
163	2015/06/02 17:11:18.218	L	수신	80
164	2015/06/02 17:11:18.201	L	송신	40
165	2015/06/02 17:11:18.171	L	송신	51
166	2015/06/02 17:11:18.151	L	송신	11
167	2015/06/02 17:10:59.579	L	수신	00

Figure 7. Protection coordination communication history

22.9KV LOW VOLTAGE LOOP TEST BED

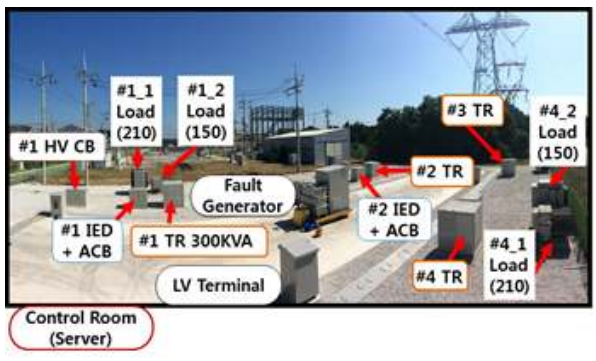


Figure 8. Low voltage loop system test bed

Figure 8 is the low voltage loop system test bed at Go-chang. To confirm the operation characteristics of the

loop equipment and algorithm that adopted IED and operating system we build the test bed.

Low voltage loop system equipment

Table 1. Low voltage loop system equipment

Item	Spec.	Quantity
TR	300kVA, 22.9kV/380/220V	4
ACB	600V, 800A	4set(16ea)
IED	(optimal communication)	4
Server	(operating system)	1

Table 1 is the spec. and quantity of the loop system equipment at test bed.


Figure 9. Transformer and ACBs with IED

At Figure 9, left is the 300kVA transformer. And right is ACBs with IED. There are main ACB and IED at upper side, 2 ACBs to loop other transformer's secondary and 1 ACB for load at bottom.

Equipment for loop system test

Table 2. Equipment for loop system test

Item	Spec.	Quantity
Load (fixed)	3P, 150kvar	4
Load_(variable)	3P, 210kvar	4
Fault Generator	18, 20, 23, 28, 40kA	1
LV Terminal Unit	220/3380V	5

Table 2 is the spec. and quantity of equipment for loop system test. LV terminal unit is used to connect the low voltage fault generator with loop system.


Figure 10. the fixed load and low voltage terminal unit

Figure 10 is the 150kvar fixed load and low voltage terminal unit.


Figure 11. Variable load and fault generator

Figure 11 is the variable load voltage fault generator. Variable load can adjust from 10kvar to 70kvar with 7 steps. Fault generator which is connected to the low voltage terminal unit can supply 18, 20, 23, 28, 40kA at low voltage system, and it is easily carried by motor

We tested protection coordination for the contingency of the transformer, low voltage distribution line, between HV CB and transformer. Test for the communication and index point between IED and operating system were done. Figure 12 and Figure13 are the result of the test.

1	1-1	2015/08/14 06:31:40,250	자동	정	AB__	723A	728A	55A	9A
2	2-1	2015/08/14 06:17:50,420	자동	정	A__N	856A	69A	59A	774A

Figure 12. Fault current data

1	2015/08/14 06:31:40,340	열림	CLS 트립
2	2015/08/14 06:30:54,480	닫힘	현장
3	2015/08/14 06:17:50,510	열림	CLS 트립

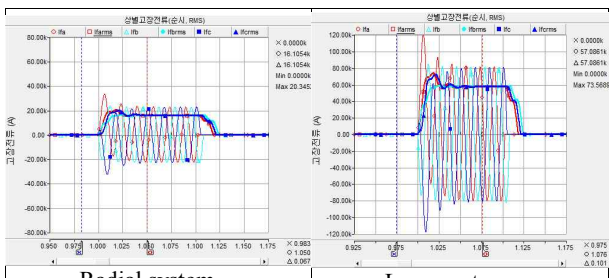
Figure 13. Operation history of ACB

LOW VOLTAGE LOOP SYSTEM OPERATION

We simulated the low voltage system's fault current at radial and loop. Also we calculated fault current by different %z. And we compared the case when radial system replaces by loop system.

Calculation fault current

We compared the fault current when low voltage side fault at radial system and loop system. Transformer's spec is 500kVA, % Z = 4.5. And 4 transformers are operated with parallel at loop system by EMTDC program.



Radial system	Loop system

Figure 14. fault current analysis results

The fault current of the three-phase short circuit, respectively. 16.1kA at radial system, and 57.1kA at loop system like Figure 14.

%Z of transformer

When we use transformer (three-phase 500kVA, % Z = 4.5) for radial system to a loop system, the three-phase short circuit current is generated 57.1kA.

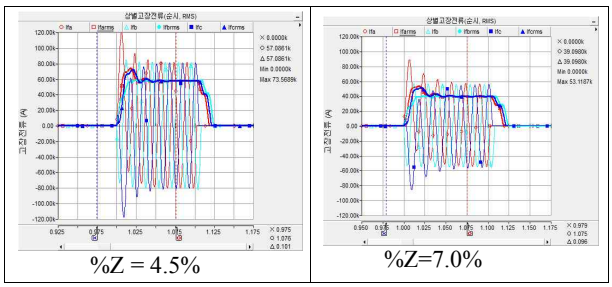


Figure 15. fault current analysis results

In order to reduce the fault current, we designed transformer's % Z is 7.0% for loop system. Then the fault current was reduced to 39.1kA(Figure 15).

Effect of low voltage system

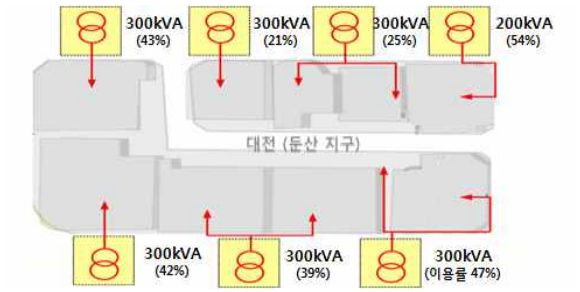


Figure 16. Down town area in radial system

At the down town area about 5,000 square meters, there were 7 transformers in radial system. The total contract power is 1,817kW, average load 764kW by radial system like a Figure 16.

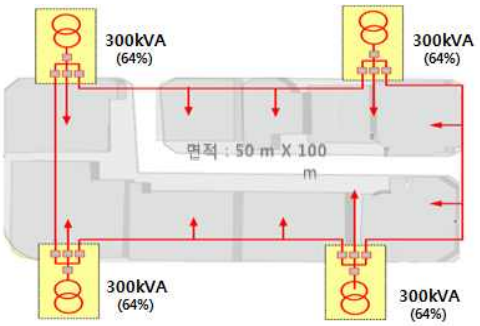


Figure 17 Down town area with loop system

Figure 17 shows that if we replace radial system to loop system.

Table 3. Effect of loop system to radial system

Item	Radial	Loop
Number of transformer	7	4
Total capacity of transformer	2,000kVA	1,200kVA
Average utilization rate	38.0%	64.0%
Maximum utilization rate	52.0%	86.0%
Loss of transformer	9.0kW	6.3kW

If we replace radial system to loop system. We could reduce the number of transformer to install from 7 to 4. The loss of transformer is reduced and the utilization rate of transformer is increased for the same load

CONCLUSION

At the low voltage radial system, when fault occurs at transformer or low voltage distribution line, customer experience the interruption. The utilization rate of transformer is low. And the space required to install the power equipment is in sufficient at downtown area

We developed the low voltage loop system to solve the problem of radial system. We simulated the loop system's fault current and loss with EMTDC program, and tested by simulator and prototype equipment.

Additionally, low voltage loop system could reduce the loss of transformer, by separating the transformer using the HV CB and Main ACB at low voltage side at the time of late-night and weekend with light load by IED and operating system.

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