NEW PROTECTION COORDINATION SYSTEM ACCORDING TO ESS AND RENEWABLE ENERGY EXPANSION

Kang-se, LEE
KEPCO-HQ, Korea
accent@kepco.co.kr

Jong-myung, KIM
KEPCO-HQ, Korea
aimhigh@kepco.co.kr

Boo-hyun, SHIN
KEPCO-HQ, Korea
vectorist.kepco@kepco.co.kr

ABSTRACT

In step with the expanded development of renewable energy, the Korea Electric Power Corporation (KEPCO) pursues ESS installation for distribution lines in order to ensure stable power system operation and distribution-type power connection. Renewable energy development bases on discharging action; and ESS, on charging /discharging action depending upon the situation.

According to failure location, fault current values are affected. Therefore, there are concerns over potential malfunction of protective device cutting off fault section according to fault current value. In this situation, this study seeks to establish optimal protection coordination system in reflection of change in fault current according to two-way and ESS charging/discharging status in the existing forward-direction protection coordination review system.

INTRODUCTION

Recently the increasing global attention to climate change response and energy industry, renewable business based on solar energy generation, wind power generation, etc. is expected to grow further. Connection to distribution system is also increasing in this situation. However, renewable energy has unstable output to possibly influence system stability negatively. As a solution to this problem, ESS (Energy Storage System) is considered for system stability. Under the ESS method, power is supplied and stored to be used in the case of power shortage in diversified manner of application. Therefore, ESS can help stabilize renewable power generation such as solar power and wind power generation whose output is subject largely to weather.

The connection capacity of distribution system is limited for power generation source of renewable energy. But, in the ESS system, power generation amount can be stored in ESS during the day times while discharging in night times to increase the connection quantity. Presently, the KEPCO is considering protective coordination regarding existing protective devices (CB, Relay, Recloser, etc.). Depending upon charging / discharging action according to the connection between renewable energy and ESS, fault current can vary. Thus, a new protective coordination system will need to be established for optimal faulty section shutoff.

MAIN CONTENTS

1. Characteristics of distribution lines

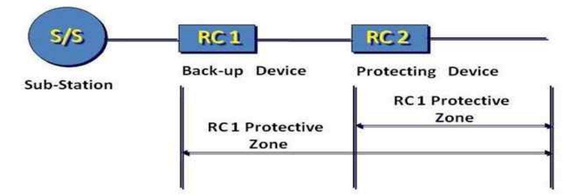
Distribution lines supply power to broadly dispersed receptors. So, their load varies diversely and there are a variety of different facilities. For small-scale power supply, devices such as small transformer and switches are installed on supporting structure. Many electric wire-fixing devices are also attached to supporting structure. Supporting structure, etc. are exposed to the outside; load should be diversified for different places such as ordinary residential houses, commercial stores and large-scale factories; and all sorts of electricity works are going on. In this situation, power failure takes place frequently all the time here and there. There are far diverse causes such as faulty equipment, vehicle collision, excavation, bird contact, and tree contact. For stable power supply, such factors need to be considered to find the optimal fault preventive method. If fault cannot be prevented, technology will be necessary to minimize the section of power failure.

2. Definition of protective coordination

Distribution lines have at least 1 protective device including substation CB to minimize failure section. Main examples of distribution-system protective devices are substation CB (Circuit Breaker), Recloser, ASS (Auto Section Switch), and fuse.

The principal role of protective devices is to open itself in the event of failure in its own load area and separate sound section from faulty section to minimize/reduce potential damage of such a failure.

Of the protective devices subject to protective coordination, those located in the load side (farther from substation) are Protection Device and those located closer to power source (closer to substation) are Protected Device.

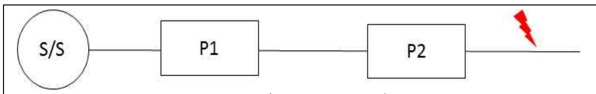


<Fig1> Backup & Protecting device

There are three main methods of protective coordination. First is to utilize the time gap of action. It is to calculate each protective devices' time of action and see if the gaps are at least a certain amount of time. Protected device (near power source) should have a longer action time than that of protecting device (near load) to make possible the protective coordination. The action time of protected device less the action time of protecting device is called the time gap of action between the two devices. If this action time gap is larger than the coordination time gap set in each protective device, coordination is deemed to work.

The second method is to utilize the fault current differences under the principle that, in distribution lines, faulty current values decrease from the power source side to load side (end). The method is mainly used for protective device without time-current (T-C) characteristic (instantaneous current relay) but inappropriate to be utilized alone in distribution lines. By extremely shortening its action time, it is used primarily for huge-scale fault current.

The third method bases on action frequency differences. It can be used for protective device with a reclosing function. The method is to reach coordination by differentiating action frequency of two devices.



<Fig2> example

For instance, if P2 action frequency is lowered than that of P1 (P2 1 time, P1 2 times); P2 reaches lock-out earlier than P1, even though they are activated simultaneously, in the event of load-side failure; faulty section is separated. Therefore, P1 maintains input status to reduce power failure section. Such a function is mostly provided by protective devices and can achieve coordination regardless of the T-C characteristic of protective device.

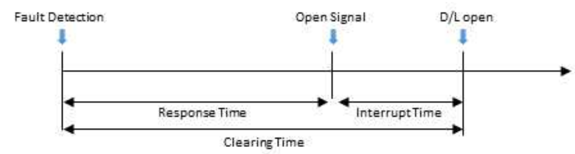
3. Protective coordination of extra-high voltage distribution system

3.1 Protective coordination method of extra-high voltage distribution system

For the protective coordination of extra-high voltage distribution system, the action time difference-based method is most frequently utilized among the methods mentioned above. Protective devices function in three steps as follows;

Detect current in lines. → In the event of value outside the set value, postpone as long as the set period of time then generate an open signal. → Shut-off device (GA, etc.) identifies the affected line at the open signal. → Reduce power failure section.

That is, if any faulty current is detected in line, action time is determined according to protective device-specific T-C characteristics. If the failure is not removed, an open signal is issued. After the open signal, switch (GA, GM, etc.) action is needed to separate the failure section. For this reason, failure clearing requires a little more time.



<Fig3> Example of clearing time

a) Response Time: time taken from fault detection to open signal generation

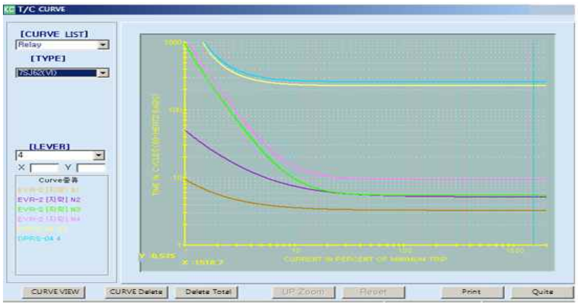
b) Interrupt Time: time taken from open signal reception to the completion of actual line division (almost fixed depending upon machine types)

c) Clearing Time: time taken from fault detection to the completion of actual line division

3.2 KEPCO's NDIS protective coordination system

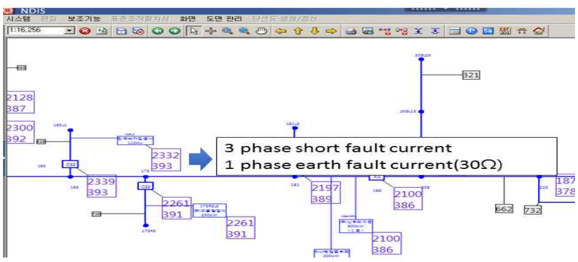
The KEPCO has been operating GIS (Geographic

Information System)-based NDIS (New Distribution Information System); and developed and operated a system implementing protective coordination of each distribution line by utilizing the existing GIS-based distribution system.



<Fig4> protective coordination results (T-C curve)

Methods of protection coordination are as follows.
First, a target device subject to protective coordination is selected. Second, corrections are entered for protective devices of CB (Relay) and Recloser. Fig 4 shows time-current characteristic curve and is used to review the action time of protective devices. X-axis represents current (A), thus, Y-axis is protective-device action time (cycle).
In regards to the explanation of protective coordination principles; if it is assumed that there are substation CB (including Relay), Recloser, and customer CB (including OC(G)R); in the event of a failure on the load side, customer, fault current is experienced from the CB to customer side (the closer to the load side, the lower the current value to impedance value, etc.). In order to reduce faulty section in the most idealistic manner, customer CB should instantly act not to trigger Recloser and CB to have no effect on distribution line. To enable such, the CB action time needs to be the largest and action time should decrease as it nears load side (protecting device). In other words, when action time is CB > Recloser > customer Relay, in order, coordination is deemed possible.

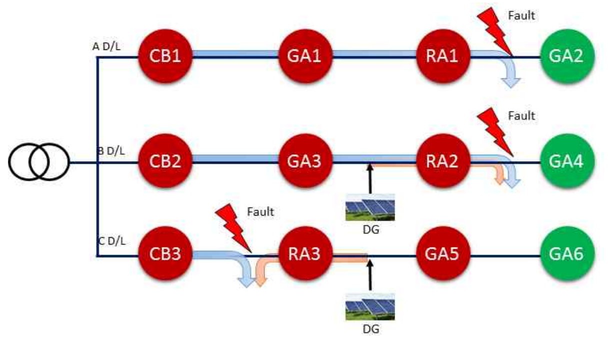


<Fig5> NDIS protective coordination review results

The KEPCO protective coordination review system presents letter of review, current values (fault current, load current), section-specific line type and impedance calculation values. The KEPCO actively utilize such data in its protective coordination review in the event of huge load fluctuation, new protective device establishment, or removal, etc.

4. Protective coordination in renewable energy connection

Recently, renewable energy is increasingly connected with KEPCO distribution system. Moreover, for the promotion of renewable energy, the KEPCO lowered the limit of distribution line connection capacity recently to actively pursue renewable energy connection such as solar energy. KEPCO calls renewable energy sources as distributed type power source instead of centralized source as they are scattered around. With the connection of distributed type power source, the distributed generator side is also regarded as the power side including CB, requiring extra attention in the event of failure.



<Fig6> Example of fault current upon distributed generator connection

A D/L is a distribution line without the connection of DG (Distributed Generator). From the power CB1 to fault point, fault current flow in a single direction. However, B D/L shows the connection of DG. In the event of a failure between RA2 and GA4, fault current increases to disturb correct failure type identification. C D/L is a failure between CB3 and RA3. Fault current flows from CB3 in the forward direction and through DG in the reverse direction. If this current is larger than RA3 minimum action current, RA3 experiences a failure to separate a wrong section.

5. Protective coordination in ESS connection

5.1 Necessity for ESS connection

For DG connection, distribution line should have a sufficient capacity. Also, due to the numerous DGs, power system stabilization is negatively affected. As a solution to this problem, ESS (Energy Storage System) is discussed. ESS is installed either in a large-capacity method and small-capacity method.

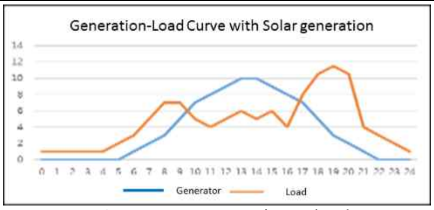
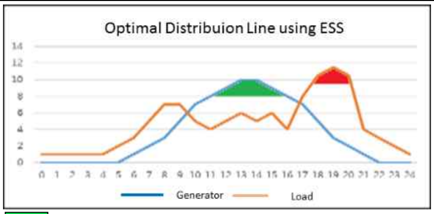
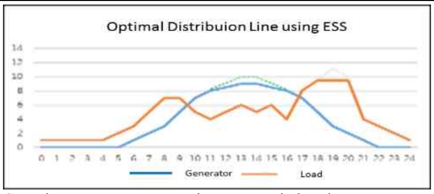
The large-capacity ESS application is as follows;

<Fig7> Large-capacity ESS

<Fig8> Small-capacity ESS

- Ease the S/S capacity limit for DG acceptance.
- Optimize system operation via Peak Shift.
- Ease voltage drop in seasonal load surge.
- Stabilize long-span and load-end system operation.
- Ease overload in winter night-time load.
- Ease DG connection impossibility and serious load fluctuation.
- Ease low-voltage and overload. Replace new installation and expansion.

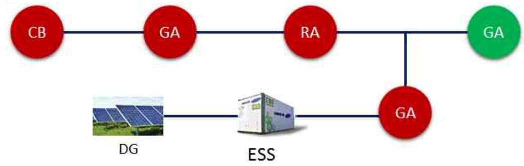
Small-capacity ESS installation is planned, if requested, in downtown places where new installation or expansion is impossible; or when quality power is requested for key customers to secure reserves.

Generation load curve	 DAY: power generation > load NIGHT: power generation < load
ESS charge/ discharge time	 surplus power generation: charge night load peak: discharge
Load Pattern after ESS	 Surplus power generation→ peak load shift to optimize distribution line operation

<Fig9> Power generation-load curve by application type

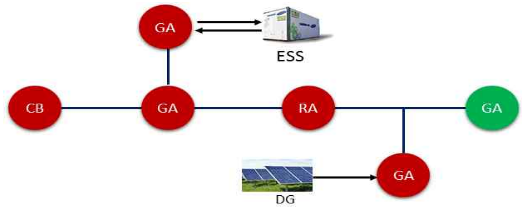
5.2. ESS connection with renewable energy

The KEPCO is establishing ESS connection method for distribution lines to which its connection is impossible due to accumulated connection capacity excess. ESS can be connected either to DG customers or distribution line.



<Fig10> Example 1 of ESS connection

In Fig 10, DG and ESS are connected after the mandatory threshold to charge the power generated by DG during the day times while discharging it at nights.

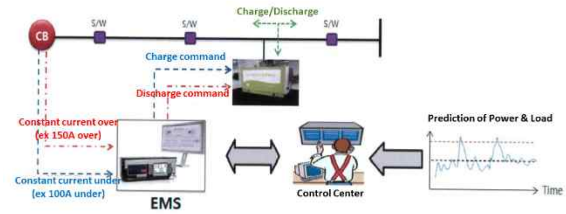


<Fig11> Example 2 of ESS connection

In Fig11, ESS is directly connected to distribution line. By installing a larger-capacity ESS than that in Fig 14, the DG-generated surplus power can be saved and sporadic power can be stabilized.

5.3 Distribution line ESS control

The KEPCO plans to develop and operate EMS capable of controlling ESS charge/discharge in step with ESS expansion. Operational standard will be established in line with distribution line operational characteristics for ESS application purposes; and general control center will monitor distribution line load amount and generation amount to remotely regulate ESS charge or discharge.

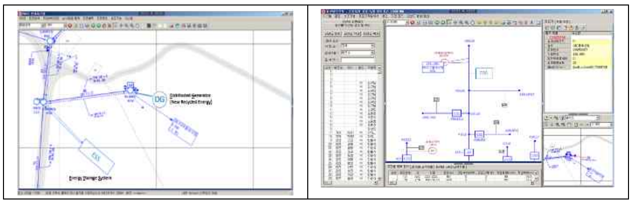


<Fig12>EMS(Energy Management System) example

6. New protective coordination system development

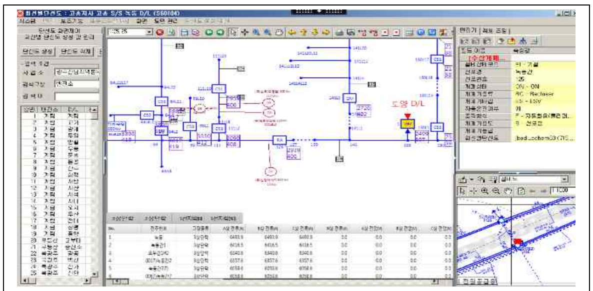
In the event of failure according to DG discharge (power generation) and ESS charge/discharge action, fault current could vary. Therefore, the KEPCO pursued to develop an improved version of protective coordination system.

The present system provides fault current values, impedance, and T-C curve in protective coordination review results in terms of images and texts. The new improved system will present DG discharge and fault current values according to ESS charge/discharge in text and image (GIS).



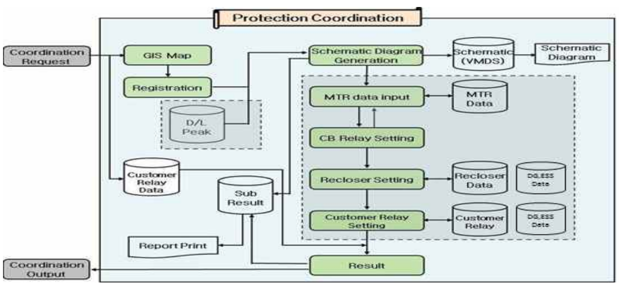
<Fig13> NDIS plan with DG and ESS connection

Fig 13 shows GIS system where DG is connected with ESS. Its protective coordination results are in Fig14



<Fig14>Fault current in new protective coordination system

The improved system shows values according to each fault type (3 phase short circuit, 2 phase short circuit, 1 phase earth fault (0,30Ω)) in the form of list in the bottom part; unlike the existing system that showed only 3 phase short circuit and 1 phase earth fault values on the plane. So users can view fault current value, select T-C curve and set protective device value.



<Fig15> New protective coordination system algorithm

Fig15 shows the algorithm of KEPCO's new protective coordination system. Moving outside the existing interpretation of one-way fault current, the KEPCO assumed two-way fault current flow to show protective coordination and fault current values so that users can set protective devices and enjoy optimized protective coordination.

CONCLUSION

This paper analyzed change in fault current and its direction according to the connection between renewable energy (DG) and ESS. For stable power supply, the KEPCO investigated fault current change in the present one-way protective coordination system depending upon two-way aspect, renewable energy discharge and ESS charge/discharge action. Also, reference data are provided through the system to set the protective device values. Users are expected to gain help in setting the optimal values of protective device and reducing fault section.

REFERENCES

[1] Kwang-ho Kim, 2007, "Distribution engineering", Bookshill, Seoul, Korea, p327-370

[2] Sang-ok Kim, 2013, "A Simulation Program for Protection Coordination in the Power Distribution System with Distributed Generators", The Korea Society for simulation

[3] Jung Kang, 2015, "Distributed Generator Distribution System connection Technology Standard", KEPCO

[4] Hun-Chul Seo, 2014, "Study on the Protection Coordination in Distribution System with ESS", KIIEE

[5] Yong-hwan Kim, 2015, "Analysis on Malfunction of Protection Coordination in Distribution System Interconnected with Large-scale ESS", KIIEE