A Study on Ground-Fault Protection of Major On-Site Electric Facilities at NPPs

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1. Introduction

The stable operation of unit auxiliary transformers (UATs) and standby auxiliary transformers (SATs), which can be the most important equipment in on-site electrical facilities at nuclear power plants (NPPs), can be more important than anything else, and they must be coordinated by the correct setting values of protective relays. Protection coordination are taken into account as the highest priority in the power equipment protection.

Since the optimized power reactor 1000 (OPR1000) is designed to have the same secondary and tertiary voltages of UAT and SAT and also, the same ground fault characteristics of UAT and SAT, it is necessary to select the correct protective relay setting value to handle the ground fault properly and accurately. In this regard, the objective of this study paper is to select the exact setting values for UAT, SAT secondary and tertiary-side ground fault protection relay and switchgear (SWGR) incoming circuit breaker.

Moreover, since the calculation of the reasonable error ratio for the residual ground fault detection method of a protective relay like SWGR incoming circuit breaker (CB) should be required, in this study it was calculated on the basis of data measured at the site. Also, the coordination of the ground fault protection relay was derived using the electrical system engineering program, and the protection relay coordination was verified to be optimized through the establishment of a standardization approach.

2. Protection Issues and Calculation Result

In this section, we explain the issues of the protection relay coordination between SWGR incoming CB, and UAT and SAT ground protections at NPPs. And we will calculate the stable setting values by using field test results to improve the plant stability.

2.1 Protective relay coordination issues

Due to its structural characteristics, SWGR incoming CB measures the ground fault current based on the residual circuit method. The residual circuit method can induce a ratio error of up to 6% when it is conservatively calculated because of combining three current transformers (CTs). In this reason, the 4.16 kV SWGR incoming CT ratio at OPR1000 plants is 3000/5, which means that an error range of up to 120 A can be induced.

UAT and SAT neutral ground fault CT uses just one zero-phase CT and does not have a large error range.

If the protection relay could be coordinated without considering the error ratio of two positions between SWGR incoming CB, and UAT and SAT neutral, the stability of NPP electrical systems may be reduced. Fig. 1 shows the unsatisfactory protection-coordination between the SWGR and the transformer through the electrical transient analyzer program (ETAP).

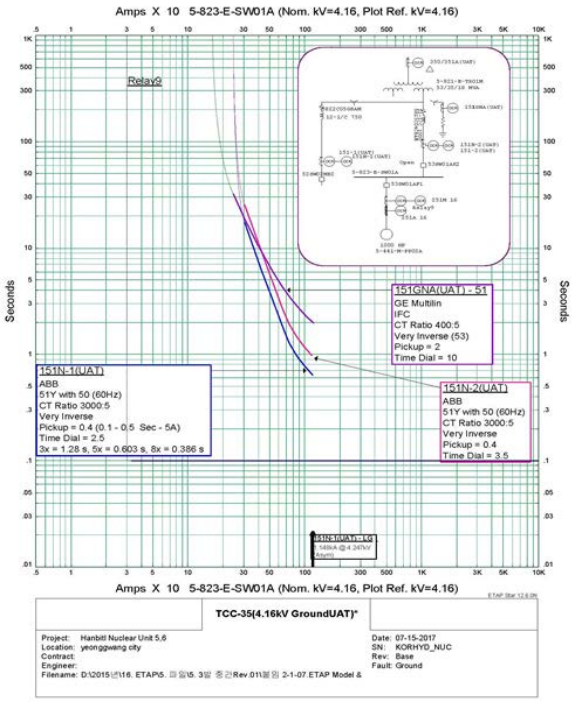

Fig.1 Unsatisfactory time current characteristic curve

2.2 Effects of unsatisfactory protection coordination

The operation-trip of the protective relay is designed differently for each protected position, and the SWGR incoming CB and feeder relay are connected to each circuit breaker trip. However, the upper parts of UAT and SAT are connected to an isolated phase bus (IPB) and they do not have each circuit breaker, which means that there are many trips to separate all parts connected to the transformers.

Since it is impossible to install a circuit breaker in the IPB, trips will occur in all main breakers of the power plant at the time of detection of an electric fault in UAT and SAT. And it means that AC power is not supplied to all sections of NPPs.

In other words, if the protection setting is accurately calculated, only one circuit breaker is tripped. However, if protection coordination is unsatisfactory, all the AC power in NPPs will be lost.

The trip places are all breakers connected to UAT and SAT in power station such as switch yard CB, main generator breaker, excitation system breaker, all SWGR breakers, etc.

Fig. 2 shows the SWGR feeder relay trips to CB (1), SWGR incoming relay trips to CB (2), and also shows that protection relay (3) confirms that all CBs indicated as (4) are tripped

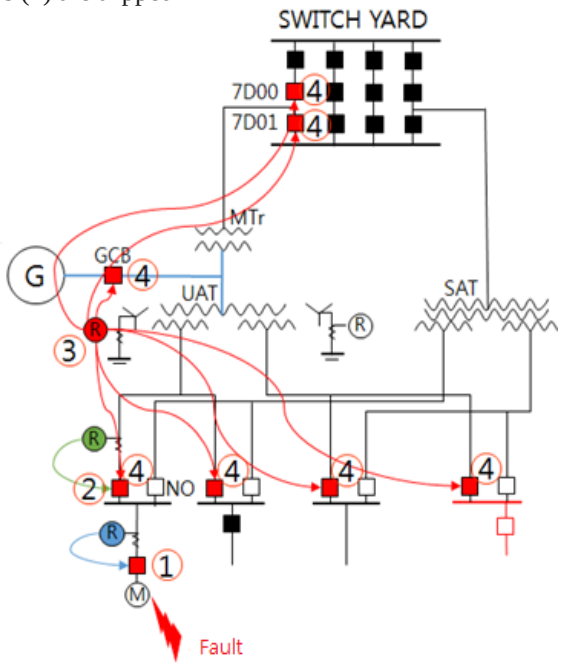

Fig.2 Trip operation in each position

2.3 Field test result calculation

For the 3000/5 current transformer with a large error rate in the residual circuit method, the field test results were calculated using the residual circuit method. The test was carried out by measuring the current transformer in each phase and the test result by the residual circuit method in the actual protection relay was calculated summing the three-phase vector. It was known that calculation results had a maximum value of 0.75%, which was confirmed to be much smaller than the expected value of 6%.

This result means that protection relays using the residual circuit method have small errors like protection relays using a single CT.

Table I. Calculation result

Maker: ABB CT Ratio: 3000/5			
Location	Result(%)	Location	Result(%)
SW02M-j2	0.2	SW01A-m2	0.75
SW02M-b2	0.5	SW01A-k2	0
SW02N-c2	-0.17	SW01B-B2	-0.17
SW02N-g2	-0.33	SW01B-d2	0

2.4 Application to a protective relay

In ground fault accidents, the UAT and SAT neutral points should be the maximum ground fault current of 20% and SWGR incoming CB should be the maximum ground fault current of 10% as ideal values considering phase current unbalance and arc ground faults. Also by applying these setting points, it can be confirmed in Fig. 3 that the electric power system at NPPs can be stably protected.

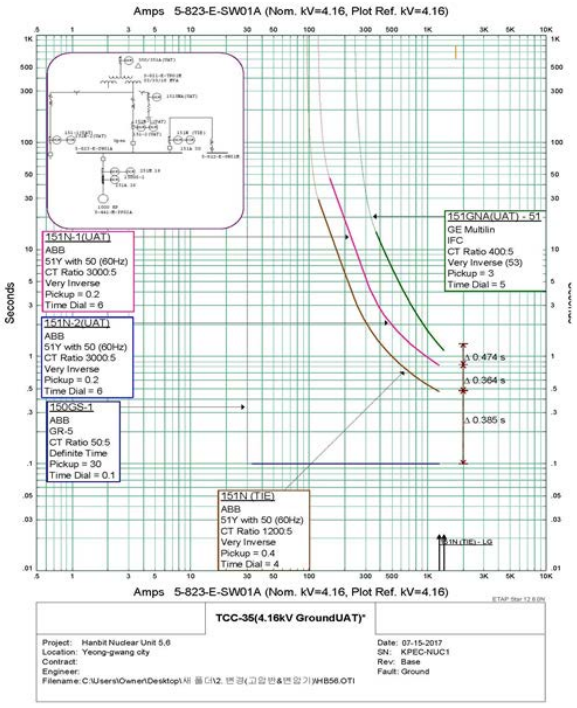

Fig. 3 Satisfied time current characteristic curve

3. Conclusions

As a calculation result of the field test, it was concluded that the CT ratio error could be considered regardless of detection methods. Based on these results, the maximum ground fault current of 20% is suitable for UAT and SAT and the maximum ground fault current of 10% is suitable for SWGR incoming CB. It was calculated that it is appropriate to operate as a standard for the ground protection coordination of OPR1000.

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