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RENEWAL WORKS OF UNDERGROUND TRANSMISSION SYSTEM IN KEPCO

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ABSTRACT

In this paper, we introduce the renewal works of the SCOF cable and XLPE cable of underground transmission system in the Kansai Electric Power Company （KEPCO）. We also introduce our endeavour to keep reliable facilities.

KEYWORDS

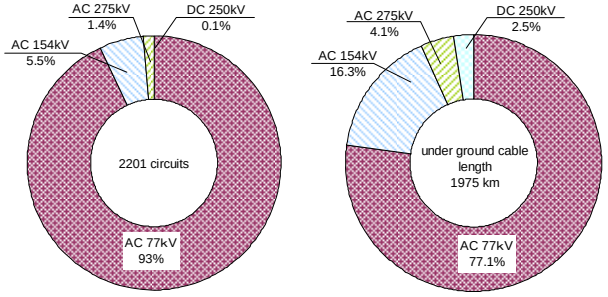
SCOF cable, XLPE cable, renewal works,

1. The outline of underground lines in KEPCO

The KEPCO'S underground transmission systems more than 77kV consist of 2201 lines, and its total circuit length reaches 1975km. Our transmission system is consisted of main three voltage classes, such as 77kV, 154kV, and 275kV. The 77kV transmission lines occupy about 93% of the lines and about 77% of the length. （Fig.1.）

For the underground transmission cable, the SCOF cable with lead sheath was first adopted for 77kV in 1938, and it reached higher voltage up to 275kV. The SCOF cable with aluminum sheath was adopted in 1970, and had been used generally. The XLPE cable was first adopted in 1972. Thereafter, the amount of XLPE cable has been increasing every year, the XLPE cable has exceeded that of the SCFF cable since 1982.（Fig.2.） Because the oil feeding equipment is unnecessary, the XLPE cable is easy for us to install and to maintain. Now, as almost all of the new cables are XLPE, the existing 77kV cables reaches 60% of the total.

There are three basic methods to install the cable, the conduit installation method, the tunnel installation method and the direct buried method. In comparing the two major methods excluding the costly tunnel, the conduit installation method has advantage that the replacement work or the work of the reinforcement is easier and quicker. However it has disadvantage that the metal-sheath of the cable in the manhole deteriorates due to the cable stretch from the conduit according to the load fluctuation and the soil temperature variation. In case of the direct buried method, the cable scarcely moves. Therefore, it is not necessary to consider the cracking of the cable sheath caused by the metal strain. However the renewal work is very difficult, especially in the metropolitan area. In the renewal point of view, we have adopted a conduit installation method. The conduit length is 1501km, and this length has accommodated with 72% of the cable section length.



(a) circuits (b) circuit length

Fig.1. The proportion of the facilities in KEPCO

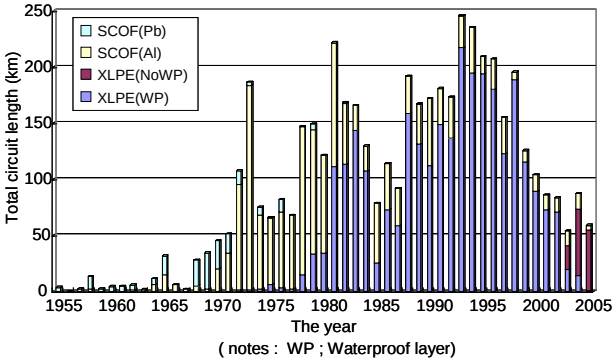


Fig.2. The amount trend of underground lines in KEPCO

2. Key points to renew the system

As for in KEPCO, the underground cables which are aged 30years are increasing, therefore, we have to consider the possibility of breakdowns of related facilities for various factors. Thus, for the purpose of the stable supply of electric power and effective use of existing facilities, we started the study to establish the standard of the renewal works based on the investigation of removal product and the diagnosis of deterioration. Also we are always planning that the most effective renewal of deteriorated facilities.

In KEPCO, key points to renew the underground systems are summarized as three points of the following;

1. (Long-term reliability): Estimating long-term reliability assuming that it greatly depends on the manufacturing progress, the specifications and the circumstances of each cable.
2. (Precaution measure for the similar facilities): After each trouble, checking similar facilities which might cause the same accident.

3. (Safety and environment): Considering the safety and environment when we would renew the facilities.

Based on these concepts, some renewal works, especially of 77kV facilities which occupy the large amount in KEPCO, are described below.

3. Examples of renewal works in SCOF

An insulation characteristic of SCOF cable is extremely stable, deterioration of cable insulation performance is slight even if we use it for many years. However, in metal sheath of the cable, metal fatigue might be brought by various factors such as materials itself, a manufacturing method, the inappropriate installation or the inappropriate assembly, an installation environment, the load fluctuation or the soil temperature variation. Thus, estimating the residual life of SCOF cable, we pay attention to the metal fatigue.

Considering the key points to renew the system, we carry out next four items mainly as renewal works for the SCOF cable.

1. Renewal works of SCOF cable with lead sheath within several years (long-time reliability)
2. Renewal works of three-core SCOF with up-and-down route within 10 years (Precaution measure for the similar facilities)
3. Deterioration evaluation of aluminum sheath (long-time reliability)
4. Deterioration investigation by removal product (Safety and environment)

In this chapter, we describe these.

3-1) Renewal works of SCOF cable with lead sheath within several years

Necessary abilities of metal sheath are protection of insulation from external force, mechanical strength against inside oil pressure, and so on. To satisfy these functions, lead or aluminum is used for sheath material. Lead sheath is easy to process and superior in corrosion resistance. Therefore, we adopted SCOF cable with lead sheath in primary period when the SCOF cable adopted in 1970. （Fig.3.）

As the facilities aged, the metal fatigue of lead sheath caused a lot of oil leakage. After evaluated mechanism of these oil leakage, we were convinced that the metal fatigue of lead sheath might occur easily for the conduit installation method. Then, we have decided to replace the SCOF cable with lead sheath by the SCOF cable with aluminum sheath or by the XLPE cable within several years.

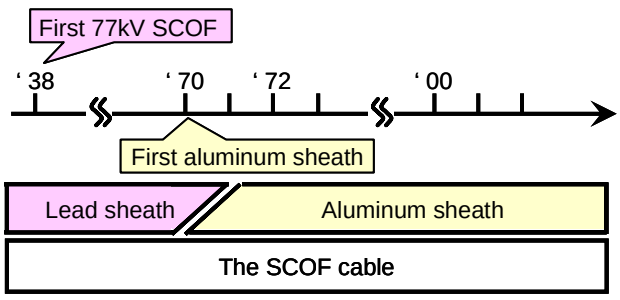


Fig.3. The history of SCOF cable

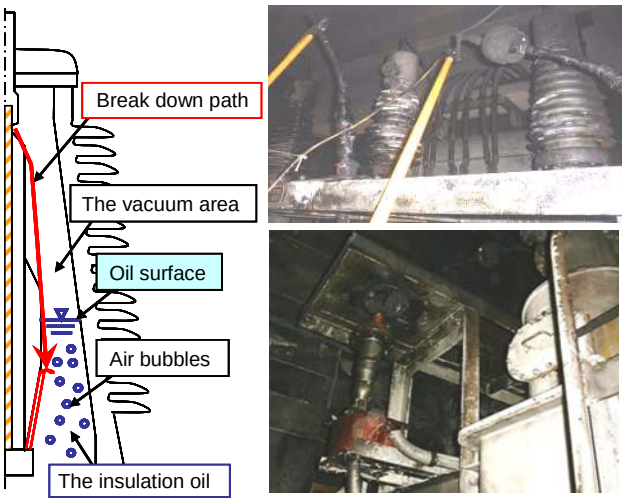
3-2) Renewal works of three-core SCOF with up-and-down route within 10 years

When large oil leak occurred in the three-core cable facility with up-and-down route, a short-circuit accident might occur in its terminations. For this reason, we concluded following measures.

If large oil leak would occur in termination higher than 10m from the oil leak point, the leak would cause the fall of oil level in termination, and a vacuum area might occur in termination. When the vacuum area occurred in termination, the insulation performance might lose suddenly. Thus, the termination would break down, and the short-circuit accident might occur.

Actually, we have an experience in a certain lines that the short-circuit accident occurred in the three-core cable facility with up-and-down route more than 10m. We started renewing works for the similar facilities.

They will end within about 10 years.



【 the termination 】 【 The photograph 】

Fig.4. An accident of three-core SCOF in KEPCO

3-3) Deterioration evaluation of aluminum sheath

For the purpose of evaluating the residual life of the SCOF cable with aluminum sheath, we have investigated the deterioration of aluminum sheath by calculating the distortion of aluminum sheath or by studying the removal product.

Generally, it was thought that deterioration factor of SCOF cable could be attributed to mechanical fatigue in the material sheath, these might occur by heat behavior of a cable mainly with a load change. Thus, we have convinced that it is effective to investigate the distortion of metal sheath in order to evaluate the residual life. [1]

There are many SCOF cable facilities aged over 30 years in KEPCO, it is important for us to diagnose the deterioration and to estimate the residual life of the metal sheath. We figured out the offset behavior of the SCOF cable, calculate the aluminum sheath distortion.

Here, we described the evaluation method of the aluminum sheath distortion.

(a) Deterioration mechanism

Because the deterioration of aluminum sheath is

occurred by metal fatigue, we have estimated the following deterioration mechanism.

As the result of the load fluctuation and the seasonal soil temperature variation, the expansion and contraction of the cable within conduit would be caused, and the distortion of the cable sheath would occur in both sides of the joint box. The daily expansion and contraction of the cable would cause the metal fatigue.

Therefore, aluminum sheath would break, and oil leak might occur in the future.

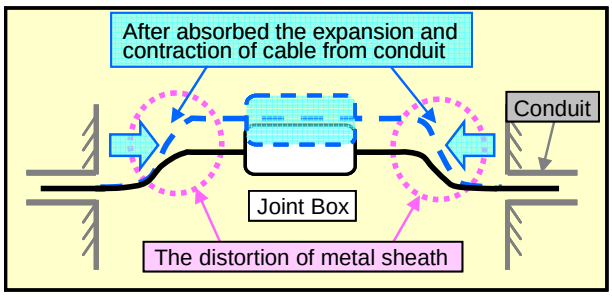


Fig.5. Cable distortion in both sides of joint box

(b) The examination method

The examination is as following steps.

【step.1】

Because the distortion of aluminium sheath is caused by the expansion and contraction of the cable, we measure the difference of the marking position of the duct edge in between summer and winter, and compare it with a theoretical value.

【step.2】

We estimate the distortion of aluminium sheath from the measured value.

【step.3】

From relations of the aluminium sheath distortion and the number of times until breaking sheath, we can determine the residual life.

Therefore, we have confirmed that the large distortion of the aluminium sheath was caused by the difference of the expansion and contraction of the cable of both sides of the joint box, and the life of a cable would lower.

We have inspected the facilities periodically. As these results, we have picked up the several abnormal facilities. (Fig.7) As they are assumed to suffer historical large stress, we will proceed to renew these facilities based on the distortion of the sheath. On the other hand, we can confirm that estimated life of the cable is enough when aluminium sheath does not have large accumulated distortion value.

3-4) Deterioration investigation by removed cable and joint

We would pay attention to the deterioration degree of the insulation paper and insulation oil, and would investigate the removed SCOF cable and its joint.

To investigate the insulation paper, we measure deterioration degree of paper and we check whether the carbonized mark which is the evidence of the partial discharge exists or not. To investigate the insulation oil, we adopt a gas analysis method.

The result of investigating removal product doesn't show the deterioration of the paper itself but the carbonized mark on the paper is recognized till now.

We will continue to pick up removal samples to investigate the deterioration trend.

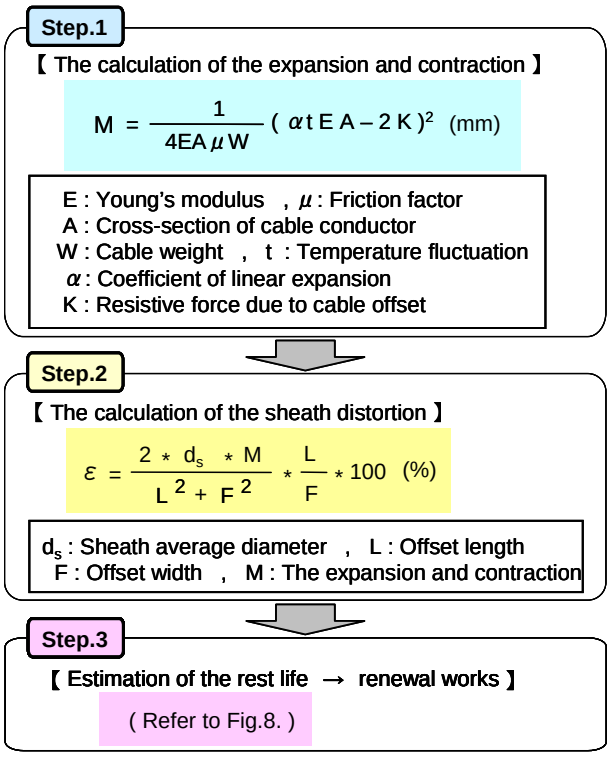


Fig.6. The examination method

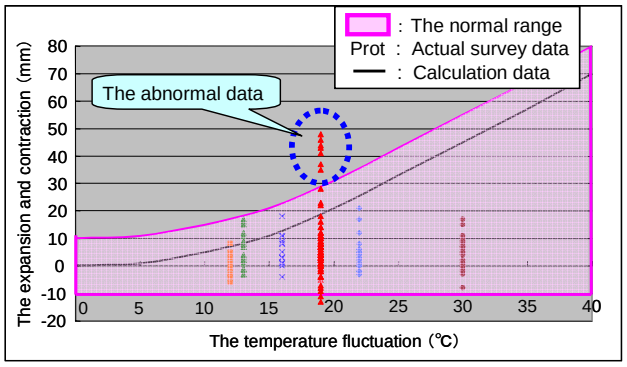


Fig.7. The expansion and contraction of the cable

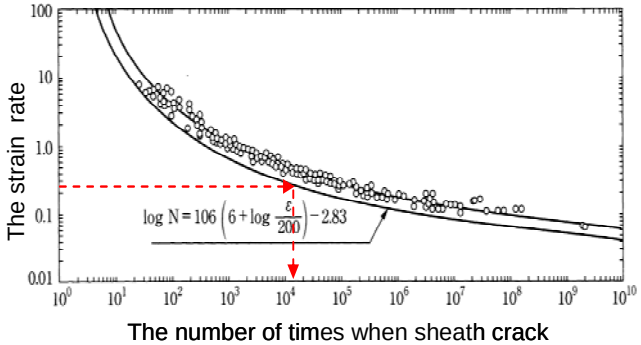


Fig.8. The S/N curve (Aluminium sheath)

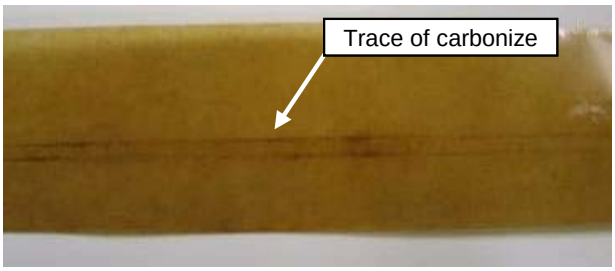


Fig.9. An investigation example of the insulation

4. Examples of renewal works in XLPE

There are two types of the manufacturing method to cure XLPE insulation. One is the steam curing process type, the other is the dry curing process type.

At first, the steam curing process by the water vapor had been developed. Thereafter, it had been replaced by the dry curing process. Fig.10. shows the history of the XLPE cable curing procedure in KEPCO. The XLPE cable was adopted for 77kV in 1972, it has been used generally.

Now, we categorize the XLPE cable into three major types followings, the steam curing process cable and the dry curing process cable, and the cable with the laminate waterproof layer.

The XLPE cable with the laminate waterproof layer was developed to prevent the penetration of water from the outside. In KEPCO, we have adopted the dry curing process XLPE cable since 1980's, and the XLPE cable with the laminate waterproof layer since 2001.

The deterioration factors of the XLPE cable are caused by the water-tree or the inappropriate installation or the inappropriate assembly, and so on. In near future, the XLPE cable aged over-30-years-designed-life will be increasing in KEPCO. Then, the renewal works are considered as an one of the most important activity. Considering the Key points to renew the system, we carry out next three items mainly as renewal works of the XLPE cable.

1. Renewal works of the steam curing process XLPE cable within several years (Long-term reliability)
2. Timely renewal works of the similar facilities to prevent future trouble (Precaution measure for the similar facilities)
3. The diagnoses and the deterioration investigation by the removal product (Safety and environment)

This chapter introduces these.

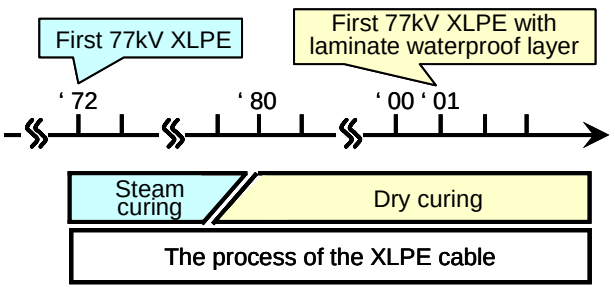
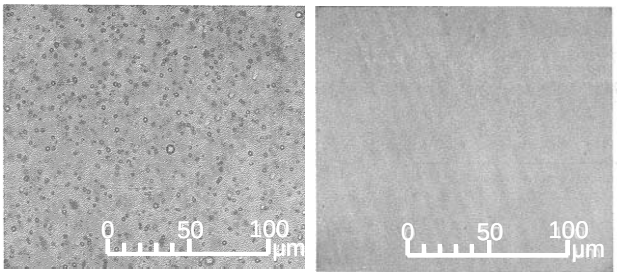


Fig.10. History of the XLPE cable curing procedure

4-1) Renewal works of the steam curing process XLPE cable within several years

In the early years of XLPE cable, it had been produced by the steam curing process. In this system, the defect called the void had occurred within the XLPE because the water vapor had penetrated into the XLPE during the manufacturing process. (Fig.11.)[2] These cables might break down by this defect which would cause the water-tree. In fact, there were a few cables broken down by the water-tree in KEPCO. (Fig.12.)

Thus, we are planning the renewal works based on the history of the XLPE cable curing procedure. The cables which were manufactured before 1980's with the steam curing process, shall be renewed prior to the dry cured cables.



(a) Steam curing process (b) Dry curing process

Fig.11. The micrograph in XLPE insulation

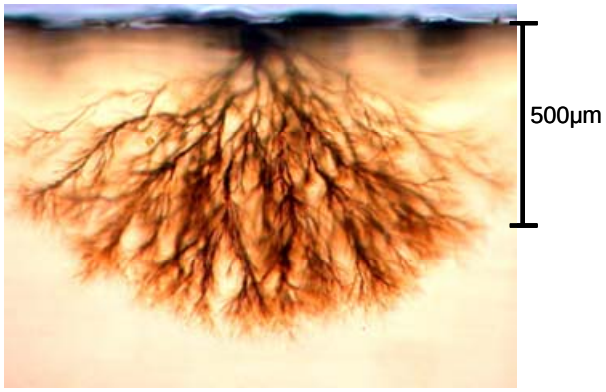


Fig.12. The observed water-tree from removed cable

4-2) Renewal works of the similar facilities prevent future trouble

In KEPCO, when the trouble occurred, we would study it, and we would renew the same facilities based on the result which is evaluated by the investigation.

Far example, one trouble occurred in the terminations assembled in the primary period of the XLPE cable, and this cause from the setting error of standardized value in the past. We study a few samples from the facilities built in the same period. Then, as the precaution measure for the similar facilities, we can confirm whether there were the same trouble facilities elsewhere.

4-3) The diagnoses and the deterioration investigation by removal product

We confirmed that the dry curing process cable which is employed 1980's has the satisfied insulation performance over 30 years in the early stage. However, there is only a few evaluated actual characteristic data of the cable aged over 30years, we have to figure out the following the residual life estimation by the diagnoses, and also plan renewal time by investigating the removed product.

(a) The diagnoses

The diagnoses were essential technology for the renewal works, and would prevent a cable accident by the aged deterioration.

Recently, we began studying the loss current method and the residual charge method to diagnose the water-tree deterioration.

However, these methods would have a few problems to limit the measurement under the power on lines and not to specify the deterioration point, and so on. In the future, we would try to develop the new diagnoses, the measurement under the power lines, the non-destructive testing to estimate the deterioration, and so on.

(b) The investigation by removal product

We have investigated the facilities aged about 30 years for the purpose of estimating the rest life, and have collected the data

We would extract the samples from the removal product by considering the aged or the installation situation, and we would study the water-tree or the breakdown voltage.

As the result of investigation, we have confirmed that the aging might be correlative with the breakdown voltage.

However, these results are not enough to clear the relationship, we would try to investigate the removal product for the purpose of evaluating the relationship between the aged and the deterioration of XLPE cable.

5. We think the future

Until an effective deterioration diagnosis technology is established, we figure out the following things. One is the renewal works of the similar facilities which might cause the same accident, the other is the investigation of the removal product. Here, we pay attention the used materials or the assembled method whose are different in each manufacturers. We should renew the facilities based on these knowledge, considering the possibility of the accident which occurred in the future.

It is also important to do renewal works of existing facilities quickly. In KEPCO, we will install a cable in an empty conduit to make the renewal work quicker. However, in some cases which we don't have enough empty conduits, we have to examine some renewal plans including the construction of the new conduit route. We also have to develop the new joint box or the new method of connection for the quick-fit.

Continuing these actions, we think that we might be able to form facilities with high reliability for the future.

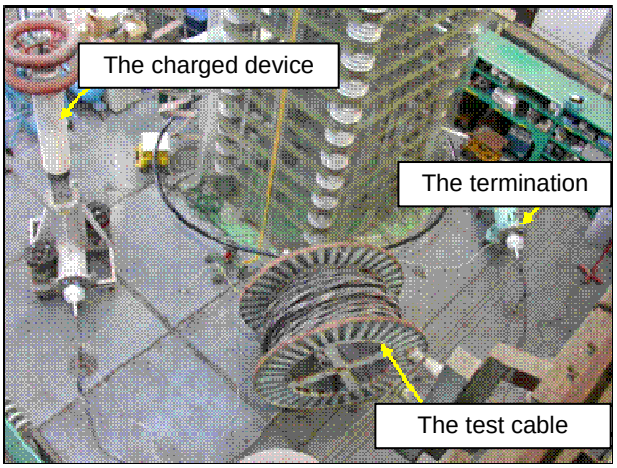


Fig.13. The summary of the charging examination

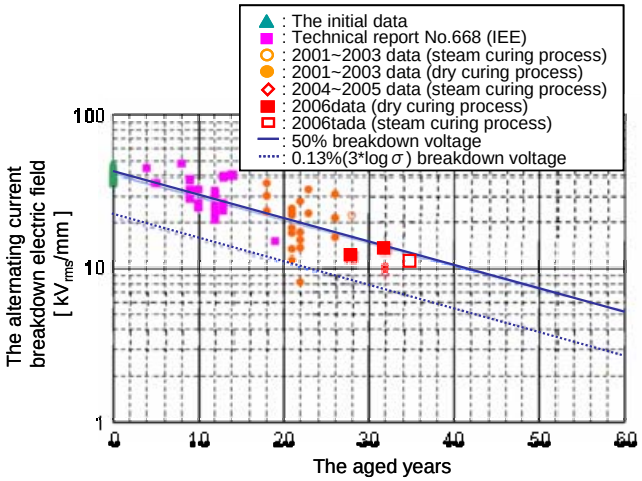


Fig.14. The deteriorating performance of the removal product

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