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UPGRADING QUALITY OF 275KV Y-BRANCH PRE-FABRICATED TRANSITION JOINT

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ABSTRACT

In order to utilize existing underground power cable line effectively, the demand of Y-branch transition joint box (hereafter called as YJB), which can branch the existing line by jointing new line*, is increasing for EHV cable line in recent years.*
This paper introduces (1) upgrading of manufacturing inspection for 275kV YJB, (2) performance evaluation of installed YJB at the time of rapid temperature change in the manhole, and (3) workability of installation and recovery for such large and heavy YJB in the narrow manhole.

1. INTRODUCTION

In underground EHV power transmission lines, the demand using YJB to effectively branch system has increased. In 2002, with Tokyo Electric Power Co., Ltd (hereafter called "TEPCO"), J-Power Systems Corp. (hereafter called "JPS") has jointly developed YJB which is capable of jointing different types of cables, SCFF and XLPE cables. On the demand of the other utilities, YJB has already been installed in a tunnel and is applied for actual commercial circuits of a power station outgoing line [1].
In applying this YJB to system change works for Kansai Electric Power Co., Inc. (hereafter called "KEPCO"), it was planned applying YJB to existing manhole without modification of it to save construction period. Therefore, it was necessary not only to carry large and heavy weight (approx. one ton) YJB epoxy units into an existing narrow and small manhole for SCFF cable, but also to assemble them. The verification of the assembling method and the construction in a space which simulates a narrow and small manhole, the verifying the recovery measures from accident, and the result of rapid cooling test in atmosphere which assumes open manhole during winter season are reported herewith.
Furthermore, as a result of reviewing the past trouble of 66kV class YJB, we have encountered a case in which a trouble occurred due to external damage originating the surface of epoxy during production of epoxy unit. The result of study on reliability improvement for quality control during epoxy unit production is also reported herewith.

2. CONSTRUCTION OF 275kV YJB

Fig. 1 shows the construction of YJB. At XLPE cable side, epoxy unit and stress relief cone, which have been quality-controlled and electrically tested in advance at the factory, are assembled together at site, and are compressed with a spring. At SCFF cable side, oil-immersed insulating papers are wrapped around and an epoxy bell-mouth is positioned around. Features of the construction of YJB are as follows:
1) Epoxy molded component of large and complex shape
2) Integral molding of aluminum high-voltage electrode in epoxy unit
3) Epoxy unit for both SCFF and XLPE cables
4) YJB can be used with one bank empty sealed by insulating plug.

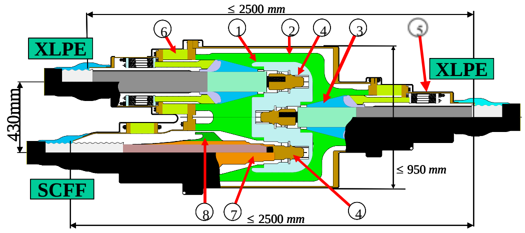

Fig. 1 Construction of YJB

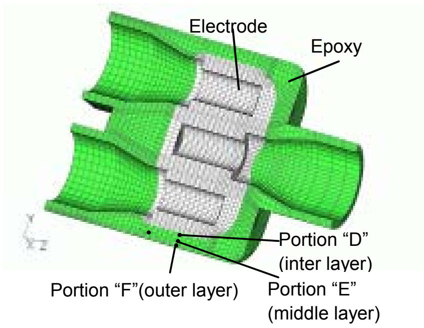

Fig.2.Model of thermal Stress analysis 275kV YJB epoxy unit (For Figs. 3-1 and 3-2, analysis was conducted with a model having outer casing and compound.)

3. IMPROVEMENT ON RELIABILITY DURING PRODUCTION OF EPOXY UNIT

3-1 Necessity of measures against external damage during production of epoxy unit

As a results of manufacturing process review, the following measures to avoid external damage during production of epoxy unit were taken for further

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improvement.

(1) From the past case examples of 66kV YJBs, there is an instance where external damage on the surface during epoxy production was the cause of trouble.

(2) In the case of production of large and heavy epoxy unit, production is performed through various processes, such as baking of the conductive layer, with variety of equipment. During the course of these processes, appropriate measures are taken to avoid external damage.

(3) In the case where operation is made in a manhole, YJB suffers sudden temperature change as shown in Fig 3-1 due to sudden drop of ambient air temperature when the manhole is opened during winter season. Through thermal stress analysis, it was then found that large stress yielded on the surface of epoxy as shown in Fig3-2.

(4) At the time of screening various defects during shipping test of epoxy unit, there still exist the following issues.

- There are processes having high probability that external damage may occur during heat-shock test, when epoxy unit is taken out or put in an oil-filled cooling bath, and when wipe out the oil on the surface of epoxy unit after test.
- Since the applied stress on the surface of epoxy during AC voltage with PD is lower than that at high-voltage electrode side, screening accuracy decreases when external damage occurs test.

3-2 Measures against external Damage on the surface during production of epoxy unit

To improve reliability of YJB which further demands are expected, the following measures against external damage is to be taken during production of epoxy unit.

(1) Draw a plan to prevent external damage and to dissolve rolling during transportation and vertical placement work of each process is aimed by applying the vertical placement jig dedicated to epoxy unit as shown in Fig. 4, and performing machining with the equipment of various processes on an integrated jig installation.

(2) For the heat-shock test, considering the following points, studied to change the test method from a conventional method which is carried out in oil-filled circumstance to that in air-filled where products with less possibility to cause of external damage:

- As a verification of thermo-mechanical actual value of epoxy unit, perform heat-shock test with a sample in a conventional way to evaluate under oil-filled circumstances.
- On the other hand, for a shipping test, apply larger mechanical stress than the stress generated during actual service due to ambient temperature change onto the epoxy unit to perform screening of all units.
- Using thermo-mechanical analysis, it is confirmed that they are equivalent, the stress generated on the surface of epoxy under both oil-filled and air-filled circumstances as shown in Fig5.

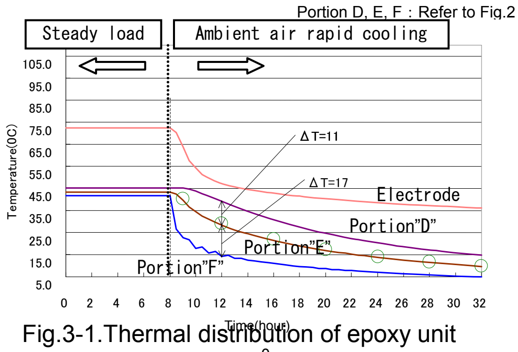

Fig.3-1.Thermal distribution of epoxy unit (40→0 ^{0}C)

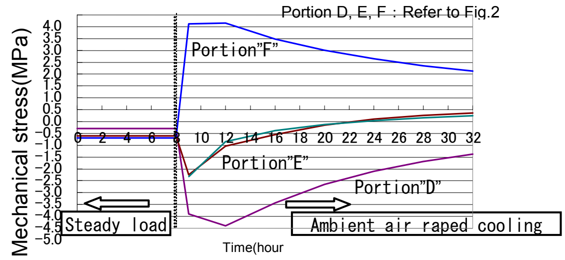

Fig.3-2.Stress distribution of epoxy unit (40→0 ^{0}C)

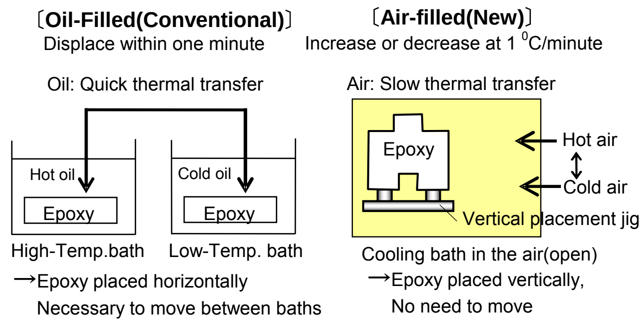

Fig.4.Outline of heat-shock test for epoxy unit

Table 1 shows the stress generated at every heat-shock test. Air-filled method showed crucial result on the surface where external damage can be detected. On the other hand, oil-filled method showed crucial result inside epoxy. But the stresses revealed are sufficiently larger than that generated during operation, and the high-voltage electrode side can be screened with PD test. It was confirmed air-filled method was substantially effective as shipping test.

Table 1. Stress created at every heat-shock test method of epoxy unit

Cooling conditions / Stress created section		YJB (Unit:MPa)	
		Oil-Filled	Air-Filled
		20⇄ 80℃ each 1H	-30⇄ 90℃ each 2H
On the epoxy electrode	D: At electrode side(inner layer)	1.88	1.70
	E: (Middle layer)	11.4	4.95
	F:At surface side(outer layer)	6.62	8.94

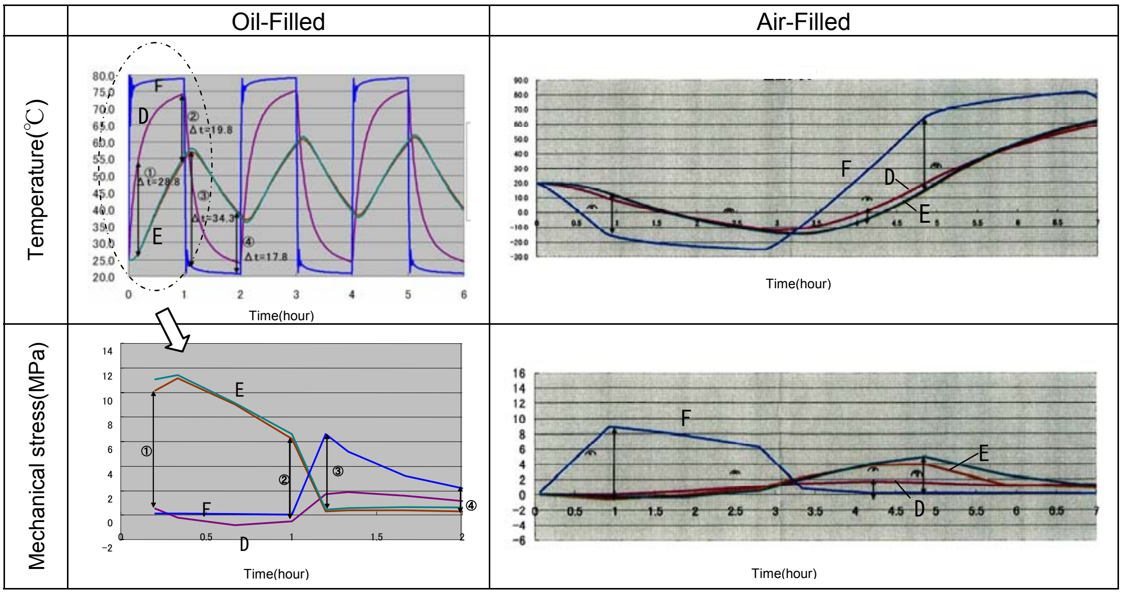

Fig.5. Thermal and stress distribution of epoxy unit during heat-shock test

3-3 Vibration management after mounting the case onto epoxy unit

After the epoxy unit is assembled into the outer case, possibility of external damage becomes less, but it may be subject to vibration and there is a risk of overturn and falling during transportation to the site and carrying into a manhole. Accordingly, acceleration sensor was attached to all epoxy units as the external damage management of the products.

4. OUTLINE OF YJB-APPLIED LINE IN A NARROW MANHOLE AND ITEMS TO BE STUDIED

In order to reduce construction period, KEPCO planned to modify the four to three lines by connecting a YJB to the existing SCFF and new XLPE cables without modification of existing manhole for SCFF cables.

Since it became necessary to install YJB in a narrow and small manhole for the existing SCFF cable, the following issues were raised and studied:

1) To determine methods of assembling YJB to maintain bending radius of cable larger than its allowable value in a narrow construction space as shown in Fig. 6.
2) Measures against external damage and vibration in the case that a large and heavy epoxy unit is installed in manhole

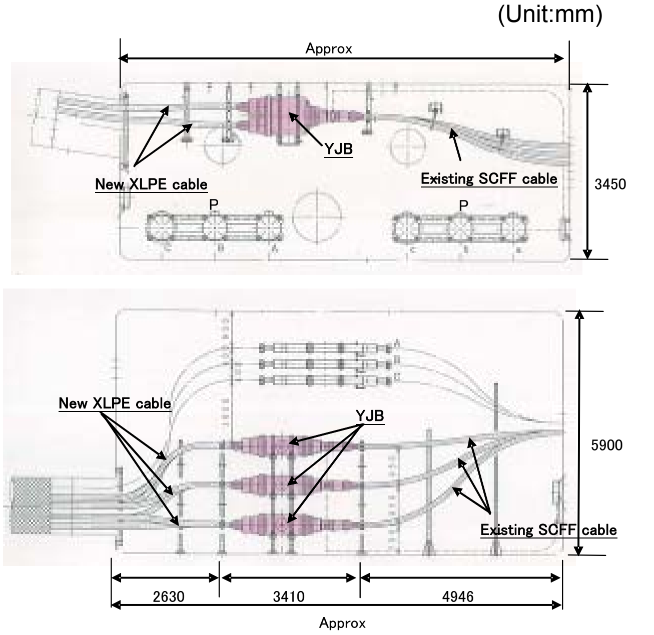

Fig. 6. Cable layout in existing small manhole for SCFF cable

5. VERIFICATION OF CONSTRUCTING 275 kV YJB IN A NARROW MANHOLE

5-1 Construction method in an existing narrow manhole

Fig. 7 shows construction flow of 275 kV YJB in a narrow manhole. In the case where sufficient construction space is maintained, such as in tunnel, a construction method in which epoxy unit is fixed as shown in Fig. 8, each cable is once pulled back, and is then inserted into the unit, may be adopted. But in the case of this time, construction space of the existing narrow manhole was limited. This

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created an issue that cable bending radius was below its allowable value when it was pulled back at the two-mouth XLPE cable side. Furthermore, parallel construction works of XLPE and SCFF cable sides may also cause an issue from the view of foreign particle management.

From the above, a method was employed, in which a dedicated assembly cart was used in a clean room to move and insert the unit so that XLPE at two-mouth side fixed with its allowable bending radius kept unchanged (i.e. shape of final installation) is assembled and the clean room is then thrown open to have SCFF at one-mouth side inserted.

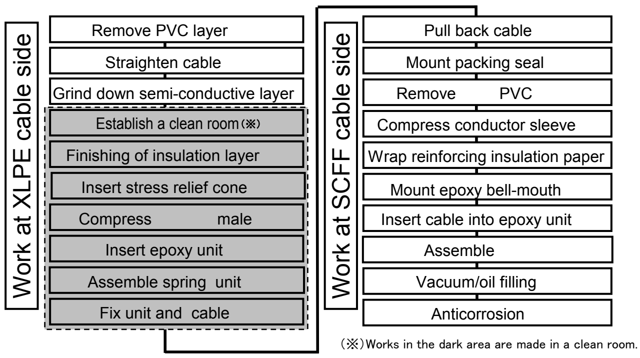

Fig7. Installation flow of 275kV YJB at narrow

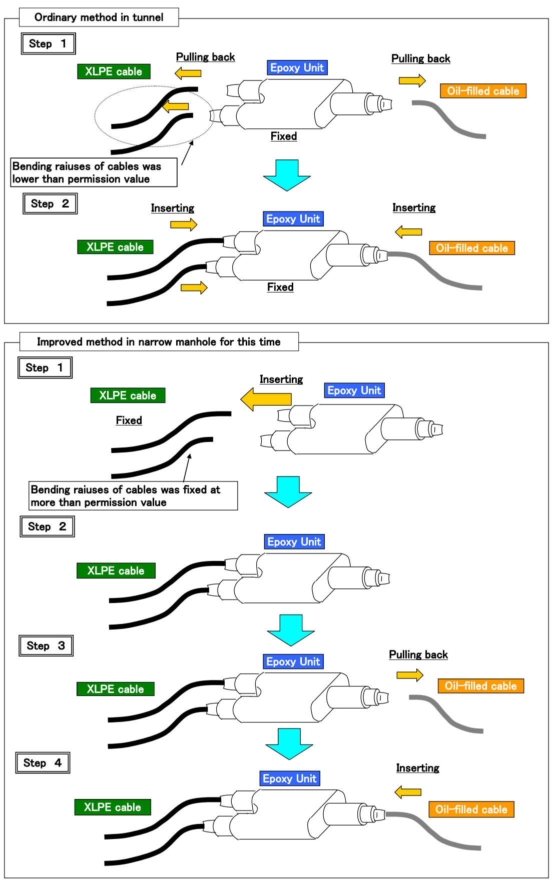

Fig.8. Method of constructing YJB

5-2 Carrying of epoxy unit into the existing narrow manhole

Since 275kV YJB epoxy unit is huge, its dimensional difference from the manhole cover is small, and it weighs remarkably heavy, it is important to take measures to avoid external damage during carrying in the manhole. The following measures were, therefore, taken:

- Prepare and apply a carrying case for epoxy unit.
- To prevent external damage during passing through the carry-in hole, mount a guide rail on the side of carrying case for the unit, and carry it in with it fitted to the guide pipe installed on the carry-in hole.
- To prevent external damage from causing during carrying in through the manhole, along the guide rail installed on the floor the manhole.

A simulated manhole whose dimensions are the same as the narrow manhole on the site was constructed and conducting carrying in test of epoxy unit. It was confirmed to be carried out successfully. Fig. 9 shows the appearance of the test.

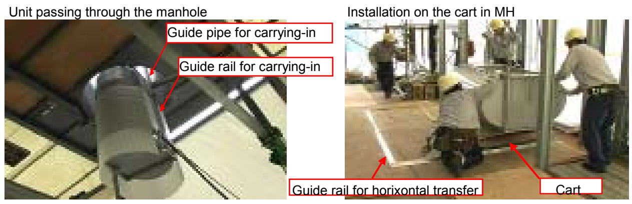

Fig.9. Appearance of carrying test of the epoxy unit into the simulated narrow manhole

5-3 Verification of 275kV YJB construction

Verification of construction of 275kV YJB was conducted at the simulates environment and construction space of the site. Fig.10 shows the YJB construction condition. As a result, it was confirmed that both two-mouth (XLPE) and one-mouth (SCFF) sides can be constructed without problem.

As a result of analyzing construction period, it was confirmed that two-mouth at XLPE cable side will take about 12 hours and about 13.5 hours at SCFF cable side. They are used to work schedule, permissible hours of road-use, and other plans for actual line construction in the future.

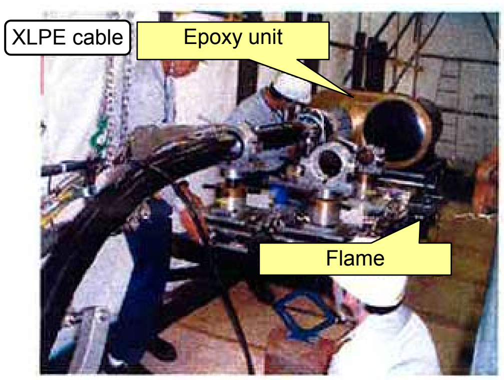

Fig. 10. Condition of YJB construction (at XLPE cable side)

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5-4 Long-term loading cycle test and lightning impulse withstand voltage test

After construction of YJB, long-term loading cycle test and lightning impulse withstand voltage test were conducted in accordance with JEC3408 [2]. Table 2 shows each test conditions, while Table 3 temperature conditions of the conductor during long-term loading cycle test.

In the case of branch line which includes YJB, any of the cables are operated within the allowable conductor temperature under actual service operation. XLPE at the power supply side is regarded as the reference. The number of times that XLPE at the power supply side reaches the allowable conductor temperature, 90 ^{0}C, is assumed to one cycle so that the conductor temperatures at load side SCFF and XLPE fall within its difference from that of XLPE at the power supply side under service operation.

It was confirmed that both the long-term loading cycle test and lightning impulse withstand voltage test have been carried out successfully. Fig. 11 shows the condition of long-term cycle test.

Table. 2. Test Conditions of Long-term cycle test and lightning impulse withstand voltage test

Long-term loading cycle test	Voltage	260kV （to the ground）
	Heat cycle	8h ON／16h OFF
	Period	30 days（30 cycles） Including 5 cycles of short-time allowable temperature
Lightning impulse test		±1155kV（high temperature※）×3 times

※）See table 3 for temperature conditions of each cable.

Table. 3. Maximum conductor temperature at loading cycle test

Target	Conductor temperature under the a actual load conditions※※	Temperature difference from XLPE at the power supply side	Conductor temperature during long-term loading cycle test
XLPE at the power supply side	73℃	-	90℃
XLPE at the load side	50℃	23℃	67℃ or higher
SCFF at the load side	50℃	23℃	67℃ or higher

※※）Current value in the actual line（XLPE at the power supply side：1260A、XLPE and SCFF at the load side:630A）

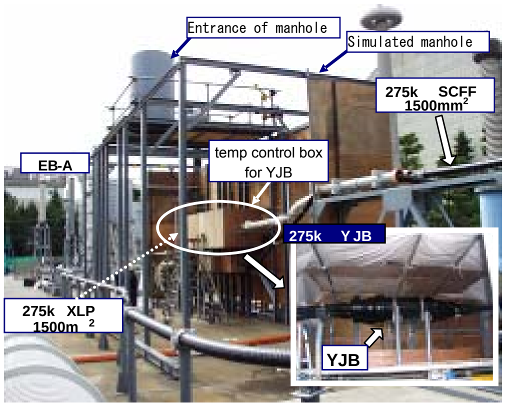

Fig.11. Condition of Long-term cycle test （simulated small and narrow manhole）

5-5 Performance verification under rapid cooling

When sudden temperature change takes place in a manhole such as the manhole is open during winter season for instance, analysis result shows that thermal stress on the YJB surface reveals larger than steady state. From this result, performance verification was conducted using samples obtained during long-term loading cycle test. Table 4 shows the test conditions, provided that conductor temperatures of each cable assume to be those under actual line conditions (see Table 3). Fig. 12 shows an example of YJB ambient temperature during rapid cooling test (at the 10th cycle).

The result of performance verification test shown in Table.4 was satisfied.

Table 4.Test conditions of performance verification test

Item		Conditions	Remarks
Performance verification test under rapid cooling	Rapid cooling temperature	0℃±5℃	Assuming that the manhole is open during winter season
	Range of temperature change	0℃～40℃ (ΔT=40℃)	
	Rapid cooling time	Longer than 4 hours	Time at which thermal stress becomes maximum from the analysis result
	Number of times	10 Times	Equal to number of heat shock test
	Applied Voltage	159kV	Normal voltage to ground
Lightning impulse test		± 1155kV ×3 times	Under high temperature ※）See table 3
AC withstand voltage test		275kV x10min	With PD measurement

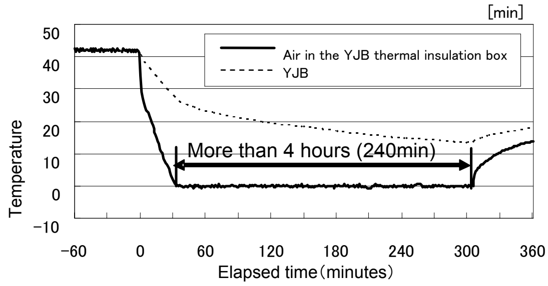

Fig.12 Results of sudden cooling test (an example of the 10th cycle)

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5-6 Result of verification test on re-jointing of YJB on the recovery from cable accident

Following rapid cooling test, construction verification of YJB recovery assembly from external damage of line was made. Assuming recovery of external damage on the SCFF cable at YJB one-mouth side, verification of construction in which re-jointing was made changing from SCFF cable joint to insulation plug, and thereafter assuming recovery of external damage of XLPE cable at two-mouth side, verification test was carried out by once pulling out the XLPE cable and then reassembled.
As a result, construction was successfully made. After that, AC275kV was applied for ten minutes as an AC withstand voltage test and lightning impulse withstand voltage test shown in table 2 was conducted. Results were satisfactory. Following that, three sets of YJB were assembled in actual line as shown is Fig.13. In November 2005, the line commenced commercial operation.

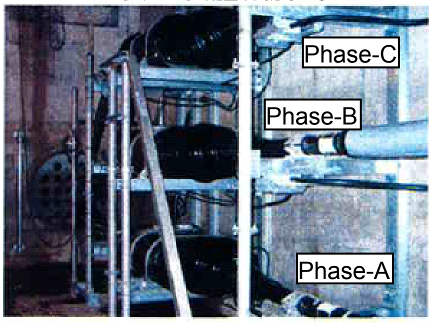

Fig. 13. An example of site installation of YJB (in the narrow manhole of KEPCO)

6. FURTHER APPLICATION OF YJB AND THE FUTURE PLAN

JPS is currently undertaking construction of 275kV YJB for TEPCO. Figure 14 shows the scheme of the line.

In this construction work, nine sets of YJB for three circuits are installed. XLPE 2500mm^2 cable is installed to the single-mouth side and two SCFF cables are installed to the two-mouth side. Two circuits are in operation and one circuit will be in commission in June 2007. Fig. 15 illustrates the installed YJB in tunnel for TEPCO.

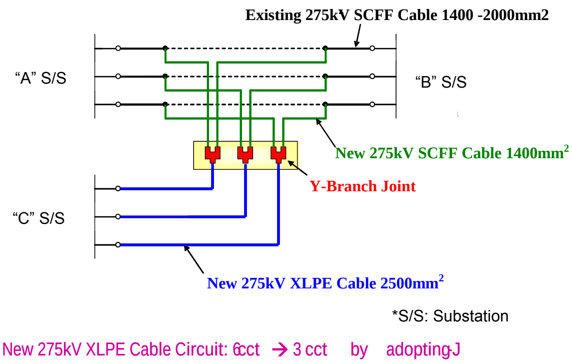

Fig. 14. Outline of line using 275kV YJB for TEPCO

Fig.15. Installed YJB in the tunnel of TEPCO

Year	Client	Location	Configuration	Size	Q'ty
2001	Other utility company	Tunnel	XLPE / SCFF / cap	275kV XLPE 1×600mm^2 275kV SCFF 1×200mm^2	3
2005	KEPCO	Manhole	XLPE / XLPE / SCFF	275kV XLPE 1×1500mm^2 275kV SCFF 1×1500mm^2	3
2005 ～ 2007	TEPCO	Tunnel	SCFF / SCFF / XLPE	275kV XLPE 1×2500mm^2 275kV SCFF 1×1400mm^2	9

——— New XLPE , ········ New SCFF, – – – Existing SCFF

Fig.16 Installation recode of 275kV YJB

As mentioned above, since YJB is capable of being coupled with different types, and as shown in Fig. 16, it is compatible with other types of configuration, it is in high demand, and its increase of future applications for a replacement of aged existing equipment and other usage is considered to be expected. JPS will contribute to effective system buildup by producing and constructing highly reliable YJB for the future.

In conclusion, we would like to express our gratitude to TEPCO and KEPCO in recognition of their support for development and quality improvement of YJB.

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[2] Standard of the Japanese Electrotechnical Committee, "JEC-3408-1997 High Voltage Tests on Cross-Linked Polyethylene Insulated Cables and Their Accessories for Rated Voltages from 11kV up to 275kV"