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# Installation of 500 kV DC PPLP-insulated oil-filled submarine cable

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**Résumé**

Dans ce document, on décrit le développement et l'installation de câbles sous-marin de 500 kV en courant continu, qui sont isolés au papier imprégnés à l'huile. Ces câbles peuvent transmettre jusqu'à 2800 MW, c'est la plus grande capacité dans le monde en un système bipolaire.

Pour la matière isolante, on emploie le papier laminé avec le film de polypropylène (PLPP). De plus, on emploie des capteurs à fibres optiques. On les met dans le câble pour le contrôle. Le résultat des essais fut une étape importante dans le développement commercial des câbles sous-marins de 500kV à courant continu.

Pour poser le câble au fond de la mer, on a développé une machine qui peut creuser le sol. Elle a une bêche avec un jet d'eau. Avec elle, le câble se tire, se pose et s'enterre de 2 à 3 mètres de profondeur simultanément.

On a exécuté l'installation des quatre câbles d'avril à décembre 1998. Elle a réussi. Après des épreuves de tous les systèmes de courant continu, on commencera à transmettre l'énergie électrique en 2000.

**Abstract**

This paper describes the development and installation of a 500 kV DC oil-filled submarine cable. The cable newly developed transmits up to 2800 MW, the world's largest capacity, with single bipole system.

Focus was given to the development of polypropylene laminated paper (PPLP) insulation. In addition, optical fiber sensors were incorporated into the cable for the maintenance. The test results were a milestone in the construction of the 500 kV DC commercial submarine cable line.

During laying of the cable, a newly developed plough-type cable-embedding machine, with a water jet, was employed to bury the cable 2～3m in the seabed simultaneously.

The four cables were successfully installed from April to December in 1998. After systematic test, the DC system will be commenced in the year of 2000.

## 1. Introduction

This paper outlines the development and construction of a 500kV DC oil-filled submarine cable which links between Honshu and Shikoku island in Japan. This cable line is planned to transmit power from a coal power station of Shikoku island to Honshu island. The route length is 50km. A single bipole system (metallic return) was selected. Four submarine cables in total are installed, i.e., two cables of positive and negative poles, a return cable and a spare cable. All of the cables are of the same construction. Because a spare cable is installed taking account of a cable failure.

This cable is the largest one of DC submarine cables in the world, transmission capacity of 2800MW and 3000mm$^2$ conductor. Transmission of the 2800MW power necessitated the development of a cable capable of carrying an unprecedented ampacity of 2800A. A conductor size of more than 3000mm$^2$ was required when employing a conventional kraft paper insulation. These conditions led to the application of Polypropylene Laminated Paper(PPLP) insulation because of its higher DC and impulse breakdown strength compared to kraft paper which would decrease the insulation thickness, thereby enabling downsizing of the cable and the reduction in the total thermal resistance of the cable. PPLP was employed as the insulation material, which is the world first application to DC cable. Through fundamental tests on PPLP, breakdown tests on the prototype cables, mechanical and electrical tests on the final designed cable according to the relevant CIGRE recommendations, and a long-term reliability test, PPLP proved to be superior to kraft paper as the insulation material for DC oil-filled cables.

In addition, twelve optical fibers are incorporated into the single-core power cable. Optical fibers are for outer damage sensing and for cable temperature sensing to enhance the reliability of the cable line in service.

This area, Kii channel, abounds in fishing resources and fishery is flourishing. In addition, since sea traffic in the Kii channel is busy, the cables are buried 2～3m under the seabed throughout the route for protection against damages by anchoring and trawling.

A new type of cable laying and embedding machine was employed, which can dig seabed and lay the cable with high speed. This machine can run across Kii channel for two days.

Four cables were laid from April to December 1998. This cable line is to be first put into commercial use in July 2000.

## 2. Outline of cable line

An outline of cable line planned to be constructed for the DC link between Honshu and Shikoku islands is summarized in Table 1 and Fig.1. The construction of the submarine cable is shown in Fig.2. This cable line is to be first put into commercial use at ±250kV DC 2800A bipole in the year of 2000 and to be upgraded to the ±500kV DC system in the future.

**Table 1 Outline of Cable Line**

| | |
|---|---|
| Transmission capacity | 2800MW |
| System voltage | ±500kV DC bipole |
| Rated current | 2800A<br>(Overload:3500A for 30min) |
| Number of cable | 4 cables (including a spare cable) |
| Route length | 50km(Submarine:48km,Land:2km) |
| Maximum water depth | 75m |