Power Feeding Equipment for Optical Submarine Cable Systems

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Abstract

A submarine cable system is fed power from power feeding equipment that supplies constant current. Such power feeding equipment is expected to enable an ultra-high voltage output to supply power for long-distance submarine cable systems, as well as supporting long-period operations. This paper introduces power feeding equipment for application to NEC's submarine cable systems that achieves compact, high voltage and high reliability characteristics.

Keywords

submarine cable, high voltage, high withstanding voltage, high reliability, constant current control

1. Introduction

The power feeding equipment installed at a landing station feeds power to the component equipments mounted in a submarine cable system.

This paper introduces power feeding equipment that has achieved compact, high voltage and high reliability characteristics, as well as being capable of application to a transpacific long-distance submarine cable system.

2. Outline of the Submarine Cable System

The submarine cable system is composed of the optical wavelength division multiplexing equipment (WDM) that transmits light from the land, submarine repeaters that amplify the optical signals, power feeding equipment that feeds power to the submarine repeaters and the monitoring equipment that monitors the equipment performance. **Fig. 1** shows an example of the system configuration.

The power feeding equipment supplies constant DC current to the submarine repeaters. To improve the reliability of the system power feeding, power feeding equipment sets with

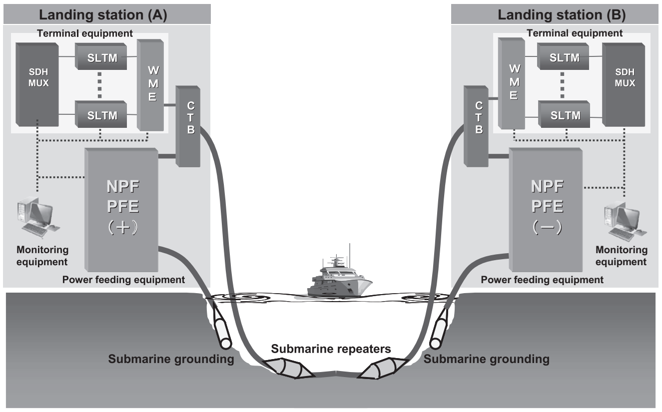

Fig. 1 System configuration.

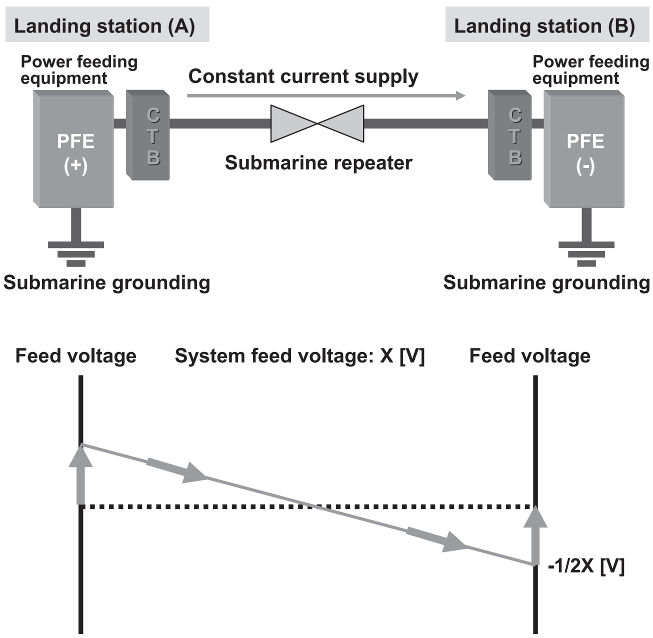

Fig. 2 Example of voltage allocation in the case of power feed from both stations.

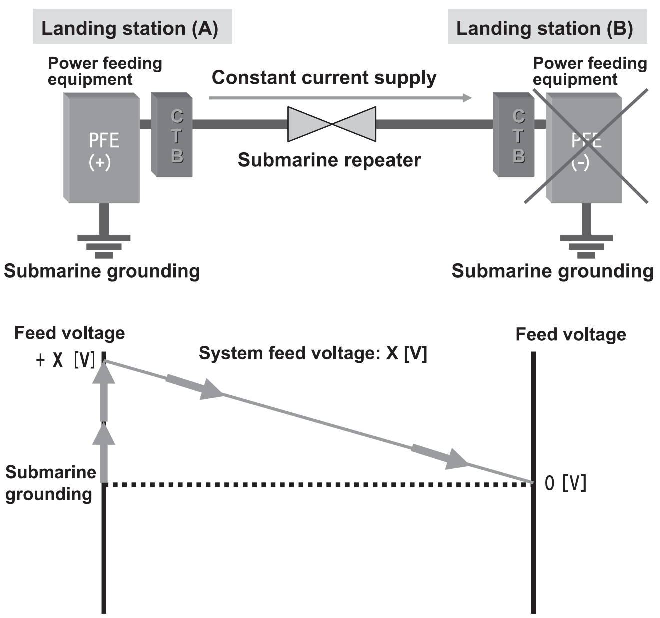

Fig. 3 Example of voltage allocation in the case of a power feeding equipment fault.

the capability of feeding all of the system voltages requirement are installed at landing station at both ends of the system. The voltages to be supplied to the submarine repeaters are allocated to supply the power feeding equipment at both ends. **Fig. 2** shows an example of voltage allocation for a case in which power is fed from both stations.

Usually, each of the two landing stations feeds both positive and negative voltage corresponding to 1/2 of the total system voltage. If a fault occurs in either of the power feeding equipments, the one at the opposite landing station feeds the total system voltage in order to enable a constant current supply to the submarine repeaters. This system redundancy is intended to improve the system reliability. **Fig. 3** shows an example of voltage allocation in the case when a fault occurs with either of the power feeding equipments.

3. Outline of Power Feeding Equipment

The power feeding equipment provides the function of supplying a constant DC current stably to the submarine repeaters via the submarine cable. The DC-DC converter circuitry supplying a constant current as well as the feedback controller circuitry controlling the constant current are provided in redundant configurations. This architecture enables system redundancy based on both-station power feed capability, while high reliability is ensured for each piece of equipment.

In addition, the power feeding equipment for a submarine cable system also provides the following functions:

(1) Control of the power feed path switching circuit for the submarine branching unit (BU function);
(2) Low-current supply for measuring the DC resistance in the case of a short-circuit fault in the submarine cable;
(3) Superimposition of an AC low-frequency signal for use in submarine cable location search (EL function).

3.1 Power Feeding Equipment Configuration

The NEC power feeding equipment consists of four kinds of racks. This arrangement can deal with the various requirements of the system power voltage supply, which is determined according to the submarine cable length. It does this by increasing or decreasing the number of constant-current DC-DC converters. The system voltage is determined by the number of submarine repeaters and the length of the cable and a higher voltage is required as the distance increases. **Photo** shows an external view of a basic equipment layout with four racks.

The high-voltage generator block produces a high voltage output. This high voltage output is generated via multiple

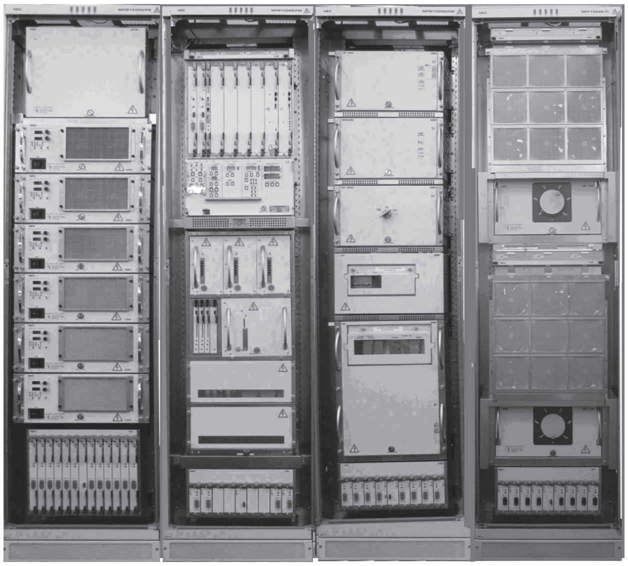

Photo External view of equipment.

converters that convert 48 V DC into a constant current output.

The power feed output monitor/controller block performs digital control and monitoring of the power feed output, operates the equipment, collects/monitors the equipment alarm information and interfaces with the monitoring equipment.

The power feed path switcher block switches the power feeding equipment output destination between the submarine cable and a test load. It also switches the power feed grounding, which is at the power feed input switch, between the submarine grounding and the station grounding. In addition, the switch also has the function of discharging the high voltage in the submarine cable and the connector to the submarine cable fault location test set (FLTS).

The test load block incorporates a load corresponding to the total system voltage. It ensures ease of maintenance thanks to the capability of checking the power feeding equipment functions by isolating the equipment from the submarine system.

3.2 Reliability

In order to feed a constant current stably, the power feeding equipment is provided with high reliability by adopting n+m redundancy in the DC-DC converter block that generates high voltage and 2+1 redundancy in the output controller block that controls the constant current. This reliability does not rely on any of the other equipment in the system. The high reliability of the system is further enhanced by the system redundancy based on the two-station power feed. **Fig. 4** shows the block diagram of the power feeding equipment.

3.3 Safety and Serviceability

Since the power feeding equipment generates a high voltage, to ensure a high level of safety is one of the critical aims.

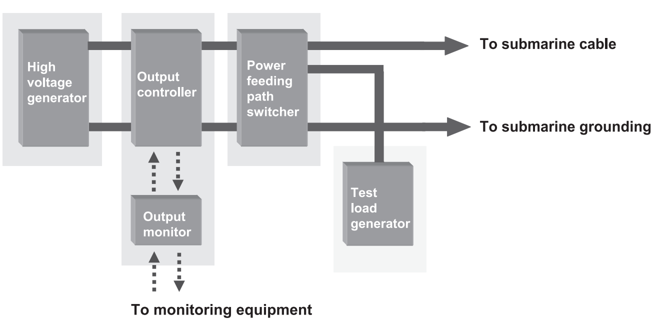

Fig. 4 Block diagram of power feeding equipment.

In addition, the system is designed in consideration of its ease of maintenance.

(1) The high voltage unit is locked with a key so that it cannot be removed easily. Unlocking with the key immediately shuts down the power feeding equipment.
(2) The operational high voltage circuitry has a protection cover on the front. Removing this protection cover immediately shuts down the power feeding equipment.
(3) In consideration of the presence of the high voltage circuitry at the rear, the door is locked by a key so that it may not be opened easily. Opening this door immediately shuts down the power feeding equipment.
(4) Emergency stop buttons are installed on the front and rear panels. Pressing either of these buttons immediately shuts down the power feeding equipment.
(5) A function for discharging the residual load of the submarine cable is provided in order to prevent electric shock hazard.
(6) When shut down, the power feeding equipment can be isolated from the submarine system in order to facilitate maintenance.
(7) Replaceable units are implemented as plug-ins that can be inserted or removed via the front panel.
(8) The forced cooling fan can be replaced without stopping the power feeding equipment.

4. Power Feeding Equipment Specifications

4.1 Reduced Size and Higher Output Power

While a long-distance submarine cable system requires a maximum power feed voltage of around 15,000 V, the maximum voltage of previous power feeding equipment was only 10,000 V and power feed from a single station was therefore in some cases not possible. Although the power could usually be fed from two stations, there has been the risk of a system stoppage in case of a failure with the power feeding equipment of one of the station or of a fault in the submarine system due to the incapability of feeding power to the fault location. This issue has recently become an important one in the reception of submarine cable system orders.

To increase the system feed voltage from a single station to 15,000 V, it is necessary to improve the traditional withstanding voltage specification of 15 kV. As sufficient spatial and creeping distances should be reserved to improve the withstanding voltage, this would increase the equipment size, resulting in the impossibility of installing the equipment conveniently in the limited space of the landing station.

This problem was solved by doubling the output capacity per high-voltage converter in order to improve the withstanding voltage performance and to greatly reduce the equipment footprint by taking the following measures.

(1) Screening between the high-voltage section, low-voltage section and cabinet and development of a 3D structure for reserving the spatial and creeping distances between them.

(2) Implementation of a low-voltage controller of a smaller size for reserving the space for mounting the high-voltage section.

(3) An increase in the withstanding voltage and a decrease in the size of the high-voltage connector.

(4) An increase in the withstanding voltages and a decrease in the sizes of the high-voltage relay and noise filter by applying modularization.

(5) An increase in the withstanding voltage and a decrease in the size of the high-voltage current sensor.

(6) Improvements in the efficiency of the high-voltage converters for increasing the power density, and an improvement in the reliability by adopting forced cooling.

(7) Expansion of the rack dimension from the previous 1.8 m to 2.2 m, which is identical to the dimension of the ETSI rack of the WDM equipment, in order to increase the number of mountable units.

4.2 Comparison with the Previous Equipment Configuration

The previous power feeding equipment with a 10,000 V output was composed of ten racks, and the installation space was 0.8 m wide/rack × 10 racks = 8 m. If it is assumed that the 15,000 V equipment introduced in this paper would use the same output configuration, it would be composed of 12 racks so the width would be 9.6 m.

However, the power feeding equipment introduced in this paper only requires an installation space of 0.6 m/rack × 6 racks = 3.6 m. As the depth is 0.6 m, which is identical to the previous equipment, the installation footprint is 38% of the previous equipment, thereby achieving a large reduction in the occupied space.

Table Main specifications.

Feed voltage	15,000 V	
Feed current	0.6 to 1.6 A	
BU/low current feed functions	Const ant current mode	Constant voltage mode
Setting current/voltage	0 to 500 mA	30 to 1,000 V
EL function	IN SERVICE	OUT OF SERVICE
Frequency	4 to 50 Hz	4 to 50 Hz
Amplitude	0 to 80 mAo-p	0 to 150 mAo-p
DC bias	--	500 mA
Input voltage	DC -48 V	
Dimensions (rack)	600 (W) × 600 (D) × 2,200 (H)	

4.3 Remote Monitoring/Control

Since the power feeding equipment has the function of feeding power to submarine repeaters, it is often installed in a landing station near a coast thus differing from the type of station location in which the optical terminal is installed. As a result, it is often required that the power feeding equipment is remotely controllable from a station located in an urban area in order to quicken and facilitate maintenance.

To meet this requirement, we have added the function for executing remote status monitoring and control of the equipment by extending the equipment alarm-monitoring interface. The same functions as those provided on the equipment's control panel can be remotely controlled, including the basic functions for starting and stopping the power feed output as well as the parameter settings and startup control of the BU/low current feed and EL functions. **Table** shows the main specifications of the equipment.

5. Conclusion

We have recently developed advanced power feeding equipment with a 15,000 V feed capability that is applicable to long-distance systems. This has made high voltage power feeding possible to the transpacific submarine cable systems. In addition, an equipment size reduction of 38% has been achieved, thus enabling optimum use of the installation floor space.

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