

Very Compact and High Voltage Power Feeding Equipment (PFE) for Advanced Submarine Cable Network

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Abstract: Submarine cable systems are energized by power feeding equipment (PFE) that supplies constant current to the wet plant. This paper describes NEC's brand-new PFE that achieves very compact, high voltage and high reliability characteristics, which are essential for the advanced submarine cable systems of today and tomorrow.

1. Introduction

With the rapid progress of the global network and cloud computing, submarine cable systems are evolving towards higher capacity and diverse network by incorporating such technologies as 40Gb/s and Optical Add Drop Multiplexing (OADM). In such advanced submarine systems, a PFE with compact and very high power with enhanced controllability is essential. This is obvious from the fact that, as the submarine repeaters are continuously advancing towards higher output power and wider gain bandwidth, the required power-feeding voltage/current is in turn increasing accordingly.

In this paper, we describe NEC's latest PFE, with the output electrical power of up to 16,500 Watts, which is to our best knowledge, the most powerful product, in the industry today. Such a high power capability is essential to feed the wet plant with single-end feeding capability even for the ultra-long distance submarine systems.

2. Power Feeding Scheme

The PFE is to supply constant DC current to the submarine repeaters. To improve the reliability of the power feeding system, two PFEs, both of which are capable of

feeding to the end of the system, are installed at both ends of the system. This scheme is well accepted in the industry as "single-end feeding capability with double-end feeding configuration". In this scheme, the voltages to be supplied are balanced between the two PFEs, as shown in Figure 1.

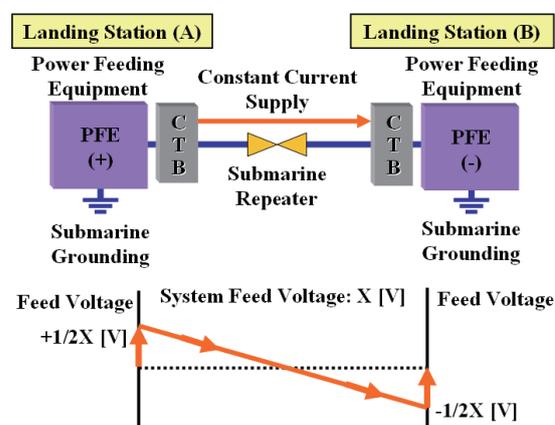


Figure 1 Power Feeding Configuration with Dual-End Feeding

In Figure 1, each of the two landing stations feeds either positive or negative voltage corresponding to 1/2 of the full system voltage.

Figure 2 shows an example of voltage allocation when a fault occurs at one of the PFEs. If one of the two PFEs fails, the other one automatically takes care of the

total system voltage in order to feed the entire system. This system redundancy is intended to significantly improve the system reliability.

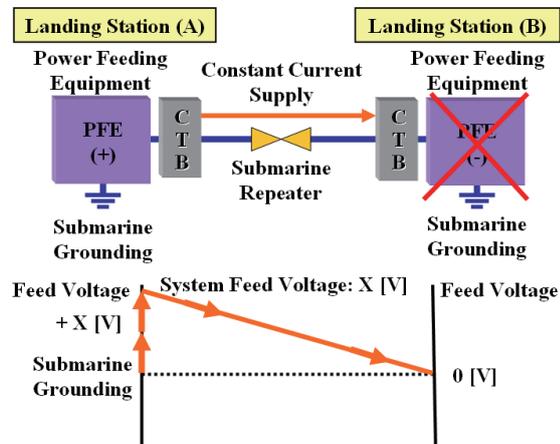


Figure 2 Power Feeding Balancing in Case of a PFE Failure

3. Overview of NPF Series PFE

3.1. Functionality

The developed PFE is named “NPF series”, and inherits all the basic functions supported and field-proven by the previous model.

First, DC-DC converters and common parts inside the equipment are configured with redundancy. This architecture ensures high reliability and availability, together with single-end feeding capability with dual-end feeding configuration.

The PFE also provides the following functions;

- (1) Remote Control of the power feed path switching circuits in the submarine branching units (BU control function),
- (2) Low-current supply for measuring the DC resistance in the case of a shunt fault in the submarine cable (DC current function), and
- (3) Superimposition of an AC low-frequency signal for submarine cable localization (EL function).

3.2. Configuration

Figure 3 shows the typical block diagram of the NPF series PFE. The PFE consists of four kinds of functional blocks;

- (1) High-voltage generator block,
- (2) Power feed output controller/ monitor block,
- (3) Power feed path switcher block, and
- (4) Test load block.

Each functional block is implemented by each different rack, which is the Power Regulator (PR), Power Monitor (PM), Switch (SW) and Test Load (TL).

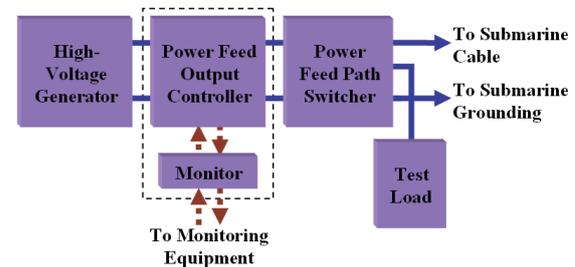


Figure 3 Block Diagram of NPF Series PFE

The high-voltage generator block produces a high voltage output. This employs the latest scheme of series-resonant power converter, which contributed to downsize the PFE thanks to its high-efficiency characteristics.

The power feed output controller/monitor 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 direction between the submarine cable and the test load. It also switches the power feed grounding between the submarine grounding and the station grounding. In addition, the switch has a function of discharging the high voltage potential in the submarine cable and a connector to the submarine cable fault location test set (FLTS).

The test load block incorporates a dummy 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.

The NPF series PFE is configured in 2 to 6 racks of ETSI (ETS300-119-2) standard, depending on the power feeding conditions. Figure 4 show an example of the rack arrangement.



Figure 4 An Example of NPF Series PFE

4. Equipment Performances

4.1. Compact Size and High Output

The NPF series PFE is designed to output electrical power up to 16,500 Watts, and it can supply a maximum of 15,000 V or 10,000 V with currents of 1,100 mA or 1,650 mA, respectively.

As shown in Figure 4, the PFE can be configured in 2 to 6 racks each measuring 600mm (W) x 600mm (D) x 2,200mm (H). The reduction of the equipment footprint is achieved by applying the following technologies and advancements.

(1) Separating and screening among the high-voltage section, low-voltage section and cabinet, as well as the development of a 3D structure maintaining the spatial and creeping distances among them.

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

(3) Improvements in the efficiency of the high-voltage converters for increasing the power density, while maintaining the reliability by adopting forced cooling.

4.2. High Reliability

The NPF series PFE provides the following functions for the improved reliability.

(1) Equipment redundant configuration (REGULAR/STANDBY)

In the case that a fault occurred in a REGULAR side, the STANDBY side feeds the power with a single-end feeding scheme.

(2) Redundancy of power feeding converter

With “n out of (n+1)” redundant configuration, sufficient output power is maintained stably, even if one may fail.

(3) Redundancy of a current control block
Output current block/Output control block is configured in redundancy. The NPF series PFE can supply a constant current continuously and stably, even if one of these blocks may fail.

(4) Alarm duplication

Two majority logic methods are applied to shut down the output current.

4.3. Safety and Serviceability

Since the PFE generates a high voltage, high level of safety is the highest priority. In addition, the system is designed for 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 equipment.

(2) The operational high voltage circuitry has a protection cover on the front. Removing this protection cover immediately shuts down the PFE.

(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 PFE.

(4) Emergency stop buttons are prepared on the front and rear panels. Pressing either of these buttons immediately shuts down the PFE.

(5) A function for discharging the residual potential of the submarine cable is provided in order to prevent electric shock hazard.

(6) When being shut down, the PFE 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 disabling the power feeding equipment.

4.4. Branching Unit (BU) Control

A constant current or a constant voltage can be supplied to BU by the NPF series products.

4.5. Fault Localization

The following functions are provided for fault localization.

(1) Electroding

An AC low-frequency signal (4-50Hz, 80mA0-p) is superimposed on a nominal feeding current when the system is in-service. In an out-of-service mode, an AC low-frequency signal (4-50Hz) is superimposed on a power feed current (0.5A DC). The maximum Electroding current amplitude is 150mA0-p.

(2) Low constant current supply

Low current below 500mA is supplied to localize a cable earth fault point.

4.6. Protection of Exogenous Noise

The following function is provided for protection of exogenous noise.

(1) A clamp circuit is mounted for lightning surge.

(2) In the case of sea earth fault, a sea earth is automatically switched to a station earth. A manual switching is also feasible.

4.7. Remote Monitoring/Control

Since the power feeding equipment has the function of power feeding to submarine repeaters, and maybe installed in a remote landing station. In such a case, the PFE is remotely controllable from a station located in an urban area in order to quicken and facilitate maintenance.

To meet this requirement, we have an optional function for executing remote status monitoring and control by Unified Management System (UMS). The same functions as those provided on the equipment's control panel can be remotely accessible, including the basic functions for starting and stopping the power feed output as well as the parameter settings and start-up control of the BU/low current feed and EL functions.

5. Conclusion

We have described very compact and high voltage PFE for advanced submarine cable networks. The PFE, for example, can be applied to the systems that requires up to 15,000 V of feeding voltage. This has enabled highly reliable power feeding for longer distance systems. Thus it is expected that the NPF series can be readily applied not only for today's submarine environments, but also for next generation systems with more demanding requirements.