Enabling International Communications - Technologies for Capacity Increase and Reliability Improvement in Submarine Cable Networks

INOUE Takanori, AIDA Ryuji, YAMAGUCHI Katsuji

Abstract

The submarine cable system plays an important role in the international communication network as a key component of the infrastructure which connects countries worldwide. The requirements of the submarine cable system include: large-capacity transmission for meeting huge traffic demand; network flexibility for efficient connections between multiple countries, and network reliability improvements to minimize the effects of faults such as cable breaks. This paper describes the latest technologies deployed in submarine cable systems in order to meet these requirements.

Keywords

submarine cable system, multi-level modulation format, digital coherent technology, optical submarine branching unit, submarine OADM, remotely controlled power feed switching

1. Introduction

The key components of the submarine cable system include: submarine cables containing multiple pairs of optical fibers; submarine repeaters equipped with optical amplifiers; submarine branching units that connect multiple landing stations; terminal equipment that transmits and receives data signals, and power feeding equipment that supplies electrical power to the submersible equipment (Fig. 1).

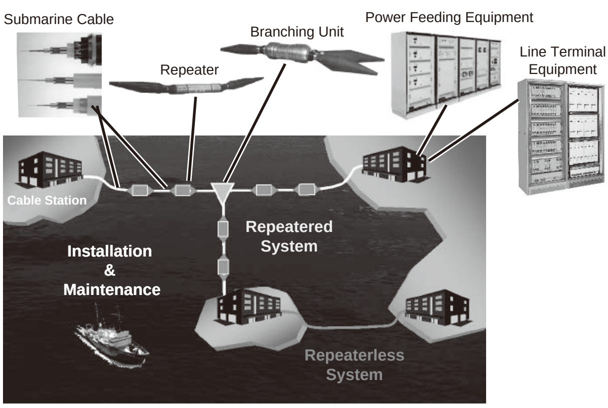

Fig. 1 Components of a submarine cable system.

NEC applies the latest technologies to these components in order to meet the demands of the modern international capacity market, such as increased network capacity and improved operational efficiency.

2. Large-Capacity Transmission Technologies

Submarine cable systems provided by NEC are capable of transmitting one hundred signals at 100 Gb/s per fiber pair, which means that a system accommodating eight fiber pairs (16 fibers) per cable can have an ultra-large capacity of 80 terabits per second. The transmission capacity of an 80-Tb/s system is large enough to allow simultaneous communications of up to 1.24 billion telephone circuits or the transmission of data equivalent to about 2,100 DVDs (4.7 GB/disc) per second.

Below, we introduce the topics of multilevel modulation format and digital coherent technologies that are used to implement such large capacities.

2.1 Multilevel Modulation Technology

Multilevel modulation formats are capable of coding information in multiple bits per symbol. For instance, the QPSK (Quadrature Phase Shift Keying) modulation format can code 2 bits per symbol by superimposing bit information "00," "01," "11" or "10" on an optical carrier with phases shifted by increments of 90º. The QAM (Quadrature Amplitude Modulation) modulation format can increase capacity further by coding the amplitude in addition to the phase, so 8QAM and 16QAM are capable of coding using 3 and 4 bits respectively. Furthermore, combining multilevel modulation formats and polarization multiplexing technologies enables even greater capacity.

The main advantages of multilevel modulation formats include improvement of the spectral efficiency and the non-necessity of increasing the symbol rate. On the other hand, increases in the number of levels would limit the transmission reach because the distance between adjacent symbols in a constellation becomes closer and the robustness against the non-linear effects produced during propagation becomes lower. In a submarine cable system, it is important to select the optimum modulation format according to the requirements of the system.

2.2 Digital Coherent Technology

Digital coherent technology combines coherent detection with high sensitivity, polarization division multiplexing, and the latest digital signal processing techniques such as the electrical compensation of signal degradations accompanying transmission. It is put to practical use as a key technology for increasing the capacity of optical communication systems.

Fig. 2 shows the configuration of a digital coherent receiver. The coherent detector converts the received optical signal into a series of electrical signals containing the optical phase information by combining with a local oscillator in an interferometer. The electrical signals are then digitized by the analog-to-digital converter and input into the digital signal processor. The resulting signal is decoded after chromatic dispersion compensation, polarization mode dispersion compensation, polarization de-multiplexing, frequency offset and phase estimation in the digital signal processor. Any bit errors produced during propagation are then corrected by the forward error correction.

We have commercialized 100 Gb/s digital coherent technology and lead our competitors in applying it to submarine cable systems.

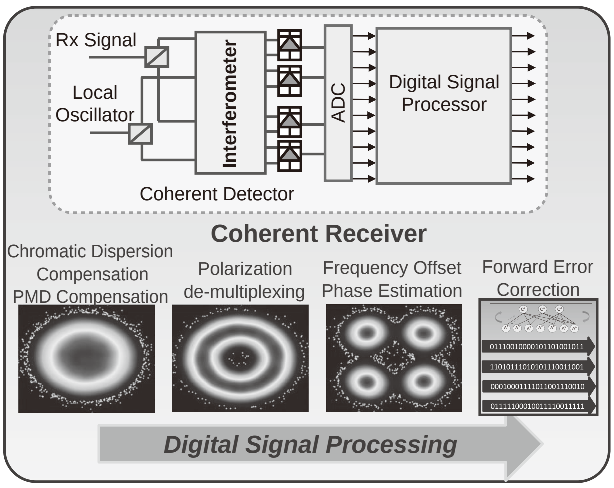

Fig. 2 Digital coherent receiver.

3. Submarine OADM Technology

BUs (branching units) can be used in order to connect several countries and regions efficiently in a submarine cable system. In this section, we introduce the OADM (Optical Add Drop Multiplexer) system which can provide more efficient, more flexible submarine cable networks.

3.1 Submarine OADM Network

Fig. 3 shows a submarine cable network based on a conventional fiber branching system. Fig 3(a) and (b) indicate the physical path and logical path, respectively.

For example, consider the traffic from Terminal-1 to Terminal-4. In a conventional network, the traffic must go through Terminal-2 and Terminal-3. This results in additional equipment costs for routing, as well as high latency in accordance with the cable length.

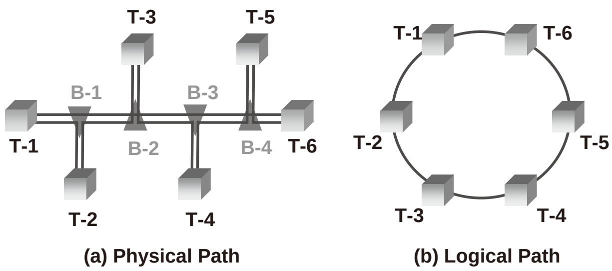

Fig. 3 Conventional network system.

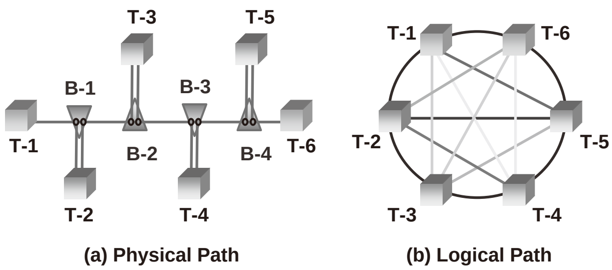

Fig. 4 OADM network system.

Photo Submarine branching unit.

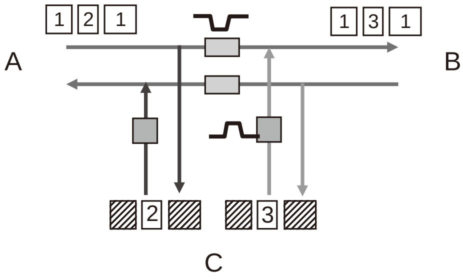

Fig. 5 Example of OADM configuration.

Next, Fig. 4 shows the OADM system. Each BU selects a pre-defined range of optical signals to be transmitted on each branch, while other signals continue to travel along the trunk of the cable system.

In this case, the traffic between Terminal-1 and Terminal-4 can be connected directly in the OADM system. The equipment costs and the latency can thereby be significantly reduced in comparison with the conventional network. In addition, it is possible to build a mesh network as shown in Fig. 4(b). The mesh network can maintain the traffic between the landing stations against potential cable failure.

3.2 Submarine OADM Branching Unit

As shown in Photo, the BU has three branch cables in total in order to connect the optical signal paths and the power feeding path between the three branches.

The OADM system has several waveband based signals (sub-bands) in each optical fiber. The sub-band signals are connected to each other among multiple landing stations. Fig. 5 shows an example of OADM configuration in a branching unit.

Fig. 5 shows that the traffic signals of sub-band 1 are connected between stations A and B. Similarly the traffic signals of sub-bands 2 and 3 are connected between stations A and C, and between stations B and C, respectively. The bandwidth of the sub-bands can be modified so that flexible networks can be built according to the network demand.

Thanks to a high reliability and high performance design, our submarine branching unit can provide a high water pressure resistance and airtightness to withstand a water depth of up to 8,000 meters and a high voltage resistance of 15 kV to support even transpacific transmission. The BU is also designed for an operational lifetime of 25 years.

4. Robust System Recovery Design against Cable Fault by Power Feeding Path Switching

This section introduces the method of system recovery against a cable fault using the power feeding path switching function provided by the BU (Brunching Unit).

Submersible repeaters deployed in the seabed are powered by the PFE (Power Feeding Equipment) installed in the landing stations via the power feeding conductor in a submarine cable. The power feeding configuration of the submarine system is designed and configurable in such a way that it is possible to power the submersible repeaters in the sections not affected by the cable faults - in order to continue service to these sections.

Below, we describe as an example the power feeding configuration of a system connecting three landing points via a BU.

In the configuration of a cable system connected via a BU, the power feed path is classified into the trunk section (Fig. 6: between stations A-B) and the branch section (between station C and the BU). In normal operation, the power on the trunk section is supplied from both PFEs installed in trunk stations (Station A: positive polarity, and Station B: negative polarity), equally sharing the voltage between each other (called Double End Feeding). On the other hand, the power on the branch section is supplied using a single PFE installed in branch station (Station C: negative polarity), with which the PFE feeds power to the sea ground (GND) of the BU (called Single End Feeding).

The PFE installed in the trunk stations (stations A and B) usually has a voltage output supply capacity which can cover the full load of the trunk section, namely the resistance of the cable and the voltage drop across the submersible repeaters. In case of a shunt fault in the trunk section (in which the power feeding conductor of the submarine cable is grounded to seawater), the output voltages of the PFE in stations A and B are adjusted and balanced automatically to feed the power up to the location of the grounded shunt fault. This makes it possible to maintain the powering to all submersible repeaters regardless of the fault location and the traffic carrying capability is maintained as long as the transmission paths (optical fibers) of

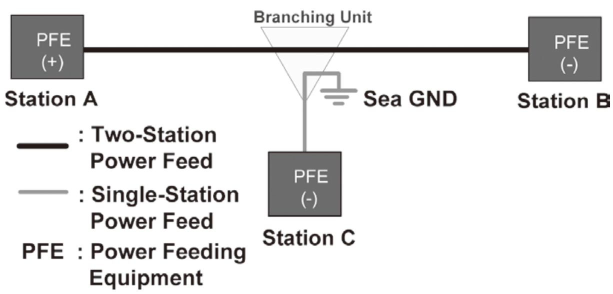

Fig. 6 System power feed path configuration (Normal operation).

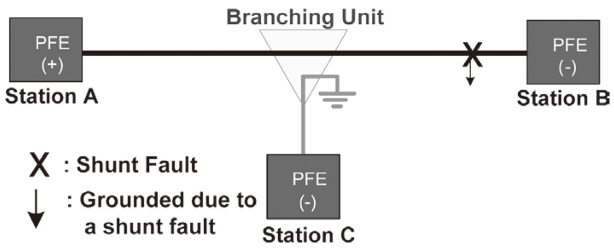

Fig. 7 Shunt fault in trunk section.

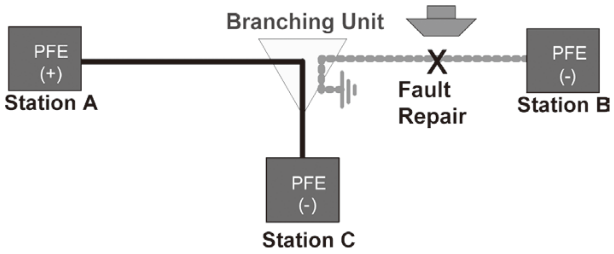

Fig. 8 Power feed path configuration to restore the section outside of the fault section (section under repair).

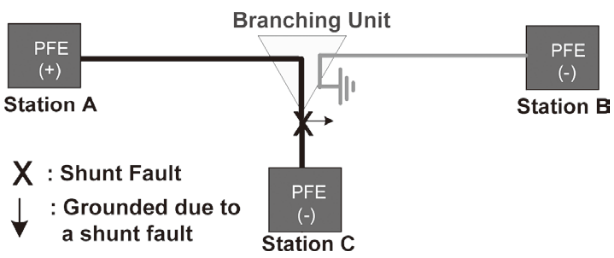

Fig. 9 Power feed path configuration in the case of a shunt fault in a branched section.

the submarine cables are intact (Fig. 7).

When the faulty point described in the above is repaired by a cable repair ship, the power feeding path of the BU is switched from between stations A-B to between stations A-C. By this switching operation, a power feeding path between stations A-C can be established, and the traffic carrying service between stations A-C - where the section is not affected by the cable fault and repair - can be continued (Fig. 8).

In the case that a shunt fault occurs in the branch section, the power cannot be supplied to the submersible repeaters located between the BU and the fault point, and traffic from/to branch station is interrupted. However, the interrupted traffic can be recovered by switching the power feed path of the BU to establish the power feeding path from the trunk station A to the grounded point in the branch section due to the shunt fault (Fig. 9).

In previously-designed systems, the above power feeding path reconfiguration was performed while the system was in an out-of-service condition, namely by stopping the PFE in each station temporarily and adjusting the PFE line current supplied to the BUs to activate the power feeding path switching. This past method required longer down time because of the need for complicated PFE line current adjustments between stations. However, newly-designed systems are capable of switching the power feeding path by a remote command from the network management system installed in the landing station(s). This latest method not only reduces the out-of-service time required for power feeding path reconfiguration, but also enables power feeding path reconfiguration scenarios to respond to various faults in complicated systems connecting multiple BUs.

As seen in the above, our submarine cable system is designed to support power reconfiguration scenarios in any shunt fault case in order to maximize traffic carrying capability and to minimize service interruption.

5. Conclusion

Our submarine cable system business provides a full turnkey service covering the entire process up until the delivery of the system to the customer. The process begins with the oceanic survey and proceeds to the route design, oceanic installation work including cable laying, development and manufacture of submarine cables, terminal equipment and submarine equipment, as well as equipment installation and system testing. We have already constructed a large number of submarine cable systems in this way.

In the future, too, we will continue to develop and exploit innovative technologies to contribute to the creation of a more connected and affluent global society.

Authors' Profiles

INOUE Takanori
Manager
Submarine Network Division

AIDA Ryuji
Manager
Submarine Network Division

YAMAGUCHI Katsuji
Manager
Submarine Network Division

Information about the NEC Technical Journal

Thank you for reading the paper.
If you are interested in the NEC Technical Journal, you can also read other papers on our website.

Link to NEC Technical Journal website

Japanese | English

Vol.8 No.1 Solving Social Issues Through Business Activities

Vol.8 No.1

September, 2013

Special Issue TOP