POWER FEEDING SOLUTION FOR FESTOON-LIKE REPEATERED SUBMARINE CABLE SYSTEM

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Abstract: Power feeding equipment and return earth systems are key components of a repeatered submarine cable system, which provide power to the submersible equipment and enable the system's operation. Double-end feeding design with single-end feeding capability is usually adopted to improve the reliability of a power feeding system for a point-to-point repeatered segment.
This paper describes a new design of power feeding solution for a festoon-like repeatered submarine cable system. It is more cost-effective than a traditional design but with equal reliability. The power circuit reconfiguration and fault isolation can be easily achieved by using a high voltage power switch during system operation and maintenance. The features and benefits of the power feeding design are detailed in respect of system reliability, safety, cost effectiveness and the flexibility of operation.

1. INTRODUCTION

In a repeatered submarine fibre-optic cable system, the submerged plant must be fed by power feeding system, which always includes power feeding equipment (PFE), cable termination cubicle (CTC), return earth system and the copper conductor in cables.
To supply a precisely controlled constant DC current to the submersible repeaters with high reliability, a series of protection mechanisms are adopted in power feeding systems. At equipment level, a duplicated PFE is designed with 1+1 redundancy converter units. At system level, a dedicated station earth is equipped as a back-up of the ocean ground. At network level, PFEs double-end feeding design with single-end feeding capability is usually adopted for a point-to-point segment.
For multiple destination repeatered systems with branching units (BU), the power feeding configuration shall be subject to the network architecture and the system design requirement. Generally, the PFEs in trunk sites supply the power to main trunk, while the PFE in the branch site supplies power to the spur. In the event of a cable fault occuring, the power reconfiguration and traffic recovery can be achieved via a power switch BU in the system.
For a festoon-like repeatered submarine cable system as shown in Figure 1, the traditional design is to adopt a double-end feeding configuration for each segment to ensure the PFE system reliability.

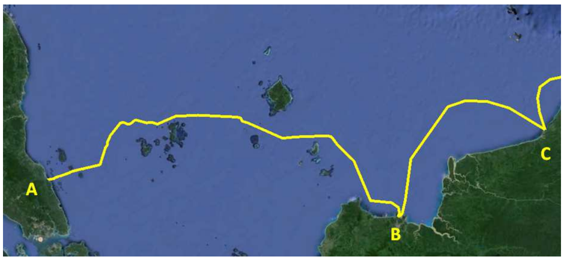

Figure 1 Route Overview of Festoon-like Repeatered Submarine Cable System

Thus, two sets of in-line PFEs will be installed at the intermediate site of double landing. The traditional system architecture and power feeding configuration[1] is shown in Figure 2 and Figure 3.

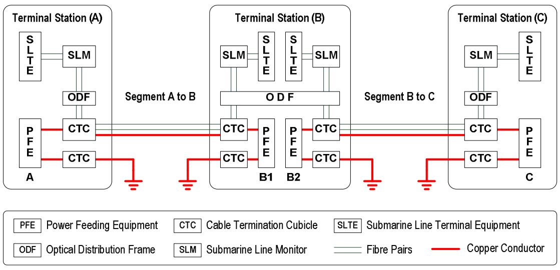

Figure 2 The Traditional System Architecture in Festoon-like Repeatered System

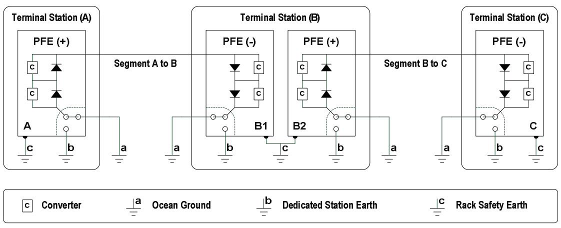

Figure 3 The Traditional Power Feeding Configuration in Festoon-like Repeatered System

In this paper we present a new design of power feeding solution for festoon-like repeatered submarine cable system, which simplifies the PFE configuration without degrading the system reliability. The power circuit reconfiguration and fault isolation can be easily achieved by using a high voltage power switch during system operation and maintenance.

2. NEW SOLUTION OF POWER FEEDING CONFIGURATION

Take a festoon-like repeatered system with two segments for example. There are three landing sites A, B and C. For optical signal transmission, there are three digital line sections (DLS), A-B, B-C and A-C (via B). For a power feeding configuration, the two segments can be considered as a whole system. Thus, PFEs can be installed only in site A and C. The copper conductors in the cables are connected in site B and the current passes through directly without earthing. The system architecture is indicated in Figure 4.

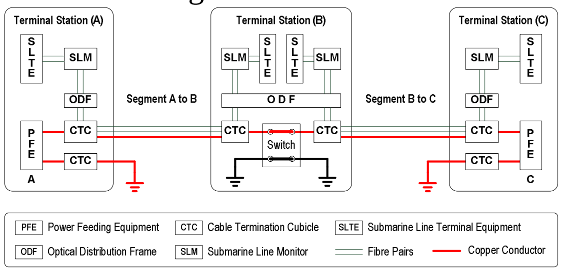

Figure 4 The New Design of System Architecture in Festoon-like Repeatered System

To achieve the system power circuit reconfiguration and fault isolation during cable fault and system maintenance, a rotary high voltage (HV) power switch[2] is installed in site B, which can be manually operated to change the power path status, as shown in Figure 5.

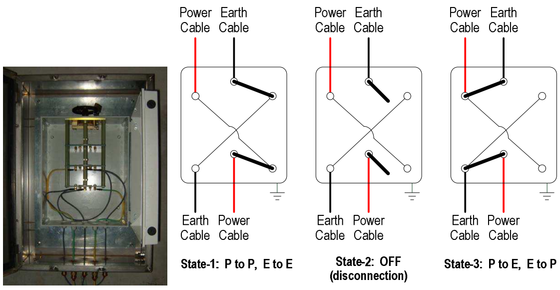

Figure 5 Rotary HV Switch Profile and Power Reconfiguration of Three Statuses

The new solution of power feeding configuration is indicated in Figure 6 with a rotary HV switch equipped.

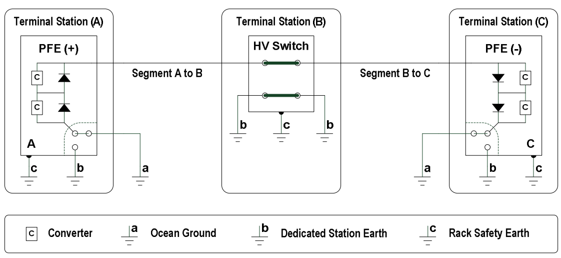

Figure 6 The New Design of Power Feeding Configuration in Festoon-like Repeatered System

Reliability and Availability

The PFE configuration combines the two segments as a unified power feeding system. All the submerged repeaters can be fed by the PFEs installed in site A and C, which make up a double-end feeding configuration. Based on the system voltage drop budget, we select the suitable PFE specification with single-end feeding capability. The system power feeding configuration can be automatically switched from double-end feeding mode to single-end feeding mode if either PFE failed.

For DLS A-B (B-C), the reliability models are the same for the traditional configuration and new-design configuration, as shown in Figure 7. The two sets of PFEs form the 1+1 redundancy logically.

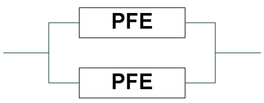

Figure 7 Reliability Model of PFEs in Double-end Feeding Configuration

For DLS A-C, the new-design PFE configuration has the same reliability model as that shown in Figure 7. The traditional configuration has a reliability model as shown in Figure 8. Thus, the new design has even higher availability than the traditional configuration.

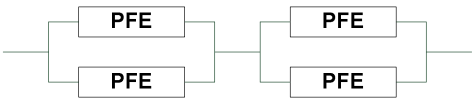

Figure 8 Reliability Model of Traditional PFE Configuration for DLS A-C

Operation Safety

To meet the safety requirement, the HV switch doesn't support automatic switching or remote operation via the network management system.

The HV switch, with a simple mechanical design, can be manually operated by rotating the hand wheel. It is designed with manually operated actuators that include a safety cam detent for positive contact positioning and safety interlocks. The high voltage rotary switch is built with a lockable centre off position for safe working practices.

The HV switch product is strictly qualified and field proven in high voltage environments. It has been validated up to 30kV, in spite of this, the system must be powered off before any switching operation.

Fault Isolation

In site A and C, duplicated PFE with 1+1 converter unit redundancy is adopted for equipment level protection. A dedicated station earth is installed to achieve the system level protection against ocean ground failure and/or potential difference out of limits between ocean ground and station earth.

Ordinarily, PFEs at site A and C would operate at half the system voltage, one positive, the other negative. In the event of a cable shunt fault, the shunt fault point has a potential equal to zero and the PFE in each site would change its output voltage automatically to keep the constant current unchanged.

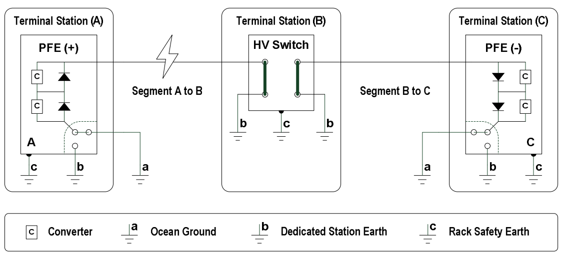

Figure 9 Fault Isolation via HV Switch

When an open fault occurs due to cable break or during cable repair of shunt fault, the system power feeding state shall be reconfigured to achieve fault isolation.

Firstly, the system shall be powered off and the power feeding configuration can be switched via the HV switch. The copper conductor from each segment should be connected to the respective dedicated station earth in site B. The segment with the fault will be isolated and the segment without fault will be changed to single-end feeding mode, the system traffic can be partly recovered after repowering, as shown in Figure 9.

Cost Effectiveness

The equipages of PFE and return earth system for the traditional and the new design are the same in site A and C.

In site B, the new design needs to configure a rotary HV switch, while the traditional solution needn't. The HV switch has a high reliability but low cost.

Compared with the traditional solution, the new design saves two sets of PFEs with spares as well as two sets of ocean ground in site B, which is more cost effective, as shown in Table 1

No.	Products in Site-B	Traditional Configuration	New-Design Configuration
1	HV Switch	No need	1 set
2	PFE and Spares	2 set	No need
3	Ocean Ground	2 set	No need

Table 1 Comparison between the Traditional and New-design PFE Configuration

Normally, the copper conductors in cables of the two segments are connected directly via HV switch without earthing. The power path will be changed only during the fault isolation. Thus, the ocean ground is not necessary in site B considering the short term application. The station earth can fulfil the cable earthing requirement.

3. CONCLUSION

In this paper, a new design of power feeding solution for festoon-like repeatered submarine cable system is presented. Compared with the traditional solution, the new design simplifies the power feeding configuration. The rotary HV switch is configured in the intermediate site instead of two sets of PFEs, and he ocean ground could be saved. The new configuration is more cost effective without degrading the power feeding reliability. The HV switch is manually operated only, to ensure the safety of power system. The system power path can be reconfigured for fault isolation and system maintenance, which gives more flexibility of operation. This new configuration is a feasible and deliverable power feeding solution for the festoon-like repeatered submarine cable systems.

4. REFERENCES

[1] Neville J. Hazell, Christopher E. Little "Undersea Fiber Communication Systems" 366-373

[2] Liyuan Shi, "Application of Power Switching for Alternative Land Cable Protection between Cable Landing Station and Beach Manhole in Submarine Networks", SubOptic 2013