Tai-Peng Submarine Cable Operation Procedure Verification and Transient Measurement Analysis

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I. Preface

The power system in Penghu was an outlying island type independent power grid, and the power supply was mainly supported by the Jianshan Power Plant, composed of 12 diesel units with a total gross installed capacity of 120MW. Similar to other outlying islands, the scale of the power system in Penghu is small so the failure of the feeders may cause island-wide power outages. In addition, the fuel supply relying on transportation also causes the cost of power generation in Penghu higher than that in Taiwan. To cope with the issues mentioned above, the construction of Tai-Peng submarine cable connecting the power grids in Taiwan and Penghu was planned in the Seventh Transmission and Transformation Project. After more than ten years of construction, Circuit 2 had been energized by the system for 168 hours since October 22, 2021, and was later joined into the Tai-Peng system at light load on October 30 in the same year. Afterward, Circuit 1 had been energized for 168 hours since November 2 and joined into the system on November 9. Taiwan Power Company officially announced that the power grids of Taiwan and Penghu are connected.

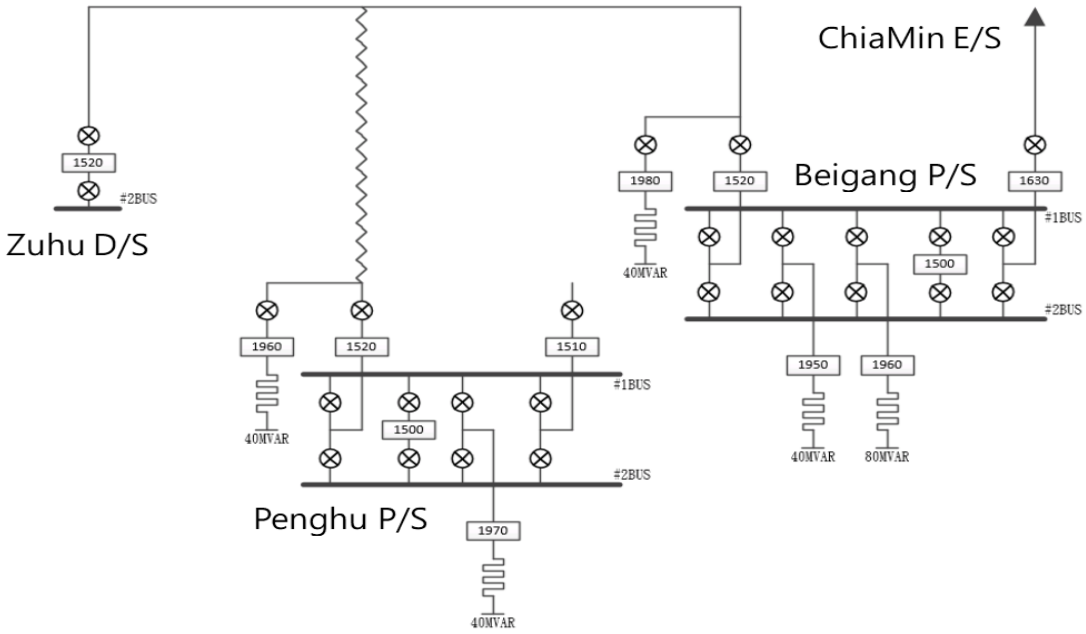

Figure 1Single-line diagram of a submarine cable system

II. Research methodology

As members of the Tai-Peng submarine cable project team, we assisted in verifying the energization and connection procedures of the Tai-Peng submarine cable with the Real Time Digital Simulator (RTDS) and recorded the actual data with transient recorder. In this paper, the results of this study are illustrated by two cases. The first case is the simulation of the current transformer phase checking process during the cable energization while the second case is the measurement of Tai-Peng system connecting process.

First of all, the single-line diagram of the Tai-Peng submarine cable system is shown in Figure 1. Since the capacitance value generated by the cable is more than the overhead line, the excess reactive power can easily lead to the phenomenon of voltage raised at the end of the cable. In

order to control the voltage within acceptable limits, shunt reactors are installed to compensate the reactive power in this case. However, too much compensation may lead to the instantaneous current AC component peak less than the DC offset component. In other words, the current waveform will not cross the zero point. As a result, in this condition, if an unbalanced ground fault occurs, the circuit breaker of healthy phases will be difficult to extinguish the arc as the current does not cross the zero point, which may even lead to failure. Therefore, the confirmation of whether the current crosses the zero point when operating the reactor is an important issue of this study. To make sure that the line differential relays operate properly, it is necessary to use the Penghu #1970 bus reactor as a load for checking the phase of the current transformers. Figure 2 shows the transient current waveforms following the switching of Penghu #1960 with line shunt reactors #1960 and #1980 closed. It can be clearly observed in the simulation results that the instantaneous current of the Beigang #1520 circuit breaker doesn't cross zero point, and the duration is about 0.5 seconds. If Penghu #1960 is opened and then Penghu #1970 is closed, the procedure can avoid the phenomenon that the current doesn't cross zero point. During these reactors switching on and off, the bus voltage variation of Penghu and Beigang is controlled within 5%, which under the requirements of the operation regulations. The right side of figure 2 shows the measured waveform of the actual operation of Circuit 2 energization on Oct.22, and three-phase currents cross the zero point, which is similar to the simulation results.

In the second case, the connecting point of the Taiwan-Penghu system is located on #630 circuit breaker at 69kV bus in Penghu P/S, where the two ends of the circuit breaker before the connection belongs to the Taiwan system and Penghu system, respectively. Therefore, to verify whether the Taiwan and Penghu systems are synchronized, it is necessary to measure the voltage signals on either side of #630 at the same time. Figure 3 shows the waveforms when systems were connected. The waveforms, from top to bottom, include the differences of voltage, phase angle and frequency, close signal sent by the synchronism relay, and the 52a signal of the circuit breaker. The red line in the figure is the time close signal sent by synchronism relay, the voltage difference is -0.12pu, the angle difference is 4.61°, and the frequency difference is 0.12 Hz. The blue line in figure is the time circuit breaker closed, the voltage difference is 0pu, the angle difference is 1.82° and the frequency difference is 0.08Hz.

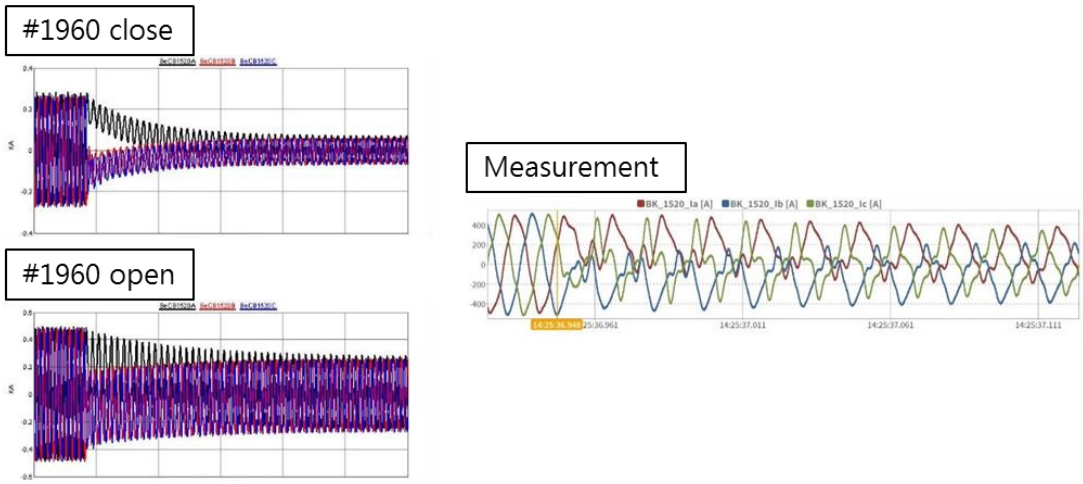

Figure 2Simulation and Measurement Current waveforms of Beigang #1520.

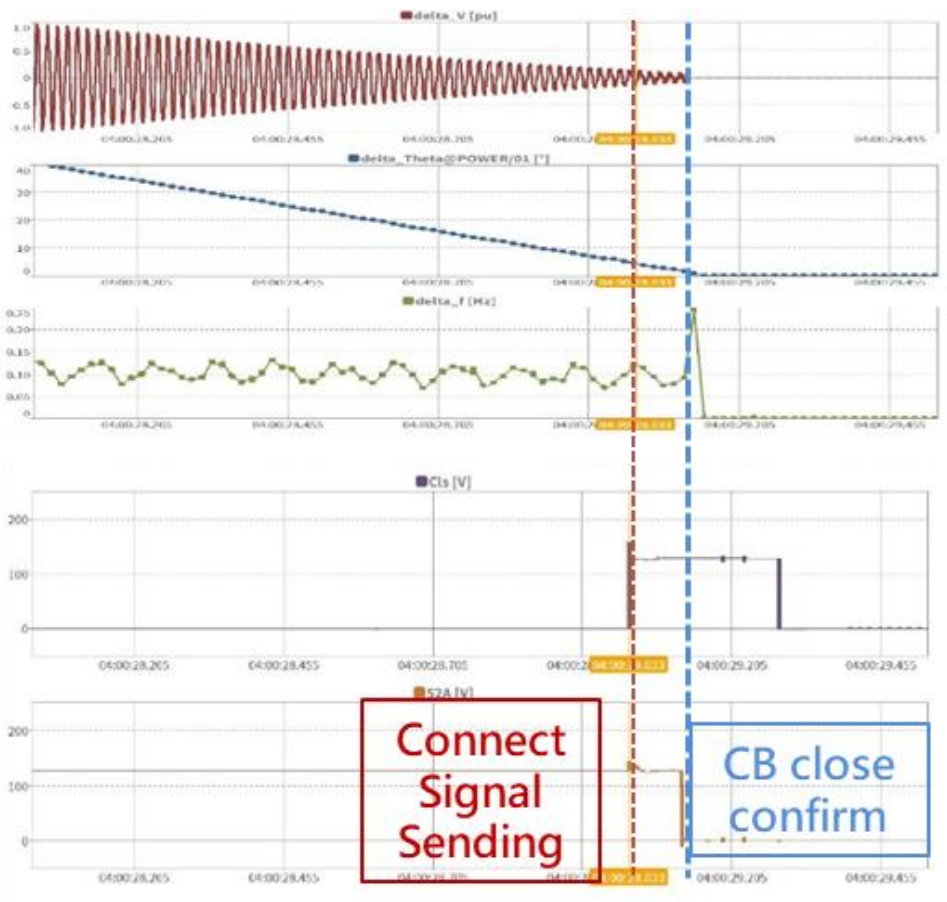

Figure 3 Measurement Waveform of Tai-Peng System Linking.

III. Conclusion

In this study, the RTDS is used to verify the operation procedure in advance, and a transient recorder is set up to measure the actual waveforms during the energization and connecting process of the Taiwan-Penghu submarine cable. The electromagnetic transient (EMT) simulation with RTDS ensures that the current will cross the zero point and the voltage is controlled within acceptable limits during energization process. The high-resolution measurement record data is not only used to verify the correctness of the simulation, but also used to analyze the transient and steady state of system. The analysis result is an important reference material for future operations.