AC 154kV Submarine Interconnection System between Hwawon and Anjwa Island in Korea

Jongmin Park[1*], Inho Lee[1], Youngguk Kwon[1], Jungnyun Kim[1], Seungik Jeon[1],
Wanki Park[1], Kwangyeol Lee[1], Jaeseung Kim[2], Hyoungsoo Shon[2]
[1]LS Cable & System, Republic of Korea
[2]KEPCO, Republic of Korea
*Email: stissue@lscns.com

Abstract: The Hwawon – Anjwa submarine cable system including the biggest submarine power cables in Republic of Korea, field repair joint and termination has been in commercial service on November 2010. It was a landmark project in Republic of Korea, also for LS cable and KEPCO(Korea Electric Power Corporation), through four years of concentrated system engineering and construction. AC 154kV XLPE insulated 3 core submarine power cable with a fiber optic cable integrated will relieve the increasing power demands according to the feasibly anticipating offshore wind farm grid near the Anjwa Island. With respect to installation of the biggest size and weight of cable in Korea ever, the planning and optimization of the loading and installation equipments has been performed. The south-west sea of Korea with strong side currents in excess of 3 knots and frequent storm force winds was a challenging itself. In spite of harsh marine environment, Global marine and LS Cable have adopted the new laying methodology of twin simultaneous installation and accomplished without interruptions during approximately 2 weeks of actual implementation period. Two cable lines of 7 km each have been laid simultaneously to minimize construction period and costs upon the request of KEPCO and the whole length was protected with specially designed polyurethane pipes throughout the cable laying process. Additional cable protection methodology such as rock berm or direct burial has been applied over the laid cables by half of 2011.

1 INTRODUCTION

Hawon-Anjwa project is the double circuit interconnection project between Hawon (main land) and Anjwa island using AC 154kV 3 core XLPE submarine cable. The route length is approximately 7km and maximum water depth is 40m. Detailed marine survey is one of the most important activities in the submarine cable project to avoid any errors or mistakes during the cable laying operation. For this project, not only desktop survey (DTS) but also pre-lay survey was conducted as part of the marine survey. After gathering all the information from DTS and pre-lay survey, the route conditions were thoroughly investigated and examined. According to the result of marine survey, the cable laying and burial method and protection methods were determined. Due to the strong wind, fast tidal current in the cable route, the actual installation was quite challenging. In this paper, not only the installation but also development, qualification tests as well as commissioning of the system are described. The Table 1 is show the specification of submarine power cable and some of the hydrological data of the cable route.

Table 1: Specification of Cable and Hydrological Data

Item	Description
Cable specification	154kV XLPE 3core 500mm^2
Total length	Approx. 7km x 2circuits
Laying method	Simultaneous laying and burial (2 circuits)
Tide/wave	Tidal: Max. 6.1knot(about 3m/s) Wave : 1~2.5m
Max. water depth	40m

In order to verify the cable system, a series of electrical and mechanical tests were performed in accordance with CIGRE recommendation (Electra No.171 and 189) and IEC 60840 and the result showed superior reliability and performance for quite rough installation condition.

2 DEVELOPMENT OF THREE CORE SUBMARINE CABLE AND REPAIR JOINT

2.1 Submarine power cable

The design requirements of AC 154kV XLPE 3 core fibre optic embedded power submarine cable system are summarized in Table 2.

Table 2: Requirement of submarine cable

Item	Designed value
System Voltage	AC 154kV
Maximum Voltage	AC 170kV
BIL	750kVp

Figure 2 and Table 3 show the configuration and dimension of 3 core cable.

Figure 2: Typical picture of three core submarine cable

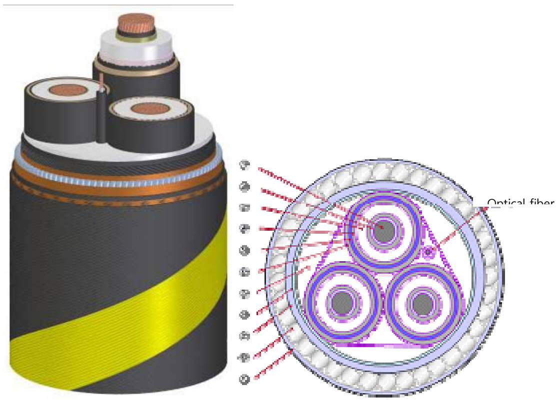


Table 3: Construction of three core submarine cable

Item	Type/Material	
① conductor	compact round, stranded, annealed uncoated copper wires	
② conductor screen	Extruded inner semi-conductive compound	
③ Insulation	Extruded XLPE	
④ insulation screen	Extruded outer semi-conductive compound	
	Semi-conducting swell-able tape	
⑤ Metallic sheath	Lead	
⑥ Corrosion-proof layer	Semi-conducting PE sheath	
⑦ filler	Polypropylene yarn	
⑧ binding tape	weaved tape	
⑨ buffer layer	Polypropylene yarn	
⑩ Wire amour	Galvanized steel wire	
⑪ Outer bedding	Polypropylene yarn	
Diameter (mm)	Appox. 203	
Weight (kg/m)	Air	Approx. 83
	Water	Approx. 48

2.2 FIBER OPTIC CABLE

Waterproof layers (PE sheath, extruded lead layer, PE buffer layer and waterproof filler) are included in fiber optic unit to avoid losses due to moisture penetration and mechanical stress. The configuration and dimension of the optic unit are shown in Figure 3 and Table4.

Figure 3: Fiber optic cable

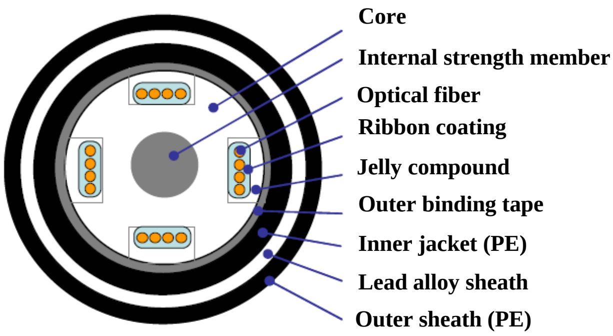


Table 4: Construction of fiber optic cable

Item	Type/Material	
Fiber type	Single mode	
Internal strength member	FRP	
slot core	PE	
filler	PE	
Metallic water barrier	Lead alloy	
Outer sheath layer	PE sheath	
Outer diameter(nom/min)	20.0/16.0 mm	
Weight (kg/m)	Air	About 1.085
	Water	About 0.771

2.3 JOINTS

FACTORY FLEXIBLE JOINT (FJ): The copper brazing method (same diameter) was employed to connect conductors in order to keep the same diameter with cable. X-ray examination is also used to detect any defects after brazing operation.

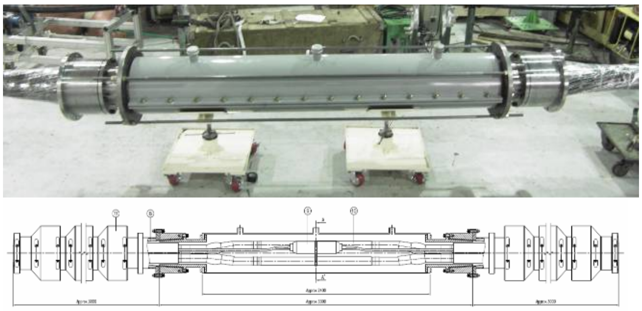
TMJ (Tape Moulded Joint), which uses same material with cable insulation, is used as a factory flexible joint. After construction, final outer diameter is approximately same as cable diameter. The target voltages of AC withstand voltage and impulse withstand voltage to verify the factory joint are selected as 300kV/1hr and ±1035kV/10times.

To optimize condition of the insulation layer, numerous simulation and experiments are performed by using Electric Field Analysis, FEA(Finite Element Analysis) and DOE (Design of Experiment).

FJ undergoes mechanical stresses such as tension, bending and twisting during manufacturing and laying operations. Thus, the mechanical stress analysis needs to be performed to determine the proper cable design. The mechanical optimization for the cable design is carried out by evaluating the strength of the conductor, insulation and steel wire armor. FEA as well as theoretical analysis is used to calculate the mechanical stress.

REPAIR JOINT (RJ): The repair joint is designed to have sufficient mechanical strength to withstand crushing and tensile load during handling, laying and operation. And, waterproof and cathodic corrosion protection is necessary to design the repair joint for submarine power cable. The schematic drawing and picture of repair joint are shown in Figure 5.

Figure 5: Repair joint



In addition, bend restrictor for repair joint housing is designed to maintain Minimum Bend Radius (MBR) during installation. The bend restrictor must have proven strength exceeding that of submarine power cable. FEA (Finite element analysis) is performed to calculate stress and deformation. Based on FEA result, the bend restrictor is designed and manufactured to have sufficient structural safety.

Figure 6: FEA analysis (deflection & stress contour)

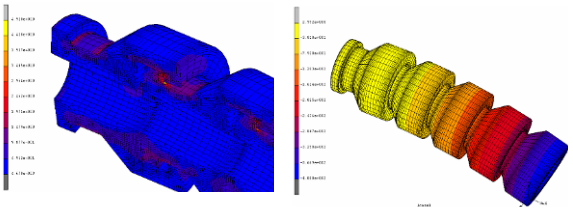
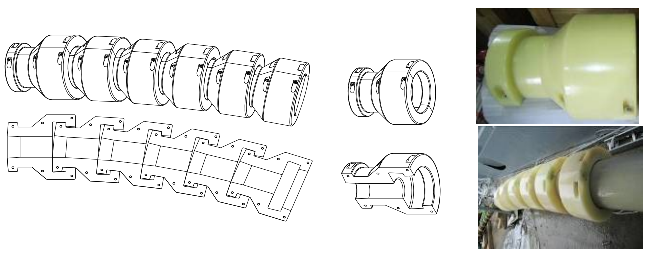


Figure 7: Real model of Bend Restrictor



3 QUALIFICATION TEST

The mechanical and electrical tests are conducted in sequence. Prior to the electrical tests, cable is subjected to the mechanical tests such as coiling test and tensile-bending test as show in Figure 8 and 9.

Figure 8: Coiling test

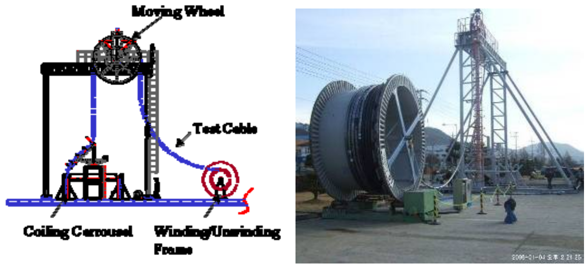
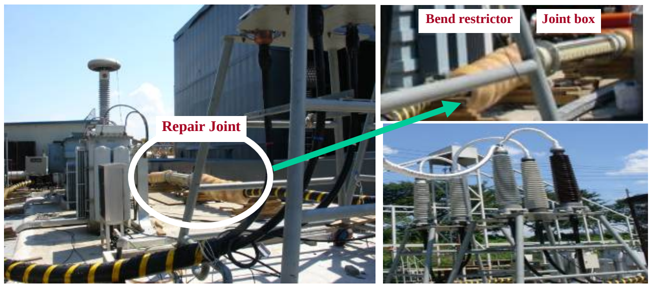


Figure 9: Tensile-bending test

After completing the mechanical tests, the electrical tests are carried out. The test loop for electrical test is shown in Figure 10.

Figure 10: Test loop for electrical test



AC test is performed in accordance with IEC 60840. Table 5 shows the conditions of mechanical and electrical test and the results.

Table 5: Conditions of mechanical and electrical test and the results

Test item		Test condition	Result
Mech-anical (Cable)	Coiling test	-Number of coiling : 1time, 8turns	Good
	Tensile-bending test	-Number of bending : 3 times -Tensile force : 42.9kN	Good
	Tensile Test	-Duration: 15min -Tensile force: 40.7kN	Good
	Test of conductor watertight-ness	-Water pressure: 4kg/㎠ -Duration : 10 heating cycle	Good

	Test of shield watertight-ness	-Water pressure: 3kg/㎠ -Duration: 10 heating cycle	Good
Elect-rical (Cable & Joint)	Partial discharge (room temp.)	-Voltage: 1.75 U_0 (153kV)/10s -Voltage for PD test : 1.5U_0(131kV) -Range: under 5pC	Good
	Tan δ	-Conductor temp.: 95~100℃ -Voltage: U_0 (87kV) -Range: under -10×10-4	Good
	Heating cycle test	-Conductor temp.: 95~100℃ -Period: 20cycle, 8 hours heating (Min. 2 hours continued) / 16 hours cooling -Voltage: 2U_0 (174kV)	No B.D
	Partial discharge (room temp./high temp.)	-Voltage: 1.75U_0 (152kV)/10sec -Voltage(PD): 1.5U_0 (131kV) -Range: under 5pC	Good
	Lightning impulse withstand voltage test	-Conductor temp.: 95~100℃ -Impulse: +/- 750kV/10times -2.5U_0 (222kV)/15min (Room temp.)	No B.D

The cable system has passed the type test successfully. No breakdown was occurred during AC withstand voltage test and impulse withstand voltage test.

4 INSTALLATION

Before the installation, extensive survey was conducted to determine the bathymetry, topography and hydrological properties of submarine cable route. According to the survey result, the submarine topography is bedrock from Anjwa island to the 3.4km in the direction of Hawon. There is over 30m depth of water and the slope is about 7.5%. The depth is gradually decreased to the 3.6km and keeps it about 20m until the landing point of Hawon. The tidal current is Max. 6.1Knot (about 3m/s) and there were many typhoons until September 2010. Therefore, the installation was planned after October to avoid any potential typhoon.

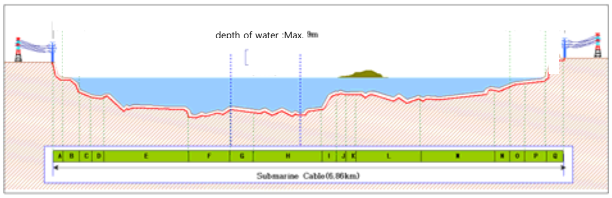
The cables were transported by the cable laying vessel from the dong-hae factory in east side of Korea to the laying point in West Sea. The double circuits' submarine cable were wounded together to lay them simultaneously. The submarine cable was laid in one continuous length of approximately 7km.

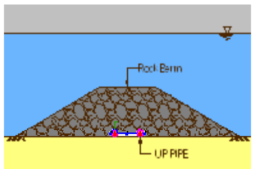
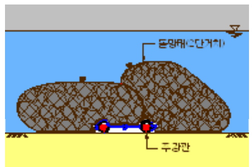
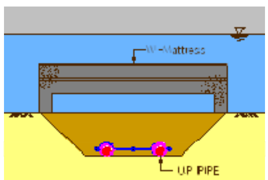
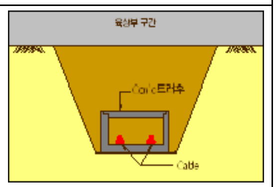
When selecting the protection method of cable, initially the steel pipe and UP pipe were examined. Finally the UP pipe was selected because of the excellent prevention of abrasion and shock-absorbing in bedrock section. And the pulling tension could be reduced under 10 metric ton. Also it could be reused when repairing the cable.

Before cable laying operation was commenced, the cables were already equipped with the UP pipe. Cables were also protected by rock dumping, trenching and stone bag after laying on the seabed. Finally, the outdoor terminations were installed at the each end point to connect with the existing overhead lines.

The cable protection method in each section of cable route is show in Fig.12.

Figure 12: Cable protection



Type	Rock Berm(Bedrock)	Stone-bag(Bedrock)
Secti-on	D,F,H,M,N	C,E,G,I
Secti-onal view	 with UP pipe	 with steel pipe
Type	W-Mattress(fish farm)	Land
Secti on	B,O,P	A,Q
Secti-onal view	 With UP pipe	

Before mobilizing to the site, the cable laying vessel was altered to accommodate strong tidal current. The band was added beside of chute for cable protection by turning the vessel to 90° degree in strong tidal current. The guide was positioned in an elevated position for cable protection in vertical movement of the vessel. The vessel, chute and actual cable laying operation are show in Figure 13 and 14.

After installation, the commissioning test which is AC withstand voltage test and insulation resistance test was performed successfully.

Figure 13: Cable Laying Vessel

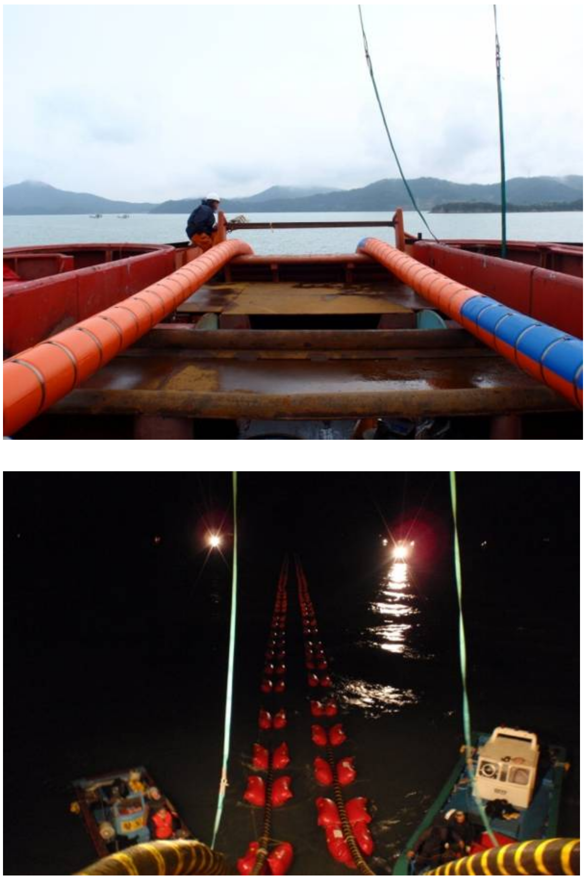


Figure 14: Simultaneous Cable Laying

5 CONCLUSION

The AC 154kV XLPE 3core fibre optic embedded power submarine cable system has been successfully developed and installed. The system is now in operation. Several offshore wind farms are being planned to be constructed in Korea, Especially in the west side of Korea for 5GW project. The success of this project will enable us to explore more opportunities in offshore wind farm markets, not only domestic but also overseas countries.

6 REFERENCES

[1] " Recommendations for mechanical tests on submarine cables", Electra 171, 1997

[2] " Recommendations for testing of long AC submarine cables with extruded insulation for system voltage above 30(36) to 150(170)kV", Electra 189, 2000

[3] " Power cables with extruded insulation and their accessories for rated voltages above 30kV up to 150kV", IEC60840, 2004