



**FOUNDATIONS**

**OF**



**XLPE INSULATED**

**CABLE**

Edited by

Wang Wei  
Zheng Jiankang  
Li Huachun  
Luo Jinsheng  
Ren Xiaohong  
Zhao Ping

**交联聚乙烯电缆基础教程**

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**【Abstract】** From using point of view, this book go into particulars all performance of the material and construction on XLPE insulated power cable from theoretical and performance calculation, and tell about the option, installation, operation, maintain, test on site, hand-over and prevention test, test standard and standard demand over this base. This book also introduce the some managerial experiences used to XLPE insulated power cable on the Electric Power Supply Bureau, and analyse the development tendency of XLPE insulated cable.

The book is a studied and worked handbook of engineer necessity used on the XLPE insulation cable, a reference book of engineer at the Electric Power Supply Bureau in China.

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# Introduction

Along with power industry rapid development, amount of power cable usage have happened a wonderful change, the use of XLPE insulated power cable especially in recent years. The skilled worker on the spot needed to know the knowledge of technical characteristic, install and operation, maintenance and hand-over test on new insulation cable — XLPE insulated power cable.

Today, we have more of teaching material on oil paper insulation cable and oil filled paper insulation cable, but don't have a book of detail introduced XLPE insulation cable. So, our author sum a some of experience on the spot and knowledge in theory, and the technical material of training for staffs written by old Ministry of Water Conservancy and Electric Power on XLPE insulated cable. From the more side of technical characteristic, cable manufacture, install and operation, maintenance and hand-over test, up-to the minute developed on line test technology, we introduce the knowledge of XLPE insulation cable, semiconductor screen, insulation configuration design, type selection of cable and accessory. the side content on line test is see for the first time . this content has more help for extensive use of XLPE insulated cable.

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Xi'an Electric Power Supply Bureau; Li Huachun, Beijing Electric Power Supply Bureau; Luo Jinshen, Hangzhou Electric Power Supply Bureau; Zhao Ping, Shijiazhuang Electric Power Supply Bureau. An great many of help has been achieved by the more old experts in the whole nation and all author when this book is writed. Hereon, we express our thank for your supply.

Because of our interpreted boundless the traces, we have collected the technical material was limited at the same time, we adjure hugeness reader to give our criticism, this can tell our to do advancement.

**Author**

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## Chapter one Development history of XLPE insulated cable

Although only 30 years' usage and development XLPE insulated cable has, it has been widely used for its good mechanical behavior, convenient installation and maintenance, good insulating ability. Its transmission capacity is larger than the oil-impregnated paper insulation cable in the same section and its production process is easy so that we can produce it at larger scale with the development to the material industry and some other properties.

Nowadays, the practical voltage of XLPE insulated cable is up to 400kV while it is been used in the transmission and distribution system, and in the test operation condition the practical voltage can be 500kV. In the developed capitalism countries, the medium-low voltage XLPE insulated cable had developed and been operated in 1930s to 1940s. From Tab. 1. 1, we can see, with the increasing of the voltage, the oil-impregnated paper insulation, PVC insulation, non-drain paper insulation, butyl rubber and etc. were not operated, but PE, XLPE synthetic rubber material was developed rapidly during the World War II, the voltage class became higher. After 1972, the XLPE insulated cable over 110kV was developed.

Fig. 1. 1 and Fig. 1. 2 are the curve of the voltage class development of the cable. From them, we can find a high speed with the development of the XLPE insulated cable as plastic insulated cable development. For example, the development history of the XLPE insulated cable in Japan is:

Tab. 1.1 Development of XLPE and PE insulated cable in countries of the world

Country	Age	Insulated type	Voltage grade/kV	Section /mm <sup>2</sup>	Max electricfield strength /( $kV \cdot mm^{-1}$ )	Insulation thickness/mm	Remark
USA	1970	XLPE	138				Test installation
USA	1981	XLPE	345		10.0	26.2	Trial-manufacture
Sweden	1973	XLPE	145	500	7.0	20.0	Operation
Sweden	1973	XLPE	245		12.0		Operation
Japan	1970	XLPE with silicon oil					Operation
Japan	1970	XLPE	154		20.0		Operation
Japan	1978	XLPE	187/225	1 000	15	25.0	Trial-manufacture
France	1969	XLPE	225/250/	1 200	8.3	22.0	Trial-operation
France	1981	PE	400	1 500	15.0	27.0	Trial-manufacture
Germany	1968	PE	110				Operation
Germany		PE	220		10.0		Trial-manufacture
Germany	1981	PE	400				Trial-manufacture
Italy		EPR	150	400	6.3	24.3	Operation
Hungary		PE	120	240			Cable system with cooling water

In 1955, this kind of cable was prepared firstly.

In 1961, the voltage class was up to 33kV.

In 1962, the voltage class was up to 66kV.

In 1965, the voltage class was up to 77kV.

In 1969, they can produce the XLPE insulated cable at 110kV.

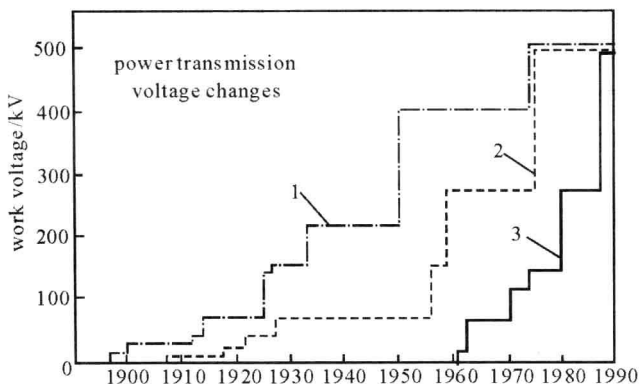


Fig. 1.1 Development history of oil paper and XLPE cable

1—abroad oil paper cable; 2—internal oil paper cable; 3— plastic insulated cable

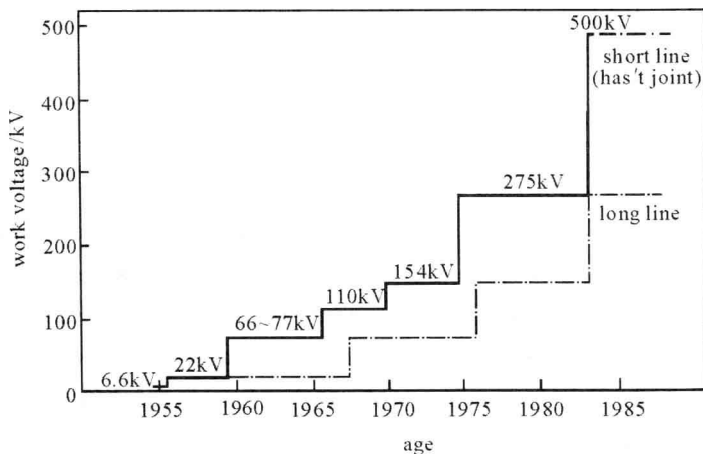


Fig. 1.2 Development history of maximum working voltage of XLPE cable

The high-speed represent the speed of the XLPE insulated cable development of the developed industrial countries from the trends of XLPE and PE insulated cable development (Tab. 1. 1). Today, the usage of XLPE insulated cable has been occupied 85% of the amount of the copper in the whole power cable production in Japan. XLPE insulated cable at 275kV have been operated and XLPE insulated cable at 500kV whose section is 2000mm<sup>2</sup> have been prepared in Japan. North Europe, East Europe, Russian etc. have produced this kind of cable in a large number. In Sweden, XLPE cable had been produced in 1965. By the end of 1975, XLPE cable at 12kV had accounted for 70% of the total, and XLPE cable at 24~84kV had accounted for 100% of the total. In the United States, the low-voltage oil-impregnated paper cable and plastic cable are used together in 1964, and over 15kV, the PE insulated cable and the XLPE insulated cable began to trial run. In Germany, PVC insulated cable could be used at 6~10kV, but in Britain, non-drain oil-impregnated paper insulated cable was used and the plastic cable was restricted. In 1970, in the field of low-voltage power cable from 10kV to 30kV, the number of the PE cable was 16% of the total and XLPE cable was from 6% to 8% of the total in countries of the world. In the later period of 1970s, the PE insulated cable and XLPE was developed rapidly because the material problems like the water tree and electric tree in insulated material of medium and low voltage power cable were solved in America. Moreover, at 15kV system, the plastic cable was used in a large number but the oil-impregnated paper cable was almost eliminated. Tab. 1. 2 indicates the ratio of usage of different cable types in America in 1971.

**Tab. 1.2 The ratio of usage of different cable types in America**

Insulated type	Medium voltage(MV)	Low voltage(LV)	Equipment cable
Oil-impregnated paper	0.7		
XLPE	43.0	87.9	86.6
PE	50.8	2.8	6.5
PVC		3.1	2.7
EPR	1.4	1.1	1.1
Butyl rubber	4.1	5.1	1.1

In 1975, the rubber insulated cable and plastic insulated cable began to have the lead in the competition with the oil-impregnated paper insulated cable. In the United States, the MV and LV cable was 99% of the rubber and plastic insulation's total, among them in 15kV, PE and XLPE insulated cable were 95% of the total, EPR insulated cable was 2% of the total, the ratio of the oil-impregnated paper was less than 1%. In Germany, the plastic cable at 1kV formed 90% of the total, at 10kV, XLPE was 5%, PE was 8%, PVC was 12%, oil-impregnated paper was 72%; from 25kV to 35kV, XLPE was 34%, the oil-impregnated was 42%. In 1980s, the ratio of the oil-impregnated decreased to 20%, the ratio of XLPE increased to 56%. In Britain, under 1kV and below, PVC and XLPE were 67% the total and increased to 75% in 1980s. In later period of 1980s to early period of 1990s, at 10kV, XLPE insulated cable would exceed oil-impregnated paper cable slightly especially in some new projects, and oil-impregnated paper insulated cable would be eliminated. From 20kV to 30kV, XLPE insulated cable and other rubber and plastic cable would be 80% of



the total or more, in high-voltage cable field, XLPE insulated cable would reach the ratio of the oil-impregnated paper insulated cable's usage. Although the extra high voltage (EHV) as 765kV, XLPE insulated cable cannot as good as the oil-filled cable. In the future, it will be possible that XLPE insulated cable will catch up with oil-filled cable or exceed the oil-filled cable because the manufacturing level of XLPE insulated cable has the high operating temperature. For this reason, the carrying capacity of XLPE cable will be increased; XLPE insulated cable also has some other advantageous, such as short bending radius, little weight, no need of oil supply system, convenient maintaining and installation.

We introduce it in respect of the manufacturing technology. Early days, XLPE made steam as the medium for heating and pressurizing, so we call this method is gone by the name of wet cross-linking. According to common opinions, that insulated material of XLPE insulated cable has the microporous measuring with micrometer, and the steam of wet cross-linking will seep into the molten PE easily in the condition of high temperature and pressure, so this method will increase the number and the size of the microporous exists in XLPE. In early period of 1970s, the manufacturers from countries of the world developed dry cross-linking to reduce the microporous and water exist in XLPE, and the reliability of the operation of XLPE insulated cable was improved. In later period of 1970s, there was a new and important breakthrough in respect of the manufacturing technology that the new screen material of semiconductor and the super clean insulated material were developed except furthering the good physical property and electric property. It reduced the impurity in insulation, and in respect of manufacturing process, imported the