

# Preface

Viewed from the distribution of the energy resources throughout China, though the total reserves are abundant, the resource distribution and productivity distribution are rather unbalanced. The coal resource is mostly located in the North and Northwest China, the hydropower resource is mainly located in the Southwest China, the onshore wind energy and solar energy resources are mainly located in the Northwest China, while the energy demands are mainly concentrated in the Central China and China's east coastal areas. The distance between the energy base and the load center is up to 1000 km. The energy resources used for power generation are mainly coal and water, and the energy resources and productivity development are reversely distributed, which is the basic national condition of China. Since the reform and opening-up, the electricity demand of China has been continuously and rapidly increased, and the scale and capacity of the newly built power sources have been increased. Subject to the energy transmission capacity and environmental protection requirements, China will inevitably develop the long-distance and large-capacity power transmission technology to improve the development and utilization rate of the resources, alleviate the pressure in the energy transmission, and meet the requirements of the environmental protection.

The UHV power transmission technology is the power transmission technology with the highest voltage level in the world presently, and the most prominent characteristic thereof is the large-capacity, long-distance, and low-loss power transmission. The transmission capacity of the 1000 kV UHVAC system is about 4–5 times that of the 500 kV extra-high voltage (EHV) AC system. The development of the UHVAC and UHVDC power transmission can effectively solve the issue of large-scale power transmission. In addition, compared with the EHV power transmission line, the UHV line occupies less land resource and achieves quite prominent economic and social benefits under the same power transmission capacity. The building of the national-level power grid in which the UHV grid acts as the backbone and the grids of all levels develop in a coordinated manner, meeting the basic national condition of China that the energy resources and economic development are reversely distributed and according with the China's overall arrangement for energy-saving and emission reduction, is the effective way to

realize the coordinated development of grids and power sources and the urgent demand for the construction of the resource-saving and environment-friendly society.

In the world, a few countries such as the former Soviet Union, Japan, America, Italy, and Canada have ever conducted tests and researches on the UHVAC power transmission technology. During 1981–1994, the former Soviet Union successfully built a total of 2364 km 1150 kV power transmission lines, among which, the Ekibastuz–Kokshetau line (495 km in length) put into operation at 1150 kV in 1985 was the first UHV power transmission line put into actual operation in the world. Japan built the 1000 kV UHVAC double-circuit power transmission line in the 1990s, which, however, was under the 500 kV reduced voltage operation all the time. The overseas DC power transmission project with the highest voltage level that has been built and put into operation is the Itapúa Power Transmission Project in Brazil, which includes double-circuit DC line with voltage level of  $\pm 600$  kV and rated transmission power of 3600 MW. The Soviet Union ever planned to build a  $\pm 750$  kV UHVDC power transmission line project from Ekibastuz to Tambovskaya Oblast, the first engineering practice of the UHVDC power transmission technology in the world, and commenced the construction in 1980, but finally ceased the construction due to the political and economic reasons, after the completion of the construction of 1090 km-long line.

The research on the UHV power transmission was started relatively late in China. Since 1986, the research on the UHV power transmission has been successively included in the key science and technology research programs during China's "Seventh Five-Year Plan," "Eighth Five-Year Plan," and "Tenth Five-Year Plan". During 1990–1995, the Significant Project Office of the State Council organized the "Demonstration of Long-distance Transmission Modes and Voltage Levels"; and during 1990–1999, the State Scientific and Technological Commission organized the monographic researches such as the "Preliminary Demonstration of UHV Power Transmission" and "Feasibility of Application of AC Megavolt Ultra-high Voltage for Power Transmission". State Grid Corporation of China put forward for the strategic concept of "establishment of the UHV-based robust state grid" in 2004 the first time to focus on the construction of a network system in which the UHV grid acts as the backbone and the grids of all levels develop in a coordinated manner. China Southern Power Grid Co., Ltd. also began to study the feasibility in the construction of  $\pm 800$  kV DC power transmission project in 2003. In 2006, the National Development and Reform Commission formally approved the 1000 kV UHVAC Demonstration Project from Southeast Shanxi through Nanyang to Jingmen connecting the North China grid and Central China grid. In 2007 and 2010, China respectively completed and put into operation the 1000 kV Southeast Shanxi–Nanyang–Jingmen UHVAC Power Transmission Demonstration Project and  $\pm 800$  kV Yunnan–Guangdong and Xiangjiaba–Shanghai UHVDC Power Transmission Projects. Since then, the UHV power transmission has accomplished a rapid development in China. Up to August 2017, six 1000 kV UHVAC power transmission lines and nine  $\pm 800$  kV UHVDC power transmission lines have been built and put into operation. There is still another 1000

kV UHVAC power transmission line and the other four  $\pm 800$  kV UHVDC power transmission lines will be put into operation at the end of 2017. Moreover, one  $\pm 1100$  kV UHVDC power transmission line is being built and will be put into operation in 2018..

The UHV power transmission is the engineering technology leading the world's power transmission technology. Its rapid and successful development in China has fully proven the tremendous achievement accomplished by China in the technological aspect of the electric power system. Meanwhile, the complexity of the UHV power transmission technology and the urgency of its development in China require that the professional personnel engaging in the work related to the electric power system have a deeper understanding and mastery of it. Based on the significant research results obtained by Zhejiang University High Voltage Laboratory in the field of UHVAC and UHVDC power transmission in the last decade and the abundant practical experience accumulated by Zhejiang Electric Power Design Institute in the field of UHV power transmission engineering over the years, and in combination with the relevant research results in the aspect of UHVAC and UHVDC power transmission technology and the actual operation experience in China and abroad, this book systematically introduces the key technical issues existing in the UHVAC and UHVDC power transmission.

This book consists of four sections containing a total of 28 chapters, and focuses on the study of the overvoltage, insulation coordination and design of the UHV power grid. Section I, consisting of three chapters provides an overview of the development of the UHV power transmission and the system characteristics and economy thereof. Section II, consisting of ten chapters discusses the UHVAC system. Section III, consisting of ten chapters discusses the UHVDC system. Section IV, consisting of four chapters discusses the design of the UHVAC substation and UHVDC converter station as well as UHVAC and DC power transmission lines. Hao Zhou is responsible for the final compilation and editing of the whole book, and Wenqian Qiu, Xu Deng, Jiyuan Li and Jingzhe Yu act as the chief reviewers.

We sincerely hope that this book can better help the readers understand the UHVAC and UHVDC power transmission technology and can provide reference for the research work carried out by the technicians engaging in the work related to the electric power system. This book is jointly edited by the relevant researchers from Zhejiang University, Zhejiang Electric Power Design Institute, State Grid Zhejiang Electric Power Company, China Electric Power Research Institute, China Southern Power Grid Corporation, East China Grid Company Limited, Southwest Electric Power Design Institute, and North China Electric Power University. The editing of this book has received the guidance and help from numerous experts. Gratitude is hereby expressed to Academician Han Zhenxiang, Academician Chen Weijiang, Professor Zhao Zhida, Professorate Senior Engineer Zhou Peihong, Professorate Senior Engineer Zhang Cuixia, Professorate Senior Engineer Li Yongwei, Professorate Senior Engineer Gu Dingxie, Professorate Senior Engineer Nie Dingzhen, Professorate Senior Engineer Tian Jie, Professor Kang Chongqing, Professor Cui Xiang, Professor Li Chengrong, Professor Wen Fushuan, Professor

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The editing of this book had been in progress for nearly 8 years and agglomerates the research results of the authors. Nevertheless, due to the authors' limited theoretical level and practical experience, inappropriateness and errors are unavoidable. Any comment will be highly appreciated.

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Hao Zhou

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Zhou, H.; Qiu, W.; Sun, K.; Chen, J.; Deng, X.; Qian, F.;

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