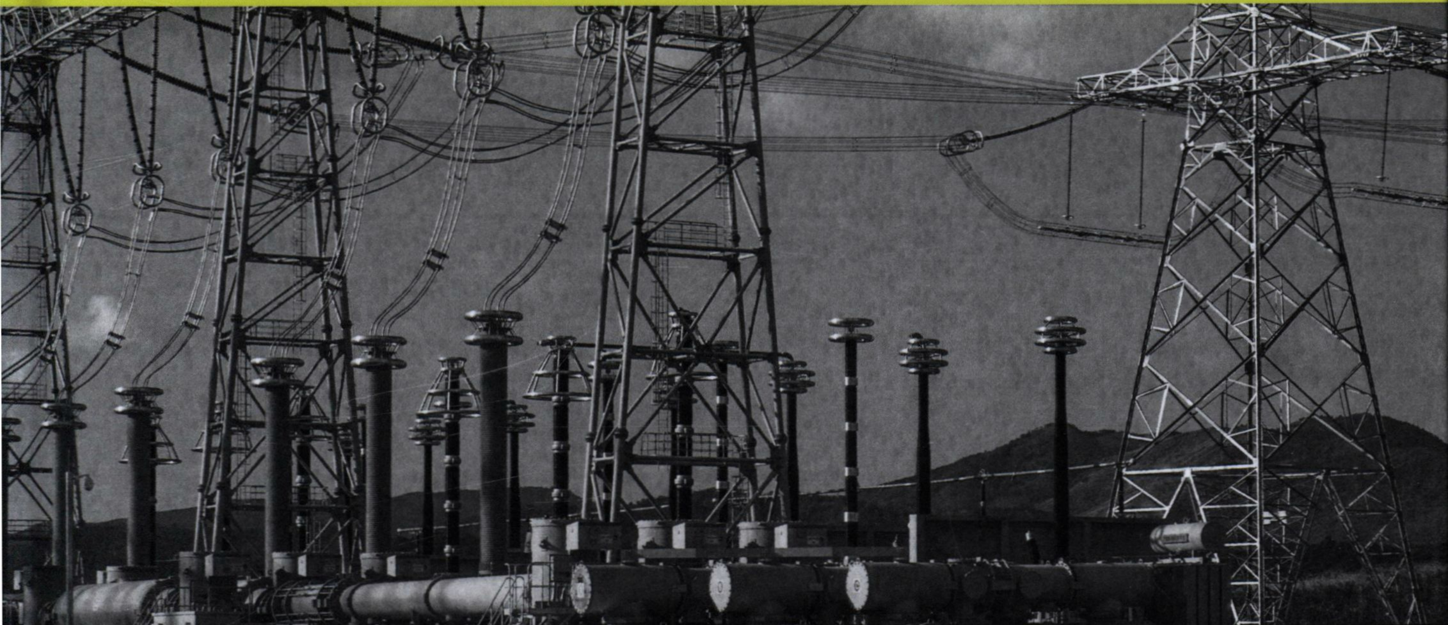
INSPECTION AND MONITORING TECHNOLOGIES OF TRANSMISSION LINES WITH REMOTE SENSING



YI HU
KAI LIU

中国电力出版社
CHINA ELECTRIC POWER PRESS

INSPECTION AND MONITORING TECHNOLOGIES OF TRANSMISSION LINES WITH REMOTE SENSING

YI HU • KAI LIU

Inspection and Monitoring Technologies of Transmission Lines with Remote Sensing presents the world-class practices developed by the State Grid Corporation of China (the organization responsible for the world's largest power transmission network) in solving the challenges of maintaining and guaranteeing the reliability of transmission lines, given the physical size, geographical, and climate variance to which high-voltage transmission lines in China are subject. These monitoring strategies have widespread application in view of the increasing global demand for energy and the need to improve power grid vulnerability from both external and internal factors. The remote sensing technologies outlined will improve mitigation capability enabling the identification of threats in good time to maintain a safe and reliable operation of transmission lines.

Key Features

- Organized in five sections, covering power line fundamentals, remote sensing technologies, inspection technologies, fault detection technologies, and on-line monitoring
- Covers current and developing technologies, including satellite remote sensing technology, infrared and ultraviolet detection technology, helicopter inspection technology, and condition monitoring technology
- Covers operational and technical principles, as well as equipment used in transmission line inspection and monitoring, with a focus on practical equipment and systems parameters to ensure secure operation and maintenance of transmission lines.

Inspection and Monitoring Technologies of Transmission Lines with Remote Sensing provides authoritative guidance for those working in transmission line operation and high-voltage engineering works and power grid planning enabling them to deliver control technologies that ensure safe and consistent transmission operation.

About the Authors

Yi Hu is professor and vice president of the China Electric Power Research Institute, Wuhan, China. He has received several first-class, second-class, and other special awards from the State Grid, Chinese Electric Power, and from the government for his achievements in EHV and UHV transmission, high-voltage engineering, and transmission line inspection and maintenance.

Kai Liu is senior engineer and department director of the China Electric Power Research Institute. He has published more than 30 papers in academic journals and received provincial and state grid rewards on his achievements in transmission line inspection and maintenance.

Electrical Power Engineering

ISBN 978-0-12-812644-8

ELSEVIER

ACADEMIC PRESS
An imprint of Elsevier
elsevier.com/books-and-journals

中国电力出版社
CHINA ELECTRIC POWER PRESS

9 780128 126448

INSPECTION AND MONITORING TECHNOLOGIES OF TRANSMISSION LINES WITH REMOTE SENSING

HU • LIU

ACADEMIC PRESS

Inspection and Monitoring Technologies of Transmission Lines with Remote Sensing

Yi Hu and Kai Liu
China Electric Power Research Institute, Beijing, China

中国电力出版社
CHINA ELECTRIC POWER PRESS

ELSEVIER

ACADEMIC PRESS
An imprint of Elsevier
elsevier.com

Academic Press is an imprint of Elsevier
125 London Wall, London EC2Y 5AS, United Kingdom
525 B Street, Suite 1800, San Diego, CA 92101-4495, United States
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

ISBN: 978-0-12-812644-8

Publisher: Jonathan Simpson
Acquisition Editor: Glyn Jones
Editorial Project Manager: Naomi Robertson
Production Project Manager: Susan Li
Designer: Mark Rogers

Typeset by MPS Limited, Chennai, India

Inspection and Monitoring Technologies of Transmission Lines with Remote Sensing

Preface

Transmission lines are important components of power grids, and the status of transmission line equipment directly affects the safe and reliable operation of power grids. In consideration of the requirements of long distance and large capacity power transmission, alternating current and direct current ultra-high voltage transmission lines have been put into commercial application and operation successively. The distribution areas of high voltage transmission lines are wide, and the meteorology and geology, etc., along transmission lines are complex, which significantly affects the safe and stable operation of transmission lines. In order to guarantee the reliable operation of lines, the research and application of line inspection and monitoring technology with remote sensing is very necessary.

In recent years, with the in-depth research of power transmission lines inspection and monitoring technology by remote sensing, many new technologies, tools, and methods are applied in the operation and maintenance of transmission lines. For instance, satellite remote sensing technology can be used to monitor lines in wide areas; infrared and UV detection technology can be used to conduct noncontact nondestructive detection on targets; inspection technology with helicopter and inspection technology with UAV have the advantages of wide inspection range and high efficiency; online monitoring technology can monitor operating conditions of transmission lines continuously or periodically. The application of these new technologies and methods provides an effective means for accurately and fully knowing the operation condition of transmission lines, and finding line faults and hidden dangers in a timely fashion, and it plays an important part in guaranteeing the safe and reliable operation of transmission lines, and so the prospects for this application are very good indeed.

This book is compiled to meet the requirements of the personnel who are responsible for the operational and technological management of power transmission lines, and is based on reference to the relevant materials and relevant research results. The book is divided into five chapters. The structure, main parameters, and electrical and mechanical characteristics of transmission lines are introduced in Chapter 1, Parameters and characteristics of transmission lines, and the characteristics and principles of infrared and UV detection technology and remote satellite sensing technology, and their application in line monitoring are introduced in Chapter 2, Remote sensing and remote measurement technology of transmission lines. The characteristics and application of helicopters, UAVs, and robot inspection technologies are the main contents of Chapter 3, Tour inspection technology of transmission lines; detailed information about line detection and detection methods and devices are covered in Chapter 4, Transmission lines detection technology. The main content of Chapter 5, Devices and technology for monitoring transmission lines, is the online monitoring technology of transmission lines, including online monitoring devices and their application on lines with icing, pollution, and windage yaw, etc.

The book has been compiled principally by Hu Yi and Liu Kai; and Liu Ting, Liu Yan, Xiao Bin, Peng Yong, Han Fang, etc. participated in the compilation. In addition, those who participated in the research of inspection technology with remote sensing include Wang Linong, Hu Jianxun, Xu Ying, etc. In the process of compiling the book, the strong support of Liu Kaipei, Lin Fuchang, and others has been invaluable, and we give our sincere thanks to them!

Because of the nature of the text as regards editing, it is hard to avoid any errors, and readers' corrections are expected, and their forbearance requested!

Contents

CHAPTER

Parameters and characteristics of transmission lines

1

1.1 GENERAL DEVELOPMENT AND MAIN STRUCTURE OF TRANSMISSION LINES

1.1.1 GENERAL DEVELOPMENT OF HIGH VOLTAGE TRANSMISSION SYSTEMS—CURRENT STATUS

Modern large power plants are mostly built in resource concentrated places, while most electricity load centers are clustered in industrial zones and metropolises. As the distances between power plants and load centers are long, high voltage, high power capacity, and long distance transmission lines are economical ways of transmitting electrical energy. Therefore, transmission lines, as an important component of a power system, carry out the functions of transmission and distribution of electrical energy. To reduce electrical power loss in the process of electric power transmission, different voltage classes are adopted for transmission lines, based on transmission distance and capacity [1].

In 1882, the French physicist Deprez was the first to complete a long-distance direct current transmission test, which had practical significance that resonated in the history of the electric power industry. Through a 57 km telegraph wire (a steel wire 4.5 mm in diameter), at a voltage of 1500–2000 V, the electrical energy generated by the direct current generator (installed in Miesbach coal mine) was transmitted to the first electrically lit international electrotechnical exhibition, at the Glass Palace in Munich, and used to provide electricity for a set of foundation pump motors. After the 1880s, the application in engineering of alternating current transmission technology began. In 1891, the Frankfurt power line, the world's first three-phase alternating current high voltage transmission line, running from Laufen to Munsen Riverside, with a total length of 175 km and voltage of 15.2 kV, was put into operation in Germany.

In 1908, the first 110 kV transmission line was built by the United States, and the first 230 kV transmission line was built and put into operation in 1923. After the 1950s, the world power industry developed rapidly, voltage class was continuously increased, and the scale of power grids was continuously enlarged. In 1952, the first 380 kV alternating current transmission line in the world was put into commercial operation in Sweden, followed in 1964 by the world's first 500 kV alternating current transmission line; 735 kV, 750 kV, and 765 kV transmission

Inspection and Monitoring Technologies of Transmission Lines with Remote Sensing.
DOI: http://dx.doi.org/10.1016/B978-0-12-812644-8.00001-1

lines were built in Canada, the Soviet Union, and the United States successively during the period of 1965–69. Later, some countries also conducted research on ultra-high alternating current transmission technology.

Meanwhile, project construction for direct current transmission systems was also rapidly developed. Following the success of the high voltage direct current transmission project of the island of Gotland, Sweden, put into industrial operation in 1954, the total number of high voltage direct current transmission projects put into operation worldwide until the end of 2008, was more than 76, and the total power capacity topped 70,000 MW. More than twenty 450–600 kV direct current transmission projects were included.

In 1954, the first 220 kV high voltage transmission line self-designed and constructed by China was built; in 1972, the first 330 kV extra high transmission line in China was built; in 1981, the first 500 kV extra high transmission line was put into operation, and China became the eighth country with a 500 kV extra high transmission line; an 1000 kV ultra-high alternating current transmission line was put into operation in 2009, making China the country with the highest voltage class of alternating current transmission, a status it retains today [1].

Though direct current transmission research and project construction were embarked on later, their development was rapid. In 1978, the Zhoushan HVDC transmission project with Chinese independent technology was put into commercial operation, and then the application and development of direct current transmission began in China. At the end of 2009, the Yunnan–Guangdong ± 800 kV ultra-high voltage direct current transmission project with a rated capacity of 5000 MW was successfully initiated in single-stage production; the Xiangjiaba–Shanghai ± 800 kV ultra-high voltage direct current transmission demonstration project with a rated capacity of 6400 MW was put into operation in 2010. China has become the country with the highest voltage class of direct current transmission.

1.1.2 STRUCTURE AND MAIN PARAMETERS OF TRANSMISSION LINES

1.1.2.1 Composition of transmission lines

The elements of transmission lines mainly include conductors, lightning shield wires (or overhead ground wires, or basically, ground wires), fittings, insulators, towers, guy wires and foundations, etc., as shown in Figs. 1.1 and 1.2.

1.1.2.2 Each component and its role

1.1.2.2.1 Conductors

Conductors are the elements used to conduct current and transmit electricity.

Bare metal conductors, also called bare conductors, are adopted in general overhead transmission lines. Conductors are fixed in towers for the purpose of transmitting electric current. Since conductors bear tension force, and operate in atmosphere for many years, and are affected by wind, ice, rain, snow, and