两大领域前沿成果展示
国内与国外专家汇集
学术研究与技术应用兼备
来自28个国家和地区

国内外最新继电保护及控制技术研究

（下册）

中国电机工程学会继电保护专业委员会 编

中国水利水电出版社
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内 容 提 要

本书是第六届现代电力系统自动化和保护国际学术研讨会（APAP2015）论文集，收录了来自20个国家和地区的174篇论文。这些论文反映了国内外电力系统继电保护和自动化业界共同关注的问题及最新研究成果，内容涉及继电保护、变电站自动化、电网安全稳定控制、电网运行及分析、高压直流输电及电力电子设备控制保护、分布式发电、配电网保护和控制等。论文集内容丰富，实用性强，对电力系统保护和控制技术研究有较高参考价值和借鉴意义，可供相关学者、专家以及工程技术人员参考。

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前　言

中国电网是世界上发展最快的电网。大容量远距离、交直流混联电能输送，大规模可再生能源接入，以及新一代电力电子设备的应用，满足了中国经济发展在电能生产与输送方面的需求，也给继电保护、自动化和控制系统带来了许多新的问题和挑战。

现代电力系统自动化和保护国际学术研讨会（APAP）于 2004 年由韩国明知大学 Lee Seung-jae 教授发起，其目标是为电力系统继电保护和自动化领域的专家、学者搭建一个国际性的学术交流平台。同年 10 月，在韩国济州岛召开第一次会议。2007 年、2009 年在韩国济州岛召开了第二次、第三次会议。2011 年在中国北京召开了第四次会议。2013 年 10月在韩国济州岛召开了第五次会议。

南京素有“江南佳丽地，金陵帝王州”之美称，也是中国科技最为发达的城市之一。在这座古老而又现代的城市里，聚集着大批电力自动化企业，已成为中国该领域最重要的研发和产业化基地。他山之石，可以攻玉。为借鉴国际同行的研究成果和运行经验，应对面临的问题和挑战，中国电机工程学会继电保护专业委员会决定在南京承办第六届现代电力系统自动化和保护国际学术研讨会（APAP2015），并将会议主题确定为“当前和未来电力系统中保护、自动化和控制系统面临的机遇与挑战”。相信广大与会代表能在这个平台上结识同行，分享新思想、新技术、新经验，共同推进本行业技术进步。

研讨会的征文和筹备，得到了相关各方大力支持和协助。研讨会共收到来自 22 个国家和地区的论文摘要共 268 篇。经评审，最终录用 174 篇，汇编成集。值此论文集出版之际，我们衷心感谢所有关注、支持和帮助本次研讨会的单位和个人。

中国电机工程学会继电保护专业委员会

2015 年 9 月

Foreword

Electric power system in China experienced the fastest development around the world in the past decades. Application of bulk long-distance power transmission on hybrid AC / DC transmission lines, adoption of large-scale renewable energy generation, installation of new generation power electronic equipments, meet the needs of China's economy development on electric energy generation and transmission, but also bring about many new problems and challenges to protection, automation and control system.

APAP was initiated in the year of 2004 by Professor Lee Seung-Jae from Myongji University in Korea. The goal of APAP is to build an international platform for experts, scholars and engineers to carry out academic exchanges in the field of electric power system protection, automation and control. The 1st APAP was held in October of the same year, followed by the 2nd one in 2007, and the 3rd one in 2009 in Jeju Island, Korea. The 4th one moved to Beijing, China in 2011, and the 5th one returned to Jeju Island in October 2013.

Nanjing is known as the "Beautiful place in the south of the Yangtze River and imperial state at Jinling" in the history. Now she is one of the most developed cities in high technology. With a large number of electric power automation enterprises, this ancient and modern city has become the most important research and manufacture base in this field. Wise men learn by other's mistakes. In order to learn from research results and operation experience around the world, to deal with the problems and challenges facing today, Relaying Protection Study Committee of CSEE (Chinese Society for Electrical Engineering) is pleased to organize the 6th International Conference on Advanced Power System Automation and Protection (APAP2015) in Nanjing. The theme of the conference is “Opportunities and challenges for PACS in existing and future power system”. We believe that on this platform the delegates can get to know each other better, share new ideas, new technologies and new experiences, and promote progress in the industry jointly.

Strong supports from relevant parties are essential to run the conference. 268 synopses from 22 countries and regions were received, among which 174 full papers were accepted finally and published in this proceedings. We would like to thank all the bodies and individuals for your attention, support and assistance.

Relaying Protection Study Committee of CSEE

September 2015

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A New Dynamic Optimization Method of Voltage and Reactive Power Control Strategy for UHV System

Xin Wang, Shicong Ma, Jian He, Shanshan Wang, Zeng Bing, Jian Zhang

Abstract--**With the rapid development of electric power demand, a national wide and interconnected power grid based on ultra high voltage (UHV) technology is formed in China to improve further utilization of fossiland other renewable energy. The fluctuation of transmission power on UHV line, which is caused by uncertain power output of renewable energy or outages of main power plant, needs reactive power optimization and voltage control to ensure system safe and stable. From the time dimension, the dynamic optimizationmethodis used to switch on/off the low voltage capacitors or reactors to reduce the traversing reactive power in this paper. At the same time, the voltage of UHV line is dispatched to meet the demand of reactive power in the maximal degree. Finally, a simplified mathematical model of UHV grid is adopted to illustrate the proposed method. The simulation results showed that the DPM can effectively solve the sequential reactive power optimization problem.**

Index Terms--**Dynamic optimization Method, Reactive power, Renewable energy, Ultra high voltage (UHV), Voltage control**

I. Introduction

WITH the rapid development of economic society and electric power demand, the ultra high voltage (UHV) grid has been formed to in China to improve further utilization of fossil, hydro, wind, solar energy and other resources, which ensures the optimal allocation of electric energy across the country. However, the random and intermittent characteristics of renewable energy integrated to system cause the fluctuation of transmission power on UHV line and bring new threats to system operation. Thus, the reactive power optimization and voltage control of UHV grid has been widely concerned in system planning and operation [1], [2].

The reactive power optimization is a typical nonlinear problem, which synchronously has the continuous variables and discrete variables. There is already a rich literature to utilize the optimal power flow and global optimization algorithms to dispatch the reactive power, which ignores the time behavior of power system [3], [4], i. e. the traditional day-ahead operation schedule only focuses on the optimal allocation of reactive power for each time interval, and lacks attention to the overall optimization for the whole research horizon. Thus, the dynamic programming method is used to optimize the operation and control sequence of reactive power compensation devices and line voltage in this paper.

Dynamic programming is an effective tool to solve the optimal problem on multistep decision process, where a multistep process is converted into a series of single stage problems. The dynamic programming has been widely used in power system analysis, e. g. power system stability enhancement [5], [6], system reliability and planning [7]. Especially in reactive power optimization, a dynamic programming approach is presented to find a proper dispatching schedule for the shunt capacitors in a distribution substation as well as on distribution feeders in [8]. Considering the overall economy of power system operation, the dynamic programming is adopted to optimize the reactive power on UHV transmission lines for 24 hours a day.

The fluctuation of active power on UHV transmission lines causes wide variation of reactive power, which brings a great burden on the reactive power balance and voltage control. In the practical engineering, the fixed shunt reactors are installed on the high voltage side to compensate the charging power. According to the transmission power, the shunt reactors and capacitors on the low voltage side should be switched on/off to reduce the traversing reactive power [9].

In the present study, we investigate the sequential reactive power compensation schemes of UHV grid to ensure the overall traversing reactive power minimum. First, a mathematical model of UHV transmission line is introduced. Based on this model, a numerical method is presented to calculate the reactive power loss and compensation amount. Secondly, we propose a time-series reactive power optimization model, where the number of shunt low voltage capacitors / reactors and line voltage are considered as control variables. Finally, the dynamic programming is used to solve the proposed time-series optimal problem.

The remaining part of this paper is organized as follows. Section II introduces the power model of UHV transmission line. Section III describes the proposed time-series reactive power optimization model. Case studies are discussed in Section IV. Conclusions are drawn in Section V.

II. Traversing Reactive Power

A. Reactive Power and Voltage Characteristics

Since the unit resistance is far smaller than the unit reactance, the UHV grid can be considered as lossless line [10]. The equivalent circuit of UHV transmission line is illustrated in Fig. 1.

The voltage and current equations of lossless line can be formulated as