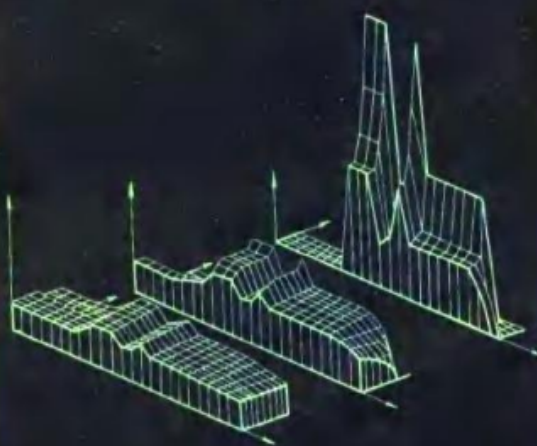


言茂松 著

电能价值当量分析与 分时电价预测

— 电力市场的定价理论与方法



中国电力出版社

XAH94/10

98
F407.615
3
2

电能价值当量分析与
分时电价预测

——电力市场的定价理论与方法

言茂松 著



中国电力出版社

内 容 提 要

电能价值当量是一个新的概念和方法。它试图科学地评定每台发电机组每一小时生产电能的价值,这在电力系统的规划、运行和管理中有广泛的理论与实践意义,发电厂和用户的分时电价的设计、还贷能力的评估,以及在电力市场环境下实时上网电价的预测是它目前最典型的应用。

本书从经济学的观点,用现代分析的模型化方法,揭示电能生产价值当量的数量规律,即电能价值规律,为评估电力生产及还贷,设计与预测分时电价提供了理论与方法。所有这些主要是针对发展中国家的特点而发展的。

为了面对广大电力系统管理、运行和规划的领导以及第一线的技术与经济工作者,本书基于最低限的知识准备,扼要而系统地介绍电能价值当量的概念和分析方法。书中给出了以我国某电力系统实际数据为背景的数字算例,可帮助读者理解和应用。

本书可供电力系统技术经济管理的领导、工程师、经济师、会计师、软件工程师以及大专院校相关专业的师生阅读。

图书在版编目(CIP)数据

电能价值当量分析与分时电价预测/言茂松著.--北京:中国电力出版社,1997

ISBN 7-80125-471-6

I. 电… II. 言… III. ①电能-价值-当量②电力价格-预测
IV. F407.615

中国版本图书馆CIP数据核字(97)第19175号

中国电力出版社出版、发行
(北京三里河路6号 邮政编码100044)
三河市水利局印刷厂印刷
各地新华书店经售

1998年1月第一版 1998年1月北京第一次印刷
850毫米×1168毫米 32开本 7印张 179千字
印数0001—3460册 定价9.40元

版权专有 翻印必究

(本书如有印装质量问题,我社发行部负责退换)

Electricity Value Equivalent
&
Time-of-Day Electricity Price Forecast
—Pricing Theory & Method
in Power Market

Yen Maosong

China Power Press

ABSTRACT

The Electricity Value Equivalent (EVE) is a new term and a new methodology which intends to measure the value of generating the electricity for each hour and each unit. It is meaningful both in theory and practice in the field of power system planning, operation and management. At present, the most possible applications of EVE are the time-of-day pricing and the real time price forecasting for a power market.

In this book, the quantitative pattern of the EVE theory i. e. the law of value of electric power generation, is revealed in view of economics using modern analytic modeling. This provides a theory and a method to evaluate the value of energy and capacity for the generation system and to design and forecast the time-of-day price, as well. All of them are developed especially for developing countries.

This book is written so that it can be easily understood by readers such as engineers and managers responsible for power system administration, operation and planning and others responsible for on-going technical and economic work who have limited modern theoretical knowledge. The concept and method of EVE is described briefly, but systematically, with focus on the calculation of the basic time-of-day price and on the forecast of the pumping and generating time-of-day price for pumped-storage plants.

Numerical examples based on the data of real power systems in China are also provided in this book, which may be helpful for

readers to understand and use the EVE theory and method.

A research area involved in this book needs further study because EVE theory is a new concept and methodology, so that there are lots of open questions. Thus, the book may be a great inspiration for the related scholars and graduate students for their research activities.

The book is written for electric power managers, engineers, economists and accountants, who are interested in operation economics and price regulation of power systems and for teachers and students who major in power systems, system engineering and management, etc.

序

经过近 10 年的快速发展,从 1987 年到 1995 年,我国电力工业的装机容量从 1 亿 kW 增加到 2 亿 kW,总体规模已居世界前列。与此同时,我国电力体制改革逐步深入,自 80 年代中期实行集资办电以来,多家办电已成定局。在电力工业以“公司制改组、商业化经营、法制化管理”为基本取向的改革目标指引下,从现在起到 2010 年,我国电力工业在持续、健康、快速发展的同时,在发电领域将逐步引入竞争机制,发展独立法人的发电公司,并逐步实行各发电公司按电价竞争上网,即按同类发电厂最低电价顺序上网的政策。这对促进电力企业加强管理、降低成本,具有重要意义。在电网建设管理方面,除坚持电网主网架由国家统一规划、统一建设、统一调度、统一管理外,随着大量独立法人的发电公司的出现,介于发电厂与用户之间的电网将成为电力交换的场所,市场运行机制将成为今后电网运营的基础。我国电力工业管理体制的改革与当前国际上全球范围的电力体制逐步打破垄断、非管制化 (de-regulation)、引入竞争机制、形成有限的电力市场的总趋势是一致的。其根本目的在于更合理地配置能源资源,提高资源利用率,促进电力工业与社会、经济、环境的协调发展。

毫无疑问,电力市场的形成与建立科学、合理的电价机制密切相关,而完善的电价体系对调控电力供用起关键作用,这已逐渐成为人们的共识。如实行峰谷电价,引导电力用户调整负荷,进而调整产业结构;实行峰谷电价,鼓励发展有调节能力的水电;实

行分类销售电价，按国家产业政策引导电力消费等，已在部分地区实施。因此，在当前国际国内电力工业发展、改革的大环境中，电价的研究无疑具有极为重要的意义。

合理的电价形成机制和电价体系的建立需要科学理论的指导，也需要可以具体操作、计算的方法和手段。我国在计划经济体制下，缺乏对电价理论的研究，近年虽有不少研究成果问世，但系统的科学著作几乎是空白。言茂松先生的新著《电能价值当量分析与分时电价预测》以经济学方法研究电价，介绍了“电能价值当量”理论及其在分时电价预测中应用的问题。书中用现代分析的模型化方法，揭示了电能生产价值当量的数量规律，即首先在特定目标和约束条件下，建立相应的优化模型，用这些模型评定有限电力资源的影子价格和成本（见第二章的§2-1和第三章的§3-1），用摄动方法计算电力市场需求的边际成本和效益（见第二章的§2-2和第三章的§3-2），在此基础上形成电力系统的总成本与总效益，进而根据所建立的一系列分担原则，实现总成本与总效益在负荷轴和时间轴上的两维展开，建立电能价值当量图表，展现其价值当量的时空特性。本书在介绍上述理论、方法的核心内容之后，又将其具体应用于用户分时电价设计和抽水蓄能电站抽水与发电的分时电价计算，以表明其理论、方法应用的广泛性。

与传统会计学方法确定电价的机制不同，书中所提出的经济学方法不着眼于账面收支平衡，而注重于电力资源的充分利用，其实质是边际成本理论在电价问题研究中的应用和发展。运用这一理论、方法所建立的电价形成机制，更能适应电力市场的需求，有利于促进电力工业的进一步发展。

本书是作者多年研究工作积累的成果，内容丰富，资料翔实，理论、方法论述清楚，特别是有实际系统的算例可供参阅，十分可贵。书中所论述的理论观点虽为一家之言，所提出的方法还有待更多实践的检验，但作为电价理论、方法的不可多得的学术著作，它的出版对我国进一步的电价研究和实际应用，无疑会起到

相当的促进作用。

中国科学院院士
中国电力科学研究院总工程师 周孝信

1997年元月于电力科学研究院

前 言

传统上是垄断的电力工业,在全球正在酝酿深刻的体制变化,总的趋势是引入竞争机制,形成有限的电力市场。其中电价问题越来越成为一个新的课题和研究方向,学术论文也在稳步增长。在我国改革开放的大环境中,电价已成为一个引人注目的大问题,它不仅政策性很强,而且理论与实践都很复杂,因而在加强政策性研究的同时也应重视电价理论与方法的研究,以揭示电能的价值规律,指导电价的设计与实施。

大体上,研究电价问题存在两大类方法,即会计学方法和经济学方法。会计学方法着眼于账面上的收支平衡,而经济学方法则注重于电力资源的充分利用。现代的经济学家大多认为,像电力系统这样资金与资产高度密集、与社会经济生活息息相关的公用事业性企业,应当采用经济学方法,其中最著名的是边际成本理论和方法。世界银行能源处的报告中明确指出,在发展中国家推荐采用边际成本方法定价。

本书扼要介绍了电能价值当量的理论及其在分时电价设计与预测中的应用。它基于一个这样的事实:电能不能长时间大规模储存,因此每个电厂在每小时的生产成本和效益是可以计算的,从而构成分时电价的基础。本书介绍了电能价值当量的基本理论及其分时电价的计算方法,包括确定性的方法和随机性的方法,以及抽水蓄能电站的分时电价过程预测。归根到底是试图在小时级上建立和运用电能生产消费的价值规律。本书不涉及有关电价问题中的政策、体制、管理和计量等问题。

电能价值当量理论及其在各类分时电价中的应用,其内容是

很丰富的,并且在学术和理论方面它还在不断深化和发展。在工程应用上也是多层次的。它不仅可用于基本(用户)分时电价,而且可用于自主经营(BOT)电厂的和非属电力公司发电(NUG)的上网电价、自备电厂的上网电价、调峰电厂的上网电价、水电占优的季节分时电价以及抽水蓄能电厂的发电和抽水电价,还可用于互联电力系统,如省市间互联、区域电网间互联的电力交换等等。本书不可能包括这么多内容,因此仅局限于基本分时电价的计算以及一个比较复杂的抽水蓄能电站抽水与发电的分时电价过程预测。这些理论与方法只要用些少量技巧就可用于电力市场环境下发电上网电价的预测。

本书共六章。第一章:概述。包括电价的功能、定价的模式、发展的历史和电能价值当量分析的概貌。第二章:确定性模型的理论准备。它是理解和应用以下理论和方法的知识准备,如果你有一定的基础,可以有选择地阅读。第三章:确定性电能价值当量分析及其分时电价计算。它是一个最基本的模型与方法,它要用到第二章的概念、模型和软件。第四章:随机性模型的理论准备。它是为下一章作知识准备的,主要涉及随机生产模拟理论和随机情况的优化方法,如果没有这方面知识,理解和应用下一章的内容会有困难。第五章:随机性电能价值当量分析及其分时电价计算。它是一个比第三章介绍的确定性模型更精致的模型,因而一般讲也是一个更好的方法。第六章:抽水蓄能(PS)电站的电能价值当量分析及其分时电价预测。它给出了全年小时级的分时电价过程,为制定抽水与发电电价提供了依据,为评价还贷能力作出估计,甚至可进一步为发展它的实时电价系统作好准备。其中包括了一个比较复杂的优化模型和若干成本与效益的分担准则。

应当说明的是,在经济学的定价方法中模型化是它的一大特点,通常要用到现代的分析工具和相应软件。上海大学(原上海工业大学)将提供这些软件和服务。如有需要,可与(021)56631515-2567、2568联系。

这项电价的研究工作曾得到国家自然科学基金会、电力工业

部、华东电业管理局和上海市电力局的大力支持。特别是上海市电力局已经将该成果初步用于分时电价系统工程的实施，进而获得1993年上海市科技进步二等奖，及其软科学推荐一等奖。谨向曾支持和帮助过本项研究工作的单位和个人表示衷心的感谢。在此应提到贺毅群先生，他完成了第三章最初的建模与软件开发；李渝曾先生曾提出过有益的建议；童琪波先生完成了各章的算例；张少华和童琪波先生完成了第六章的大部分软件开发和实例研究工作；他们虽然都曾经是我的学生，但是现在他们都已经成为这方面的专家；此外还应当特别提到陈松泉先生和庄思成先生，他们曾先后以不同的方式指导、支持和参与讨论了这项研究，作者从他们那获得了不少鼓励。在此一并致以衷心的感谢。

最后还要感谢我的妻子陈星煌，在一些人对我回国从北京迁往上海从事电力市场和电价理论研究还很不理解的情况下，她给了我在工作和生活上的极大的支持与鼓励，谨以此书作为她付出的回报。

言茂松

1997年3月 于上海大学（原上海工业大学）

FOREWORD

A significant change is brewing in monopolized power systems all over the world. The main trend is to introduce a competitive mechanism, so as to form a limited electricity power market. The problem of electricity pricing is increasingly being studied and the number of papers on the subject is rising steadily. During the reformation and opening of China, electricity pricing has become a big problem, which is not only strongly policy natured, but complex, both in theory and practice. Therefore, at the same time of strengthening the policy natured study, the research of electricity price theories and methods should also be taken seriously, so as to reveal its law of value and guide both price design and implementation.

The study of electricity pricing can be divided into two kinds of methods, namely the Accounting Approach and the Economics Approach. The former places stress on the billing balance, while the latter considers the full utilization of power resources. Most modern Economists consider that in those utility-natured businesses such as a power system whose funds and assets are highly concentrated, that the Economist Approach should be used. Among them, the marginal cost theory is the most famous. It is clearly proposed in a report of the World Bank's Department of Energy that the marginal cost pricing approach is recommended to the developing countries.

This book summarily deals with the electric value equivalent

theory and its application in the calculation and forecast of the time-of-day price. The time-of-day price is based on the fact that electricity basically can not be stored on a large scale for a long term, which enables the calculation of the per hour production costs and benefits of every power station. This book will introduce the elementary theories of the Electricity Value Equivalent (EVE), the basic consumers' time-of-day price calculation methods including the method of certainty and uncertainty and the time-of-day price forecast for a pumped-storage power station. In the final analysis, the law of value in power production and consumption is attempted to be set up and even applied at the hourly level. The problems of policy, system organization, management and measurement involved in electricity pricing will not be discussed.

The Electricity Value Equivalent theory as well as its application in different kinds of time-of-day prices has a substantial content. It is developing continuously in academics and theory and its application in Engineering is multi-layered and multi-sided. It can be developed not only for the basic consumers' time-of-day pricing and the pumped-storage power station's time-of-day price forecasting, but also for the pricing in Building-Operation-Transfer (BOT) power stations, Non-Utility Generation (NUG) power stations, cogeneration power stations, system peaking stations. As well, it can also be developed for electricity interchange prices in interconnected utilities (between province and town, or different areas, etc.) However, since it is impractical to comprise so much content, this book is confined to only the calculation of the basic consumers' time-of-day price and the forecast of pumping and generation time-of-day price for a pumped-storage power station. It can be used into the Pool Purchase pricing (PPP) for next day in Electricity power market for developing countries as long as with a few skills.

The book has six chapters as follows:

- Chapter 1: Introduction.
- Chapter 2: Theory Preparation of the Certainty Model, which are the fundamentals for the understanding and application of the following chapters; selective reading may be profitable here for the reader with a good foundation.
- Chapter 3: Electricity Value Equivalent (EVE) Analysis and Basic Time-of-Day Price Calculation, which is a basic method of the book and where the concepts, models and software proposed in Chapter 2 are used.
- Chapter 4: Theory Preparation of the Uncertainty Model, Which include the stochastic production simulation and a stochastic optimized method for generation system.
- Chapter 5: Electricity Value Equivalent (EVE) Analysis in uncertainty and its Basic Time-of-Day Price Calculation, where the concepts, models and software proposed in Chapter 4 are used.
- Chapter 6: Analysis of the Electricity Value Equivalent (EVE) and Forecast of the Time-of-Day Price for a Pumped Storage (PS) Power Station.

It should be pointed out that the economics approach with modeling usually requires modern analysis tools and corresponding software and support. Shanghai University (formerly Shanghai University of Technology) can offer the software and service. When the need arises, call telephone number (021) 56631515-2567, 2568.

The research work has received a great deal of support from the National Nature Foundation of China, the Ministry of Electric Power Industry (formerly the Ministry of Energy) of China and the Shanghai Electric Power Bureau. In particular, it has been applied preliminary to the implementation of the time-of-

day price system engineering by the Shanghai Electric Power Bureau and proceeded to win the award. It won the second class merit award in the '93 Shanghai Science and Technology Progress Prize and won first in the soft-science group of the above prize.

Convey my hearty thanks to all the above units and individuals that supported and assisted the research work. Moreover, I wish to thank Mr. He Yiqun for his accomplishment of the initial modeling and software development in Chapter 3, to thank Mr. Li Yuzeng for his profitable suggestions and to thank Mr. Zhang Shaohua and Mr. Tong Qibo for their accomplishment of part of Chapter 5 and 6, Although they have been my students, now they are experts in this area additional thanks to Mr. Chen Songquan for his support to the research at the beginning of the projects. and especially to thank Mr. Zhuang Sicheng who took part in the discussion and who encouraged the author a lot. My sincere thanks to all of them.

Finally my special thanks go to my wife Chen Xinghuang for her comprehension, patience and assistance in making the writing of this book possible.

Yen Maosong

Oct, 1997

Shanghai University

(formerly Shanghai University of Technology)

目 录

序	
前言	
第一章 概述	1
§ 1-1 电价的基本功能	1
§ 1-2 会计学与经济学的电力定价模式	3
§ 1-3 发展历史的简要回顾	5
§ 1-4 电能价值当量理论及分时电价计算梗概	8
第二章 确定性模型的理论准备	15
§ 2-1 线性规划与影子价格	15
§ 2-2 供求关系与边际成本	21
§ 2-3 确定性电源优化的价值分析模型 VAGS-1简介	22
§ 2-4 VAGS 系列简介	30
§ 2-5 电力不足概率 <i>LOLP</i>	31
§ 2-6 电量不足期望值 <i>EUE</i>	37
第三章 确定性电能价值当量分析及其分时电价计算	39
§ 3-1 容量和电量的经济学成本	39
§ 3-2 容量和电量的经济学效益	40
§ 3-3 电费的组成	46
§ 3-4 分担准则和价值当量	46
§ 3-5 电能价值当量图表及基本分时电价	50
§ 3-6 基本分时电价的数字算例	52
§ 3-7 基本分时电价的用户奖惩分析	67
§ 3-8 水电占优系统的季节分时电价简介	70
第四章 随机性模型的理论准备	74
§ 4-1 为什么需要随机性模型	74
§ 4-2 持续负荷曲线的概率学解释	76