高等学校统编精品规划教材

能源动力类专业英语
（水利水电动力工程专业方向）

主　编　陈启卷

副主编　周大庆　孙　石　曾洪涛

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内容提要

本教材是为满足高等学校能源动力类专业英语（水利水电动力工程专业方向）教学需要而编写的。内容涉及水力发电工程的特点和用途、水电站的类型、大坝和过水设施、水轮机及其相似理论，水轮机选型、汽蚀、水电站电气设备、水轮机调节、厂房布置、水电站运行和控制等方面的知识及新技术和新动向。兼顾了专业英语和专业知识两者的特点。

本教材可作为能源动力类专业（水利水电动力工程专业方向）的本科生和研究生的专业英语教材或水力发电工程双语课程的教材，也可供从事能源动力及电力工业领域的工程技术人员和专业人员参考。

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序

能源是人类赖以生存的基本条件，人类历史的发展与能源的获取与使用密切相关。人类对能源利用的每一次重大突破，都伴随着科技进步、生产力迅速发展和社会生产方式的革命。随着现代社会与经济的高速发展，人类对能源的需求急剧增长。大量使用化石燃料不仅使有限的能源资源逐渐枯竭，同时给环境造成的污染日趋严重。如何使经济、社会、环境和谐与可持续发展，是全世界面临的共同挑战。

水资源是基础性的自然资源，又是经济性的战略资源，同时也是维持生态环境的决定性因素。水力发电是一种可再生的清洁能源，在电力生产中具有不可替代的重要作用，日益受到世界各国的重视。水电作为第一大清洁能源，提供了全世界1/5的电力，目前有24个国家依靠水力发电提供国内90%的电力，55个国家水力发电占全国电力的50%以上。

我国河流众多，是世界上水力资源最丰富的国家。全国水能资源的理论蕴藏量为6.94亿kW（不含台湾地区），年理论发电量6.08万亿kW·h，技术可开发装机容量5.42亿kW，技术可开发年发电量2.47万亿kW·h，经济可开发装机容量4.02亿kW，经济可开发年发电量1.75万亿kW·h。经过长期的开发建设，到2008年全国水电装机总容量达到17152万kW，约占全国总容量的21.64%；年发电量5633亿kW·h，约占全部发电量的16.41%。水电已成为我国仅次于煤炭的第二大常规能源。目前，中国水能资源的开发程度为31.5%，还有巨大的发展潜力。

热能与动力工程专业（水利水电动力工程方向）培养我国水电建设与水能开发的高级工程技术人才，现用教材基本上是20世纪80年代末、90年代中期由水利部科教司组织编写的统编教材，已使用多年。近年来随着科学技术和国家水电建设的迅速发展，新技术、新方法在水力发电领域广泛应用，该专业的理论与技术已经发生了巨大的变化，急需组织力量编写和出版新的教材。

2008年10月由西安理工大学、武汉大学、河海大学、华北水利水电学院在北京联合召开了热能与动力工程专业（水利水电动力工程方向）教材编写会议，会议决定编写一套适用于专业教学的“高等学校统编精品规划教材”。新

教材的编写，注重继承历届统编教材的经典理论，保证内容的系统性与条理性。新教材将大量吸收新知识、新理论、新技术、新材料在专业领域的应用，努力反映专业与学科前沿的发展趋势，充分体现先进性；新教材强调紧密结合教学实践与需要，合理安排章节次序与内容，改革教材编写方法与版式，具有较强的实用性。希望新教材的出版，对提高热能与动力工程专业（水利水电动力工程方向）人才培养质量、促进专业建设与发展、培养符合时代要求的创新型人才发挥积极的作用。

教育是一个非常复杂的系统工程，教材建设是教育工作关键性的一环，教材编写是一项既清苦又繁重的创造性劳动，好的教材需要编写者广泛的知识和长期的实践积累。我们相信通过广大教师的共同努力和不断实践，会不断涌现出新的精品教材，培养出更多更强的高级人才，开拓能源动力学科教育事业新的天地。

教育部能源动力学科教学指导委员会主任委员
中国工程院院士

2009年11月30日

前言

随着水力发电工程的大量建设，使得该行业具有应用全世界最先进的技术和全球采购最先进设备的特点。对外交流与技术设备的频繁引进，迫切需要从事水力发电技术的本专科学生和工程技术人员提高专业英语阅读水平和加强英语交流能力。

本书内容主要涵盖了水力发电工程领域的有关技术问题。包括水力发电工程的特点和用途、水电站的类型、大坝和过水设施、水轮机及其相似理论、水轮机选型、汽蚀、水电站电气设备、水轮机调节、厂房布置、水电站运行与控制等。内容大多摘自原版英语技术资料和教材，既有系统性和完整性，也有明显的专业性。并尽力做到专业特点突出，内容新颖，知识面宽，难度适中。

全书分为10章，涉及了水力发电工程建设、运行和管理的全过程，涉及专业词汇1000余个。全书的编排力求保持能源动力类专业（水利水电动力工程专业方向）知识的系统性和完整性，而且符合英语教学的特点。为了方便学习，有些章节还附有练习，书后附有总词汇表和有关专业术语中英对照表。

本书由武汉大学陈启卷教授担任主编，河海大学周大庆、武汉大学曾洪涛和长春工程学院孙石担任副主编。书中第1章、第2章和第10章由陈启卷编写，第9章由周大庆编写，第3章、第6章由孙石编写，第4章、第5章由长春工程学院杨晓菊编写，第7章、第8章由曾洪涛编写。全书由陈启卷统稿。武汉大学研究生刘文辉、河海大学研究生茅嫒婷等也参与了部分书稿的整理和编写工作。

武汉大学胡雪蛟教授审阅了全书，并提出了许多宝贵的修改意见，在此表示衷心地感谢。

本书在编写过程中得到了教育部能源动力学科教学指导委员会的大力支持，在此表示衷心地感谢。

由于编者水平所限，书中难免存在缺点和错误，敬请读者批评指正。

编者

2010年12月

Contents

1

Introduction to Electricity Generation

Electricity defines the modern world. Everything that we think of as modern products, including electric lights, radios, televisions, home appliances, electronic devices, computers and all the paraphernalia of the information age depends their operation, their existence, on electricity.

Today the residents of developed countries take electricity for granted while those of under developed countries and regions yearn for it. The supply of electricity is a complex and expensive business. Increasingly, electricity has also become a security issue. While people untouched by modernity can still live their lives without electricity, a modern industrial nation deprived of electricity supply is like a dreadnought without its engines. It becomes helpless.

This book is a specialized English textbook on the subject of hydropower engineering for use in university courses on hydroelectric technology. Fundamentals of hydraulics and hydrology are used to present the basic theory that is necessary to understand hydropower engineering.

1. 1 History of the electricity generation industry

The roots of the modern electricity generating industry are found in the early and middle years of the nineteenth century and in the works of men such as Benjamin Franklin, Alessandro Volta and Michael Faraday. Faraday, in particular, was able to show the relationship between electricity and magnetism, a relationship that made it possible to generate electricity with moving machinery rather than took it from chemical batteries as was the case in his days.

The wide understanding of electricity coincided with the development of the steam engine, and the widespread use of gas for fuel and lighting. In the U. S. , Thomas Edison developed the carbon filament that produced light from electricity. Similar work was carried out in the UK by Sir Joseph Swan.

Illumination offered the first commercial use in electricity, but it was an insufficient foundation for an Industry. What accelerated the growth of electricity generation was the use in traction power. Electric trams for urban transport and the underground railway system in London were the kinds of projects that stimulated the construction of large power stations in the last two decades of the nineteenth century.

Its origins might be in the nineteenth century, but few would dispute that the growth of the electricity was a twentieth century phenomenon. There is little doubt, too, that it will become the world's most important source of energy. Vital modern developments such as computer and communications are impossible without it. It is worth remembering, however, most of the key elements necessary for electricity generation, transmission and distribution were developed during the century before the last one.

1.2 The evolution of electricity generation technologies

The earliest power stations used reciprocating steam engines to generate power. These engines were not ideal for the purpose because they could not easily develop high rotational speed to drive a generator effectively. This difficulty was eventually overcome with the invention of the steam turbine by Sir Charles Parsons in 1884. Fuel for these plants was usually coed to raise steam in a boiler.

Hydropower also entered the power generation mix at an early stage in the development of the Industry. Much of the key work on different turbine types used to capture power from flowing water was carried out in the second half of the nineteenth century.

By the beginning of the twentieth century both the spark-ignition engine and the diesel had been developed. These also could be used for making electricity. Before the World War Ⅱ work also began on the use of wind turbines as a way of generating power. But until the beginning of the 1950s, steam turbine power stations burning coal, and sometimes oil or gas, together with hydropower stations, provided the bulk of the global power generation capacity.

In the 1950s, the age of nuclear power started. Once the principles were established, the constructions of nuclear power stations were accelerated. It was widely believed that nuclear was a modern source of energy for the modern age. It was cheap, clean and technically exciting.

Nuclear power continued to expand rapidly in the U. S. up to the late 1970s. In other parts of the world, uptake was less rapid but Great Britain, France and Germany invested heavily. In the Far East, Japan and South Korea worked more slowly. Russia developed its own plants and India began a nuclear program, so did China.

From the end of the 1970s the nuclear industry, which used to be lustrous, began to tarnish. Since then its progress has slowed dramatically, particularly in the west. In Asia, however, the dream remained alive.

At the beginning of the same decade, in 1973 to be precise, the Arab-Israeli war caused a major upheaval in world oil prices. By then oil had also become a major fuel for power stations. Countries that were burning it extensively began to seek new ways of generating electricity and interest in renewable energy source began to take off.

The stimulus of rising oil prices led to the investigation in a wide variety of different alternative energy technologies such as wave power, hot-rock geothermal power and the use of ethanol from crops instead of petrol or oil. However, the main winners were solar power and wind power.

Development took a long time but by the end of the last century both solar and wind technologies had reached the stage where they were both technically and economically viable. There were considerable reasons to hope that both would be able to contribute significantly to the electricity generation mix in the twenty-first century.

One further legacy of the early 1970s that began to be felt in the electricity Industry during the 1980s was a widespread concern for the environment. This forced the industry to implement wide-ranging measures to reduce environmental emissions from fossil-fuel-fired power plants. Other power generation technologies such as hydropower were affected too.

The gas turbine began to make a major difference during the 1980s as an engine for power stations. The machine was perfected during and after World War Ⅱ as an aviation power unit but was soon transferred to the power industry for use in power plants supplying peak demand.

During the 1980s the first large base-load power stations using both gas turbines and steam turbines, in a configuration known as the combined cycle plant, were built. This configuration has become the main source of new base-load generating capacity in many countries where natural gas is readily available.

The first years of the twenty-first century have seen renewed emphasis on new and renewable sources of electricity. Fuel cells, a technically advanced but economically expensive source of electricity, are approaching commercial viability. There is renewed interest in deriving from oceans, from waves and currents, and from the heat in tropical seas. Offshore wind farms have started to multiply around the shores of Europe.

The story of the twenty-first century is likely to be the contest between these new technologies and the old combustion technologies for dominance in the power generation industry. And while they battle for supremacy there remains one technology, nuclear fusion, which has yet to prove itself but just might sweep the board.

1. 2. 1 The politics of electricity

During the last years of the nineteenth century, when the technology was in its infancy, the generation of electricity was regarded as one more opportunity for entrepreneurs and joint of stock companies to make money. After all, electricity was not unique. There were other means of delivering energy: district heating was already common in the USA and some European cities while hydraulic power was sold commercially in cities such as London.

As a consequence the early history of the electricity industry was one of small, privately owned companies. Gradually, however, the distribution of electricity rendered most of other ways of distributing energy across a network obsolete.

In the twentieth century, as the primacy of electricity became obvious, the distribution of electricity gradually became to be seen as a public service. Like water, sewage and later gas supply, electricity was needed to operate a modern civilization. In much of the world, the electricity industry was absorbed by government and became publicly owned. In countries such as the USA where this did not happen, legislation was introduced to govern the supply.

In the late twentieth century, political ideologies changed. Government's ownership of industry, including the electricity industry, began to be seen as unnecessary and uneconomic. A move began to convert publicly owned utilities into privately held companies. Alongside with this, utility legislation was relaxed to open electricity markets for competition.

By the beginning of the twenty-first century this had become a global phenomenon. A few centralized governments still retained full control over their electricity industries but most paid at least lip service for the concept of liberalization.

Liberalization has resulted in both successes and failures. California recorded the most dramatic failure when liberalization resulted in a virtual breakdown of its electricity system, with almost catastrophic consequences. The cost of electricity in California rose dramatically as a result. Elsewhere prices fell after liberalization.

If state's control of the electricity industry was seen to be overbearing and too rigid, a liberalized industry may have too much freedom. Economic rather than political considerations are paramount. This makes the government's policy more difficult to implement.

Renewable energy offers a good example. A government that wants to increase the proportion of electricity generated from renewable sources cannot simply issue an order. It must use taxes and systems of allowances and penalties; generating companies may choose to pay the penalties if that is the most economically attractive option. In that case the desire of the government is ignored.

It is impossible to predict whether modern-free market rules will continue to dominate the electricity industry. Life is full of ironies: instances of policies that are turned on their head by one generation and then are turned again a generation later are far from rare. It would be hasty to assume that this will not happen in the utility industries.

1.2.2 The size of the industry

How big is the electricity industry? Tables 1.1 and 1.2 provide the answer. Table 1.1 shows the amount of electricity generated across the globe in 2000. Production is broken down in the table both by region and by type.

Gross electricity generation in 2000 was 14618TW • h. This was equivalent to roughly 1670000MW power stations running continuously for a year. In fact, the actual global generation installed in 2000 was over twice of, 3666000MW.

When generation is broken down by type, thermal generation is seen to be dominant. This category refers to power generated from coal, oil or gas. These three kinds of fuel were responsible for 9318TW • h, taking 64% of all the electricity generated in 2000. Hydropower was the second most important source, providing 2628TW • h (18%) with nuclear power a close third (2434TW • h, 17%).

Table 1. 1 **World electricity production (in TW • h), 2000**

Region	Thermal Power	Hydro Power	Nuclear and Other power	Geothermal Power	Total
North America	2997	658	830	99	4584
Central and South America	204	545	11	17	777
Western Europe	1365	558	849	75	2847
Eastern Europe and Former USSR	1044	254	266	4	1568
Middle East	425	14	0	0	439
Africa	334	70	13	0	417
Asia and Oceana	2949	529	465	43	3986
Total	9318	2628	2434	238	14618

Table 1. 2 **World electricity generating capacity (in GW), 2000**

Region	Thermal Power	Hydro Power	Nuclear and Other Power	Geothermal Power	Total
North America	662	176	110	17	965
Central and South America	68	115	3	3	189
Western Europe	360	147	128	14	648
Eastern Europe and Former USSR	299	80	49	0	428
Middle East	97	4	0	0	101
Africa	82	20	2	0	104
Asia and Oceana	684	171	70	5	930
Total	2252	713	362	39	3366

Regionally, North America produced the largest amount of electricity in 2000, followed by Asia and Oceana. The most striking regional figure is that of African production, 417TW • h or less than one-tenth of North America. Central and South America also have an extremely low output, 777TW • h. If one wants to identify the poorest regions of the world, one needs to look no further than this table.

Table 1. 2 provides figures for the actual installed generating capacity which existed across the globe in 2000. The figures here broadly mirror those in Table 1. 1, but there are

one or two features to note.

Firstly global nuclear capacity is only half that of global hydropower capacity but contributes almost as much electricity as nuclear capacity does. This reflects the fact that hydropower plants cannot run at 100% capacity throughout the year because they depend on the supply of water and it will vary from season to season. Nuclear power plants, by contrast, work best if they are always operated flat out.

Secondly the gross capacity, 3366GW was twice as much generating capacity as was required to generate the electricity in Table 1. 1, if every station was running flat out all the time. Clearly many plants were working at less than half capacity. We have already seen that hydropower cannot run at full capacity. There will, in addition, be spare capacity in many regions of the world that is only called on during times of peak demand.

We might also note, as both tables indicate, that Central and South America relied on renewable resources, for the majority of their electricity. In every other regions of the world, thermal power plants are dominant. The composition of the world's power generating capacity is not likely to remain static. New types of generation are becoming ever more competitive and these can be expected to prosper as the present century advances. Renewable technologies, particularly, will advance as environmental concerns and the cost of fossil fuels restrict the use of thermal power stations. What these advancing technologies are and how they work form much of the subject matter for the remainder of this book.

1. 3 Pattern of demand

The demand for power fluctuates from minute to minute, day to day, season to season. To study the pattern, the graph of load against time, which is called a load curve, is plotted.

Fig. 1. 1 shows the load curve of a system for a particular day. Generally the peak demand is expected between mid-morning to noon and then in the evening, with a night-time low demand from, say midnight to early morning. The magnitude of the peaks and valleys depends upon the nature of the load connected, pattern of activities of the concerning population, the climate, etc. Generally, the demand at the weekends is less than the demand on week days. In colder countries, the winter demand is much more than the summer demand. The figures show a weekly load curve of a network (Fig. 1. 2)

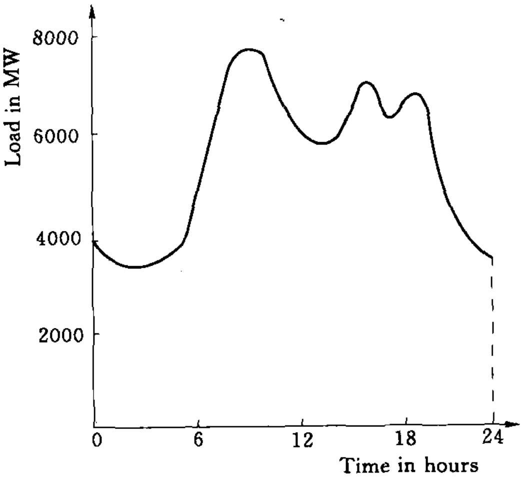

Fig. 1. 1 Daily load curve

If a curve is drawn of load expressed as percentage of maximum load against time, the

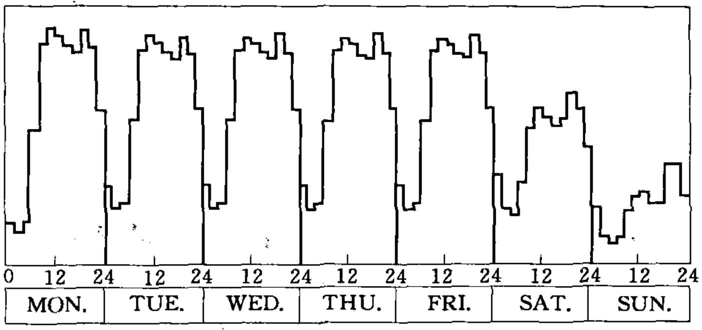

Fig. 1. 2 Typical weekly operation of a power grid

basic shape of the curve does not change and then it forms a useful basis for comparison for different days in the system itself and for comparison with other systems.

The load duration curve (Fig. 1. 3) is the curve of load vs. the duration of the load equal to or above a particular value. This curve can be constructed from the load curve itself.

The areas under the load curve and the load duration curve will be the same as they represent the total energy generated during the period. If we draw load duration curves for different quarters of a year, they may be as follows (Fig. 1. 4).

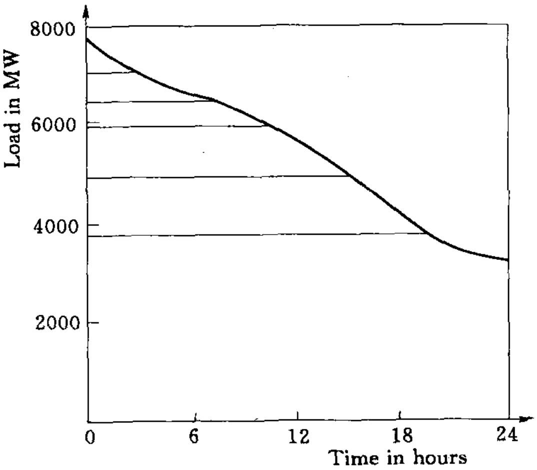

Fig. 1. 3 Load duration curve

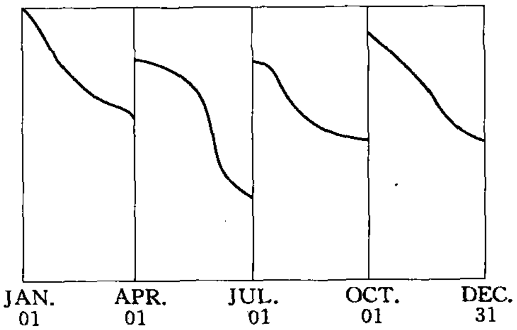

Fig. 1. 4 Quarterly load duration curve

From the load curves, it is seen that the minimum demand may be 50% to 80% of the maximum demand in a day. This proportion may be 30% to 50% over a period of one year. The problem of providing for daily or yearly maximum loads is one of the most important problems which the power generating industry has to deal with. To meet the daily peak would require generating plants to be kept ready for operation for a short period every day and the heaviest yearly peaks may require some plants to operate for only a few hours or a few days out of the whole year and expenditure on such plants, though essential, earns very little revenue. It has, therefore, been the policy of electricity supply authorities throughout the world to encourage all possible ways a leveling up of their system load curves in order to achieve more uniform and, therefore, more economical, loading of the plant. On the commercial side, this problem has been tackled by selling power at a special low tariff for off-peak periods, and charging higher rates for peak power, resulting in the non-essential demand such as storage heating using high consumption domestic appliances etc. , being shifted to off-peak periods. In spite of these measures, variations still remain but with reduced magnitude.

1.4 Categorisation of power stations

To meet the varying power demands, different categories of power stations have to be provided in the grid. They are divided into three categories (Fig. 1.5).

(1) Base load plants.

(2) Medium load plants.

(3) Peak load plants.

Base load plants work for a period of 5000 hours or more in a year. Medium load plants work between 2000 and 5000 hours a year and peak load plants work less than 2000 hours in a year. (These ranges are only approximate.) Base load plants must be very efficient plants with a low cost of power generation, though they may need heavy capital investment, which is economically justifiable. These plants have to run continuously and therefore, there is very little operational flexibility.

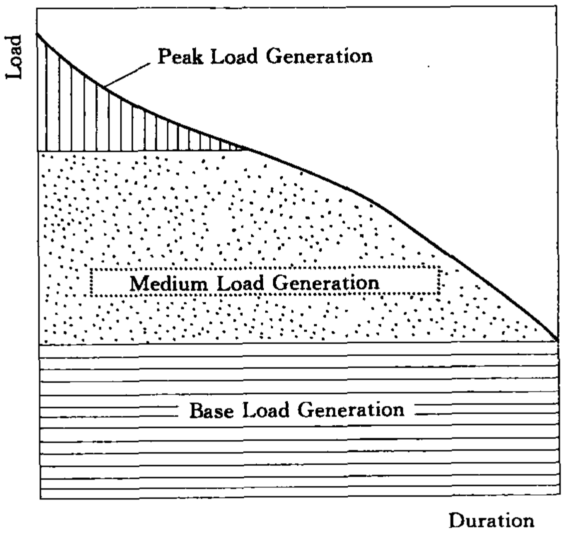

Fig. 1.5 Annual load duration curve

Medium load plants are operated predominantly on week days. The cost of generation may be higher than base load plants. These plants may have some operational flexibility.

The peak load plants, as these would be used for a short duration, the load factor being between 5% and 25%, investment in which can be comparatively less and corresponding reduction of efficiency is acceptable and economically justifiable.

To date the main source of power generations for different categories of plants are as follows.

1.4.1 Base load plants

(1) Coal-based thermal plants consisting of high output steam turbines working with high pressure, high temperature steam.

(2) Nuclear plants with high output steam turbines working with low pressure steam.

(3) Hydroelectric plants of run of river type where storage is not possible because of other constraints.