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POWER SYSTEMS OF EAST EUROPEAN COUNTRIES

Problems and Methods for Control and Development

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This book is dedicated to the late Professor F.C.Schweppe, our friend and collaborator. He was a modest man, never sparing himself, particular when others needed his help. The idea to publish this book belongs to him, but he did not finish his part. All of us will treasure his memory.

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Contents

FOREWORD

Present–day Europe is undergoing irreversible changes.In so doing, ever wider possibilities are opening up for economic interaction between countries of Eastern and Western Europe. One of the natural forms of such interaction is the increased exchange of electric power between national power systems (NPS) and their international amalgamations, leading towards their eventual consolidation for parallel operation.

At present, several international, interconnected power systems are operating in Europe, such as UCPTE (twelve West European countries), NORDEL (four North European countries), that of East European countries (including the former USSR countries).

The extension of territorial boundaries of interconnected electric power systems provides for a more economically efficient utilization of fuel and energy resources while supplying electric power (and heat in the case of centralized heating) to users, as well as facilitates the solution of a number of ecological problems associated with the production, transmission and distribution of electric power. This accounts for the current interest in analyzing the desirability of parallel operation of interconnected power systems in Eastern and Western Europe.All the more so since the Unified Power System of the former USSR is connected via a d.c. back–to–back sub–station with the NPS of Finland which is part of the interconnected power system of the North European countries; links exist between Hungary and Austria.

The study of such problems calls for a fairly substantial knowledge of the current status and prospects for developing national and interconnected electric power systems in Europe, as well as of the methods and means used in on–line supervisory control and in planning the development of those systems.

In May 1987, the International Institute for Applied Systems Analysis (IIASA) held an international task force Meeting on Electric Power System Planning. The main topics under discussion included: the current status of power system planning in Western and Eastern countries; multiple–attribute optimization and interactive decision support systems;

and a number of new issues associated with power system planning.

The most active role in this task force meeting was played by Prof. F.S.Schweppe. In the discussions, special attention was given to the fact that the scientists and experts from both Western and Eastern countries lacked adequate information on the procedures, methods and techniques used in the development planning and on–line supervisory control of electric power system in various countries.

Prof. Schweppe proposed the idea of preparing under the auspices of IIASA a book aimed at Western readers, which could describe the interconnected power systems of Eastern Europe, as well as the technologies and methods employed for decision–making in controlling the operation and development of this mayor energy pool. At the last years (1988 — 1992) economy–politics situation in the countries of East Europe and in the states–republics of the former USSR changed significantly. But, new circumstances increase the necessity of the interrelations between interconnections of the East and West Europe.

The book offered to the readers was written by a group of experts from the Soviet Union and Czecho–Slovakia (in view of the fact that the Central Dispatching Department of the interconnected electric power systems of East European countries is located in Prague), including some members of IIASA's scientific staff. The book describes the current status of the electric power systems of Eastern Europe in parallel operation (Chapter 1). The information contained in this chapter and characterizing the energy resources, electric power generation and parameters of electric power systems is given for the period of stable economic development up to 1990 and only serves to provide a general impression of the scale of the described objects of control. In Chapters 2 and 3, considerable attention is given to the description of the means and procedures of on–line supervisory control of these interconnected systems,including a description of systems for load and exchange power control, methods for calculating and optimizing electric and energy regimes, as well as the reliability of electric power systems. The two concluding chapters describe the methodological principles, methods and mathematical models used in decision–making for developing the national and consolidated power systems of East European countries.

The authors further wish to thank Mr. R.Iveson of the Electric Power Research Institute (EPRI) and Mr. C.Mancini of the Italian Commission for Nuclear and Alternative Energy Sources (ENEL) for their favorable reviews and constructive comments which considerably helped to improve the contents of the book in its final revision. The authors are grateful to Academician A.E.Sheindlin, Vice President, Executive Director and of the Moscow International Energy Club for support in publication of this book.

We hope that this book will contribute to a better understanding of

the methodology and practical experience of electrical power system planning in European countries and may prove useful when the time comes for interconnecting the electric power systems of Eastern and Western Europe.

Academician *Yuri N. Rudenko*
Editor

Chapter 1

CHARACTERISTIC OF INTERCONNECTED POWER SYSTEM OF THE EAST EUROPEAN COUNTRIES

1.1 Production and consumption of energy resources in the East European countries

The general regularities of the world energy development wholly concern the East European (EE) countries. Some quantitative indices of fuel energy resources of these countries and their estimates for the perspective are given below. Considering the economico-geographical characteristics and peculiarities of mutual location of the countries that are important to analyze their NPS development conditions, these indices and estimates are given separately for the former USSR (f/USSR) and other East European countries.

Tables 1.1 and 1.2. present dynamic of the actual data on production and consumption of energy resources in the f/USSR and other East European countries. Analysis of these data enables several important trends to

Table 1.1: Production and consumption of primary energy resources in the f/USSR

Years	Total million t.c.e.	Including				
		Coal	Oil*	Natural gas	Nuclear energy	Hydro energy
			Production			
1960	695	57	31	9	0	3
1965	995	44	36	17	0	3
1970	1285	36	40	21	0.1	3
1975	1625	31	45	21	0.4	3
1980	1957	25	45	26	1.2	3
1985	2200	20.3	38.6	34.2	2.3	3.3
1987	2350	19	38	36	2.5	3.3
			Consumption			
1960	634	62	27	18	0	3
1965	857	49	30	18	0	3
1970	1089	40	34	22	0.1	4
1975	1400	35	37	24	0.5	3.1
1980	1697	28	39	28	1.4	3.7
1985	1800	23.5	33	37	2.5	4.0
1987	1950	22	32	39	2.7	4.3
	Share of energy resources on electricity production					
			(in % of total consumption)			
1960	20.5	23.0	4.2	26.8	—	100
1965	23.4	27.9	6.5	24.7	—	100
1970	24.3	27.5	13.1	21.6	100	100
1975	24.6	30.9	15.7	12.4	100	100
1980	24.3	33.4	14.1	15.0	99.5	100
1985	25.0	35.0	12.0	18.0	99.5	100
1987	25.5	36.0	11.0	19.0	99.5	100

* Here and below including gas condensate

Table 1.2: Production and consumption of primary energy resources in the East European countries

Years	Total million t.c.e.	Including				
		Coal	Oil	Natural gas	Nuclear energy	Hydro energy
			Production			
1960	985	67.1	23.8	7.1	—	2
1965	1350	55.3	28.2	14.1	0	2.4
1970	1680	47	32.2	17.9	0.1	2.8
1975	2090	41.2	36.1	19.8	0.4	2.4
1980	2458	37	35.5	23.3	1.3	2.9
1985	2800	35	35.0	25	2.0	3.0
1987	2828	36.1	33.0	25.1	2.8	3.0
			Consumption			
1960	965	67.8	23	7.2	—	2.1
1965	1305	55.6	27.3	14.6	0	2.5
1970	1620	47.6	31.5	17.9	0.1	2.9
1975	2020	41.1	35.9	20.0	0.4	2.5
1980	2385	36.2	35.9	23.6	1.3	3
1985	2700	35	35	25	2.0	3
1987	2781	34.4	34	25.8	2.8	3
		Share of energy resources on electricity production (in % of total consumption)				
1960	20	22.5	3.6	26.8	—	100
1965	22	25.8	5.3	23.8	100	100
1970	23.2	27.5	10.4	21.5	100	100
1975	23.8	31.4	12.2	18.3	100	100
1980	24.4	34.8	11.4	15.1	99.5	100
1985	25.0	38.0	10.0	12.0	99.5	100
1987	26	40.0	8	11	99.5	100

be noted:

- production of the fuel-energy resources exceeds their consumption;
- in 1975-1980 growth of oil share in the total resource recovery stopped and began to decrease;
- gas share increases steadily in the total production of resources, from 1980 nuclear energy fraction became appreciable, hydroenergy share became stable, in 1981-1985 the coal share decrease practically ceased;
- share of energy resources used to generate electric energy in the f/USSR was stable in 1965-1970 and rose steadily in the remaining East European countries;
- coal fraction used to generate electricity steadily increases,fraction of oil (from 1975) drops.

The conditions for provision of the f/USSR national economy with energy and fuel become more complicated due to displacement of almost the whole increase of fossil fuel production to the eastern often almost inaccessible regions of the country with severe climatic conditions, principal limitedness of hydrocarbon fuel reproduction and growth of the Energy complex (EC) capital–intensity as a whole. These conditions influence primarily thermal power plants (TPP) as the largest fuel consumers (up to 40% of energy fuel consumed in the country).

For the decade (1970-1980) the fossil fuel consumption by the power plants increased almost 1.5 times; in 1985 it was 11% higher than at the level of 1980 (Table 1.3).

In the period to 1980 the specific fuel consumption on electricity generation considerably decreased as compared to the preceding period mainly due to increase of unit capacities, increase in the share of electricity production using steam of higher parameters and cogeneration development. However, later on these factors will to a great extent be exhausted and a number of tendencies are expected that will result in the increase of fuel rate in power plants due to deterioration of the coal quality, change over of the operating TPP to the manoeuvrable conditions, decrease in the share of high–grade fuel in the fuel balance structure of power plants, limitation in the development scales of fossil-fried cogeneration plants in the european part of the country. The considered tendencies even with regard for energy conservation measures in the sector (dismantling and reconstruction of economically inefficient equipment, increase in thermal load of the existing cogeneration plants, etc.) have already led to the slowing down of rates of

Table 1.3: Production of electric and heat energy and fuel consumption in the f/USSR power plants

	1970	1975	1980	1985	1990
Electricity production, billion kWh	740.0	1038.6	1293.9	1544.2	1652.6
Of which thermal power plants, bilion kWh	613.0	892.4	1037.1	1162.4	1158.9
Heat energy production, million GJ	8870	11080	13400	15600	16540
Of which thermal power plants (including district boiler plants of the f/USSR Ministry of energy), million GJ	2120	2850	3660	4420	4640
Fossil fuel consumption by thermal power plants, million t.c.e.	326.8	438.8	503.0	560	549.5

specific fuel consumption decrease in the central power plants: for 1981-1985 it decreased approximately by 2 g/kWh, whereas for 1975–1980 — by 12 g/kWh.

With respect to the high grade fuels (gas and fuel oil) the thermal power plants are considered as "the marginal consumers", since the economic effect of using gas and fuel oil in TPP instead of solid fuel is significantly lower than for other categories of consumers (boiler plants, industrial furnaces, etc.). Therefore, the high–grade fuel must be alloted to TPP in the last place and with reduction of its resources they are considered as the first plants (including operating ones) for lowering the use of gas and fuel oil in the national economy. Nevertheless, up to now a share of the high–grade fuels (natural gas and fuel oil) predominated in the fuel balance structure, it even increased in the period from 1970 to 1985 (Table 1.4).

The f/USSR energy program stated the goal of substituting fuel oil by natural gas at the operating TPP. The fuel oil fraction in the total consumption of energy resources by TPP must be reduced even at the first stage (that ends at the turn of the 80s and 90s of the current century) as compared to 1980.

Necessity of substituting fuel oil by natural gas results in the fact that the additional gas resources will be used mainly by the town boiler and

Table 1.4: Structure of fuel balance of the f/USSR thermal power plants, %

Years	Fuel oil	Natural gas	Solid fuels (coal peat,schist)
1970	23,1	23,3	53,6
1975	29,4	22,6	48,0
1980	35,7	23,6	40,7
1985	26,1	40,0	33,9
1990	16,4	54,2	29,4

cogeneration plants where fuel combustion is complicated by environmental considerations and as an exception by the condensing power plants that do not have in the nearest decade the real fuel alternatives, for example, intended for energy supply of the oil and gas production regions in Western Siberia.

In this period it is planned to create the conditions for speeding up coal production and increasing its role in the fuel balance of electric power industry in the subsequent years.

Later on the natural gas production will reach the maximum level and be stabilized (Fig. 1.1). Under these conditions the conservation of natural gas resources is expedient to meet fuel demands of the natural economy for the residential sector, for its direct use in industrial furnaces and technological installations and as a raw material for further conversion.

In this connection the problem of reducing the scales of natural gas consumption in the electric power industry arises as a result of refusal from constructing new gas–fueled TPP and its consumption decrease at the operating power plants.

Considering the above said, the dynamics of fuel balance structure of the f/USSR power plants is characterized by the following factors:

- stabilization (after reduction) of coal share;
- decrease of natural gas fraction;
- elimination of fuel oil as a main fuel and its use mainly to kindle and illuminate the torch of energy boilers at the coal-fueled TPP.

In the other european countries whose NPSs are members of Interconnected Power System of the East European countries (IPS–EE), the problems of further development and improvement of the electric and heat energy production on the base of fossil fuels are stated [127]. All the East European

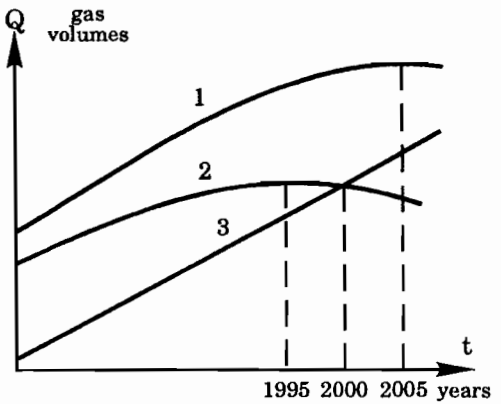

Figure 1.1: Dynamic of production and resources of natural gas for power plants in the f/USSR: 1 — production; 2 — resources for power plants; 3 — demands of non–energy consumers.

countries have large reserves of low–grade solid fuels, on the base of which a series of countries continue to increase electricity generation (in 1985, for example, the East German power plants on brown coal produced about 83% of electricity). There are substantial additional possibilities for raising electric power generation at hydro power plants (HPP) in Poland and Romania. Nevertheless one of the principal problems for the East European countries is to limit the hydrocarbon fuel consumption and to decrease the demand for such high–grade fuels as gas fuel oil in connection with the growing deficiency of fuel oil and preferable use of gas for the non–energy needs.

The electricity import from the f/USSR (in 1985, for example, its share amounted to 23.5% of the total electric energy consumption in Hungary) plays an appreciable role in the supply part of energy balance of the East European countries.

1.2 General characteristic of IPS–EE

In the mid–fifties, national power systems existed in the f/USSR, East Germany, Czecho–Slovakia. In the other East European countries they were

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