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USSR Report

ENERGY

(FOUO 4/81)

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On behalf of all of us in FBIS I wish to express appreciation to our readers who have guided our efforts throughout the years.

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ELECTRIC POWER

UDC 620

POWER DEVELOPMENT, SIMULATION PROBLEMS

Kiev ELEKTRONNOYE MODELIROVANIYE in Russian No 6, Nov-Dec 80 pp 3-6

[Article by P. S. Neporozhniy, V. A. Venikov]

[Text] After completing the last year of the Tenth Five-Year Plan period successfully, the Soviet nation is preparing a worthy reception for the 26th party congress, a most important event in the life of our motherland.

"Each congress," stated Comrade L. I. Brezhnev at the June (1980) CPSU Central Committee Plenum, "opens up new horizons for our party and country. I am confident that this will also be true of the coming congress which is being called upon to determine the strategy and tactics of the fight for the next stage of Communist construction."

Translating into life Lenin's legacy, the party is implementing successively the program on the comprehensive development of the productive forces of the country.

Today, marking the 60th Anniversary of Lenin's GOELRO [State Committee on Electrification of Russia] plan, it is necessary to recall once more what a great basic role in the fate of the Soviet economic and cultural construction was played by what was the first in world practice, the state long-range plan for the comprehensive development of the national economy on the basis of electrification -- the GOELRO plan -- developed on the initiative of V. I. Lenin.

V. I. Lenin, in his report on the activity of the All-Union Central Executive Committee and the Soviet of People's Commissarsat to the Eighth All-Union Soviet Congress, which opened on 22 December 1920 in the Bolshoi Theater, dwelt in detail on the electrification problem. He called the GOELRO plan the second program of the party and advanced his historical formula: "Communism is Soviet power plus electrification of the entire country," which became the generalized summary of Lenin's doctrine on electrification as the material-technical basis of Communism.

Lenin's principles laid in the GOELRO plan remain urgent even now in spite of the immeasurably greater scale of electrification and the colossal qualitative changes in our power engineering. The essence of these principles is expressed in the continuous concentrations of the unit capacities of electric power plants and machines, the centralization of electric power distribution, and the advanced rates of growth of the electric power industry as compared to the growth rates of industrial production. This also involves the comprehensive utilization of water resources and building high voltage electric power transmission lines, especially ones capable of providing electric power to entire economic regions of the country.

The GOELRO plan advanced a grandiose program for that time for building 30 regional electric power plants with a total capacity of 1,750,000 kw to increase the electric power output in the country to 8.8 billion kw.

By successfully transforming the GOELRO plan into life the Soviet people, under the leadership of the Communist party, achieved great successes in the industrialization and creation of a reliable electric power base for the development of the production forces of the country. Already in 1931,the GOELRO plan was fulfilled, while in 1935, the capacity of the electric power in the USSR exceeded the planned capacity by 2.5 times.

Now electrification rates keep growing constantly due to an increase in capacity, improvement of equipment and methods of construction. Thus, 500 and 800 megawatt units operate in thermal electric power plants. The first 1200 megawatt power unit is beginning to operate at the Kostromskaya GRES, and the capacities of individual hydraulic machines are increasing. Six hundred forty megawatt hydraulic machines are being installed at the Sayano-Shushenskaya GES, the capacity of the Krasnoyarskaya GES alone is six million kw, and more powerful plants are being built.

The capacities of AES are increasing at accelerated rates. Three power units of one million kw each were installed at the largest of them -- the Leningradskaya and Chernobyl'skaya AES. In 1980, the USSR electric power plants will produce about one trillion 300 billion kw-hours of electric power.

It should be stressed that at present the search for reserves and their maximum utilization for increasing labor productivity and raising the efficiency of utilizing labor resources has become more urgent. This means that today a broad approach to optimizing the work of power engineering is necessary, taking into account its effect on the subsystems related to it. The consideration of a constantly increasing number of extensive feedbacks within power engineering is required taking into account that power engineering itself is part of the global system, including the national economy as a whole, as well as the biosphere. In this connection there originates the problem of controlling the environment on the basis of a sharp expansion, up to the planetary scale, of the sphere of regulated power and biological processes monitored by man.

Entirely new problems will be solved in the foreseeable future. Among them consideration should be given to electric power plants with nuclear breeder reactors, new methods for obtaining, transforming, transmitting and distributing power, assimilating thermonuclear energy, utilizing solar power and many others. A highly urgent problem is to increase scientific-technological progress in electric power engineering which, today, occupies advanced positions in the world in such indicators as unit capacities of power units, voltage levels of electric power networks and scales of thermification development in which USSR exceeds western countries. In our country, less conventional fuel is used for the production of each kilowatt-hour than in many western countries. Our electric power plants are equipped with more efficient domestic units, powerful nuclear reactors and new electric equipment.

The single power system [YeES] of the USSR, controlled from a single dispatcher center, spans a territory of ten million square kilometers where over 220 million people live. It consolidates 750 electric power plants with a total capacity of over 210 million kw. Power system associations or the European socialist countries and the Mongolian People's Republic, operate in parallel with the USSR YeES. The CMEA "Mir" Power Association has no equal in capacity of electric power plants (above 300 million kw) and scale of territory they span. Our power system is already the most perfect as compared to the power systems of other countries. New complex problems originate in controlling such a system and they are solved by cybernetic methods. Power engineering ideas, as a large complex system incorporated in the GOELRO plan, are now being developed according to the scientific school of G. M. Krzhizhanovskiy, V. I. Lenin's coworker, who laid the foundation of modern power engineering science. Obviously, these ideas must be supplemented and developed in the light of modern scientific-technological progress. Simulation methods must play a special role in this. Obtaining data on the reality of an object by means of a discrete approximation model, adequate in this or another respect to the investigated object, became a commonly accepted method of conception in science and engineering. Now the problem of object conception has begun to be reduced to the problem of its simulation. Simulation in this sense began to span the entire width of the concept, obviously, without exhausting it in depth.

Optimization models of complex systems, including power systems, were found to be entirely necessary for the realization of those purposes which appeared and are appearing continuously in the process of developing power engineering as a large system.

Simulation, by achieving by some method a reflection of reality, makes it possible to study its objective characteristics. In this cognitive method, the studied object (the original) is related in some way to another object (the model). In this case, the object-model is capable in this or another respect of replacing the original at several stages of the cognitive process. All forms of models with their huge number of different variations find their application in power engineering problems.

Of great importance is the fact that, at present, there is a basic turning point occurring in the development of power systems and their automation. This turning point is not fully manifested nor fully recognized by everybody as yet; however, it is becoming quite perceptible in practice and theory. The time is coming when automation will acquire a decisive role in controlling normal, post-emergency and transitional, including emergency, operating modes. A transition is being implemented now from analysis problems that up to now were basic in investigating electrical system modes to synthesis problems dictated primarily by the rapid development of the systems themselves, as well as their automatic control. It should be noted that in solving synthesis problems which, under modern conditions, acquire an entirely different nature as compared to analysis problems it is necessary to find methods and means for influencing the electric power system, which would impart the desired properties to the considered process or group of processes. It is precisely this statement of the problem in the theoretical, as well as the practical program leading to the creation of an adaptive mode automatic control and corresponding new apparatus that modern power engineering is beginning to realize.

Power engineering is becoming more and more of a cybernetic type of system and principally requires new methods for its design and control. The successful solution of these methods that are very complex and cannot be reduced to one previously formulated algorithm, especially needs simulation in all its forms.

As before, physical simulation that makes it possible to make more precise the nature of the occurring phenomena, correct their mathematical representation and set up comprehensive tests with new devices is of enormous importance.

The creation of an automated remote control system for the USSR YeES dictated the necessity of developing comprehensive models of the hierarchic type that would provide a retrospective analysis, control of current modes and optimal planning of future modes of the power systems. The YeES model is formed on the basis of decomposition principles that provide for a considerable reduction in the size of the model maintaining at the same time the necessary quality of mode planning and control.

The structural hierarchy of the models reflects the existing hierarchy of dispatcher control:

central dispatcher control of the USSR YeES;

consolidated dispatcher controls;

regional power administrations.

In their turn, the models of each step of the dispatcher hierarchy are created taking into account the following time levels of control:

automatic control of normal and emergency modes for providing stability and viability of the power systems;

automated control of normal modes;

operational planning of modes and plan correction;

long-term planning.

All models of the various hierarchic steps and time levels of control are formed on the basis of a single data base created by using all available data sources.

The sources include remote control data containing remote control measurements of the basic parameters of the current mode, implemented with a period from several tenths of a second to 10-15 seconds, and remote control signals of the position of the switching apparatus which are transmitted as required by the change in their initial condition; daily dispatcher reports (total consumption of basic power junctions and power regions, power exchanges over intersystem connections and the basic system-forming network etc); data transmitted as required on changes in the composition, condition and switching arrangement of the basic electric power equipment; data on monitoring measurements of modes of characteristic days of winter maximum and summer minimum of total loads; results of special tests; technical and operational data of the electrical power equipment; statistical data on operational modes for the preceding time intervals; information on available power resources and plans for their arrival at the electric power plants; information on plans for the development of the national economy with a separation of the expected power consumption increase in each sector of industry, agriculture, everyday life, etc.

Models of various time levels used at each step of dispatcher control hierarchy are formed with the preferred utilization of respective data sources. The more operational problems that must be solved by using a given model, the more rigid the requirements presented to the speed of the initial data transmission must be.

Maximum correspondence between the model and the original may be obtained only on the basis of using adaptivity principles. In this case, as data is accumulated on the adequacy of the model and original, an automatic correction of the model parameters is made.

The greatest difficulties originate in creating optimization models that indicate that the global optimum is usually understood as the minimum cost of producing and distributing the electrical and thermal power; coordination of the models used in heat supply, transport and other industries is necessary.

The indicated difficulties can be overcome only by the comprehensive use of various methods and means for modeling. Only on the basis of an organic unity of different approaches and methods will it be possible to improve the models used.

At present, the USSR YeES automated system of remote control contains a developed hierarchic complex of about 100 controlling computers interconnected by a single data network. This complex provides the necessary base for the mathematical modeling of the processes occurring in the YeES of the country -- the largest centrally controlled power association in the world.

The following work is being done for the further development of the USSR YeES control system:

improvement of the automatic control system by powerful machines and electric power plants;

wide automation and telemechanization of the distribution network;

improvement of relay protection and automatic system emergency protection devices and the formation of a single coordinated system for emergency protection control;

creation of systems for automatic regulation of frequency and resistive power;

improvement and development of automated control systems for technological processes;

development of a communications and data transmission network.

In summary, it may be noted that the expansion of the area for using the simulation methods due to the development of power engineering and the origination of new problems has posed a number of new problems. They are as follows:

consolidation of the similitude theory and the theory of experiment planning which are essentially a single scientific discipline;

an increase in the role of processing in the criterional form and, therefore, in a correlated shape of the results of all investigations made;

a study of the relationships between the reliability of the similitude method and simulation when they are represented in the criterional form;

the creation of the physical phenomena descriptions in the differential, integral and integral-differential forms and the development of ways for their mutual transformation into criterional relationships;

a study of the application of the similitude theory methods in probability problems; problems of mathematical statistics and problems of incomplete data for poorly described mathematical phenomena.

Special attention must be given to developing ways and methods to analyze the power problems of a simulated experiment represented in a criterional form. It is exceptionally important to use simulation methods in production problems with a proper approach to generalizing the obtained results with a suitable evaluation of the accuracy.

A broad combination of mathematical models with the physical experiment and practical experience will make it possible to consolidate theoretical and experimental investigations based, in this case, on the similitude and simulation theories and using simultaneously the theory of experiment planning.

The use of the methods and means of simulation will make it possible to approach in a new way, the solution of a number of power problems in which new problems appear and which include new electrification aspects. These new aspects are spanned by the concept of the scientific-technological revolution and reveal further the profound meaning of Lenin's formula on the role of electrification.

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ELECTRIC POWER

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PROBLEMS OF MODERN POWER ENGINEERING

Kiev ELEKTRONNOYE MODELIROVANIYE in Russian No 6, Nov-Dec 80 pp 6-10

[Article by L. A. Melent'yev--The editorial board asks readers to write articles on the possibility of using system analysis and mathematical simulation methods to solve the problems posed in this article.]

[Text] The last 20 years (1960-1980) were characterized by the greatest achievements in the development of the fuel-power complex of the country and the electrification of the national economy. During this period, the USSR petroleum and gas industries were created on a high scientific-technological level and actually formed the most powerful single petroleum-supply and single gas-supply systems of the country that produce a tremendous economic effect; systematic electrification of the national economy is being implemented at a rapid rate; the creation of a single electric power system [YeES] of the USSR and the CEMA countries is being completed on the basis of the latest achievements of science and technology. Considerable successes have been achieved in hydraulic power construction and thermification development where the USSR holdsstrong advanced positions.

The greatest achievements of the USSR in 1960-1980 in the area of the fuel and electric power supply are undeniable; as a result there is a single fuel-power complex in the country (power in its broadest concept) on the basis of all-around interchangeability. This complex includes the fuel mining and fuel reprocessing industries, the electric power and thermal power industries, united by corresponding material and data ties. Thus, a single state general power system is formed in the USSR which spans the basic components of the fuel-power complex. The factual unity of such a system is determined by the interchangeability of almost all forms of power, power-forming installations and the power resources used. Therefore, substantiated solutions on the development of the basic links (industries) that enter the general power system must be adopted taking into account the directions of the development of this system as a whole.

About one third of all capital investments in industry and about 15% of all workers are directed to the development of the general power system (the fuel-power complex). Obviously, a further increase in the indicated share of capital investments is possible for mining and the transport of fuel, for maintaining the achieved level of mining, for economical measures, etc. At the same time, a continuous and high quality power and fuel supply is a most important factor in the reliable growth of the national economy. All this indicates that the development of a general power system greatly predetermines the success of the economic development of the country, as well as the effect on the long-range economic interrelationships of the CMEA countries.

A number of negative trends are appearing in the fuel-power complex of the country related, to a considerable extent, to insufficiently active power saving, as well as the lack of development of individual links between the general power system and the national economy requirements. Moreover, insufficient attention is still being given to raising the quality of the electric power and fuel supplied to the national economy.

In recent years, a new situation is being created for the general power system of the country: power requirements (especially electric power) grow fairly rapidly, but for a number of reasons limitations originate in the development of hydrocarbon fuel production and its cost is increasing; at the same time there appears a possibility of the wide use of a new fuel -- nuclear; a necessity is recognized of accelerated development not only of gas, but also of the coal industry, etc. However, the rapid reorientation of the general power system in the necessary direction is prevented by its inertia. Therefore, it is necessary to adopt in advance important decisions in principle on the timely development of the general power system along the most efficient way. In this connection, the importance of long-range forecasting of the development of the general power system of the country, its scientific-technological progress, and the social-economic and ecological consequences is understandable.

We will describe briefly some problems that originate in this connection.

The basic problem is satisfying fully and efficiently all requirements of the developing economy of the country in fuel and power of the proper quality by assimilating the most efficient kinds of the power resources and providing for their efficient and economical consumption. The solution of this huge problem requires the implementation of extensive territorial and structural shifts, due to the necessity of the mass utilization of the power resources of eastern regions and the most rapid introduction of nuclear fuel in the power balance of the country.

During the last ten years, the USSR general power system developed fairly rapidly, by 3.1% per year on the average, while electric power developed by 6.2% per year. During the same period, the increase in consumption of power resources (including export) was provided for by approximately 80% of petroleum and natural gas, whose share in the total production of power resources increased from about 50% in 1970 to almost 70% in 1980. Correspondingly, the share of coal decreased from 35% to a level less than 30% for an absolute increase in its production. The GES share remained approximately at 3% while the share of nuclear fuel is approximately 2% this year.

Large structural changes will occur in the future in the general power system of the country. According to preliminary data, the next 20 years will see a rapid growth in the production of nuclear fuel and natural gas, an increase in mining of the basically inexpensive Kazakhstan and Siberian coal (Ekibastuz, Kuznetsk, Kansko-Achinsk coal basins). The utilization of hydraulic resources will continue and be especially considerable in the eastern regions; however, the share of hydraulic power in the power balance of the country will remain insignificant (about 3%). New renewable energy sources (solar, geothermal, wind) will be of local significance only in the considered period.

The liquid fuel problem related to the economic problem and, therefore, to the most efficient utilization of petroleum for petrochemical raw materials and motor vehicle fuel will become urgent. This requires the solution of the following problems: raising the coefficient of extraction of petroleum from the ground, increasing the extent of petroleum refining and therefore, the active replacement of fuel oil by other resources, primarily, by natural gas; efficient utilization and economy in the consumption of petroleum products; replacing petroleum products by electric power in RR transport; developing and assimilating improved technologies for obtaining high quality motor vehicle fuels from coal and, possibly also from the shale in the Volga region.

Of the key modern problems in power engineering, besides those mentioned above, the following must be emphasized 1) supplying fuel and power to the European part of the country (including the Urals); 2) developing nuclear power; 3) increasing the efficiency of electrification and electric power supply; 4) improving the thermal power supply of the country; carrying out an active power saving policy. Of great importance are the efficient developments of the gas, coal and petroleum industries, power and electrical machine building; the development of power of the eastern regions on the basis of shifting high power consuming industries to them, and a number of others. We will consider them in greater detail.

Supplying fuel to regions of the European part of the USSR. In spite of the measures taken and proposed for locating new high power-consuming industries in the eastern regions of the country (basically in Siberia) and the development of nuclear power, the requirements of the regions of the European part of the USSR (including the Urals) for organic fuel will increase considerably in the future. However, an increase in these regions of their own resources will be able to satisfy these requirements only insignificantly. Therefore, flows of organic fuel and electric power (primarily from Siberia) into the regions of the European part of the USSR will increase considerably and, therefore, it becomes necessary to select an optimal structure of these flows and efficient forms of transport to "overcome distances" of 3000km and greater. The basic sources of these fuel and electric power deliveries are the northwestern regions of Siberia, Kuznetsk and Kansko-Achinsk coal basins. Resources in Central Asia and Kazakhstan are relatively limited.

The complexity of the problem consists of determining the proportions of Tyumen' gas, Kuznetsk and Kansko-Achinsk coals to be transmitted to the European part of the USSR. Here it is necessary to take into account the following:

1) the considerable loading of the existing RR network so that the transportation of the cheap Kansko-Achinsk coal, obviously, is possible only by the wide use of a DC electric power transmission line; in the future, the productivity of one such double circuit line may reach 40 million kw (which is equivalent to transporting over 150 million tons of run-of-the-mine Kansko-Achinsk coal); it is precisely for this reason that the USSR Academy of Sciences is giving great importance to the Ekibastuz-Center DC power transmission line as one of the strategic directions of domestic power development;

2) the necessity of increasing the productivity of gas pipelines to transmit Tyumen' gas; for this it is necessary to raise the initial pressure in the pipes to about 100k gram-force/cm^2, increase the number of compressor stations (by reducing their "pitch") and utilize electric drives to the maximum extent in them. Computations show that all these measures will make it possible to increase the productivity of the gas pipelines by almost 50%. It is also important to achieve higher maneuverability of the consolidated gas-supplying system of the country by creating large capacity gas storage reservoirs. There are also other solutions to the transportation problem that should be worked on, for example, transporting liquefied gas and coal by pipelines. The delivery of power resources over distances in the order of 3000km is expensive. Therefore, the selection of optimal ways to provide organic fuels to the European part of the USSR is becoming a very complex problem.

The development of nuclear electric power plants (AES). In the very near future, it is planned to stop building condensation electric power plants using organic fuel in the European part of the USSR and accelerate the construction of AES. Up to the middle of the nineties it is advisable to build AES with thermal neutron reactors basically with capacities of 1 to 1.5 million kw and use them not only to produce electric power, but also hot water and steam. In this lies the important feature of nuclear power development in the USSR. Thus, along with very large nuclear condensation electric power plants with capacities of six to eight million kw it is necessary to build nuclear TETs (sometimes with 500 megawatt reactors) and nuclear heat supply sources that will make it possible to reduce the use of fuel oil and natural gas to supply heat. In this connection, it will be necessary to develop and assimilate new equipment in the very near future.

It is well known that thermal neutron reactors do not use the potential energy of uranium economically enough. Therefore, it is necessary to accelerate the work being successfully conducted in the USSR on developing fast neutron reactors. It is planned to introduce this type of reactors widely in the electric power production of the USSR by the end of the 20th and the beginning of the 21th centuries. Possibly, this will bring out the feasibility of building special nuclear power complexes. The use of DC electric power transmission lines in the USSR favors such a solution.

Investigations will be continued on developing high temperature reactors with steam pressures up to 90-130k gram-force/cm^2 at a temperature above 500°C; reactors that produce high temperature heat for the chemical and metallurgical industries for the production of hydrogen; equipment for maneuvering AES, etc. Work was successfully started on assimilating thermo-nuclear installations capable of providing humanity with a practically unlimited amount of power.

Expansion of national economy electrification and acceleration of development rate of electric power. The creation of new technologies for the expansion of electrification -- is one of the main directions of scientific-technological progress in the national economy as well as increasing the productivity of labor; moreover, the additional use of electric power in heavy duty and thermal processes makes it possible to free natural gas and petroleum products, replacing them with electric power, coal and nuclear power. At the same time, a considerable increase in the cost of petroleum products and also, to a certain extent, of gas, makes the increase of the electrification level, as a whole, of the national economy more effective. It is necessary also to strengthen the scientific-technological base of electric power by developing the Single Electric Power System of the USSR taking into account the changeover, to a considerable extent, to a new conception of its development which consists mainly of the following:

1) wide use of nuclear fuel;

2) creation of a highly maneuverable YeEES by:

a) using special maneuvering equipment at the electric power plants of the European part of the YeEES in the form of pumped-storage power plants, gas-turbine installations, including those operating with the use of compressed air storage, steam-gas installations, as well as highly maneuverable magnetohydrodynamic installations in the future;

b) forming a basic YeEES network with strong electrical ties in the form of 750 and 1150 kv AC and 1500 kv DC, and later 2200-2500 kv lines;

3) provide reliable and high quality electric and heat supply by creating in the YeEES the following:

a) necessary electric power reserves and transit capacities of electric networks, including distribution networks, compensating systems, etc.;

b) advanced automation, cybernetic, metering, communications and computer data processing facilities.

It is important to stress that until recently great attention was given to providing a continuous (reliable) power supply and not to raising the quality of the electrical power and heat furnished to the user. Actually, the problem consists of creating not contradictory but comprehensively acting mechanisms for the automatic control of the reliability and quality of the electrical and heat supply. Regrettably, many theoretical and practical aspects of the automatic control of the quality of the power supply are not sufficiently developed; as far as the electrical supply is concerned, this applies not so much to the frequency as to maintaining all voltage components at the proper level for consumers and creating a system to record the quality of the electrical power supplied by the system.

An important problem of the YeEES development is the timely removal of outdated and worn-out equipment from operation in order to raise the technical-economic indicators of the system.

In developing the YeEES, it is very important to find and implement an optimal structure of generating capacities. At present, this problem is complicated considerably due to the expansion of the possible set of such capacities. This problem is especially complex for the European part of the USSR due to the broad possibilities of developing AES, as well as to the necessity, for a number of reasons, of increasing the maneuverability of the YeEES. Computations show convincingly that the use of nuclear fuel and hydraulic power alone cannot solve this problem. Thus, for example, nuclear condensation electric power plants (AKES) are economical when they replace basic KES [Condensation Electric Power Plant] which use organic fuel, but they are not economical if they displace TETs using organic fuel. Moreover, they cannot (at present and in the near future) replace special maneuvering equipment efficiently. Obviously, the AKES share in the total increase of new electrical capacities should not exceed two-thirds, while GAES [Pumped Storage Electric Power Plant], peak GTU [Gas-Turbine Installation], steam-gas installations and new TETs using organic fuel should make up one-third of the total. According to computations, electric power plants will require a small additional consumption of natural gas and Kuznetsk coal which are included in the normal balance of the fuel supply to regions of the European part of the country.

In the Siberian part of the YeEES, it is important to find an optimal structure of newly built KES, TETs and GES. It should be taken into account that insufficient development of thermal electric power plants in Siberia in dry years may cause considerable harm due to enforced interruptions of the electric power supply.

It should be stressed that the required development of the YeEES is impossible without a large jump in the power machine building, electrical equipment, as well as in instrument building industries.

Improvement in heat supply industry of the country. At present, almost 40% of all power resources are used to provide heat (production of steam and hot water, direct fuel consumption for heating houses, etc.). The sources for supplying these requirements are TETs (over 35%), boilers of all kinds (over 35%) and installations for the direct consumption of fuel. Today, almost the single well-organized sector of heat supply are the TETs. Among boilers (whose number exceeds 200,000 and continues to grow) small ones prevail, many well-worn, leading to overconsumption of fuel and expenditure of manual labor. At the same time, over half the fuel oil resources and over one third of the natural gas resources are consumed for this purpose. Therefore, an important problem of power supply is an accelerated and systematic development of a centralized power supply in the country on the basis of TETs and large regional boilers operating on nuclear and organic fuels. It would be a mistake to underestimate the importance of thermification in the development of power of the USSR, including the European regions. To improve heat supply, it is necessary to have a state organ that would be directly responsible for the entire heat economy of the country as a whole.

The development of power saving policy. Saving power and power resources is achieved by the judicious distribution of the produced power resources among the regions of the country and consumer categories; by direct savings by consumers due to the creation of new technologies and equipment, etc.;

There are great possibilities for the more efficient consumption of power and power resources, as well as for raising their quality. Frequently, the cost of saving power is considerably less than the cost of increasing the production of an equivalent amount of power resources. One of the most important ways to increase the utilization of the efficiency of power resources is to correct price-setting for fuel and power.

At the same time, special attention should be given to improving the record keeping of the consumption of power resources (especially steam and hot water), the organization of outside monitoring of power and power resources consumption, and increasing the material interests of workers in their saving of power.

A substantiated solution of these important power problems requires making complex computations of many versions which is practically impossible without the wide use of mathematical simulation methods and computers. Therefore, an improvement in such methods (especially, in creating simulation-computing systems) -- is an important scientific problem.

As may be seen from the above, power workers of the country are faced with complex problems. Their successful solution depends to a considerable extent on improving methods of power control organization, including planning, to which attention is called by corresponding decrees of the party and government. Of great importance was an all-union power conference held by the CPSU Central Committee in June 1980 at which cardinal questions on supplying power to the country in 1980 were discussed, as well as prospects of power development in the Eleventh Five-Year Plan period. In solving the problems on improving planning and control, it is necessary to consider the power (a general power system) of the country as a complex hierarchic structure and find for such a structure an optimal combination of centralization principles and integrity of control.

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ELECTRIC POWER

NOVOVORONEZHSKAYA AES GENERATOR ROTOR

Moscow ENERGOMASHINOSTROYENIYE in Russian No 10, Oct 80 p 46

[Article: "Intermediate Product for a 1000 Megawatt Generator for the Novovoronezhskaya AES"]

[Text] The intermediate product weighing 250 tons is made by a technology consisting of the electric slag welding of two or more castings with the following forging of the welded block to the final dimensions. In manufacturing such forgings in the seamless form, it is necessary to make huge castings (weighing more than 500 tons) which requires large capital investments in metallurgical equipment and long assimilation schedules. The technological process developed at the TsNIITmash [Central Scientific Research Institute of Machine Building Technology] makes it possible to use forgings weighing 200 to 250 tons with a guarantee of quality.

The intermediate products made by the new technology have a higher quality than when made by the seamless forging method, because, in the welded-forged version, there is thorough monitoring of the intermediate products when they are welded and then forged. A fair uniformity of the chemical composition of the welded joints is obtained. The following forging (broaching) of the welded block with an average degree of deformation of 20 to 25% provides full uniformity of the structure and of the physio-mechanical properties in the entire volume of the forging.

The mechanical properties and the structure of the welded joints and the basic metal in the cross section of the intermediate product of up to 2000mm in diameter are practically the same and meet the highest requirements of specifications for generator rotors.

The savings from introducing the new technology exceeds one million rubles on one 1000 megawatt generator rotor. The technological process was introduced at the Izhorsk Plant imeni A. A. Zhdanov when manufacturing two rotor forgings for 1000 megawatt generators. The production of generator rotors by the developed technological process was made for the first time in the world.

The manufacturing process of these special design forgings has been described many times in the press and has been shown on Central Television.

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ELECTRIC POWER

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MODELS FOR PLANNING CAPITAL INVESTMENTS IN POWER ENGINEERING

Moscow MODELI PLANIROVANIYA KAPITAL'NYKH VLOZHENIY V ENERGETIKE in Russian 1980 pp 2, inside back cover

[Annotation and table of contents from book by A. I. Kuzovkin and V. N. Panfilov, Izdatel'stvo Energiya," 136 pages]

[Text] This book describes the experience in developing and using models of industrial planning of capital investments using the example of the USSR Ministry of Power and Electrification. A system is considered of practically realizable models for capital investments, and putting capacities in operation in a consolidated power system and the industry as a whole.

The book is intended for power engineers, economists of planning, institutes and management personnel involved in planning capital investments in developing power systems and power enterprises; it is of interest to students in power specialties in VUZ.

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REDUCTION IN HARMFUL EMISSIONS SUGGESTED TO IMPROVE TES ECOLOGICAL SAFETY

Moscow TEPLOENERGETIKA in Russian No 11, Nov 80 pp 2-6

[Article by L.I. Kropp, candidate of technical sciences, All-Union Thermal Engineering Institute: "Perfection of the Power Engineering Industry and the Environment"]

[Text] Heat and electric power stations will preserve their decisive role in the general volume of production of electricity and heat in the visible future. The rising energy needs of the national economy will be covered, in addition to the leading development of nuclear electric power stations in the European sector of the country, mainly by the broader involvement of the Ekibastuz, Kuznetsk, Kansk-Achinsk and certain other promising coal fields in energy production. Taking this long-term trend into account, the environmental protection developments in thermal power engineering must be primarily oriented on increasing the ecological level of solid fuel use, as well as significant resources of natural gas allocated for power engineering needs. From the viewpoint of organizing fuel supply, the latter also signifies that the main mass of natural gas resources must be sent to the municipal TES [heat and electric power stations]. Only temporary surpluses of this fuel may be burned at the condensation electric power stations that are located outside the cities.

The law on protection of the atmospheric air that is based on the principle of restricting the absolute discharge of harmful substances into the air basin and was adopted in the USSR in 1980, has great importance in selecting the environmental protection strategy in power engineering. According to the new law (as a supplement to the extant system of standardizing the permissible harmful pollutant concentrations in the atmospheric air), a system is being prepared for start-up that will regulate the maximum permissible emissions by each enterprise. The law will also significantly affect the selection of technical and technological solutions in primary production. It will ban those that result in increased atmospheric pollution.

At the same time, the sanitary-hygienic habitat standards are becoming stricter. In 1979, the USSR Ministry of Public Health introduced a requirement to compute the total harmful effect of sulfurous anhydride, nitrogen dioxide and carbon monoxide when they are jointly present in the atmospheric air. In the past [4], such a requirement in power engineering only covered oxides of sulfur and nitrogen. In practice this means that the content in flue gases of even an insignificant percentage of chemical underburning in the form of CO (about 0.05%) makes it necessary to reduce the permissible discharges of the two other summing components. An analogous situation occurs when background concentrations of CO are found in the atmospheric air.

One of the possible consequences of the new legislation is a trend towards restricting the height of the TES smokestacks, i.e., weakening the role of flue gas dispersal, with the simultaneous implementation of measures that curtail the absolute discharge of the main harmful components, oxides of sulfur and nitrogen, volatile ash and certain toxic trace pollutants. This trend will also be stimulated by intergovernmental agreements that are concluded in order to restrict the so-called transboundary migration of harmful substances, in the first place, of sulfur dioxide. This is especially important for the TES located in certain regions of the European sector of the country.

In contrast to many technological industries, including nuclear electric power stations, when heat and electricity are produced at the TES, different polluting components of fuel and its combustion products enter the atmospheric air through the purification system almost completely in the form of so-called organized emission that can be evacuated with the help of a powerful centralized gas-removal channel. The role of the scattered, unorganized releases of harmful substances by the main and auxiliary equipment into the production rooms is insignificant in the total material balance. This feature of electricity production promotes an increase in the TES ecological level at all sections of its technological plan: in the process of fuel combustion, as well as in the recovery and neutralization of the combustion products. Based on the change and perfection of the corresponding links in the TES technological plan, it is possible to reduce to a certain degree practically all of the harmful contaminants of flue gases, including sulfuric oxides.

Table 1.

Power of TES, fuel	Method of cyclic desulfurization of flue gases	Specific capital investments for sulfur purification		Specific annual expenditures for sulfur purification		Increase in fuel consumption at TES %
		R/kW	%	kop/(kW·h)	%	
4 x 300 MW, near-Moscow brown coal	Ammonium-cyclic	61.2	39.0	0.55	34.0	16.8
4x800 MW, Donetsk GSSh [gas, seed coal and coal fines]	Ammonium-cyclic	37.0	24.0	0.27	31.7	7.8
	Magnesite	49.6	32.0	0.27	31.7	8.1

The interest in the new technological solutions that promote a more profitable reduction in sulfuric oxide emissions with the use of solid fuel (boilers with fluidized bed, steam-gas units, energy-efficient processes and plans for isolating and recovering pyritic sulfur) is mainly due to the excessively high capital consumption and energy consumption of the traditional methods of cyclic sulfur-trapping at the TES [1]. This is illustrated by the data in table 1, based on the critical analyses of the VTI [F. E. Dzerzhinskiy All-Union Thermal Engineering Institute] and the VGPI TEP [All-Union State Planning Institute "Teploelektroproyekt"] for two power stations that burn coal. The technical and economic indicators are given for the ammonium-cyclic and magnesite methods of desulfurization for roughly 90% of the combustion products of two types of coal, near-Moscow brown coal with sulfur content of 3.3% with combustion heat of 2460 kcal/kg, and Donetsk GSSh with sulfur content of 3.1% and combustion heat of 4730 kcal/kg. Table 1 indicates the complete (national economic) expenditures in calculation for 1 kW of rated output. In the case of successful realization of the product issued by the sulfur-trapping units, and at the same time, displacement of the corresponding plants, these expenditures are reduced. In addition, a certain reduction in expenditures, for example, with the use of the magnesite method, can be attained by perfecting and reducing the cost of the technology for producing the final desulfurization products.

As is apparent from table 1, the capital investments for sulfur trapping are from 24 to 39%, while the operating expenditures are roughly one-third of the corresponding indicators of the main industry. The high level of capital investments is linked to the enormous volume of gases to be purified and the type of fuel. The increased operating expenses are significantly governed by the high energy capacity of the sulfur trapping systems. The energy expenditures converted to fuel comprise from 9 to 16% of its total consumption. This is much higher than the percentage of all the energy expenditures of a modern coal TES for in-house needs. At the same time, energy-consumption is the main criterion in evaluating and comparing the different measures to reduce harmful emissions. The higher this indicator, the lower the degree of perfection of any technological process, and the more inefficiently the primary resources are used.

From the viewpoint of simplifying the desulfurization systems for flue gases, decreasing the energy consumption, organizing this process without harmful wastes, and at the same time, without creating a TES of complex chemical production, the experience of the FRG (Saaberg-Hëlter firm) to perfect the lime method of purification using commercial gypsum, and the experience of Denmark (Niro Atomizer firm) for the so-called "wet-dry" gas purification are important.

The development and use at TES of steam boilers that burn coal in the fluidized bed significantly reduce the capital and fuel-energy expenditures per 1 T of decrease in the discharge of sulfurous anhydride as compared to the traditional sulfurization methods presented in table 1. One of the advantages of this technology is the possibility of significantly more extensive bonding of sulfur dioxide by the alkaline components of the mineral portion of fuel during its combustion, as compared to the standard coal-dust boilers. Therefore, when boilers are used with fluidized bed, in certain cases the solution to the problem of desulfurization can be drastically simplified, since there is no longer any need to create a complicated technological service that guarantees the introduction of alkaline additives into the fluidized bed, for example, limestone, as well as their subsequent regeneration.

Certain specialists make an excessively optimistic evaluation of the noted capability of the fluidized bed. Table 2, consequently, presents the results of computing the content of free alkali in fuel, usually represented in the form of CaO^{cB}, the yield of all sulfur of the fuel in the form of dioxide, as well as their molar ratio. These results are based on the data of [2,3] and are given for certain characteristic domestic fuels. The molar ratio characterizes the theoretically possible degree of bonding of sulfur dioxide with natural fuel alkali during the formation of calcium sulfate. In practice, a certain excess of free alkali above the molar ratio is required. This excess is smaller the more advanced the process.

As is apparent from table 2, the possibility of creating the simplest technology of the fluidized bed for practically complete desulfurization of gases by natural fuel alkali is quite real for the USSR power engineering only with the use of fuels that are in the upper section of the table (shale, all sorts of Kansk-Achinsk coals and Kharanorskiy fuel that is adjacent to it). A definite effect

Table 2.

Fuel (coal, shale)	CaO^{CB} content mg·equiv / kg of fuel	SO_2 output mg·equiv / kg of fuel	Molar ratio CaO^{CB}/SO_2 in percentages
Estonian shale	5350	1000	5.35
Berezovskiy	460	125	3.70
Nazarovo	620	250	2.48
Irsha-Borodino	250	125	2.00
Itatskiy	360	250	1.45
Kharanorskiy	260	187	1.40
Angren	350	820	0.425
Chelyabinsk	60	187	0.32
Bikin	50	187	0.27
Kuznètsk T (R, oxidized)	30	187	0.161
Cheremkhovo	40	690	0.058
Volynskiy	70	1630	0.043
Donetsk ASh [anthracite coal fines]	30	1050	0.029
Ekibastuz	$\leq$10	500	$\leq$0.02

from desulfurization using the technology of the fluidized bed is also possible if Angren, Chelyabinsk and Bikin coals are burned, and to a small degree, Kuznetsk coal. Although all of these fuels, with the exception of shale, have low sulfur content, their combustion in the fluidized bed has a positive effect on sanitation of the air basin when the TES is located, for example, in certain regions of Siberia that are distinguished by unfavorable meteorological features of the atmosphere. It also follows from table 2 that it is expedient to view the fluidized bed as one of the versions of the technology of direct use of Estonian shale in constructing the new power engineering facilities based on this fuel.

The free alkali content is negligible in the mineral portion of all the other coals, as is apparent from table 2. When these coals are burned in boilers with fluidized bed at the TES, therefore, in order to ensure the assigned degree of desulfurization a considerable quantity of imported raw material, the chemical agent, is needed. The creation of special technology is required. The most effective trend for the long-term use of this equipment is its substitution for outdated coal dust boilers that need disassembly, as well as modernization and expansion of the TES that are located in ecologically stressed regions of the European sector of the country and that burn sulfurous coals.

Certain aspects of this progressive trend are not sufficiently clear and need study. It is necessary that the temperature regime of the fluidized bed meet the conditions of irreversible bonding of the sulfur oxides by the alkaline components to the greatest measure. It is also important to organize the technological process so that there is guaranteed output of the final products of the reaction between sulfuric oxides and free calcium oxidesin the form of calcium sulfate, without a noticeable content of sulfides in the removed ash. This is governed by the sanitary-hygienic requirements for the storage and use of ash-slag wastes.

A very promising trend for reducing the discharges of sulfuric oxides that is based on a change in the technology of the coal TES is the preliminary extraction of pyritic sulfur FeS_2 in the fuel-preparation channel, the collection and burning of this highly sulfurous mixture in a special boiler with desulfurization of the combustion products. Their volume in this technology is comparatively low [1]. It is complicated to select the applicable method for removing FeS_2 in preparation for burning hard coals. As studies show, in contrast to the sulfurous brown coals, the pyritic sulfur in the hard coals is distributed significantly more uniformly in the organic mass of the fuel and can be effectively extracted only with particles 100-200 µm in size. This technology can be combined at the TES with the centralized preparation of coal dust.

The development and broad introduction into practice of boiler-building plants and heat and electric power stations of measures that ensure reduction in the discharges of nitric oxides with the flue gases as a result of a change in the organic fuel combustion technology is a still unresolved problem. In addition to the evident need for all possible expansion and intensification of these studies for the TES that use solid fuel, this task is still urgent for municipal TETs and large boilers that mainly use natural gas and furnace mazut. In order to guarantee the possible construction or expansion of these facilities, it is necessary to formulate methods for a more extensive reduction in the output of nitric oxides than the double reduction that was achieved in recent years by certain organizations on the gas-mazut energy units of the Kiev TETs-5, the Kostroma GRES and other electric power stations by using two-stage fuel burners, efficient organization of the introduction of inert gases into the burners, and maintenance of the minimum air surpluses in the combustion chamber during lengthy operation. In order to solve this complicated problem, it is expedient to first study the technically attainable maximum decrease in output of nitric oxides, in particular during combustion of natural gas and mazut at the TES, and to establish the degree of additivity of different measures with their complex use for this purpose. Based on the experimental materials of the Institute of Gas of the Ukrainian SSR Academy of Sciences one can assert that by using the technological procedures, the output of nitric oxides during the operation of large gas-mazut boilers can be reduced in the future to 100-200 mg/m^3. At the same time it is urgent to search for applicable methods of reducing the discharges of nitric oxides based on their reduction in the combustion products of any organic fuels, for example, with the help of introducing ammonia gas at a temperature of about 900°C in the absence of a catalyst, as well as by simultaneous purification of the gases of oxides of sulfur and nitrogen, for example, by the ozone method.

A requirement for evaluating the emissions of certain toxic trace pollutants has been advanced in recent years when plans of new and expansion of active TES are examined. It has definite foundations since these pollutants are present in insignificant quantities in the fuel combustion products [2]. They include lead, arsenic, vanadium, mercury, zinc and certain others. The majority of these elements and their compounds are in a solid state at 130-150°C temperature of the exhaust gases. They are trapped to a certain measure with the ash in the ash-traps. Only the compounds of mercury, fluorine and chlorine are mainly in a vapor state and are practically not trapped in the dry ash traps.

Table 3 presents the results of computing the relative harm from discharges of lead, arsenic, vanadium and chrome compounds as compared to the emitted volatile ash during combustion of Donetsk, Kuznetsk and Nazarovo coals, and the degree of ash trapping of 99% as an example. The content of listed elements in the volatile ash is accepted from the data of V. Ye. Chmovzh (VTI). The permissible concentration of these compounds in the atmospheric air is established from a daily average sample, i.e., in the form of the MPC_{cc} [4]. Correspondingly, when table 3 was compiled, the MPC_{cc}=0.15 mg/m^3 value was used for volatile ash. The data on fuels and their combustion products were taken from [2]. In order to evaluate the effect of trace pollutants, it is customary to assume in the calculations that the trace pollutants are trapped from the gases to the same degree as the volatile ash, i.e., by 99%. It should be taken into account that usually under these conditions, the volatile ash concentration in the atmosphere, that is governed by TES emissions, is considerably lower than the MPC.

Table 3.

Indicators	Coals		
	Donetsk (A^P=23%)	Kuznetsk (A^P=16.2%)	Nazarovo (A^P=7.3%)
Content of trace pollutants in volatile ash, mg/kg of ash:			
lead Pb	170-210	15-30	14-30
arsenic As	80-110	-	28-48
vanadium V	120-170	15-28	8-24
chrome Cr	110-150	23-56	9-15
Relative harmfulness of trace pollutants as compared to discharged ash with 99% trapping,%:			
Pb	1.3-1.6	0.14-0.23	0.1-0.2
As	0.45-0.7	-	0.14-0.28
V	1-1.5	0.15-0.24	0.11-0.22
Cr	1.1-1.6	0.26-0.65	0.14-0.28

It follows from table 3 that in the case of 99% trapping from the flue gases, the content of listed trace pollutants in the solid emissions is so small that their harmfulness can be ignored in the sanitary-hygienic evaluation of the TES. In practice, however, the relative harmfulness of the solid trace pollutants discharged into the atmosphere during the operation of the coal TES can be higher than the values indicated in table 3. This is because the distribution of such elements as lead, arsenic and certain others, is not uniform in fractions of volatile ash that differ in particle size. Their content usually increases with a reduction in particle size [2,5]. For substantiated calculations it is necessary to know not only the content of a certain trace pollutant in the fuel and volatile ash, but also its distribution in different fractions of volatile ash. This requires thorough experimental work.

The calculated estimate of the effect of trace pollutants would be drastically simplified if the USSR Ministry of Public Health agencies had experimentally established MPC_{cc} and $MPC_{m.p}$ standards for the main types of volatile ash that is currently conditionally equated to nontoxic dust. These standards make a summary calculation of the toxicity of all trace pollutants and such compounds as free calcium oxide and free silicon oxide. Serious substantiations for the practical expediency of this approach are the transfer of almost all trace pollutants into the volatile ash during fuel combustion, the giant scales of energy use of the main solid fuels, especially Ekibastuz, Kuznetsk and Kansk-Achinsk coals, as well as the relative stability in their mineral composition.

Table 4.

Measure	Multiplicity of decrease in ash discharge into atmosphere (range)	Supplemental effect
Optimizing agitation regime of settling electrodes	1.3-2.0	Conservation of operating and repair expenditures
Improvement in aerodynamics at inlet to multiple-pole electric filter	1.1-1.4	-
Decrease in coefficient of excess air α, reduction in infiltration on channel with α = 1.6 for every Δα=0.1	1.3-1.4	Conservation of energy resources
Decrease in temperature of exhaust gases in safe limits for the boiler for every 10 K:		
during combustion of sulfurous hard coals and any brown coals	1.1	-
during combustion of low-sulfur hard coals	1.2-1.3	Fuel conservation
Increase in active section or volume of apparatus for every 10%	1.5	-

The discharge of toxic trace pollutants into the atmosphere can be radically curtailed by extensive purification of the flue gases of ash. As the calculations show, the decisive role here is played by the efficient trapping of the finest fractions of volatile ash of 5 μm and lower, since these particles contain the main quantity of trace pollutants. The efficiency of certain ash-trapping apparatus in trapping trace pollutants can therefore be evaluated from the change in the so-called countable concentration of ash particles in the gases. It is understandable that during ash trapping, the mass concentration of volátile ash drops more drastically than the countable.

Perfection of the operation of electric filters plays a large role in solving the problem of reducing the absolute discharge of volatile ash, including its fine fractions. This is because the majority of energy units that run on coal are equipped with electric filters. In addition to the long-term developments in this area that cover such urgent problems as increasing the reliability of the main assemblies of delivered equipment, creation of different means of conditioning flue gases, and search for more efficient methods of using high voltage rectified current, it is also very important to have the maximum consideration for the operating experience of the TES, the tuning and other organizations. A rough estimate of the comparative efficiency of different measures that reduce the volatile ash emission during the operation of electric filters and which is based on this experience is presented in table 4. Some of these measures are directly linked to a change in the technology of the main industry.

The listed trends do not at all exhaust the ways to perfect the power engineering industry associated with environmental protection. The real outlook for the main production and for reducing harmful discharges is found in the energy-efficient refining of Kansk-Achinsk coals according to the plan suggested by the ENIN [G. M. Krzhizhanovskiy Power Engineering Institute] with combined heat carrier. In this plan, thermal breakdown of the coal dust is carried out without access of air and rapid heating to 500-850°C with the help of flue gas and products of the actual process, parts of semicoke or coke, circulating in the system. The introduction of a large unit using this method, with output of 1 million T of coal per year that is planned in the near future will permit a more complete evaluation of its ecological indicators. Another serious problem is the organization of ecologically safe storage of enormous masses of ash-slag wastes in the region of powerful coal TES. It is consequently urgent that studies be made on creating the technology to guarantee neutralization, disposal of ash during its removal, and prevention of its possible and noticeable leaching out during lengthy storage.

One should stress in conclusion that in order to successfully solve a vast circle of environmental protection problems in power engineering, a complex approach is necessary. It consists of combining ecologically efficient changes in the technology of the main production with perfection of diverse means for purifying the polluted gas streams.

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