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USSR Report

ENERGY

(FOUO 3/81)

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ELECTRIC POWER

UDC 621.311.25:621.039.001.86

FIFTEEN YEARS' EXPERIENCE IN OPERATING NOVOVORONEZHSKAYA AES

Moscow ELEKTRICHESKIYE STANTSII in Russian No 11, Nov 80 pp 8-12

/Article by V. K. Sedov et al., engineers: "Fifteen Years' Experience in Operating the Novovoronezhskaya AES imeni 50th Anniversary of the USSR"/

/Text/ In 1979 the electric-power engineers of the Novovoronezhskaya Nuclear Power Station (NVAES) marked the 15th anniversary of the start-up of the first electric-power unit. During these elapsed years they have accumulated a great deal of experience in operating the functioning units.

The Novovoronezhskaya AES imeni 50th Anniversary of the USSR has four fuunctioning electric-power units with a total planned rated capacity of 1,455 MW. The fifth power unit, with a rated capacity of 1,000 MW, is currently being prepared for operation.

It is important to note that all the power units of the NVAES are pilot models; they have been used to work out and implement the plan and design solutions which formed the basis of the concept of the water-moderated, water-cooled electric-power nuclear reactor (VVER). Experience gained in operating these power units has convincingly demonstrated that an AES with VVER-type reactors is a reliable and safe source of electric power, ensuring a sufficiently high degree of efficiency in utilizing nuclear fuel.

The basic parameters of the NVAES reactors are cited in Table 1 and are also described in /L. 1, 2/.

Technical and economic operational indicators. /in boldface/ Table 2 cites the technical and economic indicators for the period 1974--1979, which characterize the qualitative growth and developmental dynamics of the NVAES.

It may be seen from the data of Table 2 that the output of electric power during the past five years (without an increase in rated capacity) grew by more than 9 percent, achieving a figure of more than 10.5 billion kW-hrs in 1978.

Table 1

Parameter	Power Unit I	II	III	IV	V
Rated electric capacity of unit, in MW	210	365	440*	440*	1000
Type of reactor	VVER-210	VVER-365	VVER-440	VVER-440	VVER-1000
Thermal capacity of reactor, in MW	760	1320	1375	1375	3000
Pressure of coolant (heat carrier) of first circuit, in kgs/ cm^2	100	105	125	125	160
Temperature of coolant, in °C:					
at inlet into the reactor	252	252	265	267	290
at outlet from the reactor	271.1	277.8	290.5	295.8	322
Number of turbogenerators in a unit	3	5	2	2	2
Rated electric capacity of a turbo-generator, in MW	70	73	220	220	500
Number of reactor's circulating loops	6	8**	6	6	4
Productivity of steam generator, in tons per hour	230	325	455	455	1469
Steam pressure, in kgs/cm^2	32	33	47	47	64
Productivity of main circulating pump, in thou. m^3/hr.	5.6	7.1	7.0	7.0	20
Capacity required by the main circulating pump, in MW	1.53	1.53	2.26	2.26	5.3
Planned value of total efficiency, in %	27.63	27.65	32.0***	32.0***	33.3
Outlay of electric power on internal needs, in %	8.0	7.3	7.15	7.15	5.5

*Planned values cited.
**Seven circulating loops are in operation.
***At a turbine condenser pressure of 0.035 kgs/cm^2.

Table 2

Indicator	1974	1975	1976	1977	1978	1979
Production of electric power, in millions of kW-hrs. . .	9664.1	9138.1	9750.8	10080.0	10517.0	9915.8
Release of electric power into the power system, in millions of kW-hrs. . .	8927.5	8427.0	8999.7	9310.0	9723.0	9158.7
Outlay of electric power on internal needs, in % . . .	7.62	7.78	7.70	7.65	7.55	7.82
Coefficient of using rated capacity	0.760	0.717	0.763	0.791	0.825	0.789
Total efficiency, in %	28.27	28.37	28.48	28.71	28.88	28.54
Product costs of released electric power, in kop./(kW-hr.)	0.644	0.643	0.632	0.634	0.609	0.613

The coefficient of using the rated capacity of NVAES rose from 0.760 in 1974 to 0.825 in 1978 (a relative increase of 8.5 percent). This increase was brought about by means of raising the level of operation and the quality of repairs.

The total efficiency (performance) over the five-year period rose by 0.61 percent (in relative terms by 2.1 percent), and in 1978 it amounted to 28.88 percent on an average. This increase in efficiency occurred as a result of raising the vacuum in the turbine condensers and the temperature of the feed-water, brought about by raising the quality of equipment utilization and improving the operation of the circulating systems, in particular, by means of introducing thermal and vacuum cleaning of the condensers.

Improving all the above-listed indicators ensured the reduction of the resulting economic indicator--the production cost of releasing electric power during the last five years from 0.644 to 0.609 kop./(kW-hrs.)--a relative reduction of 5.4 percent. If we compare the technical and economical indicators of the NVAES with the indicators of the best TES's /thermal electric-power stations/, then the AES with its VVER reactors is fully competitive, and with respect to a number of indicators it even surpasses the best TES's.

Certain lowered indicators for 1979 were caused by increased volumes and time periods required for repair operations during planned-preventive repairs on Units III and IV.

Utilization of nuclear fuel. /in boldface/ During the lengthy period of operation by the NVAES reactors considerable experience has been accumulated in organizing the fuel cycle of nuclear reactors.

Refueling of the reactors is conducted once a year sequentially in all units; at this time extensive annual planned preventive maintenance is combined with the process of refueling the reactors. It should be noted that the NVAES has been successful in conducting the refueling with the complete removal of fuel from the active zones in order to control the status of the interior surfaces of the reactor housing and the interior facilities.

The planned depth of burn-out for the spent fuel being removed is constantly increasing. Thus, the planned average depth of burn-out for the fuel being removed, which for the VVER-210 is equal to 12.85 kg/t, for the VVER-365 -- 27.8 kg/t, and for the VVER-440--28.3 kg/t, has been exceeded.

In the reactor of Unit I this was achieved by means of introducing a grouping regime of the active zone, close to the zonal-type, and by utilizing a fuel-enrichment assembly (TVS) with a 3 percent enrichment (up to 30 units). In the reactor of Unit II the increase in the burn-out of the fuel to be removed was ensured primarily by means of introducing a TVS with a 3 percent enrichment without absorbent elements (pels). The excess of actual burn-out of fuel being removed over what was planned for the VVER-440 in Unit III was caused primarily by the conversion of this reactor to sub-feeding by a fuel which has an enrichment of 2.4 percent and 3.6 percent, standard for the VVER-440.

For the VVER reactors a definite influence on the fuel burn-out is exerted by utilizing a TVS of ARK [expansion unknown] cassettes with an enrichment of 2.4 percent in a regime of two refuelings during the operating period (run) of these TVS's. Furthermore, the systematic application of a regime of prolonging the run also brought about, to a certain degree, an overall increase in the burn-out of the fuel being removed for all the NVAES reactors.

The maximum depth of fuel burn-out in individual TVS's being removed is equal for Unit I to 30.98 kg/t (with an initial TVS enrichment of 2 percent), for Unit II--48.06 kg/t (with an initial TVS enrichment of 3 percent with pels), for Unit III--50.44 kg/t (with an initial TVS enrichment of 3.3 percent with pels), pertains to TVS's which are specially left in the active zones of reactors for the purpose of studying the behavior of fuel (heat-emission) elements (tvels) in burn-outs which significantly exceed the planned values, and estimating their resources.

Experience in operating the NVAES has shown that in the process of the fueling operation there may be a violation of the hermetic quality of the casings of individual tvels, which is accompanied by the escape of fission fragments into the coolant (heat-exchange medium).

In order to maintain a sufficiently low degree of activity within the coolant of the first circuit, to disclose in time and make a quality check on assemblies with non-hermetic tvels, AES's with VVER-type reactors utilize special control methods which are based on registering the presence of the products of nuclear fuel fission in the coolant of the first circuit.

In an operating reactor the status of the tvel casings is evaluated in accordance with the results of a radio-chemical analysis of the coolant, as well as in a supplementary fashion with the aid of loop control systems for delayed neutrons. The periodicity of the analysis is determined by the total activity of the dry remnant from testing the water of the first circuit which is monitored every day. If the total activity is less than 10^{-3} Ci/l (Curies per liter), the radio-chemical analysis is conducted once a month; if not, then it is done more frequently. The goal of the radio-chemical test analysis of the water in the first circuit is to evaluate the contents of the isotopes of iodine, barium, strontium, xenon, krypton, cesium and neptunium. In order to separate out the isotopes from the coolant tests, use is made of methods of radio-chemical precipitation onto fabric sorbents, as well as distributive chromatography and extraction methods.

Units III and IV of the NVAES have introduced a method of control over the isotope composition without test sampling. With the aid of a gamma-spectrometer based on a semiconductor detector, direct measurement is carried out in the pipeline of the combined activity in the filter bypass (in the unit for continuous purification of the water in the first circuit).

Continuous monitoring of the state of the tvel casing /can/ in an operating reactor is conducted by loop systems which allow us to monitor the developmental dynamics of the process of unsealing the tvels and issuing recommendations with regard to the periodicity of radio-technical analysis of the coolant.

During reactor refueling widespread use has been made of a method, based on calculating the activity of a gas test sample taken from out of the hermetic casing with the TVS to be tested (the so-called "dry" method).

Preliminary experiments were conducted to determine the speed of TVS heat-up in a "dry" casing. It was determined that for a TVS with a burn-out of 19.7 kgs of poison sinters/ton of uranium within 100 days following its removal from the reactor the speed of the heat-up amounts to approximately 3°C/min. for the temperature range from 35° to 150° C. Thus, the safe time for a cassette to be in a "dry" casing amounts to 5--10 minutes.

The sensitivity of this method has proved to be quite high; the indications of the gas activity of the unsealed tvels exceeds the indications of the sealed tvels by a factor of 10^3 and more. As a rule, all TVS's with unsealed tvels are revealed by the "dry" method. This method is quite simple; it requires no complicated apparatus and allows us to combine operations on monitoring tvel casings with the technical operations concerned with refueling the reactor's active zone, and thereby to reduce the time when the electric-power units are shut down.

In order to make more precise the unsealed quality of the tvel casings in the TVS which have been revealed by the "dry" method as "unsealed," the activity of the iodine-131 is determined in the water test samples, obtained when the TVS has been steeped in water--the "wet" method.

The continuous monitoring of the radio-chemical composition of the first circuit's coolant testifies to the high reliability of the TVS used in the NVAES reactors. At the present time monitoring the hermetic quality of the TVS casings when the reactor is shut down is conducted not at every refueling of the reactors, and its necessity is estimated according to the results of the monitoring of the radio-chemical composition of the coolant and the data of the system of monitoring the sealed quality of the tvel casings as well as the delayed neutrons during the operation of the reactor.

Utilization and repair of the basic equipment. /in boldface/ The high coefficients of utilizing the rated capacity achieved in the NVAES Units I--IV testify to the sufficiently high degree of reliability of the AES equipment. This is ensured both by correct utilization as well as by the timely and good-quality repair of the equipment.

The repair of the radioactive equipment of AES reactor units, as compared with the repair of the remaining equipment, has its own characteristics. First of all, we must note the following:

the limited time spent by the repair personnel in the work place leads to the necessity of enlisting a large number of workers;

prior to inspection and repair, additional labor outlays and material outlay are required to deactivate the equipment;

repairs require the formulation of special tolerances in the work place and monitoring of the radiation unit in the work place, as well as the application of individual and group means of protection from ionizing radiations;

after the repair operations have been completed, it is necessary to deactivate the tools, apparatus, and fittings, as well as to collect, remove, transport, and bury the radioactive wastes;

because of radioactive pollution or design execution, the processing (restoration) of certain parts and assemblies is impossible under plant conditions.

Repairs of the auxiliary equipment during the period between shutdowns of a unit for refueling in the strict-regime zone are performed by a minimum number of repair personnel. But during unit shutdowns for refueling, combined with planned preventive maintenance (PPR), the maximum number of personnel is required. The NVAES structure is subordinated to these requirements, and it allows us to be flexible with the repair personnel, performing the operations with a minimum one-time and yearly dose of irradiation.

A great deal of attention is devoted at the NVAES to monitoring the state of the equipment. Entrance controls conducted at NVAES on the equipment metal has the purpose of disclosing intolerable defects in equipment earmarked for installation, as well as verifying whether the equipment meets the engineering specifications. During the entrance controls a determination is made of the initial state of the equipment metal, which is necessary in the subsequent operational controls. The operational controls on the equipment metal are carried out in accordance with the existing regulations at fixed intervals. The full range of controls is carried out at least once every four years. The most important individual assemblies and equipment of the reactor installation are monitored more often; for example, the reactor outlets, the sheathing of the reactor SUZ [control and safety rod] drives, etc.

The greatest use has been made at the AES of such methods of equipment monitoring as visual-optical, x-ray-gammagraph analysis, ultra-sonic, helium-halloidal, vortex , luminescent-hydraulic methods, and the method of color defectoscopy. In order to monitor the welded joints of the reactor outlets and the D_y 500-mm pipelines, use is made of a remote-control installation, equipped with a telescopic bar. The luminescent-hydraulic method of defectoscopy is utilized in monitoring the hermetic quality of the steam-generator pipe clusters.

In addition to conducting periodic monitoring of the equipment metal, the NVAES exercises controls over the operating equipment by the means and methods of technical diagnostics.

The technological noise which arises during the operation of the equipment is registered with the aid of an installed system of vibro-acoustical controls in operative use, and in case an irregularity shows up, it is analyzed with the aid of a different apparatus under laboratory conditions. As sensors /pickups/ of the vibro-acoustical noises, use is made of piezoelectric-type accelerometers. Initial data with regard to the distribution and number of sensors is acquired during during the start-up and adjustment tests and on the basis of experience in operating the first circuit's equipment.

In addition to utilizing vibro-acoustical signals, controls are also applied on hydrodynamic noises, and these are conducted primarily during the period of start-up and adjustment operations. However, the use of such controls is limited because of the need to install sensors in direct contact with the coolant, and this brings about the appearance of additional flanged and welded joints in the first circuit.

In order to monitor the state of the reactors' installations inside the buildings, use is made of the methods of analyzing the neutron noises of the active zone, measured with the aid of four regular ionization chambers, placed on the floor plan at an angle of 90° to each other.

Diagnostics of the state of the equipment is carried out in accordance with the following scheme: the manifestation of deviations in the signal, as compared with the initial signal; determining the place where the irregularity arises; determining the specific defect which has caused the irregularity.

As a result of utilizing a system of continuous monitoring, equipment defects are revealed, as a rule, at an early stage of their development. In 1978, for example, a weakening in the rotor attachment on one of the main circulating pumps of Unit IV was discovered in time. This pump was put into repairs. Without the use of diagnostic controls, an analogous defect, as a rule, would not be revealed in time, and this could lead to a lengthy malfunction-caused shutdown of the pump.

With the aid of controls on the neutron noises, a vibration in the reactor shaft of Unit III was established to be as much as much as 0.5 mm. A planned inspection of the reactor installations within the building revealed considerable wear on the place where the reactor shaft is attached in the centering hub /bushing/. After the defect was eliminated, the shaft vibration was reduced to 0.1 mm.

The conclusion can be drawn that operative information about the state of the equipment when the power units are operating under load has allowed us to significantly increase the reliability and safety of using nuclear electric-power stations with VVER-type reactors.

Radiation safety and environmental protection. /in boldface/ The more than 15 years of experience in operating the NVAES has testified to the fact that the production of electric power at AES's with VVER's is reliable from the viewpoint of radiation safety.

The work of personnel under conditions in which there is a possible effect of ionizing radiation on human beings is rigorously monitored by the dosimetric service.

Table 3 cites the values of the average annual irradiation of NVAES personnel. It is obvious from this data that there is a trend towards reducing the irradiation; moreover, its amount is much lower than the tolerable limit. At the NVAES no excessive doses of external irradiation over the tolerable limits have been observed.

Table 3 also provides figures for the average 24-hour gaseous discharges for the entire period of the AES's operation. Their amount does not exceed 1 percent of the tolerable limit.

From the data of this same table it is obvious that the amount of aerosol discharges during the operation of the four NVAES power units comprises 0.1 percent of the tolerable limit.

The radiation situation around the AES is monitored by the exterior dosimetry service. Table 4 cites the monitoring results with regard to the principal facilities of the exterior environment.

From the data of this table it follows that the concentration of radioactive substances in the air, within the margins of measurement error, are just the same as they are 50 km from the AES. In comparing the concentrations of radioactive substances in the water and in the bottom deposits of the Don River below and above the AES along its course, no effect by the NVAES on the environment has been traced.

Training personnel at an educational-training center. /in boldface/ Present-day AES's are characterized by a complexity of equipment, a high intensity of ongoing technological processes, and increased requirements for reliability, safety, and economies in their operation; this brings about the need for special training of their service personnel.

For the purpose of providing training for Soviet and foreign specialists for AES's with VVER-type reactors, an educational training center (UTTs) was established at the NVAES in 1972. During the period of its existence here some 2,000 specialists have been trained for AES's.

Since 1976 the UTTs of the NVAES has begun to develop standardized programs for training the three categories of AES service personnel--operative, technical, and repair. At the present time the UTTs is conducting personnel training for 44 position titles and occupations.

Table 3

Year	Average Annual Dose of External Irradiation of Monitored AES Personnel, in ber.	Average Daily Amounts of AES Discharge Wastes	
		Gaseous, in Ci/day	Aerosol, in MCi/day
1965	2.03	282.5	---
1966	2.58	578.7	---
1967	2.34	417.5	---
1968	1.97	223	---
1969	2.30	174	---
1970	2.44	2.7	---
1971	1.91	1.1	---
1972	0.70	56.0	0.023
1973	0.64	82.5	0.32
1974	0.85	112.1	2.23
1975	0.95	116.4	2.26
1976	0.93	28.8	1.29
1977	0.78	18.9	1.43
1978	0.61	39.0	0.71
1979	0.60	15.3	1.71
Tolerable Limit	5.0	3,500	500

During recent years particular attention has been paid to developing skills in managing both the reactor and the unit as a whole during the UTTs training period. Such development in training is necessary so that the operating personnel acquires the practical skills of starting up and shutting down a unit, in managing a unit's systems, and in conducting technological regimes, as well as the skill of appraising situations and taking operating decisions, especially for the intelligent elimination of infractions which may arise in functioning units. The final stage to be introduced into the training program plans to organize not only the instruction of operating personnel of newly built AES's but also the retraining of personnel at existing AES units.

Table 4

Year	Concentration of Radioactive Substances in the Air, 10^{-17} Ci/l					
	On the AES Territory			50 km from the AES		
	Total Specific Activity	Concentration of Cesium-137	Concentration of Strontium-90	Total Specific Activity	Concentration of Cesium-137	Concentration of Strontium-90
1974	19.3	0.47	0.42	18.0	0.33	0.34
1975	13.0	0.4	0.51	10.0	0.3	0.53
1976	6.46	0.14	0.08	4.63	0.1	0.06
1977	20.4	0.4	0.16	22.8	0.45	0.17
1978	12.6	0.36	0.27	11.1	0.28	0.22
1979	5.9	0.42	0.3	2.5	0.24	0.14

Table 4 (Continued)

Year	Concentration of Radioactive Substances in the Water of the Don River, 10^{-12} Ci/l					
	Above the AES			Below the AES		
	Total Specific Activity	Concentration of Cesium-137	Concentration of Strontium-90	Total Specific Activity	Concentration of Cesium-137	Concentration of Strontium-90
1974	10.3	2.6	0.63	9.9	1.97	0.55
1975	11.6	1.37	0.46	9.7	1.46	0.52
1976	8.35	0.58	0.36	8.7	0.32	0.4
1977	10.0	0.43	0.47	8.7	0.42	0.6
1978	12.0	0.88	0.48	9.5	1.25	0.42
1979	9.3	0.8	0.54	8.7	0.7	0.54

Table 4 (Continued)

Concentration of Radioactive Substances in Bottom Deposits of the Don River, in 10^{19} Ci/kg

Year	Above the AES: Total Specific Activity	Above the AES: Concentration of Cesium-137	Above the AES: Concentration of Strontium-90	Below the AES: Total Specific Activity	Below the AES: Concentration of Cesium-137	Below the AES: Concentration of Strontium-90
1974	9.2	0.22	0.1	7.0	0.12	0.14
1975	18.3	0.07	0.18	12.9	0.18	0.22
1976	13.0	0.14	0.07	10.9	0.15	0.03
1977	11.2	0.07	0.14	7.1	0.11	0.09
1978	15.0	0.11	0.18	22.0	0.40	0.15

Plans for developing the USSR's nuclear-power engineering provide for the construction of a large number of nuclear power stations in the USSR and abroad with the technical assistance of the USSR. In connection with this, it is planned to create a training facility for the VVER-1000 reactor with a throughput capacity of 180 persons a year. Moreover, the establishment of one more training facility for the VVER-440 reactor is in the planning stage.

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ELECTRIC POWER

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ENSURING EARTHQUAKE RESISTANCE OF AES ELECTRICAL EQUIPMENT

Moscow ELEKTRICHESKIYE STANTSII in Russian No 11, Nov 80 pp 13-14

/Article by A. P. Kirillov, doctor of technical sciences, and V. V. Piskarev, candidate of technical sciences: "Basic Ways to Ensure Earthquake Resistance of AES Electrical Equipment"/

/Text/ Particular importance has been accorded and is being accorded to ensuring the reliable and safe operation of electric-power facilities and especially the nuclear power stations which are being built in regions of high seismic activity.

The functioning of an AES under normal conditions and emergency conditions is determined, to a considerable extent, by the operational reliability of the electrical equipment (ETO), instruments, and apparatus responsible for monitoring and regulating the nuclear process, including the emergency system for shutting down and cooling the reactor.

This calls for the necessity of conducting a complex of operations aimed at checking out the operational capability of the electrical equipment under conditions of possible seismic activities and determining the structural changes for the purpose of ensuring its continuous functioning. Particular attention must be devoted to investigating the electrical equipment belonging to Category 1 of earthquake resistance, i. e., the electrical equipment whose failure or damage brings about a breakdown in the reactor's emergency shutdown and cooling system.

In general, ETO designs constitute a complex vibration system. A thorough, theoretical study of such a system is a difficult task, and in practice it is not always carried out. The design and schematic parameters of the ETO should be selected so as to ensure the following:

the earthquake resistance of the equipment (there must not occur within it strength or fatigue breakdowns, impact collisions during seismic activities, and deviations in its operating systems must not lead to a failure of the entire system);

the absence of resonance frequencies of the structural elements in the given frequency range.

These parameters can be determined approximately by solving the equation for the movement of a system and by an analysis of the vibration processes under the effects of various exciting forces. However, taking into consideration the need to obtain reliable data, the results would be obtained at the present time by conducting physical tests on a natural scale.

Today's electrical equipment is characterized by a great diversity of design schemes, which makes it necessary to run widescale tests on practically every casing, panel, and assembly.

In Soviet practice testing ETO for earthquake resistance is conducted on VP-100, VPZK-100, and SP-2k-3 (developed by the VNIIG imeni B. Ye. Vedeneyev) types of vibration platforms, which allow us to assign accelerations of as much as 1.5 g within a frequency range of 0.6--50 Hz. Even though for multifaceted equipment tests for earthquake resistance we need a broader class of actions, the Soviet and foreign test stands are limited in their possibilities for simulating loads, but still they create conditions closely resembling those of earthquakes.

At the present time tests on ETO for earthquake resistance are being conducted within a frequency range of 0.5--30 Hz; moreover, the frequency accelerations are assigned, proceeding from the generalized response range obtained at the location site of the equipment being tested. The maximum acceleration arising on an ETO base does not usually exceed 1 g. The complementary items used in an ETO ought to remain operationally capable at accelerations of up to 3 g /L. 1/ in the frequency range of 0.5--50 Hz for 20 seconds.

The above-mentioned types of vibration platforms allow us to conduct tests for earthquake resistance on panels taken separately as well as on sections composed of such panels. Each panel (case) consists of a bearing structural component and the complementary items (relays, switches, instruments, transformers, etc.)which are attached to it.

The complementary instruments, apparatus, and individual assemblies are attached in a coordinated manner to thick, fiberglass-textolite flat surfaces mounted on a rigid frame. This frame should be open for ease of access to the complementary items located within.

It should be noted that the bearing structural components used for grouping electrical equipment at AES's abroad are made of steel bands 7 mm thick.

Increasing the rigidity of the bearing structural components considerably simplifies engineering solutions with regard to the placement of the complementary items, determining their sizes, etc., while the outlays needed to provide the additional rigidity are not great.

The tests which were conducted on ETO for earthquake resistance not only allowed us to find individual shortcomings but also to discover definite merits to the designs, as well as to issue recommendations increasing the equipment's earthquake resistance. After the implementation of additional measures, the equipment proved to be sufficiently reliable to function under the conditions of the equivalent seismic loads which we had created.

The recommendations for increasing the earthquake resistance consisted, as a rule, in increasing the structural rigidity and in strengthening the height of the panels and the area between them. In a number of instances a regrouping of the complementary items was proposed. The electrical equipment which was simulated in accordance with the recommendations was put through repeated testing, which demonstrated that these panels have a considerable reserve with regard to earthquake resistance.

It should be noted that the recommendations aimed at increasing earthquake resistance ought to be given while taking into consideration the actual conditions of the ETO's placement in the station. Thus, it is practically impossible to attach certain panel components from above, while in a number of instances difficulties arise in conducting welding operations near the complementary items, the electrical communications facilities, etc.

Results of numerous tests have shown a considerable excess of loads created by the stands in relation to the design /estimated/ seismic loads; therefore, both the technical difficulties in carrying out the recommendations and the economic concepts require a different approach in the conduct of research.

A method has been proposed for determining ETO earthquake resistance which includes stand-type testing of the complementary items for the purpose of finding the amplitude-frequency boundary /limit/ of their operational capability, as well as determining the transfer functions of the bearing components in the places where the complementary items are installed.

The estimate portion of this method consists in determining the accelerograms, taking into consideration the building's dynamic characteristics, for an earthquake at the place where the ETO is installed. Then a determination is made of the maximum acceleration in the places where the complementary items are attached on the action of the transformed accelerograms, taking into consideration the transfer functions of the ETO structural bearing components. The equipment's earthquake resistance is determined from a comparison of the amplitude-frequency boundary of the operational capability of the complementary items and the size of the maximum acceleration acting on them as a result of loads which are the equivalent of an earthquake's loads. A schematic for determining ETO earthquake resistance by means of design estimation is depicted in Figure 1.

A merit of this method is the fact that the initial data can be obtained by the estimate method or experimentally.

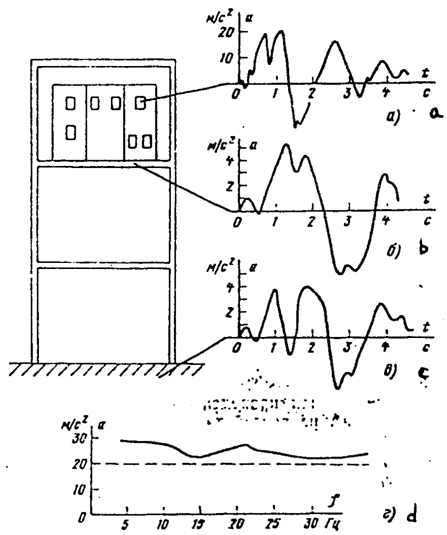

Figure 1. Schematic of Determining Earthquake Resistance of Electrical Equipment by Means of Design Estimate

Key:
- a--Acceleration arising in a complementary item
- b--Accelerogram of covering movement
- c--Estimate accelogram of earthquake affecting the structure's base
- d--Graph of the operational capability of a complementary item

It must be stipulated that the use of the frequency analysis which has been applied in the given method is possible if the system being studied is linear. Hence, operations were conducted linked with the manifestation of the mechanical linearity of the ETO panels within the given range of frequencies and accelerations. The investigations which were conducted along these lines demonstrated that in the frequency range of 1.5--30 Hz and the acceleration range of 0.2--0.8 g the panel structural components behave like elastic systems and are subordinated to the linear principle.

On the basis of the mechanical linearity of the NA-5, NA-10, A-5, and P-11 types of panels studied, the reactions of this equipment to the assigned accelerograms of earthquakes were determined.

The investigations which were conducted showed that stand-type tests create the most rigid equivalent loads.

Our task consists in issuing recommendations in sufficient measure ensuring ETO earthquake resistance and, at the same time, making it possible from an engineering point of view to implement them under natural conditions.

The first step in this direction has been made in the present article. Let us cite for the sake of comparison the results of the stand-type and the proposed methods of testing. Stand-type tests run on equipment panels of monitoring and measuring instruments and apparatus of the A-5, NA-5, and NA-10 types have demonstrated that accelerations in the most unfavorable places for attaching complementary items reach 90--120 m/c^2.

At the same time projects were carried out on calculating the reaction of a KIP and A (Control-Measurement Instrument and Apparatus) panel to the effects provided in the form of an accelerogram of an earthquake. The calculation was carried out according to the method of determining the response, as used in studies of automatic-control linear systems /L. 2/.

Figure 2 depicts an accelerogram of a design earthquake and the reaction of the upper part of an NA-5 panel in the place where the relay is attached. It is clear that the acceleration arising in the place where the relay is attached exceeds by an amount approximately double the maximum acceleration of the design accelerogram.

The stand-type tests revealed the need for a considerable increase in the rigidity of the bearing components, the use of dampers for certain of the complementary items, and a more rational grouping of them.

The method described for determining the earthquake resistance of equipment demonstrated that the measures proposed and implemented in the testing process, creating additional rigidity, are sufficient to ensure ETO earthquake resistance.

A similar approach has allowed us to develop with minimal outlays recommendations for increasing ETO earthquake resistance, which can be used subsequently in regular production.

Conclusions

1. Complementary items to be used in electrical equipment must be made vibration-resistant and should function reliably within a frequency range of 0.5--50 Hz with accelerations of up to 3 g and an additional load-time of 20 seconds.

2. It is most feasible to determine the earthquake resistance of electrical equipment experimentally by means of conducting stand-type tests.

3. Of considerable interest is the complex method of determining the earthquake resistance of equipment, including experimental and estimate design projects.

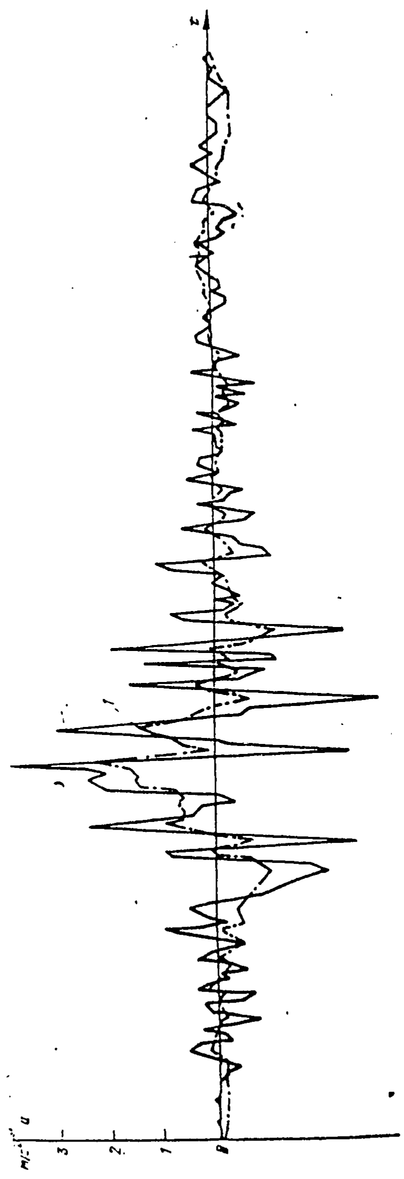

Figure 2. Accelerogram of a Design Earthquake (1) and the Reaction of a Complementary Item to a Design Accelerogram (2)

4. The most effective method for increasing the earthquake resistance of electrical equipment is strengthening the attachment of the equipment internally, i. e., among its own elements, and on the structural components.

5. It is feasible to create a standardized series of bearing structural components for the electrical equipment, allowing us to group together the corresponding complementary items, and this would lead to a reduction of stand-type tests.

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ENERGY CONSUMPTION, WORLD COAL DEVELOPMENT PROSPECTS

Moscow POTREBLENIYE ENERGII I PERSPEKTIVY RAZVITIYA UGOL'NOY PROMYSHLENNOSTI MIRA (Energy Consumption and Development Prospects of the World Coal Industry) in Russian 1980 facing page 1, pp 1-4.

[Annotation, Table of Contents and Introduction from survey volume published by TsNIEIugol']

[Text] This survey volume discusses the current state of and development prospects for energy consumption by the countries of the world. The authors examine energy reserves, world consumption of energy raw materials, the fuel and energy balance, and problems of energy conservation. The articles are based on materials published in the foreign and Soviet press. The authors determine the place of coal in supplying the world economy with fuel and raw materials. The state of and development prospects for the world coal industry up to the year 2030 are analyzed in detail.

This survey was prepared under the direction of Doctor of Technical Sciences Professor A. M. Kurnosov. Individual authors include A. M. Kurnosov, M. V. Drevnovskaya, V. I. Ignat'yev, V. S. Kravchenko, A. Yu. Sakhovaler, Ye. B. Stakhevich, I. M. Kholod, and V. K. Yasnyy.

Contents

Introduction

The future development prospects of the coal industry are closely linked with the requirements of the world economy in energy resources and the sources for meeting these requirements, that is, with energy resource reserves, as well as the status of power engineering, production prospects for the major traditional types of energy and the possibilities of industrial utilization of nontraditional sources (solar, energy of wave action, geothermal energy, etc).

The 1974-1975 world energy crisis, which was one of the most graphic manifestations of the general crisis of the capitalist system, also demonstrated that the entire structure of production of energy resources and consumption of energy raw materials in the capitalist world was being determined to a significant degree by the requirements of the moment, by the benefits to the national and transnational monopolies producing raw materials, was one-sided and was tilted toward the production of those types of raw materials recovery of which cost the least and sale of which could generate the greatest profits.

In this regard the energy crisis was caused not so much by a shortage of energy resources as by financial-economic and political reasons and by acute inflationary processes in the economy of the capitalist countries. Suffice it to say that in the United States from 1945 to 1979 the real purchasing power of the dollar declined more than fourfold, while during the first days of 1980 alone the price of an ounce of gold increased 15-18-fold over the price in 1970. All these are symptoms of an increasingly aggravated chronic sickness of the economy of the capitalist world, which is increasingly aggravating economic, social and political problems [1]. Therefore the ruling classes in these countries are seeking to resolve their domestic and foreign political problems at the expense of the interests of their worker masses, as well as the interests and natural resources of the peoples of the developing countries. From this point of view measures taken by developing countries to oppose the unjust arrangements of international exchange of goods, imposed on them by the capitalist countries and the international monopolies acting on their behalf, in particular by means of raising prices on raw material resources (primarily crude oil), is a phenomenon which is situated, so to say, on the surface of international political and economic affairs. The primary significance of these world economic processes is the endeavor on the part of industrially developed capitalist countries to achieve world political and economic domination, required by them to obtain cheap raw materials in developing and dependent countries (and in some cases labor and strategically important territories as well) and, consequently, to guarantee superprofits.

At the same time the capitalist monopolies and government authorities acting on their behalf in the nations of the West cannot ignore a growing aspiration on the part of the developing countries to consolidate their economic independence, as well as the real possibility of difficulties with the importation of raw materials and particularly energy resources, not only in connection with complications in the international political situation but even due to exhaustion of reserves from producing mineral deposits and oilfields.

Therefore there arose in the latter half of the 1970's the question of reorganizing the structure of production of the major types of energy raw materials, changing the fuel-energy balance and focusing on the most reliable sources of raw materials as regards reserves and production. In connection with this, attention was once again directed toward coal, reserves of which, as we know, comprise the bulk of world energy reserves. The change in attitude toward coal, however, has not yet led to a substantial change in coal's place in the fuel-energy balance and a sharp increase in coal production volume. This is due to the complexity of increasing the volume of coal production without the availability of reserve coal production capacity and facilities in a number of countries and converting over the equipment of consuming enterprises, as well as a complex of political, social and economic factors and, in addition, the policy of the national and transnational monopolies engaged in the production of energy raw materials.

At the same time, while in the first half of the 1970's there were plenty of forecasts on the future development of the world coal industry, following commencement of the energy crisis, the flow of these predictions, organically linked with forecasts of development of production and consumption of other types of energy, increased substantially.

We should note a characteristic feature of forecasts of the latter half of the 1970's. In the preceding period the majority of forecasts focused on the year 2000, while at the present time more and more studies are scrutinizing a period extending up to 2020-2030.

Only over such an extended period of time is it possible to trace the most significant (not temporary market fluctuations) changes in the structure of consumption of primary energy sources. This is based on the following considerations: the average service life of power generating plants, without extensive renovation, is approximately 30 years. The influence of such factors as exhaustion of resources of those fuels most heavily utilized today, climate change, ecological and demographic changes can also be more clearly traced over this longer period [2].

We should note, however, that forecasts made in the latter half of the 1970's, in contrast to forecasts made in the preceding period, as a rule do not deal with scientific and technological advances in the coal industry, coal mining process and equipment development prospects, as well as such technical-economic indicators as, for example, labor productivity, per-mine or per-longwall work loading, etc. Only certain articles examine problems of development of equipment and technology. TsNIEIugol' has in recent years published several studies which examine in various aspects the state and development prospects of the world coal industry [3, 4, 5].

However, in connection with the fact that in the last two years there have appeared a large number of new materials which reveal some new trends in world energy consumption and production which define the development prospects of the coal industry, publication of this work seems advisable.

Since, as indicated above, an examination of coal industry development trends cannot be sufficiently fully presented without an analysis of development trends in the consumption of other types of energy raw materials, this volume devotes attention to the general problems of energy consumption, with the status of the coal industry examined on this background.

Recently published forecasts do not contain any elaborate substantiations on change in the technical-economic indices of the coal industry, and therefore these questions are examined more briefly in this volume.

At the same time coal mining growth and development prospects broken down by countries and regions are of considerable interest. Therefore this question is presented in a broader aspect. Also more extensively presented are materials on energy raw materials reserves and on energy conservation, since both questions are of determining significance in evaluating the future prospects of a given energy source.

We should also draw attention to the character of the forecasts proper and the degree of their reliability. A number of forecasts on the coal industry, made prior to the energy crisis, actually extrapolated rate of production growth from preceding decades and failed to take account of the radical changes in the economic and political situation, changes which will occur in connection with limitation of the available resources of such energy raw materials as crude oil and natural gas.

The forecasts of different authors and especially forecasts made in different countries also differ substantially.

Therefore the facts presented below, which for the above-specified reason do not provide a clear and all-encompassing picture of production growth in the coal industry, at the same time help determine the principal growth and development trends in the coal industry and help gain an idea of the evaluation of coal industry prospects by experts in various countries.

From this point of view as well a synthesis and classification of forecast materials and selection of the most averaged data from these materials will unquestionably be useful, since they give an idea of the directions, principal prospects and coal industry development trends as well as an evaluation of the role of coal in the future, as one of the most stable, reliable and important sources of energy for a fairly extended period of time.

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SIBERIAN POWER DEVELOPMENT PROSPECTS

Minsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY. ENERGETIKA in Russian No 10, Oct 80 pp 3-9

[Article by USSR Academy of Sciences Corresponding Member L. S. Popyrin: "Prospects for Development of Siberia's Power Engineering"]

[Text] The 25th CPSU Congress assigned tough tasks to our country's power industry. Accomplishment of these tasks is aimed at improving the structure of the fuel-energy balance on the basis of a rational combination of the various types of fuel, extensive employment of new kinds of energy, particularly atomic energy, improved utilization of fuel and fuller utilization of secondary energy resources [1]. The percentage share of electric power is to be increased in total industrial output volume, as one of the branches which determine to the greatest degree technological advances, improvement in the qualitative level and efficiency of production, and growth in labor productivity and living standards. By 1980 new performance levels have been reached in the mining and production of various kinds of fuels and energy.

Even more grandiose tasks pertaining to development of this country's power engineering industry are stated in the decree of the November (1979) CPSU Central Committee Plenum and in Comrade L. I. Brezhnev's speech at the plenum. The plenum pointed to the necessity of persistent work aimed at further development of this country's fuel-raw materials base and power engineering industry.

This country's eastern regions are to play an important role in accomplishing the above tasks.

The process of specialization of regions east of the Urals in the fuel industry and energy-intensive industries became intensified in the course of the 10th Five-Year Plan. These regions are to provide the following output percentages: the entire increase in oil, gas and aluminum production targeted for the USSR, approximately 90 percent of increase in coal production, approximately 80 percent of increase in copper production, 45 percent of the increase in paper pulp production, and approximately 60 percent of cardboard production increase; these regions will also account for approximately 70 percent of increase in hydroelectric generating capacity.

It will be necessary, however, to transport large quantities of fuel from the East to this country's western regions, where it is in short supply. In 1975 such fuel hauls were up 350 percent over the preceding decade -- reaching a figure of approximately 360 million tons of standard fuel. This transport flow will increase (according to approximate calculations) another twofold in the 10th Five-Year Plan. Providing such a rapidly-growing flow of fuel is an increasingly more complex and costly task. Therefore the problem of placing energy-intensive industries in the eastern regions during the entire period of dominance of traditional power engineering remains an exceptionally urgent one [2].

Favorable potential offered by the majority of the eastern regions for locating industry are not limited to fuel and energy resources. Extremely important for a number of industries is the availability of water resources, the significance of which has been increasing more and more in recent years due to a very rapid growth of water-intensive industries and the limited availability of water resources in the western parts of this country.

Siberia occupies an important place among the eastern regions. It contains more than 60 percent of the USSR's potential coal reserves, approximately 40 percent of total natural gas reserves, one third of our hydroelectric powerplus oil. This creates the prerequisites for establishing the country's principal energy base here.

Excellent economic indices of fuel production and electric power generation set Siberia head and shoulders above the other parts of this country from the standpoint of development of energy-intensive branches of industry. Proceeding from this, the resolutions of the 25th CPSU Congress specify for Siberia accelerated development of the fuel industry, energy-intensive ferrous and nonferrous metallurgical plants, chemical, petrochemical, and pulp and paper plants [3].

Huge energy complexes form the basis of development of Siberia's power engineering. Siberia's fuel-energy development tasks are determined by the necessity, first of all, of providing fuel and electric power to its own, rapidly developing economy and, secondly, of accomplishing such national-importance tasks as making up for the growing deficit of energy resources in the European parts of the country and export deliveries of various kinds of fuel.

Successful accomplishment of these tasks is possible only on the basis of comprehensive long-term programs which provide for efficient utilization of capital investments, labor and material resources, coordination with development of contiguous branches and sectors of the economy, and development of new regions which are particularly rich in fuels and raw materials. Elaboration of such programs is a fundamentally new direction in the contemporary stage of development of power engineering in the USSR.

In Siberia three major energy complexes will be developed on the basis of long-term programs: the Western Siberian Oil and Gas Complex, the Kansk-Achinsk Fuel and Energy Complex, and the Angara-Yenisey Hydroelectric Power Complex.

Continuing development of the Western Siberian Oil and Gas Complex is viewed as establishment of the country's principal oil and gas production base. By 1980 crude oil production in this region will reach 300-310 million tons, while natural gas production will reach 125-155 billion cubic meters [2].

Simultaneously with increasing oil and gas production in this region, problems of oil and gas processing and transport will also be comprehensively resolved. Construction has been in progress during the current five-year plan on the Tomsk and

Tobol'sk petrochemical complexes, the Achinsk Oil Refinery, as well as casinghead gas processing plants, and partial operations will be starting up at these facilities. Unique pipeline systems will be built to convey oil and gas to refining and processing locations and for export.

The resolutions of the 25th CPSU Congress specify work on accelerated development of the second major complex -- the Kansk-Achinsk. This complex is based on a unique brown-coal basin with standard-meeting reserves of 450 billion tons, including more than 100 billion tons of proven reserves [4]. The basin can support an annual production of more than 1 billion tons of coal, with specific calculated outlays of not more than 5-8 rubles per ton of standard fuel.

In view of poor transportability, the bulk of the mined coal will be burned locally to fire power generating plant boilers. The first stage of development of the basin calls for construction of 8-10 power stations with a total generating capacity of 50-65 million kilowatts, which in the future will comprise the Siberian Unified Electric Power System (OEES Sibiri), and will also be an important source of electric power for the European part of the USSR. In addition to the direct burning of Kansk-Achinsk coal, coal will also be processed to produce an improved transportable fuel (steam coal coke fines) and valuable chemical products [5].

We should note that in addition to the nuclear power engineering development program, establishment of the Western Siberian and Kansk-Achinsk complexes forms three decisive long-term USSR fuel and energy development programs.

Also of considerable importance for development of Siberian power engineering is a sequentially implemented program of comprehensive exploitation of the rich hydroelectric power resources of the Yenisey and Angara river basins. According to a detailed utilization scheme [6], 10 huge hydroelectric power stations can be built on these rivers, with a total installed generating capacity of more than 55 million kilowatts, with a long-term average annual electric power generation total of approximately 240 billion kilowatt hours. The Irkutsk (0.66 million kilowatts), Bratsk (4.1 million kilowatts), the Krasnoyarsk (6 million kilowatts) as well as most of the generating units at the Ust'-Ilimsk GES are already in operation. In conformity with the resolutions of the 25th CPSU Congress, by 1980 the Ust'-Ilimsk GES (4.32 million kilowatts) will be working at full generating capacity, the first units will be producing electric power at the Sayano-Shushenskaya GES (6.4 million kilowatts), and construction will have begun on the Boguchany GES (4 million kilowatts).

Construction of the Angara-Yenisey string of hydroelectric power stations is accomplishing a number of tasks pertaining to the comprehensive economic exploitation and industrial development of the areas of Central Siberia. As a rule large territorial-production complexes are being developed on the base of these GES.

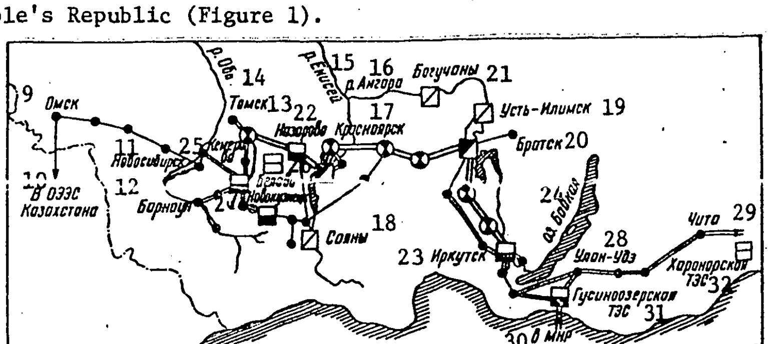
Alongside establishment of the above-listed energy complexes, development of Siberia's power engineering will also occur with the involvement of existing (Kuzbass, Cherembass) and in-development (Transbaykal) fuel bases.

We should particularly mention commencement of establishment of the Aldan-Chul'man Territorial-Production Complex in the southern part of the Yakut ASSR. It will be the first of an entire group of local territorial-production complexes within the

BAM [Baykal-Amur Mainline] zone, which will be the transportation nucleus of this system. Establishment of such complexes on the basis of exploitation of local natural resources (minerals, timber) will proceed simultaneously with opening of individual sections of the mainline to traffic.

Development of Siberian electric power engineering in the 10th Five-Year Plan. Siberia was already outstripping other regions of the country in development of electric power engineering by the beginning of the five-year plan. Per capita generation of electric power in Siberia was more than 8,000 kilowatt hours per year as compared with the national average of 4,100 kilowatt hours. Energy resources which are unique in size and efficiency and at the same time a shortage of labor resources in Siberia comprise the precondition for the country's highest level of electrification of the economy and development of new kinds of utilization of electric power. Use of electricity in the home is also expanding, including cooking, and in agriculture, especially in animal husbandry.

The foundation of development of Siberian electric power engineering is the OEES Sibiri -- one of the country's largest power systems. There are eight regional power systems within the OEES: the Omsk, Novosibirsk, Barnaul, Kuzbass, Tomsk, Krasnoyarsk, Irkutsk, and Buryat, which serve an area covering more than 2 million square kilometers with a population of 16 million. The Omsk electric power system, which is a component of OEES Sibiri, operates in parallel with the Kazakhstan OEES. The Chita power system, which territorially is in the zone of the OEES East, is linked to the Siberian OEES. Electric power is exported from Siberia to the Mongolian People's Republic (Figure 1).



1 – действующие ТЭС мощностью более 1 млн. кВт; 2 – строящиеся ТЭС мощностью более 1 млн. кВт; 3 – действующие ГЭС мощностью более 1 млн. кВт; 4 – строящиеся ГЭС более 1 млн. кВт; 5 – подстанция 500 кВ; 6 – подстанция 200 кВ; 7 – линия электропередач 500 кВ; 8 – линия электропередач 200 кВ

Figure 1. Diagram of Principal Distribution Networks of Siberian OEES

Key:

1. Operating thermal electric power stations with generating capacity in excess of 1 million kilowatts
2. Thermal electric power stations under construction with generating capacity in excess of 1 million kilowatts
3. Operating hydroelectric power stations with generating capacity in excess of 1 million kilowatts
4. Hydroelectric power stations under construction with generating capacity in excess of 1 million kilowatts

(Key to Figure 1, cont'd)

5. 500 kilovolt substation
6. 200 kilovolt substation
7. 500 kilovolt power transmission line
8. 200 kilovolt power transmission line
9. Omsk
10. To Kazakhstan OEES
11. Novosibirsk
12. Barnaul
13. Tomsk
14. Ob' River
15. Yenisey River
16. Angara River
17. Krasnoyarsk
18. Sayany
19. Ust'-Ilimsk
20. Bratsk
21. Boguchany
22. Nazarovo
23. Irkutsk
24. Lake Baykal
25. Kemerovo
26. Belovo
27. Novokuznetsk
28. Ulan-Ude
29. Chita
30. To Mongolian People's Republic
31. Gusinoozerskaya Thermal Electric Power Station
32. Kharanorskaya Thermal Electric Power Station

In 1977 total installed generating capacity of the electric power stations of the Siberian OEES equalled 30 million kilowatts, while production of electric power totaled 150 billion kilowatt hours. The degree of centralization of electric power supply reached 95 percent [7].

A unique structure of power generating facilities was created as a result of intensive development of GES and TETs in the Siberian OEES. Hydroelectric power stations comprise 50 percent of installed generating capacity in the OEES. Heat and electric power plants comprise 30 percent and condensation electric power plants only 20 percent. In combination with cheap fuel (Kansk-Achinsk, Kuznetsk and Cheremkhovo coal), this gives the OEES the country's lowest specific fuel consumption (0.33 kg standard fuel per kilowatt hour) and cost of producing electric power.

Highest-voltage electric power networks in the Siberian OEES developed in a linking chain arrangement. A 500 kv main power line has been constructed which presently runs Irkutsk-Bratsk-Krasnoyarsk-Kuzbass-Novosibirsk, a distance of approximately 3000 kilometers, with a capacity of up to 2 million kilowatts. This main power line provides fairly flexible operational control of conditions in the OEES [7].

Development of the Siberian OEES in the 10th Five-Year Plan is involving construction of large GES, industrial and district heating and electric power plants, and large condensation electric power plants [8]. The principal hydroelectric power stations under construction are the above-mentioned Ust'-Ilimsk, Sayano-Shushenskaya, and Boguchany.

Installed generating capacity at the power stations of the Siberian OEES is to increase by more than 9 million kilowatts in the course of the 10th Five-Year Plan, including an increase of 5.1 million kilowatts at hydroelectric power stations. The Ust'-Ilimsk GES is scheduled to reach full generating capacity, the first generating units of the Sayano-Shushenskaya GES, the world's largest, are to go on line, and construction has begun on the fourth hydroelectric power station of the Angara series -- the Boguchany [9].

The Berezovskaya GRES-1, with a designed generating capacity of 6.4 million kilowatts, is under construction in the Kansk-Achinsk Complex. The first units at this GRES, with a generating capacity of 800 megawatts, will go on line in the 11th Five-Year Plan. In the Transbaykal, completion of construction is scheduled for the first unit of the Gusinoozerskaya GRES (1.2 million kilowatts), and construction has begun on the big new Kharanorskaya GRES. In Western Siberia the first Surgut GRES (2.4 million kilowatts) is generating at full capacity, and construction has begun on the second Surgut GRES, to have equal generating capacity, with these two generating plants to be subsequently linked up to the Siberian OEES by the 500 kv Surgut-Tomsk power transmission line.

Other new areas which will be linked up to the Siberian OEES in the 10th Five-Year Plan include the western areas of the zone of influence of the Baykal-Amur Mainline, the area around the construction site of the Boguchany GES, and a number of rayons in Altayskiy Kray and Chitinskaya Oblast.

We should note that erection of power transmission lines is one of the important problems of development of the Siberian OEES. The large, constantly expanding territory served by the OEES and a substantial concentration of power generating plants impose greater demands on the capacity and operational reliability of the power system. At the same time, construction of electric power lines in Siberia frequently lags behind completion of power generating plants and large industrial enterprises, leading to a decline in the quality of electric power supply, to unproductive water discharge at hydroelectric power stations, etc. Serious measures have been taken in the 10th Five-Year Plan to correct this situation.

Development of centralized district heating systems. The principal factors which caused the already achieved high level of development of centralized district heating systems in Siberia have continued to operate in the 10th Five-Year Plan. These include, first of all, accelerated development and a high concentration of high heat-requirement industries; second, a high population concentration (Siberia's 10 largest cities contain more than 45 percent of its urban population); third, a harsh climate; fourth, a small percentage of liquid and gaseous fuel in the boiler-furnace fuel balance.

Under these conditions centralized district heating systems based on large municipal and industrial heat and power plants are the only reasonable and economically warranted solution for supplying heat to large cities and industrial centers. The absence or inadequate development of centralized district heating systems in a number of Siberian cities is requiring the use of hundreds of small boiler facilities burning run-of-mine coal, resulting in a high cost of thermal energy, requiring the employment of many thousands of persons with a serious shortage of manpower resources, considerable urban air pollution, and a low level of service.

Large central heat and power plants are being built in the 10th Five-Year Plan in Krasnoyarsk, Irkutsk, Omsk, Novosibirsk, Barnaul, and Tobol'sk. A number of heat and electric power plants are being enlarged [8].

The question of achieving greater efficiency and centralization of heat supply for small and medium-size cities (with a population of less than 100,000) which do not contain large, high heat-requirement enterprises, as well as rural communities is a rather acute problem under Siberian conditions. The principal ways to resolve this problem include expanding existing small heat and power plants, installing primarily hot-water, low-pressure steam and steam and hot-water boilers, construction of large central boiler facilities with the same kinds of boilers, and in certain instances (in a rural locality with favorable conditions of electric power supply and costly fuel transport) -- changeover to electric heating.

Some problems of development of the Kansk-Achinsk Fuel-Energy Complex (KATEK). Development of the unique Kansk-Achinsk Complex faces heat and power engineers with a number of complex problems. One of these is the development for 800 megawatt units (and larger units in the future) reliable single-stage steam generators fired by high-moisture low-caloric brown coal the heat engineering characteristics of which have in addition been insufficiently studied. The problem of reliability for these generating units is of particular significance. Under conditions of a tight electric power balance in the Siberian OEES, inadequate readiness of generating units could lead to restriction in supply to customers.

Development of reliable steam generators is a task which should be accomplished to a considerable degree before the end of the 10th Five-Year Plan by machine builders and power engineers. The situation with 300 megawatt units, the startup process on which was extremely slow, should not be repeated when bringing on line a fairly large series of units (no fewer than 40-50).

The P-67 boiler unit with solid ash removal, gas drying and mill-blowers, has been adopted as the principal unit for the Berezovskaya GRES-1.

Apparently KATEK electric power stations will be installing K-800-240 units up to 1990. Design work has already begun, however, on a larger, 1600 megawatt unit, in order to be ready for its adoption on schedule. Employment of such a unit should increase the efficiency of electric power generation, the pace of development of KATEK, and labor productivity in power engineering machine building.

A most important problem in the development of Siberian thermal electric power stations, and especially KATEK power generating plants, is reducing to a minimum adverse influence on the environment and on the quality of life in adjacent areas. The complexity of this problem is determined in the first place by the fact that huge power generating capacities will be concentrated in a limited area -- more than 2 megawatts per square kilometer by the end of the century (for comparison, the present "density of power generation" in the Donbass is 0.3 megawatts per square kilometer). Secondly, plants will be burning low-caloric fuel (Q_p^H=3000-3800 kcal/kg). Thirdly, weather conditions in the KATEK area are such that persisting smog can form on days of sub-freezing temperatures. A solution to this problem demands urgent, serious research. Some recommendations are obvious, namely:

to develop and to secure proper operation of highly-effective electrostatic precipitators with an efficiency greater than 99 percent;

to set up utilization of at least 50-60 percent of the ash and slag for construction and other needs, which will make it possible to avoid using large acreages for ash dumps;

to disperse power generating plants to a certain degree, locating some of them in the power consumption centers of adjacent areas of Siberia. The latter may also prove rational on the basis of water supply conditions. Some reduction in discharge of ash into the atmosphere will be obtained by employing burners being developed at the Central Scientific Research, Planning and Design Boiler and Turbine Institute imeni I. I. Polzunov, which will have high-performance combustion chambers and a high ash trapping coefficient.

The energy base of the Transbaykal. In the eastern part of the Siberian OEES, the Transbaykal brown-coal fields are promising: the Kharanorskoye and Gusinoozerskoye, which are currently in operation; and the Tunguyskoye, which is targeted for development. Construction of the Gusinoozerskaya GRES -- the Transbaykal's principal source of new power generating capacity -- is continuing in the 10th Five-Year Plan, a plant which will be fired by this coal. The first, 210 megawatt unit of this GRES went on line at the end of 1976. Completion of construction on the first phase of the electric power plant, containing 6 210 megawatt units, is scheduled for the most part in the current five-year plan. But the USSR Ministry of Power and Electrification has now ordered preparation of technical-economic substantiation for further expansion of the Gusinoozerskaya GRES, with generating capacity to be boosted to 2-3 million kilowatts [10].

Plans call for commencing construction in the 10th Five-Year Plan on a second large power generating plant in the Transbaykal -- the Kharanorskaya GRES, with a first-phase generating capacity of 1,260 megawatts, with the possibility of future enlargement to 2-3 million kilowatts.

A power transmission line between the USSR and the Mongolian People's Republic has been built in the current five-year plan: the Gusinoozerskaya GRES-Darkhan-Erdenet 220 kv line. When this line came on-stream, parallel operation began with the power system of the Mongolian People's Republic, and plans call for supplying power by this line from the USSR to the Mongolian People's Republic in the amount of 500 million kilowatt hours per year [11].

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