ANALYSIS AND OPTIMIZATION OF CALENDAR PLANS
FOR CONSTRUCTION OF HYDROPOWER PROJECTS
BY MEANS OF THE ES-1020 ELECTRONIC COMPUTER

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In the last few years, a large number of investigations and studies of models of the activities of construction organizations have been carried out. One of the main elements of such models is the calendar plan for construction work. A calendar plan of the construction process is a balanced production system coordinated in space and time with a finite set of limitations placed on it. Such limitations usually include the ordered dates of completion, the normative periods of construction of the structures and complexes, the adopted organization and technology for the construction work, the labor and material-technical resources, the dynamics of the distribution of these resources with time, the requirements established in the technical specifications, the safety rules, etc. The calendar plan, prepared by taking the above requirements into account, contains as elements for predicting the production activities of the participants in the construction work also the directive planned tasks for fixed periods of time. In this connection, calendar planning is a process of modeling the construction work and the calendar plan itself is a model with a definite degree of reliability, reflecting the realization of this process.

For any construction process it is possible to work out a set of allowable calendar plans, i.e., of calendar plans satisfying the established limitations, which differ in the sequence of construction of the structures or installations, the times of completion of the different tasks, the resource distribution, etc. Hence, the main purpose in calendar planning is the determination, for an acceptable period of time, of the optimal or near optimal work schedule, i.e., the approved calendar plan should conform in the best manner to the given specific production situation and the established objectives and tasks. The criterion for an optimal solution of the calendar plan is selected in accordance with the specific construction conditions and the activities of the construction organization: in some cases it is a minimization of the periods for bringing the structures and installations into operation, and in other cases it is a minimization of the amortized costs for fixed times of completion, etc. For this reason, in the preparation of a calendar plan for construction it is necessary to examine possible allowable alternatives. The dynamic characteristics of the calendar planning model for construction, on whose basis the control of construction is set up, are thus made manifest.

Most of the programs for computer solutions of different calendar planning problems which have been worked out and used for construction of complexes are based on heuristic and approximate methods of solution of multiplet network models in which account is taken of the limited resources. Recently, experience has been acquired with the development and practical application of different methods and complexes of programs for automated preparation of calendar plans, their efficiency has been demonstrated, and the high demand for such solutions in the engineering practice along with the need for their further improvement has been established. In the hydropower construction field, only the first steps in this direction are being taken.

Work on the development of programs for analysis and optimization of calendar plans for construction of hydropower projects, using the ES-1020 electronic computer, is being carried out at the Gidroproekt Institute since 1973.* The basis of a program to be worked out for calendar planning of construction of a hydropower project is a multiple-factor network model which takes into account the limitations in the essential resources according to the volume of capital investments, the quantities of construction machines and equipment, construction materials, labor

*The algorithms for the analysis were worked out with the participation of Engineers L. G. Galub and E. N. Lyashenko from the Scientific-Research Institute of Construction of the Government Committee for Construction of the Estonian SSR.

resources, etc. The developed program, which takes into account the priority of the different components and types of tasks, makes it possible to determine the optimal schedule for the annual, quarterly, monthly, and weekly-hourly work plans for the components, as well as to determine the need for essential resources. The work schedules and the needs for essential resources serve as the basis for organizing the material-technical supply, the operative-control management of construction, and the operative and routine control of the activities of the construction organization and its subdivisions. Moreover, in the program worked out for the setting up of the multiple-network models and preparing the initial and current data on the state of the constructed components, a minimum expenditure of manual labor is required and the time of processing of the information for the elaboration and correction of the calendar plans is reduced. An amalgamated block diagram for the program is presented in Fig. 1.

The calendar planning program consists of the following basic blocks: entering of input information, analysis of a diagram from the time estimates, distribution of resources, printing of results. The input information block consists of two parts. The first part sets up information relating to the entire construction of the hydraulic development, dates of commissioning of the units and completion of construction, total construction cost, limitations of resources and of allowable possibilities of the different executors participating in the construction work, etc.

The second part is intended for the setting-up of information relating directly to the specific installations or structures, including information about the different types of work and the periods of construction of the given installation or structure, the list of subcontractors, the list of stages for the given installation or structure, etc.

For each task the following information is given: directive dates of start and completion; initial and final task events \( i-j \); codes of leading resources and of first and second controlled resources; minimum and maximum rate of use of the leading resource in the planning unit (month, day, etc.); amount of variation of resource; labor consumption and task cost; code of physical volume and its magnitude; shift organization of task; distinctive signals of the task — initiation, continuity, parallelism in the carrying out of the task, etc.; inclusion in a stage.

The block processes the input information contained in cards or other input elements and transforms it into a form adequate for storage in direct-access external units. At the same time, the block develops data for temporary analysis. During the entering of information, control of the allowable values for all parameters is performed. The block of analysis of the diagram from the time estimates is constructed on the basis of the assumption that all tasks are performed within the minimum possible periods. For these conditions, the minimum possible length of the critical path is determined. In case of exceedance of the duration of the work in the critical path over the directive periods, the corresponding correction of the topology of the network diagram is made and a second analysis is carried out.

After the analysis of the network diagrams is made from the time estimates, the unconditional working front is formed. For this purpose, a table of priorities of the jobs is initially formed, in which the numbers of the jobs are arranged in accordance with their priority; the higher the priority of the job the earlier its entering into the