REMAINING SERVICE LIFE OF GENERATING SETS AND REPLACEMENT OF EQUIPMENT

V. N. Baikov¹ and É. U. Nezametdinov¹


Questions concerning assessment of the remaining service lives of generating sets, and equipment replacement are examined.

Keywords: hydraulic generating set; preservability; reparability; remaining life; service life; assessment of remaining service life; techno-economic substantiation.

In the past 20 years, the water-power industry of Russia has been considering the problem of remaining service life of water-power equipment — hydraulic turbines and hydraulic generators — hydroelectric power plants that have been in service for an extended time, and methods and criteria for determination of the limiting state of equipment at which it would be subject to replacement. This is associated with the fact that during these years, there has been a massive exodus of equipment to the category of “exhausted” service life, and with no programs for equipment replacement in the electric-power field.

Various proposals for evaluation of the remaining service life of hydraulic generating sets are currently being put forth. In this paper, it would be desirable to verify questions associated with this problem, and attempt to determine an initial base for its solution.

Terminologic information

According to reliability theory, all entities can, from the standpoint of potential for elimination of failure, be divided into restorable and non-restorable entities. A restorable entity is that entity, the post-failure restoration of which can be accomplished in principle, and is specified by structural solutions.

A hydraulic generating set is a technically complex entity produced in small lots. In conformity with operating rules, a system of scheduled preventative repairs (SPR), the purpose of which is to eliminate defects that have accumulated in the inter-repair period, and failures caused by emergency events by assessing the condition after repair.

It is obvious that the generating set is a restorable entity (during repairs and reconstructions, virtually all subassemblies and parts are, when necessary, restored or replaced; this is confirmed by the experience of repair workers).

During normal operation, the generating set should possess such properties as reliability, which for the entity being restored, is, in turn, characterized by a combination of more elementary properties: preservability, reparability, and longevity.

Preservability — the property of an article allowing for its continual preservation (within assigned limits) of values established for its quality indicators.

Reparability — that property of an entity, which includes adaptability to maintain and restore a serviceable state by technical maintenance and repair.

Longevity — that property of an entity allowing for retention of serviceability to a certain state (uncorrectable failure) with required interruptions for technical maintenance and repair. A state of uncorrectable failure, which can be termed limiting, sets in owing to wear, breakdown, and inexpediency of repair or continued operation (unacceptable wear).

The above-enumerated concepts are required to determine such notions applicable to a generating set as remaining service life and service life, since they are longevity indicators of the equipment.

Remaining service life is the running time of an entity to the limiting state. When total remaining service life is the limiting state, it can be determined from conditions whereby continued functioning of the entity is impossible or inexpedient.

Partial remaining service life can be determined from the condition of the entity, which is censured in technical documentation. Such partial indicators as remaining service life to first repair, inter-repair remaining service life, and average remaining service life characterize not only the longevity, but also the reparability of the entity.

Assigned remaining service life is determined by an assigned running time, after which service of the entity should be curtailed, irrespective of its condition. Assigned remaining life is inherent to large-lot series produced mechanisms for which systematized characteristic failure data exist, or special tests for remaining service life are performed. It should be noted that the question concerning introduction
of substantiated assigned remaining service life for water-power equipment on a day-to-day basis would hardly be possible.

Service life, in contrast to remaining service life, is determined not by running time, but by calendar duration of the article’s service to the appearance of the limiting state, which is indicated in technical documentation.

The concepts total service life, as determined by conditions whereby continued service is impossible or inexpedient (for generating sets, there is no standard definition), and partial service life are also possible for service life.

Service life to first (average) overhaul, service life between overhauls, and average service life differ from partial service life. These indicators are associated with reparability, and also with preservability of the entity.

Thus, if the problem stands as such, it is mentioned immediately, and should determine total service life and total remaining service life with subsequent determination of remaining service life.

Service life of water-power equipment

At the present time, the service life of a hydraulic-generating set is defined by two documents: State Standard (GOST) 5616–89 “Generators and electrical hydraulic-turbine generators-motors. General specifications,” and GOST 27807–88 “Vertical hydraulic turbines. Technical specifications and testing.” The total service life for hydraulic turbines is determined to be no less than 30 years (for turbines produced prior to 1 January 1991), and no less than 40 years for those produced after 1 January 1991), and the service life of hydraulic generators extends beyond 40 years. It is natural that in the GOST, service life is established with the formulation “no less than,” i.e., the lower limit of the service life of a hydraulic turbine and hydraulic generator is actually defined.

The service life between overhauls, which is established by builder documentation at the manufacturing plants, and rules of technical operation, and the service life of water-power equipment from GOST 5616–89 and GOST 27807–88 are, in essence, partial service lives.

For the GOST formulations under consideration, it is incorrect to speak of the fact that hydraulic turbines after 30 years (a time of 40 years has yet to be arrived at), and hydraulic generating sets after 40 years have exhausted their service lives. The concept “service life of equipment,” indicated in the GOST, correlates, in turn, with active standards and assignments whereby continued service is impossible or inexpedient, for example, with analogies, for example, with hydrotechnical structures.

Today, the majority of hydraulic generating sets that have formally exhausted their remaining service lives continue to operate on an acceptable level of reliability, and the need for urgent replacement of all of them by new ones is not foreseen in the near future. And, more probably, the possibility of this will not occur, if the productive outputs of basic manufacturing plants and possibilities of financing for reconstruction projects are considered.

This is associated with the fact that in addition to the initially high reliability of the majority of subassemblies of generating sets when placed in service by the manufacturers, a large volume of investigatory studies directed toward improved reliability of water-power equipment have been conducted by scientific-research organizations. During the course of modernization, reconstruction, and repairs, studies directed toward improvement of the reliability of individual subassemblies, mechanisms, and systems of the hydraulic generating set, have been conducted, and, as a consequence, their service lives have been extended.

Methodology for determination of total remaining service life of water-power equipment

To determine the total remaining service life or service life of a hydraulic generating set, it is necessary to define the limiting-state parameters, which are not qualitatively and quantitatively defined at the present time, but must be developed or assigned with respect to analogies, for example, with hydrotechnical structures.

The limiting state for a generating set may set in owning to wear, breakdown, and economic inexpediency of repair or continued service (excessive wear). Limiting states caused for these reasons require individual study; however, the tendency to examine only physical wear is observed when determining total remaining service life.

Problems encountered in determining total remaining service life owing to physical wear are associated with reliability determination, the methods of which are known in principle, and are brought to light in numerous publications. Mathematical (probabilistic) methods of reliability theory, which have come into widespread use in radio electronics and other branches of engineering where acquisition of a sufficient volume of statistical data is possible and feasibly justified, are most heavily developed.

Use of mathematical methods to describe the reliability of mechanical entities — machinery, instruments, mecha-