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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Hydraulic turbines, storage pumps and pump-turbines – Rehabilitation and performance improvement

Turbines hydrauliques, pompes d'accumulation et pompes-turbines – Réhabilitation et amélioration des performances

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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Hydraulic turbines, storage pumps and pump-turbines – Rehabilitation and performance improvement

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HYDRAULIC TURBINES, STORAGE PUMPS AND PUMP-TURBINES – REHABILITATION AND PERFORMANCE IMPROVEMENT

FOREWORD

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International Standard IEC 62256 has been prepared by IEC technical committee 4: Hydraulic turbines.

This second edition cancels and replaces the first edition published in 2008. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

– Tables 2 to 23 modified, completed and moved to Annex A;
– 7.3.2:
  • subclauses moved with text changes;
  • new subclauses on temperature, noise, galvanic corrosion, galling and replacement of components without assessment;
– 7.3.3: complete new subclause on residual life;
– Tables 29 to 32 moved to Annex C;
– new Annex B with assessment examples.

This bilingual version (2017-12) corresponds to the monolingual English version, published in 2017-05.

The text of this standard is based on the following documents:

FDIS	Report on voting
4/323/FDIS	4/326/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

The French version of this standard has not been voted upon.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Hydro plant owners make significant investments annually in rehabilitating plant equipment (turbines, generators, transformers, penstocks, gates etc.) and structures in order to improve the level of service to their customers and to optimize their revenue. In the absence of guidelines, owners may be spending needlessly, or may be taking unnecessary risks and thereby achieving results that are less than optimal. This document is intended to be a tool in the optimisation and decision process.

Edition 1 of this International Standard was based on the IEA document *Guidelines on Methodology for Hydroelectric Francis Turbine Upgrading by Runner Replacement*.

HYDRAULIC TURBINES, STORAGE PUMPS AND PUMP-TURBINES – REHABILITATION AND PERFORMANCE IMPROVEMENT

1 Scope

This document covers turbines, storage pumps and pump-turbines of all sizes and of the following types:

- Francis;
- Kaplan;
- propeller;
- Pelton (turbines only);
- bulb turbines.

This document also identifies without detailed discussion, other powerhouse equipment that could affect or be affected by a turbine, storage pump, or pump-turbine rehabilitation.

The object of this document is to assist in identifying, evaluating and executing rehabilitation and performance improvement projects for hydraulic turbines, storage pumps and pump-turbines. This document can be used by owners, consultants, and suppliers to define:

- needs and economics for rehabilitation and performance improvement;
- scope of work;
- specifications;
- evaluation of results.

This document is intended to be:

- an aid in the decision process;
- an extensive source of information on rehabilitation;
- an identification of the key milestones in the rehabilitation process;
- an identification of the points to be addressed in the decision processes.

This document is not intended to be a detailed engineering manual nor a maintenance document.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and nomenclature

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

Wherever turbines or turbine components are referred to in the text of this document, they shall be interpreted also to mean the comparable units or components of storage pumps or pump-turbines as the case requires.

For the purpose of this document, the term “rehabilitation” is defined as some combination of:

- restoration of equipment capacity and/or equipment efficiency to near “as-new” levels;

- extension of equipment life by re-establishing mechanical integrity.

The term "performance improvement" means the increase of capacity and/or efficiency beyond those of the original machine and may be included as part of a rehabilitation.

Many other terms are in common use to define the work of "rehabilitation" and "performance improvement", however use of the above terms is suggested. Some of the terms considered and discarded for their lack of precision or completeness include:

- upgrade or upgrading – restoration of mechanical integrity and efficiency;
- uprating – increase of nameplate capacity (power) which may result in part from efficiency restoration or improvement;
- overhaul – restoration of mechanical integrity;
- modernization – could mean performance improvement and replacement of obsolete technologies;
- redevelopment – term frequently used to mean replacement of the powerplant and could involve changes to the hydraulics and hydrology of the site usually implying a change in mode of operation of the plant;
- refurbishment – restoration of mechanical integrity usually with restoration of performance (closely resembles "rehabilitation", the preferred term);
- replacement – usually refers to specific components but may involve the complete hydraulic machine in the case of small units.

The nomenclature in this document is in accordance with IEC TR 61364, which provides the "Nomenclature" in six languages to facilitate easy correlation with the terminology of this document.

Here is a list of the acronyms used throughout this document:

- AGC: automatic generation or direct frequency control
- B/C: benefit/cost ratio
- CFD: computational fluid dynamics
- ETA: event tree analysis
- FEA: finite element analysis
- FFT: fast Fourier transform
- FMA: failure mode analysis
- FMECA: failure modes effects and criticality analysis
- FTA: fault tree analysis
- HAZOP: hazard and operability study
- IRR: internal rate of return
- MT: magnetic particle inspection technique
- NDT: non-destructive testing
- NPV: net present value
- PCB: polychlorinated biphenyl
- PT: liquid penetrant inspection technique
- RSI: rotor-stator interactions
- SNL: speed no load
- UT: ultrasonic inspection technique
- VAR: Volt-Ampere Reactive

4 Reasons for rehabilitating

4.1 General

Hydroelectric generating facilities are among the most robust, reliable, durable structures and equipment ever produced. The robustness of the equipment permits owners to continue operating these facilities without major rehabilitation for relatively long periods. As shown in Table 1, the reliable life for a turbine prior to a major rehabilitation being necessary is typically between 30 and 50 years depending on type of unit, design, quality of manufacturing, severity of service, and other similar considerations. However, all generating equipment will inevitably suffer reduced performance, reliability and availability with time, which leads owners to the fundamental question of what to do with an aging plant. This crucial question cannot be answered easily since it involves many interrelated issues such as revenue, operating and maintenance cost, equipment performance, reliability, availability, safety and mission of generating facilities within the entire system. Ultimately, an owner will have to decide to rehabilitate the plant or eventually to close it. At some point in time, delaying a major rehabilitation ceases to be an option. This may come about as the result of a major component failure or as the result of an economic evaluation. Cessation of commercial operation does not necessarily relieve an owner of the responsibility for the maintenance of the civil structures, regulation of the flows and any other issues which have an impact on an owner's liability for the plant.

The governing reason for rehabilitation is usually to maximize return on investment and normally includes one or more of the following:

– reliability and availability increase;
– life extension and performance restoration;
– performance improvement:
  • efficiency;
  • power;
  • reduction of cavitation erosion;
  • enlargement of operating range;
– plant safety improvement;
– environmental, social or regulatory issues;
– maintenance and operating cost reduction;
– other considerations:
  • modified governmental regulations;
  • political criteria;
  • company image criteria;
  • modified hydrology conditions;
  • modified market conditions.

The opportune time for starting a rehabilitation is prior to the plant being beset with frequent and severe problems, such as generator winding failures, major runner cracking, cavitation or particle erosion damage, bearing failures and/or equipment alignment problems due to foundation or substructure movement or distortion. When a generating plant has reached such a stage, it is obvious that a technical and an economic assessment of the equipment should have been conducted years before. If the time frame of rehabilitation studies is too close to the end of the useful life of the plant and its equipment, the owner may lose the option of evaluating a range of alternatives. Catastrophic failures with potential major damage and loss of life are, at some stage of the plant life, real risks. If significant improvements can be made in the revenue generating capabilities of the plant by replacement of deteriorated equipment with state-of-the-art equipment or components, there may be justification for performing rehabilitation earlier than the date at which it would be required for purely reliability or life extension reasons.

Typically, the renewed life of a turbine following rehabilitation would be more than 25 years with normal maintenance. The residual life of the generating plant is dependent on the collective residual lives of each individual component group and therefore can be determined only by assessing all of the component groups including the civil structures.

Rehabilitation should result in a unit which is very close to its as-new condition.

Table 1 – Expected life of a hydropower plant and its subsystems before major work

Plant subsystems	Expected lifetime (years)	Considerations
Civil works		
Dams, canals, tunnels, caverns, reservoirs, surge chambers	60 to 80	Duration of water rights, quality of work, state of deterioration, safety, loss of water.
Powerhouse structures, water control structures, spillways, sand traps, penstocks, steel linings, roads, bridges	40 to 50	General condition, imposed stresses, quality of material, state-of-the-art, safety, quality of steel, corrosion, maintenance.
Mechanical installations		
Hydraulic machines		
Kaplan and Bulb turbines Francis, Pelton and Fixed-blade Propeller turbines Pump turbines (all types) Storage pumps (all types)	25 to 50 30 to 50 25 to 35 25 to 35	Safety of operation, loss of water, cavitation damage, erosion, corrosion, cracks, deterioration of efficiency, performance improvement.
Heavy mechanical equipment and auxiliaries		
Flat gates, radial gates, butterfly valves, spherical valves, cranes, auxiliary mechanical equipment	25 to 40	Quality of material, operating condition, safety considerations, quality of equipment, imposed stresses, performance improvement.
Electrical installations		
Generators, transformers	25 to 40	Winding and iron core condition, cleanliness, safety of operation, state-of-the-art, general condition, quality of equipment, maintenance.
High voltage switchgear, auxiliary electrical equipment, control equipment	20 to 25	
Batteries, DC equipment	10 to 20	
Energy transmission lines		
Steel towers Concrete towers Wooden poles Lines and cables	30 to 50 30 to 40 20 to 25 25 to 40	Right of way, corrosion, safety of operation, climatic conditions, quality of material, state-of-the-art, capacity vs. service conditions.

4.2 Reliability and availability increase

A thorough rehabilitation can significantly increase reliability and availability of the units. Following a thorough and well executed rehabilitation, an availability of approximately 98 % can be expected. This normally results in less lost revenue associated with having the units out of service for planned outages and fewer unplanned outages. By their nature, forced outages for unplanned repairs usually cost significantly more than would a similar planned repair, particularly when the consequential impacts are evaluated.

4.3 Life extension and performance restoration

The useful life of the turbine can be greatly extended by the rehabilitation or replacement of turbine components. The operating characteristics and the mechanical integrity of the machine can be restored to nearly “as-new” condition, guaranteeing safe and reliable operation for a long period.