# Hydraulic machines, radial and axial - Methodology for performance transposition from model to prototype

EESTI STANDARDIKESKUS
ESTONIAN CENTRE FOR STANDARDISATION

## EESTI STANDARDI EESSÕNA

## NATIONAL FOREWORD



| | |
|---|---|
| See Eesti standard EVS-EN IEC 62097:2019 sisaldab Euroopa standardi EN IEC 62097:2019 ingliskeelset teksti. | This Estonian standard EVS-EN IEC 62097:2019 consists of the English text of the European standard EN IEC 62097:2019. |
| Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas | This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation. |
| Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 03.05.2019. | Date of Availability of the European standard is 03.05.2019. |
| Standard on kättesaadav Eesti Standardikeskusest. | The standard is available from the Estonian Centre for Standardisation. |

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile standardiosakond@evs.ee.

ICS 27.140

EUROPEAN STANDARD

NORME EUROPÉENNE

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# EN IEC 62097

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Supersedes EN 62097:2009

English Version

# Hydraulic machines, radial and axial - Methodology for performance transposition from model to prototype (IEC 62097:2019)

Machines hydrauliques, radiales et axiales - Méthodologie de transposition des performances du modèle au prototype (IEC 62097:2019)

Hydraulische Maschinen, radial und axial - Leistungsumrechnung vom Modell zum Prototyp (IEC 62097:2019)

This European Standard was approved by CENELEC on 2019-02-12. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Ref. No. EN IEC 62097:2019 E

## European foreword

The text of document 4/359/FDIS, future edition 2 of IEC 62097, prepared by IEC/TC 4 "Hydraulic turbines" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62097:2019.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2019-11-12
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2022-02-12

This document supersedes EN 62097:2009.

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## Endorsement notice

The text of the International Standard IEC 62097:2019 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

| | | |
|---|---|---|
| ISO 4287 | NOTE | Harmonized as EN ISO 4287 |
| ISO 4288 | NOTE | Harmonized as EN ISO 4288 |

# Annex ZA
(normative)

## Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

| Publication | Year | Title | EN/HD | Year |
|---|---|---|---|---|
| IEC 60193 | - | Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests | EN 60193 | - |

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# HYDRAULIC MACHINES, RADIAL AND AXIAL – METHODOLOGY FOR PERFORMANCE TRANSPOSITION FROM MODEL TO PROTOTYPE

## FOREWORD

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International Standard IEC 62097 has been prepared by IEC technical committee 4: Hydraulic turbines.

This second edition cancels and replaces the first edition published in 2009. This edition constitutes an editorial and technical revision.

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

a) In introduction, clarifications have been brought such as addition of a sentence which declares the precedence of IEC 62097 over IEC 60193 if any mismatch is found between them
b) In Clauses 3 and 4, corrections of the typographical errors
c) In Clause 3: changes to be in accordance with presentation of the terms and structure of IEC 60193 (except for the water temperature)
d) In Clause 4:
   – Deletion of the clause providing the direct step-up procedures for a whole turbine

- Introduction of a global view by using turbine A and turbine B instead of model turbine, reference model turbine and prototype turbine
- Move of section dealing with “surface roughness of model and prototype” in a new Clause 5

e) In Clause 5:
- Introduction of additional chapters to answer comments raised at the CDV stage and to clarify the subject of surface roughness of model and prototype
- Introduction of new tables for minimum recommended prototype roughness for new radial or diagonal machines and for new axial turbines
- Addition of the explanation about roughness measurement of heavily rusted surface

f) In Clause 7 (former Clause 6):
- Introduction of a new subclause for clarifications about the assumed maximum hydraulic efficiency, $\eta_{hAmax}$
- Deletion of the requirement of mutual agreement for the application of the step-up formula for very high efficiency machines exceeding $\eta_{hAmax}$
- Clarifications of the equations from 22 to 33 by doubling the equations for suiting the “two step method”

g) In Clauses 6 and 7, correction of typographical errors

h) In Clause 8 (former Clause 7), introduction of new figures for clarifying the “2 step method” and the alternative method

i) In Annex A, modification of the flux diagram to be in compliance with IEC 60193

j) In Annex B:
- Correction of the equation to obtain $\Delta_{ECO}$
- Deletion of the clause which describes the direct step-up procedures for radial flow machines

k) In Annex C, deletion of the clause which describes the direct step-up procedures for axial flow machines

l) In Annex D:
- notes become main text
- change of variable names in Subclause D.1 for clarifications

m) Addition of Annex E, about comparison of IEC standards dealing with models: 60193 and 62097

n) In Annex F, clarifications of equations by adding more subscripts

o) The Excel sheets attached to the standard are revised as itemized below
- Deletion of the routine regarding the direct step-up procedures for a whole turbine
- Deletion of the notice which requires mutual agreement when the step-up is applied to high efficiency machines exceeding $\eta_{hAmax}$
- Addition of the routine to process the normalization of test data obtained at optimum test conditions

p) Simplification of structure, calculation of optimum and individual point, step up calculation with $\eta_{hAmax}$

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

| FDIS | Report of voting |
|---|---|
| 4/359/FDIS | 4/364/RVD |

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

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

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

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

**IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

# INTRODUCTION

## 0.1 General remarks

IEC 62097 forms an element of a series of standards which deals with model testing of hydraulic machines. The series has two groups describing

a) Hydraulic turbines, storage pumps and pump-turbines – Model acceptance tests (IEC 60193);

b) Hydraulic machines, radial and axial – Performance conversion method from model to prototype (IEC 62097).

Advances in the technology of hydraulic machines for hydroelectric power plants provided background for updating and revising the scale effect methodology of IEC 60193. The advance in knowledge of scale effects originates from work done by research institutes, manufacturers and relevant working groups within the organizations of IEC and IAHR. See IEC 60193 and [1][1] to [6].

The method of calculating prototype efficiencies is supported by experimental work and theoretical research on flow analysis and has been simplified for practical reasons and agreed as a convention by [7] to [9]. The methodology is representing the present state of knowledge of the transposition of performance from model to a homologous prototype.

Homology is not limited to the geometric similarity of the machine components; it also calls for homologous velocity triangles at runner inlet and outlet [1].

According to the present state of knowledge, the formula for the efficiency transposition calculation given in IEC 60193 and earlier standards often overestimates the transposition increment of the efficiency for the prototype.

Limitations and applications of performance conversion of both standards (IEC 60193 and IEC 62097) are given in Annex E.

This document is intended to be used mainly for the assessment of the results of contractual model tests of hydraulic machines. If it is used for other purposes such as evaluation of refurbishment of machines having very rough surfaces, special care is taken as described in Annex B.

Due to the lack of sufficient knowledge about the loss distribution in Deriaz turbines, multi-stage pump-turbines and storage pumps, this document does not provide the scale effect formulae for them.

An Excel workbook concerning the conversion procedures of hydraulic machine performance is attached as a complement of this document to facilitate the calculation of the scaled value for a given test point.

When using this document, if any mismatch is found with IEC 60193, the information in IEC 62097 prevails. Annex E provides additional information for performance conversion method.



[1] Numbers in square brackets refer to the bibliography.

### 0.2 Basic features

A fundamental difference compared to the IEC 60193 transposition is the standardization of scalable losses. In IEC 60193, a loss distribution factor V has been defined and standardized, with the disadvantage that turbine designs which are not optimized will benefit from their lower technological level.

This is certainly not correct, since a low efficiency design typically produces high non-scalable losses, like incidence losses, whereby the amount of scalable losses is about constant for all hydraulic machines, for a given type and a given specific speed of a hydraulic machine.

This document avoids all the inconsistencies connected with IEC 60193. A new basic feature of this document is the separate consideration of losses in specific hydraulic energy, leakage losses and disk friction losses [4], [7] to [9].

Above all, in this document, the transposition of the hydraulic performance is not only driven by the dependence of friction losses on Reynolds number *Re*, but also the effect of surface roughness *Ra* has been implemented.

Since the roughness of the actual machine component differs from part to part, scale effect is evaluated for each individual part separately and then is finally summed up to obtain the overall step-up for a complete machine [9]. For radial flow machines, the evaluation of scale effect is conducted on five separate parts; spiral case, stay vanes, guide vanes, runner and draft tube. For axial flow machines, the scalable losses in individual parts are not fully clarified yet and are dealt with in two parts; runner blades and all the other stationary parts inclusive.

The calculation procedures according to this document are summarized in Clause 8.

In case that the Excel workbook is used for evaluation of the results of a contractual model test, each concerned party executes the calculation individually for cross-check using common input data agreed on in advance for at least one test point.