SLOVENSKI STANDARD

SIST-TP CLC/TR 60034-16-3:2005

01-junij-2005

Elektriț ni rotacijski stroji - 16-3. del: Vzbujalni sistemi za sinhronske stroje - Dinamiț ne karakteristike (IEC/TR 60034-16-3:1996)

Rotating electrical machines - Part 16-3: Excitation systems for synchronous machines - Dynamic performance

Drehende elektrische Maschinen - Teil 16-3: Erregersysteme für Synchronmaschinen - Dynamisches Betriebsverhalten

Machines électriques tournantes - Partie 16-3: Systèmes d'excitation pour machines synchrones - Performances dynamiques

Ta slovenski standard je istoveten z: CLC/TR 60034-16-3:2004

ICS:

29.160.10	Sestavni deli rotacijskih strojev	Components for rotating machines

SIST-TP CLC/TR 60034-16-3:2005 en

TECHNICAL REPORT **CLC/TR 60034-16-3**

RAPPORT TECHNIQUE

TECHNISCHER BERICHT September 2004

ICS 29.160

English version

Rotating electrical machines
Part 16-3: Excitation systems for synchronous machines - Dynamic performance
(IEC/TR 60034-16-3:1996)

Machines électriques tournantes
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(IEC 60034-16-3:1996)

This Technical Report was approved by CENELEC on 2004-07-03.

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

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Ref. No. CLC/TR 60034-16-3:2004 E

Foreword

The text of the Technical Report IEC/TR 60034-16-3:1996, prepared by IEC TC 2, Rotating machinery, was submitted to the formal vote and was approved by CENELEC as CLC/TR 60034-16-3 on 2004-07-03 without any modification.

Endorsement notice

The text of the Technical Report IEC/TR 60034-16-3:1996 was approved by CENELEC as a Technical Report without any modification.

RAPPORT TECHNIQUE – TYPE 2

TECHNICAL REPORT – TYPE 2

CEI
IEC
34-16-3

Première édition
First edition
1996-01

Machines électriques tournantes –

Partie 16:
Systèmes d'excitation pour machines synchrones –
Section 3: Performances dynamiques

Rotating electrical machines –

Part 16:
Excitation systems for synchronous machines –
Section 3: Dynamic performance

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Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

CODE PRIX
PRICE CODE Q

Pour prix, voir catalogue en vigueur
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ROTATING ELECTRICAL MACHINES –

Part 16: Excitation systems for synchronous machines – Section 3: Dynamic performance

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when the technical committee has collected data of a different kind from that which is normally published as an International Standard, for example 'state of the art'.

Technical reports of types 1 and 2 are subject to review within three years of publication to decide whether they can be transformed into International Standards. Technical reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

IEC 34-16-3, which is a technical report of type 2, has been prepared by IEC technical committee 2: Rotating machinery.

The text of this technical report is based on the following documents:

Committee draft	Report on voting
2/911/CDV	2/929/RVC

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

This document is issued in the type 2 technical report series of publications (according to G.3.2.2 of part 1 of the ISO/IEC Directives) as a 'prospective standard for provisional application' in the field of dynamic performance of excitation systems for synchronous machines because there is an urgent requirement for guidance on how standards in this field should be used to meet an identified need.

This document is not to be regarded as an 'International Standard'. It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the IEC Central Office.

A review of type 2 technical reports will be carried out not later than three years after their publication with the options of: extension for another three years; conversion into an International Standard; or withdrawal.

This report forms section 3 of Part 16 of a series of publications dealing with rotating machinery, the other parts being:

Part 1: Rating and performance, issued as IEC 34-1

Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excludig machines for traction vehicles), issued as IEC 34-2.

Part 3: Specific requirements for turbine-type synchronous machines, issued as IEC 34-3.

Part 4: Methods for determining synchronous machine quantities from tests, issued as IEC 34-4.

Part 5: Classification of degrees of protection provided by enclosures of rotating machines (IP code), issued as IEC 34-5

Part 6: Methods of cooling (IC code), issued as IEC 34-6.

Part 7: Classification of types of constructions and mounting arrangements (IM code), issued as IEC 34-7

Part 8: Terminal markings and direction of rotation of rotating machines, issued as IEC 34-8.

Part 9: Noise limits, issued as IEC 34-9.

Part 10: Conventions for description of synchronous machines, issued as IEC 34-10.

Part 11: Built-in thermal protection – Chapter 1: Rules for protection of rotating electrical machines, issued as IEC 34-11.

Part 11-2: Built-in thermal protection – Chapter 2: Thermal detectors and control units used in thermal protection systems, issued as IEC 34-11-2.

Part 11-3: Built-in thermal protection – Chapter 3: General rules for thermal protectors used in thermal protection systems, issued as IEC 34-11-3.

Part 12: Starting performance of single-speed three-phase cage induction motors for voltages up to and including 660 V, issued as IEC 34-12.

Part 13: Specification for mill auxiliary motors, issued as IEC 34-13.

Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of the vibration severity, issued as IEC 34-14.

Part 15: Impulse voltage withstand levels of rotating a.c. machines with form-wound stator coils, issued as IEC 34-15.

Part 16-1: Excitation systems for synchronous machines – Chapter 1: Definitions, issued as IEC 34-16-1.

Part 16-2: Excitation systems for synchronous machines – Chapter 2: Models for power system studies, issued as IEC 34-16-2.

ROTATING ELECTRICAL MACHINES –

Part 16: Excitation systems for synchronous machines – Section 3: Dynamic performance

1 Scope

This section briefly reviews the methods available for investigating the response characteristics of the synchronous machine with its closed-loop excitation control.

The general functional block diagram of excitation systems (see figure 1 of IEC 34-16-2) indicates the various excitation system components which have to be considered in power system stability studies.

Description of typical response, performance characteristics and indices as well as performance criteria are given.

2 Small signal performance

2.1 *Methods of describing small signal performance*

2.1.1 *General*

Small signal performance describes the response of the excitation control and the synchronous machine to signals which are sufficiently small that non-linearities can be disregarded and the behaviour of the system can be represented by a linear model. Small signal performance of components and systems can best be described as follows.

2.1.2 *Time response*

A simplified excitation system and open-circuited synchronous machine are shown in figure 1. The time response to a step change with the feedback loop closed is illustrated in figure 2. The performance indices of interest are the rise time, overshoot and settling time as indicated.

2.1.3 *Frequency response*

In a linear system, the frequency response is the frequency-dependent relationship expressed by the magnitude and the phase difference between steady-state sinusoidal inputs and the resultant steady-state sinusoidal outputs.

The open-loop frequency response characteristics of figure 1 are shown in figure 3 for the simplified excitation system with the synchronous machine open-circuited. The indices of interest are the low frequency gain G, angular crossover frequency ω_c, phase margin Φ_m and gain margin G_m. The corresponding closed-loop frequency response is shown in figure 4. Here the indices of interest are the bandwidth ω_b, the peak value M_p of the gain characteristic, and the angular frequency ω_m at which the peak value M_p occurs. These performance indices provide measures of the relative stability and indication of the time response characteristics.

2.1.4 *Complex frequency domain*

The dynamic characteristics of a control system can be evaluated by mapping the eigenvalues (characteristics roots) of its Laplace transfer function in the complex frequency domain. Typical root locations of an excitation system with the terminal voltage feedback loop open and the synchronous machine open-circuited are shown in figure 5.

A root locus plot typically maps the locations of the closed-loop poles as the loop gain is varied from zero to infinity. Figure 6 shows the root locus of the excitation system of figure 5 with the terminal voltage feedback loop closed. The poles of the closed-loop system are mapped as the value of gain K is varied. Note that figures 5 and 6 correspond to a more complex, representative, transfer function than the simplified one of figure 1.

2.1.5 *Small signal performance indices*

Typical ranges of values of small signal performance indices for an excitation system and synchronous machine are given in table 1. These data have been derived analytically using the anticipated extreme ranges (longest to shortest) of synchronous machine field time constants and excitation system time constants likely to be encountered.

These indices are measures of relative response and stability of control action. In most feedback control systems they are determined primarily by the dynamic characteristic of the system element whose output is the ultimately controlled variable. In the case of an excitation control system, the dynamic characteristics of the synchronous machine (field time constant, etc.) are the determining factors.

Table 1 – Typical range of excited control system

Small signal dynamic performance indices		
Performance index	Symbol	Range of expected values
Excitation system gain	K	30 to 800 per unit
Gain margin	G_m	2 dB to 20 dB
Phase margin	Φ_m	20° to 80°
Peak value of amplitude response	M_p	1,0 to 4,0 (0 dB to 12 dB)
Bandwidth	ω_b	2 to 75 rad.s^{-1}
Overshoot	d	0 % to 80 %
Rise time	t_r	0,05 s to 2,5 s
Settling time	t_s	0,2 s to 10,0 s
Damping ratio	ξ	0 to 1

2.2 *Effects of excitation control on system stability*

The excitation control as part of the excitation system is linked with the power system via the synchronous machine quantities which are terminal voltage, reactive and active current, field current and frequency or speed, as far as applicable. The behaviour of this complex multi-loop, multi-variable, feedback control system varies considerably with its parameters.