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Electromechanical equipment guide for small hydroelectric installations

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Guide pour l'équipement électromécanique des petits aménagements hydro-électriques

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Guide pour l'équipement électromécanique des petits aménagements hydro-électriques

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMECHANICAL EQUIPMENT GUIDE FOR SMALL HYDROELECTRIC INSTALLATIONS

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

This International Standard has been prepared by IEC Technical Committee No. 4: Hydraulic turbines.

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

Six Months' Rule	Report on Voting
4(CO)46	4(CO)51

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

Annex A is for information only.

ELECTROMECHANICAL EQUIPMENT GUIDE FOR SMALL HYDROELECTRIC INSTALLATIONS

SECTION 1 – GENERAL

1.1 Scope and object

This International Standard is used as a guide that applies to hydroelectric installations with units having power outputs less than 5 MW and turbines with nominal runner diameters less than 3 m. These figures do not represent absolute limits.

This guide deals only with the direct relations between the purchaser or the consulting engineer and the supplier. It does not deal with civil works, administrative conditions or commercial conditions.

This guide is intended to be used by all concerned in the installation of electromechanical equipment for small hydroelectric plants.

This guide, based essentially on practical information, aims specifically at supplying the purchaser of the equipment with information which will assist him with the following:

- preparation of the call for tenders;
- evaluation of the tenders;
- contact with the supplier during the design and manufacture of equipment;
- quality control during the manufacture and shop-testing;
- follow-up of site erection;
- commissioning;
- acceptance tests;
- operation and maintenance.

The guide comprises the following:

a) general requirements for the electromechanical equipment of small hydroelectric installations;

b) technical specifications for the electromechanical equipment, excluding its dimensioning and standardization;

c) requirements for acceptance, operation and maintenance.

Bearing in mind the type of installation considered, the documents shall be as simple as possible but must satisfactorily define the particular operation conditions. Over-specification is harmful to the economy of the project.

1.2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication of this standard, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 34-1: 1983, *Rotating electrical machines – Part 1: Rating and performance.*

IEC 34-2: 1972, *Rotating electrical machines – Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles).*

IEC 34-2A: 1974, *First supplement: Measurement of losses by the calorimetric method.*

IEC 34-5: 1991, *Rotating electrical machines – Part 5: Classification of degrees of protection provided by enclosures of rotating electrical machines (IP Code).*

IEC 41: 1991, *Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines.*

IEC 50(602): 1983, *International Electrotechnical Vocabulary (IEV), Chapter 602: Generation, transmission and distribution of electricity – Generation.*

IEC 56: 1987, *High-voltage alternating-current circuit-breakers.*

IEC 70: 1967, *Power capacitors.*

IEC 76-1: 1976, *Power transformers – Part 1: General.*

IEC 129: 1984, *Alternating current disconnectors (isolators) and earthing switches.*

IEC 185: 1987, *Current transformers.*

IEC 186: 1987, *Voltage transformers.*

IEC 193: 1965, *International code for model acceptance tests of hydraulic turbines. Amendment No. 1 (1977).*

IEC 193A: 1972, *First supplement to IEC 193 (1965).*

IEC 308: 1970, *International code for testing of speed governing systems for hydraulic turbines.*

IEC 545: 1976, *Guide for commissioning, operation and maintenance of hydraulic turbines.*

IEC 609: 1978, *Cavitation pitting evaluation in hydraulic turbines, storage pumps and pump-turbines.*

Considering the scope of this guide, it does not cover the initial stage of investigations, that is to say the preliminary study and feasibility study. Neither does it deal with the economic study concerning the supply and demand of energy.

To conclude, the guide does not replace the necessary engineering studies for the selection, design, manufacture, installation and testing of the equipment. It is intended only to make the purchaser aware of the important points and data to be furnished, specified and kept in due consideration in the construction of small hydroelectric plants.

NOTES

1 The IEC standards applicable for the preparation of technical documents are given in clause 1.2. In the case of small hydro developments, the necessary simplification relevant to the type of installation shall be made.

2 Where IEC standards do not cover all areas of the equipment, ISO Standards concerning specific items can be consulted, although where there is conflict between the IEC codes and the ISO Standards those of the IEC will prevail.

1.3 Nomenclature

See annex A.

1.4 Methodology

In the interests of clarity, the sequence of the necessary steps for the construction of a small hydroelectric power plant is represented diagrammatically in figure 1.

It principally covers the preparation of technical specifications, the examination of tenders, the manufacture, and finally the commercial operation and maintenance of equipment.

This sequence also shows the relationship between the different phases and areas of responsibility of all the parties concerned (consulting engineer, chief resident engineer, and users).

If the purchaser does not have in-house engineering capabilities or the services of a consulting engineer, he may call for, to facilitate relations with contractors, a "turn-key" supply, or have at least a leading contractor responsible for the supply of all or part of the electromechanical equipment (e.g. the turbine/generator package, or a "water-to-wire" package).

SECTION 2 – DESCRIPTION OF INSTALLATION AND OPERATING CONDITIONS OF POWER STATION

The following data is generally required by the equipment supplier and should appear in the enquiry. In some cases, all these data are not always readily available. Nevertheless, it must be emphasized that the more information that is given the better will the project be understood and therefore the better the technical solution which will result.

2.1 Site conditions

2.1.1 Supply a topographic survey (plan and profile) giving the altitude of the points indicated and the position desired for the main works (see figure 4), water intake, reservoir, channel, surge tank or head pond, penstock, power plant, headwater, tailwater and their main characteristics (sections, lengths, materials of the channels and penstocks, etc.). Indicate the foundation conditions (sand, rock, soft ground, etc.).

2.1.2 Attach numbered pictures with cross-references to the topographic survey described in 2.1.1, showing the setting and location of the main works.

2.1.3 Supply the chemical analysis of the water with extremes of temperature and, if necessary, the amount and size of sediments carried by the water in the area around the water intake or downstream of the sand trap, if any.

Indicate the presence of any living organisms or floating debris, etc.

2.1.4 Specify the local conditions; extremes of air temperature, humidity, occurrence of strong winds, earthquakes, etc.

2.1.5 Indicate any transport or access limitations.

2.1.6 Certain information mentioned in 4.1.5.1 and 4.1.5.3 (erection) may also be shown in the tender enquiry if this reflects a particular feature of the purchaser's own country.

2.1.7 State if it is run-of-river (see figure 3) or a scheme with a reservoir.

Indicate if there exist any particular operational constraints: e.g. multi-purpose scheme, environmental, fisheries, etc.

State and describe (with drawings) those elements of the plant which are part of an existing installation which it is foreseen will eventually be put back into use.

2.1.8 State if the plant will be manned or unmanned.

2.2 Hydraulic conditions for plant and design criteria for the units

2.2.1 Specify the maximum allowable up or down surges in the channels.

2.2.2 Provide a flow duration curve (see figure 2) with an indication of the limiting flows (guaranteed water supply, irrigation, drinking-water).

2.2.3 Specify the chosen design flow, Q_a, in cubic metres per second, and the availability in days per year.

2.2.4 Specify the extreme water-levels at the intake and at the tail-race in metres (m) above sea-level, as follows.

a) upstream max ... m
min ... m

b) downstream max ... m
min ... m

c) operational range allowed: ... m

and give the curves for:

d) level versus discharge (upstream and downstream)

e) level versus volume of the upstream reservoir or head pond (essential for a reservoir scheme).

2.2.5 Specify the desired outputs and the duration of the corresponding operations. The net heads are defined as in IEC 41. The crossflow turbines with diffusers being considered as reaction turbines.

2.2.6 State the number of units suggested.

2.2.7 Define the evaluation criteria for efficiency over the full range of operation as well as overload conditions (weighting the efficiency according to the amount of energy produced at different heads and flows). The weight to be given to a particular efficiency or overload depends on the time of utilization at the point of operation considered and the energy thus recovered from the installation. For general instructions to tenderers see clause 3.5.

NOTES

1 For low head plants with short intakes, care must be taken in the design of the intake in order to obviate hydraulic problems such as vortices and air admission.

2 The proper design of the waterways is essential in order to minimize the head losses (difference between gross and net head).

2.3 Electrical conditions for plant operation

The plant electrical conditions and requirements listed under either 2.3.1 or 2.3.2.

2.3.1 *The plant is intended to operate in isolated network*

a) *Without any other energy supply on the network*

For isolated load networks, black-start capability is essential.

i) Required network voltage V
Tolerance (under steady-state conditions) + ... % – ...%

ii) Network frequency ..... Hz
Tolerance (under steady-state conditions) + ... % – ... %

iii) Minimum output required all year round by the network ...... kW

iv) Load acceptance rate of the network (to determine whether or not a flywheel is required) ...... kW/s

v) Value of the maximum step-change in load which the network can accept + ... kW – ... kW

vi) Power factor (cos ϕ) .....

b) *With permanent connection to another electrical energy supply defined as follows:*

i) Hydroelectric unit: type ....
min output ... kW

ii) Thermoelectric unit: type ....

iii) Generator characteristics (synchronous or asynchronous):

- rated voltage V
- rated frequency ..... Hz
- rated output ..... kVA
- inertia GD^2 of rotating parts ..... kg · m^2
- power factor (cos ϕ) .....

iv) Turbine governor characteristics

The network conditions are to be defined as in 2.3.1 a), items i) to iv).

v) Voltage regulator characteristics (distribution of reactive power).

c) *Energy utilization: daily and seasonal load variations*

Output (kW)	minimum	average	maximum
Passive loads (lighting, heating, drying, ...)			
Active loads (electric motors)			
Total			

In order to decide the method of regulation and the design of the governor, it is necessary to give an indication of the load variations (load curve):

a) daily;

b) weekly;

c) seasonal.

Indicate the priority and non-priority loads (load shedding) as this is useful for designing the governor.

2.3.2 *The plant is intended to operate in parallel with a grid which imposes the frequency*

a) *Characteristics of the grid*

i) Voltage V
Tolerance + ... % – ... %

ii) Frequency ...... Hz
Tolerance + ... % – ... %

iii) Short-circuit power (at the point where the new scheme is linked to the grid) ...... kVA

iv) Power factor (cos ϕ) ......

b) *Apparent output of the largest generator working on the network* ...... kVA

2.3.3 *Energy transport and distribution*

Provide the following drawings:

– a general layout drawing of the entire proposed network, in the case of isolated load operation;

– a drawing showing the link to the grid, in the case of operation in parallel with a large grid.

The layout should also show the main centres of energy consumption and supply.

Also provide information on any possible developments of the grid.

2.4 Types of regulation and modes of operation

2.4.1 *Frequency regulation*

If the unit or the plant operates in an isolated network, or is an important part of the network, a governor is required to maintain the network frequency during load changes.

For units with low output and where hydraulic energy is abundant, simplified governors could also be used by producing a constant output at full load and dumping the unused power.

2.4.2 *Level control*

Specify if it is necessary to maintain the upstream or downstream level constant, or within a working range using the generating sets or some other discharge device. If this is so, the turbine opening must then be governed with level feedback. This is generally the case with run-of-river plants (in the river itself or in a bypass channel) or when linked to an irrigation canal.

NOTE - On isolated load, level or frequency may be controlled but not both.

2.4.3 *Flow regulation*

Specify if the units are to provide a constant flow or a variable programmed flow.

NOTE - On isolated load, flow or frequency may be controlled but not both.

2.4.4 *Simplified governing*

If the plant is to operate on a large network which imposes the frequency, its units can be fitted with simplified governors (positioners) having level feedback or load feedback. Stability may be affected in the case where part of a large grid becomes accidentally detached and simplified governors are used.

2.5 Automation, telemetry, remote control, alarms

a) Indicate if staff are available for the starting and shut-down sequences or if it is required to minimize the use of operators.

b) If the plant is unattended, specify where the alarms are to be located.

c) Specify whether the starting sequence, synchronization, loading and shut-down operations shall be:

i) manual;

ii) and/or automatic;

iii) and/or telecontrolled (in this case, indicate the location of the control centre, the carrier and the type and method of transmission of the signals).

d) Where a scheme has a reservoir, and there are several units, specify if manual or automatic control of the reservoir water is required (operation according to a programme).

e) Specify if the plant is to be the control centre for other energy supply sources in the network.

SECTION 3 – EQUIPMENT SPECIFICATIONS

The information given below is useful in establishing technical specifications and comparing the technical offers for the most important items in a small hydroelectric development.

3.1 Technical requirements

In addition to supplying the equipment, the supplier should provide the following:

a) Suitability of the proposed technical solutions with regard to the hydraulic characteristics and the operational requirements.

b) The supplier should inform the purchaser of the necessary civil work data at an early stage so that the civil work can be designed in accordance with the requirements of the equipment. Verification of the compatibility between the civil work and the electromechanical equipment (overall dimensions, floor loads, supply and verification of the preliminary civil work layout drawings, etc.).

c) Information required for erecting, starting-up, operating and maintaining the equipment.

3.2 Limits of the supply

These limits should be clearly and physically defined for each item. It should be checked that no equipment has been excluded.

3.2.1 *For the hydraulic system*

On the upstream side the limit could be trashrack and the rack cleaning machine, if installed, or the first hydraulic closure device (stop-logs, gate or valve), or any other suitable section.

On the downstream side the limit could be defined as the end of the draft tube or of the stop-logs or gate, or any other suitable section.

3.2.2 *For the electric system*

This may include all the electrical equipment, up to the first point of connection with the grid to be defined by the purchaser.

3.2.3 *Elements not normally included in the supply*

Generally the following are not included:

a) civil works,

b) telemetry and remote control.

3.3 Specifications of the elements of the plant

Without overlooking the criterion of simplicity which this type of installation requires, the selection of good quality materials, suitable technology and good machine characteristics has the advantage of affording reliability and prolonged life of the plant.

3.3.1 *Trashrack and rack cleaner*

The opening between the bars of the grating should be as large as possible, but less than the minimum dimension of the hydraulic circuit downstream (e.g. in Francis turbines, the minimum opening between the blades of the runner). Specify that the racks should be able to support the loads which can be produced when they are completely obstructed.

The rack cleaning machine, if it is required, could be manual or automatic, but in any event, the clearing away, transporting and dumping of the debris should be taken into account.

3.3.2 *Water-level control*

According to the operation of the plant, the control of level could be for information, and also for protection and auxiliary regulation.

The elements of level control are generally placed upstream of the unit (intake, dam, etc.) although in some cases it might be necessary to control the downstream level (flow requirements, downstream plant, etc.).

If the level measuring equipment is very remote from the power station, it shall be protected, together with the connecting line, against electrical surge. This is particularly important when electronic devices are used.

Moreover, the level control equipment (and other associated equipment) should be protected against damage from environmental causes or caused by a third party.

For low head stations, in most instances, the level control can be tapped at turbine inlet inside the power station.

3.3.3 *Discharge closure devices* (see figure 7)

The unit should be protected by at least one closure device, which in an emergency would close due to lack of electrical signal (this could be the admission of air in a siphon-type turbine) or activation by electrical signal. This device may be the guide vanes.

The opening of the gates and valves is generally performed by means of an actuator and with balanced upstream and downstream pressures. The actuator shall have sufficient power to enable it to open the device under unbalanced pressures.

The closure should be guaranteed under any circumstances for reasons of safety:

a) for gates, closure should be affected by their own weight;

b) while for valves and guide vanes acting as safety closing devices and not having a closing tendency, closure should be effected by a counterweight or any other device having an equivalent effect.

For the correct and lasting operation of the stop-logs and gates, it is necessary to maintain the parallelism of the fixed guides.

The valves and the gates should be designed to withstand a test pressure of 1,5 times the maximum total pressure, including surge, and to be capable of stopping the maximum discharge, including broken penstock flow conditions.