



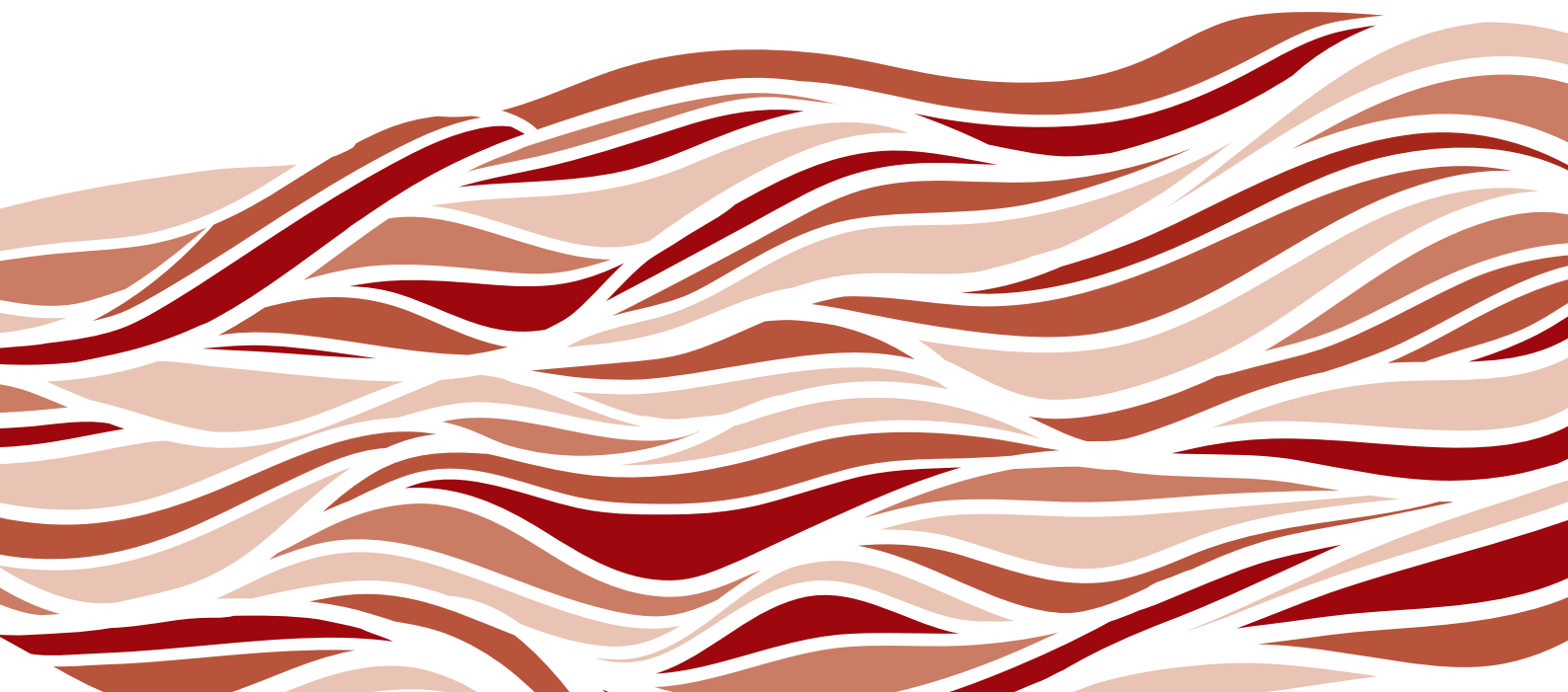
UNITED NATIONS  
INDUSTRIAL DEVELOPMENT ORGANIZATION



# Technical Guidelines for the Development of Small Hydropower Plants **UNITS**

## **Part 3: Hydro Turbine Governing System**

**SHP/TG 003-3: 2019**



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Development of Small Hydropower Plants  
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Further recommendations and suggestions for application for the update would be highly welcome.

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## Foreword

The United Nations Industrial Development Organization (UNIDO) is a specialized agency under the United Nations system to promote globally inclusive and sustainable industrial development (ISID). The relevance of ISID as an integrated approach to all three pillars of sustainable development is recognized by the 2030 Agenda for Sustainable Development and the related Sustainable Development Goals (SDGs), which will frame United Nations and country efforts towards sustainable development in the next fifteen years. UNIDO's mandate for ISID covers the need to support the creation of sustainable energy systems as energy is essential to economic and social development and to improving quality of life. International concern and debate over energy have grown increasingly over the past two decades, with the issues of poverty alleviation, environmental risks and climate change now taking centre stage.

INSHP (International Network on Small Hydro Power) is an international coordinating and promoting organization for the global development of small hydropower (SHP), which is established on the basis of voluntary participation of regional, subregional and national focal points, relevant institutions, utilities and companies, and has social benefit as its major objective. INSHP aims at the promotion of global SHP development through triangle technical and economic cooperation among developing countries, developed countries and international organizations, in order to supply rural areas in developing countries with environmentally sound, affordable and adequate energy, which will lead to the increase of employment opportunities, improvement of ecological environments, poverty alleviation, improvement of local living and cultural standards and economic development.

UNIDO and INSHP have been cooperating on the World Small Hydropower Development Report since year 2010. From the reports, SHP demand and development worldwide were not matched. One of the development barriers in most countries is lack of technologies. UNIDO, in cooperation with INSHP, through global expert cooperation, and based on successful development experiences, decided to develop the SHP TGs to meet demand from Member States.

These TGs were drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of these TGs may be subject to patent rights. UNIDO and INSHP shall not be held responsible for identifying any such patent rights.

## Introduction

Small Hydropower (SHP) is increasingly recognized as an important renewable energy solution to the challenge of electrifying remote rural areas. However, while most countries in Europe, North and South America, and China have high degrees of installed capacity, the potential of SHP in many developing countries remains untapped and is hindered by a number of factors including the lack of globally agreed good practices or standards for SHP development.

These Technical Guidelines for the Development of Small Hydropower Plants (TGs) will address the current limitations of the regulations applied to technical guidelines for SHP Plants by applying the expertise and best practices that exist across the globe. It is intended for countries to utilize these agreed upon Guidelines to support their current policy, technology and ecosystems. Countries that have limited institutional and technical capacities, will be able to enhance their knowledge base in developing SHP plants, thereby attracting more investment in SHP projects, encouraging favourable policies and subsequently assisting in economic development at a national level. These TGs will be valuable for all countries, but especially allow for the sharing of experience and best practices between countries that have limited technical know-how.

The TGs can be used as the principles and basis for the planning, design, construction and management of SHP plants up to 30 MW.

- The Terms and Definitions in the TGs specify the professional technical terms and definitions commonly used for SHP Plants.
- The Design Guidelines provide guidelines for basic requirements, methodology and procedure in terms of site selection, hydrology, geology, project layout, configurations, energy calculations, hydraulics, electromechanical equipment selection, construction, project cost estimates, economic appraisal, financing, social and environmental assessments—with the ultimate goal of achieving the best design solutions.
- The Units Guidelines specify the technical requirements on SHP turbines, generators, hydro turbine governing systems, excitation systems, main valves as well as monitoring, control, protection and DC power supply systems.
- The Construction Guidelines can be used as the guiding technical documents for the construction of SHP projects.
- The Management Guidelines provide technical guidance for the management, operation and maintenance, technical renovation and project acceptance of SHP projects.

# Technical Guidelines for the Development of Small Hydropower Plants-Units

## Part 3: Speed Governing System

### 1 Scope

This Part of the Units Guideliness pecifies the technical requirements as well as the basic requirements for the supply scope, spare parts, technical documents, inspection and acceptance, packing, transportation, storage, installation, operation and maintenance for the small hydropower (SHP) hydro turbine governing system.

This document applies to the electro-hydraulic governor (hereinafter referred to as the governor) with a working capacity of 350 N · m or above as well as an oil pressure device.

### 2 Normative references

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.

ISO 8068, *Lubricants, Industrial Oils and Related Products (Class L)—Family T (Turbines)—Specification for Lubricating Oils for Turbines*

ISO 11158, *Lubricants, Industrial Oils and Related Products (Class L)—Family H (Hydraulic Systems)—Specifications for Categories HH, HL, HM, HV and HG*

IEC 61000-4-4, *Electromagnetic Compatibility (EMC)—Part 4-4: Testing and Measurement Techniques—Electrical Fast Transient/ Burst Immunity Test*

IEC 60308, *Hydraulic turbines—Testing of the Control systems*

IEC 61362, *guide to the specifications of the hydraulic turbines control system*

SHP/TG 001, *Technical guidelines for the development of small hydropower plants—Terms and definitions.*



### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60308, IEC 61362 and SHP/TG 001 apply.

### 4 General provisions

#### 4.1 Model selection of the governor and the oil pressure device

4.1.1 The model selection of the governor and the oil pressure device shall be reasonable, the working capacity shall be matched with the turbine, and they shall be able to reliably control the turbine generator unit under the maximum water head and at maximum flow rate and have a certain allowance.

4.1.2 The actual maximum opening of the guide vane shall at least correspond to over 80% of the maximum stroke of the servomotor.

#### 4.2 Operational situation of the hydro turbine generator unit

4.2.1 The turbine shall operate under the conditions specified by the manufacturer.

4.2.2 The turbine generator unit shall be able to operate stably under various manual conditions. When operating under the manual no-load condition (the generator exciter is working in automatic mode), the relative value of the speed oscillation of the turbine generator unit shall not exceed  $\pm 0.3\%$ .

#### 4.3 Water inertia time constant and turbine generator unit inertia time constant

4.3.1 The water inertia time constant  $T_w$  of the turbine water diversion system shall not be more than 4 s.

4.3.2 The turbine generator unit inertia time constant  $T_a$  shall not be less than 4 s for the reaction turbine nor less than 2 s for the impulse turbine.

4.3.3 The specific ratio of the water inertia time constant  $T_w$  to the turbine generator unit inertia time constant  $T_a$  shall not be more than 0.4.

#### 4.4 Environmental conditions

The environmental conditions should meet the following requirements:

- a) The altitude shall not exceed 2 500 m. When the equipment is used in places with an altitude exceeding 2 500 m, the reduction in the dielectric property and the decrease of the air cooling effect shall be considered, and the user shall negotiate with the supplier.
- b) Ambient temperature is 5 °C to 40 °C .
- c) The monthly maximum relative humidity shall not exceed 85% (without condensation) during the wettest month, meanwhile, the monthly average minimum temperature shall not be more than 25 °C during this month.

#### 4.5 Oil for the hydro turbine governing system

The viscosity grade of the oil used in the hydro turbine governing system shall be consistent with the oil used in the turbine, the oil temperature scope is 10 °C to 50 °C , and the following requirements shall be met:

- a) When the oil pressure grade is not more than 12.5 MPa, L-HL hydraulic oil should be selected and the oil quality shall comply with the provisions of ISO 8068.
- b) When the oil pressure grade is more than 12.5 MPa, L-HM hydraulic oil should be selected and the oil quality shall comply with the provisions of ISO 11158.

#### 4.6 Others

If the service environment conditions do not meet the requirements, the performance indices may be negotiated by the supplier and the user.

### 5 Technical requirements

#### 5.1 Servomotor capacity

The servomotor capacity of the hydro turbine governing system shall match the design requirements for the turbine.

#### 5.2 Oil pressure grade

The oil pressure grade of the governor and the oil pressure device shall be (MPa): 2.5, 4.0, 6.3, 10.0, 12.5 and 16.0.

#### 5.3 Static characteristics (speed droop)

5.3.1 The static characteristic curve shall be approximately a straight line.

5.3.2 When the permanent difference coefficient  $b_p$  is 4% , see Table 1 for the speed dead band measured at the main servomotor.

Table 1 Speed dead band of the turbine governing system

Item	Type of governor			
	Large-scale governor ( $A > 75\,000\text{ N}\cdot\text{m}$ )	Medium-scale governor ( $18\,000\text{ N}\cdot\text{m} \leq A \leq 75\,000\text{ N}\cdot\text{m}$ )	Small-scale governor ( $3\,000\text{ N}\cdot\text{m} \leq A < 18\,000\text{ N}\cdot\text{m}$ )	Ultra-small-scale governor ( $350\text{ N}\cdot\text{m} \leq A < 3\,000\text{ N}\cdot\text{m}$ )
Speed dead band $i_x$ (%)	0.02	0.06	0.10	0.20

5.3.3 For the hydro turbine governing system of the Kaplan turbine, the  $i_a$  (the inaccuracy of the blade servo system) shall not exceed 0.8% and the allowable deviation of the measured combination curve and the theoretic combination curve shall be 1% of the full stroke of the blade servomotor.

5.3.4 For the hydro turbine governing system of the multi-nozzle impulse turbine, the position deviation between any two needles shall not exceed 1% of the full stroke and the position deviation of each needle from the average value of all needle positions shall not exceed 0.5% under the steady-state condition.

#### 5.4 Dynamic characteristics

5.4.1 The governor shall ensure the stability of the turbine generator unit under various working conditions and in various operating modes, and meet the following requirements:

- a) When the governor is operating automatically under no-load condition, apply a step-type speed command signal and observe the transition process. After it becomes stable, record the relative value of speed oscillating:
  - 1) The relative value shall not exceed  $\pm 0.25\%$  for the medium and small-scale governor;
  - 2) The relative value shall not exceed  $\pm 0.3\%$  for the ultra-small-scale governor.
- b) If the relative value of the manual no-load speed oscillating of the turbine generator unit is greater than the specified value, the relative value of its automatic no-load speed oscillating shall not be more than the relative value of the manual no-load speed oscillating.
- c) For the turbine generator unit whose rotational inertia could not satisfy the regulation guarantee calculation requirement, the relative value of its automatic no-load speed oscillating shall be negotiated by the supplier and the user separately.

5.4.2 The servomotor dead time shall not be more than 0.2 s.

5.4.3 The dynamic quality of the turbine generator unit after load rejection shall meet the following requirements:

- a) After 100% load rejection, the crest that is 3% above the rated rotation speed value in the steady state shall not appear more than twice in the speed variation process;
- b) The regulation time shall meet one of the following requirements:
  - 1) The regulation time from the moment when the servomotor starts moving toward the opening direction for the first time after load rejection to the moment when the relative value of the speed oscillating is not more than  $\pm 1\%$  shall not be more than 40 s;
  - 2) The ratio of the regulation time  $t_E$  from the start of load rejection to the moment when the deviation between the rotation speed and the rated value is less than  $\pm 1\%$  to the time  $t_M$  from the start of load rejection to the moment when the rotation speed rises up to the maximum value shall meet the following requirements:
    - It shall not be more than 8 for the reaction turbine with medium and low water head;
    - It shall not be more than 12 for the Kaplan turbine with relatively long blade closing time;
    - It shall not be more than 15 for the reaction turbine with high water head and the impulse turbine.
- c) For the turbine generator unit supplying power to the hydropower station after disconnecting from the power grid, the minimum relative speed of the turbine generator unit after load rejection shall not be less than 0.85 (except for the bulb turbine units with inrush control and a relatively long blade closing time).

## 5.5 Governor

5.5.1 The governing parameters of the PID-based governor shall be adjustable within the design scope:

- a) The minimum value of the proportional gain  $K_P$  shall not be more than 0.5 and the maximum value shall not be less than 20.
- b) The minimum value of the integral gain  $K_I$  shall not be more than  $0.05 \text{ s}^{-1}$  and the maximum value shall not be less than  $10 \text{ s}^{-1}$ .
- c) The minimum value of the differential gain  $K_D$  is 0 and the maximum value shall not be less than 5 s.

5.5.2 The permanent speed droop coefficient  $b_p$  shall be adjustable as appropriate within the scope of 0 to 10%.

5.5.3 The adjustment scope of the speed command signal shall be  $\pm 10\%$  of the rated speed.

5.5.4 The opening (load) limiting shall be adjustable within the scope from 0 to the maximum opening (load).

5.5.5 The closing time  $T_f$  and the opening time  $T_g$  of the servomotor shall be adjustable as appropriate within the design scope.

5.5.6 The governor shall be able to realize the starting, stopping and emergency shutdown of the turbine generator unit in the automatic and manual modes.

5.5.7 The governor shall be able to set the artificial dead band, its scope is  $\pm 1\%$  of the rated speed and it could be set as appropriate within its design scope.

5.5.8 When the input signal of the speed detector, the water head signal, the power signal or the servomotor position signal disappears, it shall enable the turbine generator unit to maintain the current load, the allowable deviation of the opening variation of the turbine main servomotor shall be  $\pm 1\%$  of its full stroke; meanwhile the orderly shutdown and the emergency shutdown of the turbine generator unit will not be influenced.

5.5.9 Basic requirements of the software design:

- a) The software shall employ the structured and modular design, and satisfy the regulation and control requirements of the turbine generator unit under various working conditions;
- b) The software system shall consist of the following modules: Frequency measurement, PID regulation, input/output processing, display, diagnosis and error detection.

5.5.10 In addition to the basic functions, the microcomputer-based governor also shall have the fault diagnosis and fault-tolerance control functions, and shall be fitted with the communication interface and the open communication protocol.

5.5.11 Speed detector shall meet the following requirements:

- a) Within a  $\pm 10\%$  scope of the rated speed, the static characteristic curve shall approximate a straight line and its speed dead band shall comply with the design specification value;
- b) Within a  $\pm 2\%$  scope of the rated speed, the allowable value of the measured value of the amplification coefficient shall be  $\pm 5\%$  of the design value.

5.5.12 Electric-hydraulic and electric-mechanical converter shall meet the following requirements:

- a) Under the specified service conditions, the converter shall be able to work properly and reliably;
- b) In the dead band of the electric-hydraulic converters, the oil pressure drifting, the measured deviation of the amplification coefficient and the oil consumption shall not exceed the design value and the working scope shall not be less than the design requirement value;
- c) The operating force and stroke of the electric-mechanical converter shall not be less than the design value;
- d) The electric-hydraulic and electric-mechanical converters shall be able to return to the neutral position after the power is shut off. In the stable state, the allowable deviation of the servomotor stroke variation shall be  $\pm 1\%$  of its full stroke when its power is off.

5.5.13 The flow characteristics of the main distributing valve with the specified pressure drop shall comply with the design value.

5.5.14 The governor may be fitted with closing device in stages according to the closing rule of the guide vane. Its initiating point shall be adjustable within the opening scope of 0 to 60%, its action shall be stable and reliable, and the position deviation of its initiating point shall not exceed  $\pm 3\%$  of the full-stroke of the servomotor.

5.5.15 The emergency distributing valve shall meet the following requirements:

- a) The setting of the shutdown time shall not be less than the minimum shutdown time of the servomotor under the quick emergency shutdown condition;
- b) The time delay from the action of the emergency distributing valve to the action of the main servomotor shall not be more than 0.5 s;
- c) The position signal reflecting the action state of the valve core shall be set.

5.5.16 After the hydraulic components are assembled, the oil leakage shall not exceed the design value under the specified oil temperature and the rated oil pressure.

5.5.17 The highly reliable displacement transducer near the servomotor shall be used as the servomotor feedback device. The output signals of the displacement transducer may be  $-10\text{ V}$  to  $0\text{ V}$ ,  $0\text{ V}$  to  $10\text{ V}$  voltage type or  $4\text{ mA}$  to  $20\text{ mA}$  current type. The accuracy level of the displacement sensor shall be no less than 0.5.

5.5.18 The governor should employ DC and AC power supplies at the same time which serve as standby for each other. If either of them fails, it will be switched over automatically and the alarm

signal will be triggered. When the power supply is switched over, the allowable deviation of the servomotor stroke variation shall be  $\pm 1\%$  of the full stroke. It can ensure the continuous and stable operation of the governor within the following power supply and frequency range:

- a) AC power supply:

Input voltage range:  $380/220 \times (85\% \text{ to } 110\%)V$

Frequency allowable deviation:  $\pm 10\%$

- b) DC power supply:

Input voltage range:  $220/110 \times (85\% \text{ to } 110\%)V$

**5.5.19** Insulation resistance and the power frequency withstand voltage shall meet the following requirements:

- a) The insulation resistance between electrical loops and between the electric circuit and the enclosure or the ground shall not be less than  $1 M\Omega$  in the environment with a temperature of  $15\text{ }^{\circ}\text{C}$  to  $35\text{ }^{\circ}\text{C}$  and a relative humidity of  $45\%$  to  $75\%$ .
- b) When the tests are carried out between the separate live part and the exposed conductive part, and between the circuit and the metal enclosure (or ground) in the environment with a temperature of  $15\text{ }^{\circ}\text{C}$  to  $35\text{ }^{\circ}\text{C}$  and relative humidity of  $45\%$  to  $75\%$ , they shall be able to undertake the withstand test voltage specified in Table 2 by 5 s depending on its working voltage.

**Table 2 Withstand test voltage of the hydro turbine governing system**

Unit: Volt (V)

Rated voltage $U_i$	Power frequency test voltage (AC root-mean-square value)
$U_i \leq 60$	1 000
$60 < U_i \leq 300$	2 000
$300 < U_i \leq 690$	2 500

- c) The auxiliary circuit which is not suitable to be directly supplied power from the main loop shall be able to undertake the withstand test voltage specified in Table 3 by 5 s.

**Table 3 Withstand test voltage of the auxiliary circuit of the hydro turbine governing system**

Unit: Volt (V)

Rated voltage $U_i$	Power frequency test voltage (AC root-mean-square value)
$U_i \leq 12$	250
$12 < U_i \leq 60$	500
$U_i > 60$	$2 U_i + 1\ 000$ , minimum value is 1 500

5.5.20 The electrical device shall be able to undertake the interference from the power supply, the signal source and the control port, as well as the radiated electromagnetic field interference from the ambient environment; meanwhile, the electromagnetic interference from the device itself shall be minimized, and the electrical fast transient test shall be carried out in accordance with IEC 61000-4-4. When the interference is applied, the function and action of the electrical device shall be correct, and the servomotor shall not have abnormal action.

## 5.6 Oil pressure device

5.6.1 The pressure tank shall comply with the design and use specifications of the pressure container.

5.6.2 When the working oil pressure exceeds 6.3 MPa, the pressure container of the oil pressure device shall adopt the bladder type accumulator with the oil and gas separated. When the working oil pressure does not exceed 6.3 MPa, the ordinary pressure tank with the oil and gas in contact or the bladder type accumulator may be used.

5.6.3 At the upper limit of normal working oil pressure, the volume ratio of oil to gas in the non-isolated pressure container should be 1/3 to 1/2.

5.6.4 The scope of the normal working oil pressure of the oil pressure device shall be  $\pm 2\%$  to  $\pm 5\%$  of the nominal working pressure. The emergency shutdown pressure (minimum pressure of emergency shutdown) shall be selected so that the pressure will not drop below the minimum operating pressure after shutting down.

5.6.5 At the lower limit of the normal working oil pressure and when the oil pump is not started, the volume of the pressure tank shall at least be able to provide the specified number of servomotor strokes under the condition that the pressure drop does not exceed the difference between the lower limit of the normal working oil pressure and the minimum operating oil pressure.

- a) For the Francis turbine, it shall provide 3 strokes of the guide vane servomotor;
- b) For the impulse turbine, (1.5 to 2) strokes of the needle servomotor shall also be considered in addition to 3 strokes of the deflector servomotor;
- c) For the Kaplan turbine, (1.5 to 2) strokes of the blade servomotor also shall be considered in addition to 3 strokes of the guide vane servomotor;
- d) For the governor with the pressure regulating valve, (1.5 to 2) strokes of the pressure regulating valve servomotor also shall be considered in addition to 3 strokes of the guide vane servomotor.
- e) With regard to the control system used for the isolated power system operation, the volume of



available oil may be appropriately increased, which is usually 1.5 to 2 times the aforesaid values.

#### 5.6.6 Technical requirements of the oil pump:

- a) The oil pressure device should be fitted with dual oil pumps, one for service and one for standby purposes;
- b) The working speed of the oil pump should not exceed 1 500 r/min. When the governor is under the stable working condition, the pressure rise time from the lower limit of the normal working pressure to the upper limit of the normal working pressure shall not be more than 100 s; with regard to the governor operating in the isolated power system, the pressure rise time from the lower limit of the normal working pressure to the upper limit of the normal working pressure shall not be more than 40 s;
- c) In the static or stable state of the turbine generator unit, the starting interval for the intermittently operated oil pump of the oil pressure device shall be more than 20 min.

#### 5.6.7 Technical requirements for the safety valve:

- a) When the oil pressure is 2% higher than the upper limit of the working oil pressure, the safety valve shall start draining the oil; before the oil pressure is 10% higher than the upper limit of the working oil pressure, the safety valve shall be fully opened so that the oil pressure in the pressure tank will not further increase;
- b) The leakage rate of the safety valve shall not be 1% more than the oil delivery amount of the oil pump;
- c) The safety valve action shall be correct, reliable, and free from strong vibration and noise.

5.6.8 The allowable action error of the set value of the individual pressure annunciator for the oil pressure device shall be  $\pm 2\%$  of the set value.

5.6.9 The oil flow rate in the pipeline of the control system shall not exceed 5 m/s.

## 6 Supply scope and spare parts

The supply scope and spare parts shall include the following items:

- a) Supply scope: Governor, oil pressure device, position transmitters and special cables between the governor electronic part and the hydraulic unit;
- b) Spare parts: Necessary quick-wear parts to be provided;

- c) Other equipment and spare parts to be negotiated by the supplier and the user and specified in the order contract.

## 7 Technical documents

The supplier shall submit the necessary technical documents to the user, mainly including:

- a) System schematic diagram and operational schematic diagrams;
- b) Outside view and installation drawing;
- c) Arrangement plan and wiring diagram of the main components in the panel cabinet;
- d) Documents attached to the outsourced equipment (including the hardware);
- e) Delivery inspection report and the conformity certificate (1 set/unit);
- f) Installation, use and maintenance instructions;
- g) Delivery specification.

## 8 Inspection and acceptance

See Table A.1 for the inspection and acceptance items.

## 9 Nameplate, packing, transportation and storage

### 9.1 Nameplate

The product nameplate shall be fixed at an appropriately obvious position on each product. The fabrication materials and engraving method of the nameplates shall ensure that its text is not obliterated during the entire service period. Its main contents shall include:

- a) Name and model;
- b) Rated oil pressure (MPa);
- c) Service capacity (N • m);

- d) Nominal size of the main distributing valve;
- e) Volume of pressure tank (m<sup>3</sup>);
- f) Manufacturer name, delivery date and product number.

## **9.2 Packing**

**9.2.1** Special requirements of the equipment, if any, shall be marked on the packing container.

**9.2.2** The product shall have internal packing and external packing containers, the plug-in box shall be firmly locked and fastened, the packing container shall be fitted with the dustproof, rainproof and anti-vibration measures, and shall be provided with the hoisting facility and marks.

**9.2.3** The inspections of the product before packing mainly include:

- a) Whether the accessories, spare parts, compliance certificate and relevant technical documents of the product are complete;
- b) Whether the product appearance gets damaged.

**9.2.4** The packing of the products for export shall comply with the provisions of the relevant national inspection and quarantine regulations.

**9.2.5** The packing guarantee time shall not exceed 12 months from the delivery date.

## **9.3 Transportation**

The supplier and the user shall specify the transportation tools suitable for the equipment and the requirements in the transportation process. The transportation and handling shall be carried out according to the marks on the packing containers.

## **9.4 Storage**

**9.4.1** The products shall be stored in the dust-free and rainproof warehouses with an ambient temperature of  $-25\text{ }^{\circ}\text{C}$  to  $+55\text{ }^{\circ}\text{C}$ , relative humidity of not more than 85% and without acid, alkali, salt and corrosive or explosive gases or a strong electromagnetic field.

**9.4.2** From the date of delivery by the supplier, the supplier shall guarantee that the products are free from corrosion and accuracy reduction due to improper packing within 12 months under the storage conditions specified in 4.4.

## 10 Installation, operation and maintenance

### 10.1 Installation

The product shall be installed by experienced and well-qualified competent professionals.

### 10.2 Operation and maintenance

10.2.1 Before going into formal operation, the relevant tests shall be carried out, and the specified requirements shall be met.

10.2.2 The operation and maintenance shall comply with the provisions of the normative references, the installation, use and maintenance instructions provided by the supplier as well as relevant operation specifications for the hydropower station.

10.2.3 The supplier shall provide technical support for solving the problems occurring in the installation, use and maintenance process for the equipment, and shall train the user's personnel in the aspects of the equipment installation, use and maintenance.

## 11 Quality guarantee period

Under the premise that the product is properly stored, installed and used, the product quality guarantee period shall be one year after the date of the 72-hour trial operation, or two years after the delivery date of the last batch of goods, whichever comes earlier. If the equipment gets damaged or is unable to function properly due to the manufacturing quality during the quality guarantee period, the supplier shall repair or replace it free of charge.

**Appendix A**  
**(Informative)**  
**Inspection and site acceptance test**

**Table A.1 Factory inspection and site acceptance test items of the hydro turbine governing system**

No.	Test items	Factory inspection	Site acceptance
1	Appearance inspection	✓	✓
2	Meter inspection	✓	✓
3	Inspection of the electric connection	✓	✓
4	Insulation test of the electric circuit	✓	
5	Communication function inspection	✓	✓
6	Inspection and test of the power supply	✓	✓
7	Pressure-tight test of the pressure tank	✓	
8	Test of the oil pump	✓	
9	Leakage test of the oil pressure device	✓	✓
10	Verification of the setting values of the oil pressure and oil level signals of the oil pressure device	✓	✓
11	Simulation test of the automatic operation of the oil pressure device	✓	✓
12	Inspection and test of the speed detector	✓	
13	Test of the electric-hydraulic converter	✓	
14	Adjustment of the closing time $T_f$ and opening time $T_g$ of the servomotor	✓	✓
15	Measurement of the closing and opening time scope of the servomotor	✓	
16	Action test of the operating circuit	✓	✓
17	Switching test of the regulation modes and control modes	✓	✓
18	Measurement of the practical open-loop gain and the setting test of the open-loop gain	✓	✓
19	Verification of the rotation speed command signal, opening command signal, power command signal and the permanent difference coefficient $b_p$	✓	
20	Verification of the proportional gain $K_p$ , integral gain $K_i$ and differential gain $K_D$	✓	
21	Measurement and test of the static characteristics (including artificial speed dead band) and the speed dead band $i_x$ of the governor	✓	✓

Table A.1 (continued)

No.	Test items	Factory inspection	Site acceptance
22	Measurement and test of the combination curve and inaccuracy $i_a$ of the blade servo system		
23	Synchronization test between the guide vanes (needles)		✓
24	Measurement and test of the servomotor dead time $T_q$	✓	✓
25	Measurement of the total oil consumption of the governor	✓	
26	Switching test of the fault simulation and the control modes	✓	✓
27	Automatic start-up/shutdown tests		✓
28	No-load test		✓
29	Load dump test		✓
30	Test of the guide vane closing under the tripping lower oil pressure		✓
31	Continuous loaded 72hr operation test		✓
<b>NOTE 1</b>	The items marked with “✓” in the table should be completed.		
<b>NOTE 2</b>	If the tested equipment does not have the structure and function relevant to a certain test item, such item does not need to be tested.		