



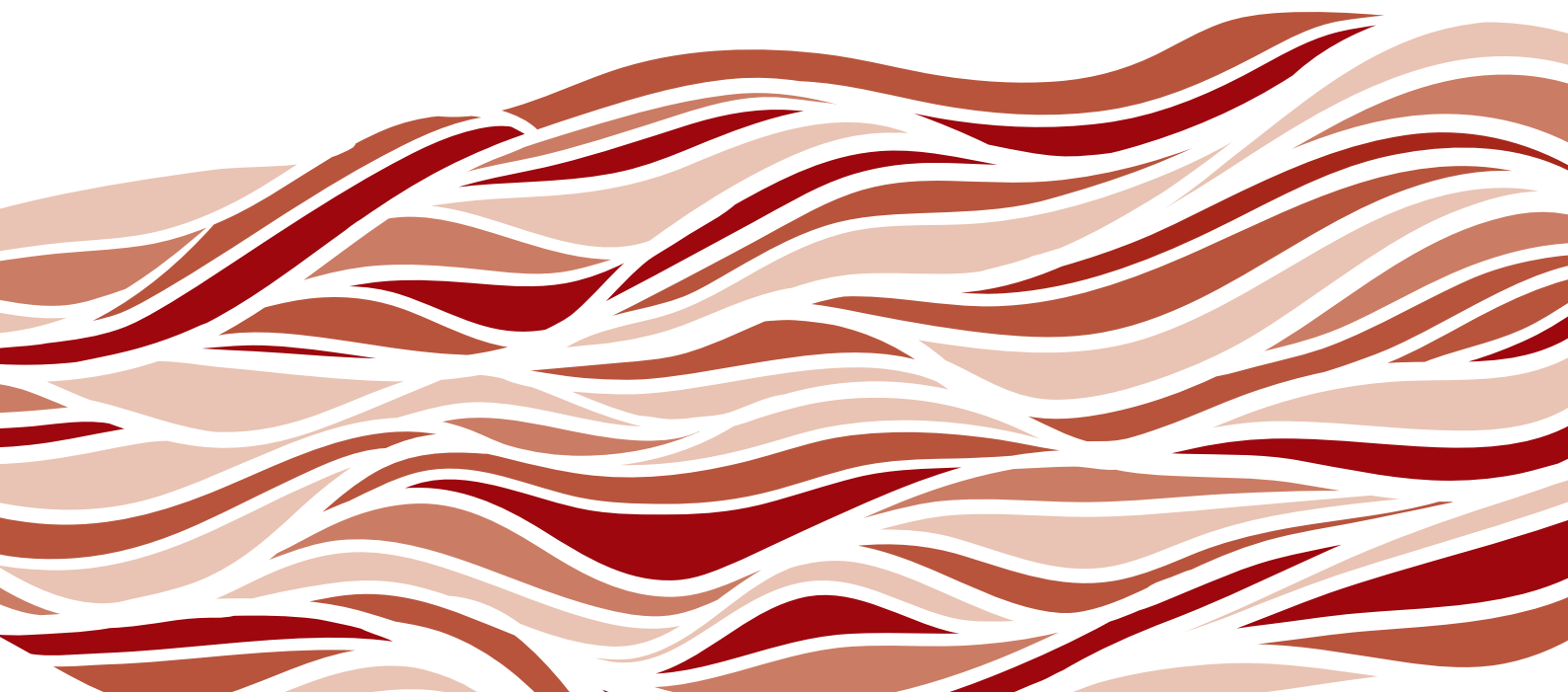
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION



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

Part 6: Monitoring, Control, Protection and DC Power Supply System

SHP/TG 003-6: 2019



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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).

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 6: Monitoring, Control, Protection and DC Power Supply System

1 Scope

This Part of Units Guidelines specifies the technical requirements as well as the basic requirements for the supply scope, spare parts, technical documents, testing, inspection and acceptance, packing, transportation, storage, installation, training, operation and maintenance for small hydropower (SHP) station monitoring, control and protection and the DC power supply system.

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.

IEC 60255-5, *Electrical Relays—Part 5: Insulation Coordination for Measuring the Relays and the Protection Equipment—Requirements and Tests*

IEC 60255-22-1, *Measuring Relays and the Protection Equipment—Part 22-1: Electrical Disturbance Tests—1 MHz Burst Immunity Tests*

IEC 60255-22-2, *Measuring Relays and the Protection Equipment—Part 22-2: Electrical Disturbance Tests—Electrostatic Discharge Tests*

IEC 60255-22-3, *Measuring Relays and the Protection Equipment—Part 22-3: Electrical Disturbance Tests—Radiated Electromagnetic Field Immunity*

IEC 60255-22-4, *Measuring Relays and the Protection Equipment—Part 22-4: Electrical Disturbance Tests—Electrical Fast Transient/Burst Immunity Test*

IEC 60255-22-5, *Measuring Relays and the Protection Equipment—Part 22-5: Electrical Disturbance Tests—Surge Immunity Test*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in the normative references apply.

4 Service conditions

4.1 Environmental conditions

4.1.1 The equipment shall be installed indoors or in weather-protected places and shall be used in the environment with clean air and without explosive hazards. The ambient air shall be free from gases and conductive dust to prevent corrosion of the metal and damage to the insulation.

4.1.2 The altitude shall not exceed 2 500 m. When used in places with an altitude over 2 500 m, it is necessary to consider the reduction of dielectric properties and the decrease of the air cooling effect, and the user shall negotiate with the supplier.

4.1.3 Ambient temperature requirement:

- a) Computer room and central control room for station-level control: 18 °C to 30 °C ;
- b) Local control unit(LCU): – 5 °C to 40 °C ;
- c) Daily average value for the ambient temperature does not exceed 35 °C .

NOTE If the indoor ambient temperature exceeds the aforesaid range, the user shall so declare to, or negotiate with, the supplier.

4.1.4 Relative air humidity requirement:

- a) Computer room and central control room for station-level control: 45% to 65% ;
- b) LCU: 20% to 90% (no condensation).

4.1.5 Dust prevention measures shall be considered for the system equipment according to the different installation places; in particular, temporary protection measures shall be taken at the

beginning of the construction and when the LCU is put into operation in stages. Reference value for the dust parameters of the equipment service place is: the quantity of dust with its particle size larger than 0.5μ shall be less than 18 000 particles/L.

4.1.6 Vibration and shock resistance requirements of the system equipment:

- a) Computer room and central control room for station-level control: The vibration frequency shall be within the range of 5 Hz to 200 Hz and the acceleration shall not be greater than 5 m/s^2 ;
- b) LCU: The vibration frequency shall be within the range of 5 Hz to 500 Hz and the acceleration shall not be more than 10 m/s^2 ;
- c) For earthquake-prone regions, the equipment structure shall be designed with the corresponding special considerations.

4.2 Power supply conditions

Within the following power supply voltage and frequency range, the power supply for monitoring, protection and the DC power supply system shall function properly and shall not be damaged within the following power supply voltage range:

- a) AC power supply:

Input voltage variation:

$110 \times (85\% \text{ to } 110\%)V$

$220 \times (85\% \text{ to } 110\%)V$

$380 \times (85\% \text{ to } 110\%)V$

- b) Allowable deviation of frequency: $\pm 10\%$

- c) DC power supply:

$220 \times (85\% \text{ to } 115\%)V$

$110 \times (85\% \text{ to } 115\%)V$

4.3 Other conditions

Other special service conditions shall be determined by and between the supplier and the user through negotiation.

5 Technical requirements

5.1 Technical requirements of the monitoring system

5.1.1 Hardware requirements

5.1.1.1 Station-level control and local-level control shall be set according to the control hierarchy and the equipment of the hydropower station and shall use the open, hierarchical and distributed system structure. The configuration principle of the monitoring system shall be:

- a) The station-level control may have a dedicated control system or the dedicated with redundant control system as required.
- b) The local-level control is composed of several sets of LCU as per the controlled equipment (such as the hydro turbine generator unit, switchyard, common station auxiliaries and hydro mechanical gates).
- c) The station-level control and the local-level control shall use the star Ethernet or loop Ethernet structure.

5.1.1.2 The monitoring system equipment may be classified according to the following principles:

- a) The equipment of the computer monitoring system may be classified into two categories as per the layout: station-level control equipment and local-level control equipment;
- b) The equipment of the computer monitoring system may be classified into three categories as per the general purpose module: computer and auxiliary equipment, network communication equipment and power supply equipment.

5.1.1.3 Configuration and technical requirements of the station-level control computer (or processor):

- a) The word length of the processor shall not be less than 64 bits and the main frequency shall not be less than 1 GHz;
- b) The computer memory shall have sufficient capacity and reserve over 40% allowance in the distribution;
- c) The computer system storage shall have sufficient storage capacity to support the storage management of the system documents, the application documents, and the real-time and historical data (including accumulated information on daily, monthly and annual basis) for implementing the control system.

5.1.1.4 Configuration and technical requirements of the LCU:

- a) The LCU shall be able to operate separately after it has been separated from the station-level control computer system, meanwhile it may be fitted with a touch screen to realize the local monitoring;
- b) The LCU may be fitted with the temperature measuring device, rotation speed measuring and control device, synchronizing device and the necessary instruments according to the design requirements;
- c) The LCU may be configured with the intelligent communication management unit. The intelligent communication management unit shall have sufficient communication interfaces to communicate with the intelligent equipment such as the excitation system and the governor system; meanwhile, it shall be fitted with the network communication interface to communicate with the station-level computer;
- d) The LCU for the hydro turbine generator unit shall be configured with the emergency shutdown button;
- e) The logic controller configured for the LCU shall meet the following basic performance requirements:
 - 1) Scanning rate: ≤ 1.8 ms/k;
 - 2) Storage capacity: ≥ 512 kB;
 - 3) Have at least the communication interface of the RS-485 bus mode;
 - 4) The capacity of the I/O point shall be more than actually available capacity and shall reserve allowance of no less than 10%.

5.1.1.5 Configuration principle of the synchronizing device:

- a) The synchronizing point shall be configured with the automatic quasi-synchronizing device and the manual quasi-synchronizing device;
- b) The automatic quasi-synchronizing device should employ the microcomputer-based product.

5.1.1.6 Configuration and technical requirements of the power supply:

- a) The station-level control of the computer monitoring system shall be equipped with the uninterruptible power supply (UPS) or the inverter power supply. In case of external AC power loss, the UPS capacity should be enough for the computer monitoring system equipment to work con-

tinuously for no less than 2 hours; the inverter capacity should not be less than the maximum power of the entire computer monitoring system equipment. The local-level control shall be equipped with the stabilized voltage supply and the switching power supply with AC/DC input simultaneously, while the inverter power supply may be equipped as well, when necessary;

- b) The uninterruptible power supply or the inverter power supply, stabilized voltage supply and switching power supply used by the equipment of the computer monitoring system shall function normally and shall not get damaged under the power supply conditions stipulated in this standard;
- c) The equipment of the computer monitoring system shall not get damaged when the input voltage drops to the lower limit or the positive and the negative polarities are reversed.

5.1.1.7 Configuration principle for lightning protection:

- a) The communication interface shall be fitted with the surge protective device;
- b) The analogue input signal fed into the central control room shall be fitted with the surge protective device;
- c) The AC input terminal of the DC power supply system shall be fitted with the voltage protector;
- d) The power supply input terminal and the voltage input terminal of the relay protection device shall be fitted with the surge protective circuit.

5.1.1.8 Technical requirements for the earthing system:

- a) The computer monitoring system shall be earthed with the common earthing grid of the hydro-power station; the earthing resistance shall not be more than 4 Ω and this earthing grid shall not be connected to the lightning protection earthing grid for the hydropower station;
- b) To avoid earthing circulating current or ground noise interference and for the safety of the equipment, the enclosure, the AC power supply, the logic circuit, the signal circuit and the cable shield layer of the computer monitoring system equipment shall be earthed according to the following principles:
 - 1) The equipment enclosure or the exposed non-current-carrying metal parts shall be earthed;
 - 2) The isolated AC power supply shall be earthed when the voltage exceeds 150 V;
 - 3) All the non-isolated computer DC circuits (including the DC power supply, the logic circuit and the signal circuit) should only have one earthing point;

- 4) When the common circuit in all of the non-isolated computer DC circuits is earthed on two or more points, the earth potential difference between any two points shall not be more than the allowable noise of the equipment at any time;
 - 5) When all the external interface devices in any cabinet (or a set of devices) are isolated, the cabinet enclosure, AC power supply, computer DC power supply and cable shield layer shall share one earthing point in that cabinet. The computer logic circuit shall be connected to the common earthing point of the cabinet at only one point in the cabinet;
 - 6) There shall not be two separate earthing grids in one piece of equipment or in the adjacent equipment;
 - 7) The earthing of the signal and cable shield layer shall be designed considering the earthing point of the corresponding sensor or the other connected equipment, avoiding earthing on two points and selecting one-point earthing at the receiving equipment terminal of the computer monitoring system, as appropriate.
- c) The earthing wires in the equipment cabinet which is a part of the computer monitoring system should be short. The common earth plate in the cabinet shall employ a copper bar with a cross section of more than 50 mm²;
 - d) The cabinet or the enclosure shall be earthed on the durable metal contacts;
 - e) When the testing instrument used for the computer monitoring system, the power supply connection and the earthing connection shall be provided for the testing instrument.

5.1.2 Software requirements

5.1.2.1 The operating system provided shall be the multi-task and multi-user operating system.

5.1.2.2 The database consists of the centralized or distributed database which shall comply with the following requirements:

- a) The structure definition of the database shall include all the data items required for the hydro-power station monitoring and management;
- b) The database shall provide convenient application interfaces that can be directly used by other commercial databases;
- c) The database shall support quick access and real-time processing;
- d) The database shall be able to ensure the integrity and uniformity of the data;

- e) The database shall be able to set or modify the data online;
- f) The analogue input shall have the attributes like the dead zone of measurement, dead zone of zero reading, dead zone of alarm, out-of-limit value and engineering unitary transformation;
- g) The real-time database shall have relevant attributes like alarm permission, the data quality code or control locking;
- h) The historical database shall provide convenient and reliable historical data storage, and query and backup functions.

5.1.2.3 Technical requirements for the application software:

- a) The computer monitoring system shall provide the application software for performing all the monitoring functions;
- b) Providing the training simulation application software (optional);
- c) Providing the online condition monitoring and the remote operation and maintenance application software (optional);
- d) The application software shall be of structural modular software, and the functional software module or task module shall be integral and independent;
- e) The application environment shall be designed so that the user could safely supplement, modify or transplant the application software;
- f) The applications shall comply with the standards for the international open system, adopt the interface specification meeting the IEC 61131-3 standards and provide favourable system expansion capacity.

5.1.3 Functional requirements

5.1.3.1 Technical requirements for the data collection function:

- a) Data collection of the station-level control:
 - 1) Collect all kinds of data on the local-level controls in real time;
 - 2) Receive command information and data on the various dispatching levels;
 - 3) Receive data information from systems other than the computer monitoring system of the hydropower station.

- b) Data collection of the local-level control shall be able to:
 - 1) Collect all kinds of analogue input (AI) (including RTD signal), digital input of the status (DI) and digital input of the accumulation in real time and simultaneously output the analogue output (AO) and the digital output (DO);
 - 2) Collect data from the intelligent devices in real time;
 - 3) Receive command information and data from the station-level control.

5.1.3.2 Technical requirements for the data processing function:

- a) Analog data processing:

It shall consist of the engineering unit transformation processing, measurement zero value processing, measurement dead zone processing, upper and lower measurement limits processing, measurement rationality processing, dead zone processing of the upper and lower measurement limits, off-limit and graded off-limit alarm processing.

- b) Status data process:

It shall consist of the status shift processing, contact chatter prevention processing and alarm processing.

- c) Data processing of the event sequence records:

It shall consist of the status shift processing, contact chatter prevention processing, time stamp processing and alarm processing. The required resolution shall be ≤ 2 ms.

- d) Main parameter trend analysis processing:

Record the variation trends of some of the main parameters such as the output from the hydro turbine generator unit, the bearing temperature, oil groove oil temperature, main transformer oil temperature and the water level of the hydropower station according to different time intervals (sampling time) so as to form trend display curves.

- e) Tripping review processing:

Record the various tripping and keep the records when the tripping occurs. The tripping review records consist of the pre-tripping and post-tripping periods. The duration and sampling interval of the two periods shall be adjustable. Accident recording time should not be less than one year.

- f) Historical data processing:

Do the statistical analysis and calculation processing of the real-time data to form historical data records and provide historical data retrieval and query means. The historical data shall be defined into the following classifications: trend category, accumulated value category, average value category and maximum/minimum value category.

5.1.3.3 Technical requirements for the alarm processing function:

- a) When some malfunction occurs, the alarm should sound. It should be an audible alarm and the display on the annunciation window should appear. The alarm sound or the audible alarm shall distinguish the malfunction and the failure. The sound may be released manually or automatically with a time delay;
- b) The alarm display information shall display the alarm message on the current image (including the occurrence time of the alarm, the malfunction name and the nature). The display colour shall vary along with the category of the alarm information. If the alarm object is displayed on the current image, the icon (or parameter) of this object will flash and its colour will vary. The flashing signal shall be released only after being confirmed by the operators;
- c) Convenient configuration image shall be provided for the malfunction and failure alarm information so that the malfunction and failure alarm information could be audibly sent to audibly relevant personnel by mobile phone (optional);
- d) Convenient configuration means shall be provided for the malfunction and failure alarm information so that the malfunction and failure alarm information could be sent to the designated mobile phone through the short message platform of the mobile phone (optional).

5.1.3.4 Technical requirements for the control and regulation function:

- a) Control mode setting of the running equipment:
 - 1) Control/regulation mode setting of the remote dispatching terminal/station-level control (whether the control and regulating modes are set separately shall be determined according to the specific dispatching requirements);
 - 2) Control model setting of the station-level control/local-level control;
 - 3) Automatic/manual control mode setting of the running equipment;
 - 4) Control authority of the common equipment/auxiliary equipment of the hydropower station shall be deployed according to the management pattern of the hydropower station.
- b) Manual operation of the single controlled equipment:

The operators may operate with the man-machine interface equipment of the station-level control or local-level control, complete the control and regulation of the single equipment and consider the safe locking.

- c) Sequence control and regulation of the LCU of the hydro turbine generator unit:
 - 1) Normal start-up/shutdown sequence control and emergency shutdown sequence control of the hydro turbine generator unit;
 - 2) Rotation speed and active power regulation of the hydro turbine generator unit;
 - 3) Voltage and reactive power regulation of the hydro turbine generator unit.
- d) Sequence control of the switchyard LCU:

The switchyard LCU shall be able to realize the reverse sequence control (locking) of the disconnector and the open/close sequence control of the circuit breaker.

- e) Regulation mode of the automatic generation control or the active power joint control (optional):
 - 1) Adjust the power according to the daily load curve given by the load dispatch centre;
 - 2) Adjust the power automatically according to the active power value set by the operator on duty at the hydropower station;
 - 3) Adjust the power automatically according to the set value of the AGC of the power grid;
 - 4) Adjust the power according to the system sequence control mode;
 - 5) Adjust the power according to the water level control mode.
- f) Regulating mode of the automatic voltage control or reactive power joint control of the hydro turbine generator unit (optional):
 - 1) Adjust according to daily adjustment curve of high voltage bus voltage of hydropower station given by the system dispatcher;
 - 2) Adjust according to the voltage value of the high voltage bus or the total reactive power given by the operator;
 - 3) Adjust according to the voltage limit value of the high voltage bus of the hydropower station.

5.1.3.5 Technical requirements for the man-machine interface and operation:

- a) The computer monitoring system shall perform the man-machine interface functions including the image display, table printing, parameter setting, and operation control and maintenance management by using the following interface equipment:
 - 1) Operator station of the station-level control, engineer station and printer;
 - 2) Local operating screen;
 - 3) Portable workstation or movable operator station.
- b) Man-machine interface and the operating requirements of the station-level control:
 - 1) The man-machine interface of the station-level control serves as the main means for the hydropower station operators to monitor and control the operation of the hydropower station; the interactions between the operators and the computer monitoring system are realized by the displayer, keyboard, mouse and printer of the operator station;
 - 2) In accordance with the hierarchical and authority-separation design principle, the operator shall only perform the operation monitoring, control regulation and parameter setting for the hydropower station equipment, but shall not modify or test the various application software;
 - 3) The operating methods of the man-machine interface shall be user-friendly, simple, flexible and reliable, the dialogue prompts shall be clear and accurate and remain consistent in the dialogue applications of the entire system;
 - 4) The controlled equipment shall be selected and controlled only on the same operator station;
 - 5) The operating steps in the operation process should be simplified and shall have the reliability check and locking functions;
 - 6) The image calling mode shall be flexible, reliable and quick in response, the image shall be called in the automatic mode or the summoning mode; the automatic mode is used for malfunctions, failure and process monitoring, and the summoning mode is used randomly by the operator;
 - 7) Any man-machine operations (including parameter modification and configuration modification) shall be recorded in the operation record.
- c) Man-machine interface and the operating requirements of the local-level control:

- 1) The operators may realize the monitoring and control of the corresponding equipment through the man-machine interface equipment of the local operating screen or the movable operator station or the portable workstation;
- 2) The operating screen shall have the function of switching over to the remote and local-level control modes; in the local-level control mode, the remote command will be locked but the data collection and transmission will not be influenced;
- 3) In the local-level control mode, the relevant operations shall be safe, reliable and simple, and shall provide the operational authority for the relevant control operations on the touch screen (optional);
- 4) In the remote control mode, the operators shall only monitor with the local man-machine interface equipment but shall not carry out control operations other than emergency operations;
- 5) Emergency shut-down (including the manual and sequence control process) operation of the hydro turbine generator unit and the closing operation of the main valve/quick shutoff gate shall not be influenced by the remote/local-level control mode.

5.1.3.6 Technical requirements for system communication:

- a) The communications between the computer monitoring system and the dispatching automation system at various dispatching levels:

For realizing the telemetering, remote signalling, remote regulating and remote control functions of the dispatching automation system (including cascade dispatching) over the hydro-power station, the monitoring system may receive the command information from the various dispatching levels from time to time and transmit the real-time working condition, operating parameters and relevant information of the hydropower station to them.

- b) The computer monitoring system can realize:
 - 1) Communication with the electric energy measuring system;
 - 2) Communication with the gate control system;
 - 3) Communication with the excitation, governor, relay protection and fault recording management system;
 - 4) Communication with the fire alarm system;
 - 5) Communication with the television monitoring system;

- 6) Communication with the automatic hydrological measuring and reporting system;
 - 7) Communication with the status monitoring and the fault diagnosis system;
 - 8) Communication with the DC power supply system.
- c) Communication between the station-level control and the local-level control:
- 1) Data collection;
 - 2) Transfer the control/regulating command and other necessary information (such as water head of the unit);
 - 3) Communication diagnosis.
- d) Communication between the LCU and intelligent devices:

The LCU shall be able to communicate with the control devices (such as the governor, excitation system, intelligent devices of the switchyard, the intelligent device of the station service system, the drainage control system, air compressor control system, and the heating, ventilating and air conditioning systems).

5.1.3.7 Technical requirements for the system self-diagnosis and self-recovery function:

- a) When the computer monitoring system is running on line, the hardware and the software in the computer monitoring system shall be subject to self-diagnosis; when any failure is diagnosed, it shall automatically send out the signal; with regard to the redundant equipment, it shall automatically switch over to the spare equipment;
- b) Self-recovery function, including the monitoring timer (watchdog) and the self-starting functions of the software and hardware;
- c) Power down protection function.

5.1.3.8 Other functional requirements (Optional):

- a) Communication with the hydrological measuring and reporting system in the reservoir to realize the linkage between the hydrological measuring and reporting information and the automatic generator control;
- b) Communication with the dam monitoring system to realize the linkage between the dam monitoring information and the automatic generator control;

- c) Communication with the equipment condition monitoring system to realize the linkage between the equipment condition monitoring information and the automatic generator control;
- d) Realization of the “unattended” operation mode through the remote system operation and maintenance;
- e) Power station intelligentization and smart level improvement based on full use of new technologies such as big data, cloud computing and the Internet of Things.

5.2 Technical requirements for relay protection

5.2.1 Relay protection performance requirements:

- a) The relay protection device shall satisfy the selectivity, fast acting, and sensitivity and reliability requirements;
- b) Microcomputer-based system shall be provided for the relay protection device; the configuration of the microprocessor shall not be lower than that of a 16 bits microcomputer;
- c) The relay protection device shall be fitted with the RS-485 communication interface or the Ethernet port for communicating with the monitoring computer system;
- d) The setting and sensitivity verification of the configured relay protection shall comply with the requirements of the design documents;
- e) The timing mode and accuracy of the relay protection device and the computer monitoring system should comply with the requirements of the design documents.

5.2.2 Relay protection configuration requirements:

- a) The electrical equipment in the hydropower station shall be configured with primary protection and backup protection (local backup or remote backup), or may additionally be fitted with auxiliary protection when necessary. The specific configuration scheme shall comply with the requirements of the design documents.
- b) If the power grid requires the hydropower station to have the voltage and frequency control functions, the voltage and frequency emergency control device or the remote control system shall be so equipped as well.

5.2.3 Technical parameter requirements of the relay protection device:

- a) Rated parameters

Rated AC input:

Voltage: 100 V or 110 V (line voltage) or $100\text{ V}/\sqrt{3}$ or $110\text{ V}/\sqrt{3}$ (phase voltage)

Current: 5 A or 1 A

Frequency: 50 Hz or 60 Hz

Power supply voltage: DC110 V or 220 V; AC110 V or 220 V

b) Power consumption

AC current circuit: When the rated current is 5 A, each phase shall not be more than 1 VA; when the rated current is 1 A, each phase shall not be more than 0.5 VA.

AC voltage circuit: Each phase shall not be more than 1 VA at the rated voltage.

DC power supply circuit: Power consumption for each protector should not be greater than 10 W (static state) or 15 W (work status).

c) Overload characteristics

Long-term switch-on of the current circuit: twice the rated current

Short-term switch-on of the current circuit: 20 times the rated current; 10 s is allowable

Long-term work of the voltage circuit: 1.5 times rated the voltage

Contact capacity: Long-term switch-on DC 220 V/5 A

d) Protective action accuracy

Constant value accuracy of the action: $\pm 2.5\%$

Constant value accuracy of the time: $\pm 1\%$ or $\pm 40\text{ ms}$

Frequency deviation: $\pm 0.05\text{ Hz}$

Slip frequency constant value: $\pm 5\%$

e) Measurement accuracy

Voltage/current (effective value): 0.5%

Frequency: ± 0.05 Hz

Power: 1%

Power factor: 1%

5.2.4 The insulation voltage withstand performance of the device shall comply with the requirements of IEC 60255-5.

5.2.5 Anti-interference performance requirements of the relay protection device:

a) Impulse anti-interference test

The device shall pass the 1 MHz Impulse interference test of severity Level 3 as specified in IEC 60255-22-1, and the performance after testing shall meet the standard requirements.

b) Electrostatic discharge anti-interference test

The device shall pass the electrostatic discharge test of severity Level 4 as specified in IEC 60255-22-2, and the performance after testing shall meet the standard requirements.

c) Radiated electromagnetic field anti-interference test

The device shall pass the radiated electromagnetic field anti-interference test of severity Level 4 as specified in IEC 60255-22-3, and the performance shall meet the standard requirements after testing.

d) Fast transient anti-interference test

The device shall pass the fast transient anti-interference test of severity Level 4 as specified in IEC 60255-22-4, and the performance after testing shall meet the standard requirements.

e) Surge anti-interference test

The device shall pass the surge anti-interference test of severity Level 3 as specified in IEC 60255-22-5, and the performance after testing shall meet the standard requirements.

5.3 Technical requirements for the DC Power supply system

5.3.1 Basic configuration requirements for the DC power supply:

a) The DC power supply system shall employ the microcomputer monitoring device and the high-frequency charger module, and the charger module shall be configured in the mode of $N + 1$;

- b) The DC power supply shall be fitted with the insulation monitoring device and the battery detecting device. The insulation monitoring device shall be able to detect the DC bus positive and negative voltage and the insulation resistance to ground.

5.3.2 Requirements for the microcomputer monitoring function of the DC power supply

- a) Measurement: Voltage of the DC system bus, output voltage and current of the charger and voltage and discharge current of the storage battery;
- b) Signal: over-high and over-low DC system bus voltage, DC system earthing, charger operating mode switching and failure;
- c) Control: Start-up, shutdown and operating mode switching of the charger;
- d) Interface: The communication interface may employ RS-485 or the Ethernet.

6 Supply scope and spare parts

6.1 Monitoring system

The hardware of the monitoring system shall include the computer control equipment, local-level control equipment, communication equipment, inverter power supply and the UPS; the software shall include the operating system, database and applications.

6.2 Relay protection system

The relay protection system shall consist of the relay protection equipment for the outgoing line, the transformer and hydro-generator of the hydropower station and the power grid's stability control equipment.

6.3 DC power supply system

The DC power supply system shall consist of the DC power supply monitoring module, the charger module and the battery.

6.4 Other equipment and spare parts

The following equipment and spare parts may be specified to be provided in the order contract signed between the supplier and the user, and may not be provided if not stipulated:

- a) Automatic instruments;

- b) Electric energy measuring equipment;
- c) Auxiliary control equipment;
- d) Dispatching communication equipment;
- e) Television monitoring system;
- f) Spare parts.

7 Technical documents

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

- a) System block diagram, the equipment list and the equipment connection diagram;
- b) Layout diagram and wiring diagram of the equipment in the cabinet;
- c) Technical data for the hardware;
- d) List of the system software and applications;
- e) Software use and maintenance instructions;
- f) Documents for the outsourced equipment;
- g) Equipment installation drawings;
- h) Equipment delivery inspection certificate.

8 Factory inspection

8.1 Test, inspection and acceptance rules

8.1.1 Factory tests and inspections

See Appendix A for the factory inspection items. Factory tests and inspections shall meet the following requirements:

- a) The devices matched with the equipment shall be subjected to quality control according to the relevant provisions;

- b) The equipment shall be inspected and tested in the production process, and complete detailed records shall be kept;
- c) The equipment shall pass the inspection by the supplier's quality inspection department before delivery. During the inspection, if any item fails to comply with the provisions of the technical specifications for the inspected product, the defects shall be eliminated; after the product passes the inspection, the compliance certificate shall be issued by the quality inspection department.

8.1.2 Pre-delivery inspection and acceptance

The pre-delivery inspection and acceptance shall meet the following requirements:

- a) If the technical specifications for the inspected equipment requires the product to be inspected before delivery, the supplier shall inform the user in advance prior to the date specified in the technical specifications after completing the factory tests and inspections;
- b) The pre-delivery inspection and acceptance shall be jointly carried out by the supplier and the user;
- c) In the pre-delivery inspection and acceptance process, the supplier shall mainly be responsible for:
 - 1) Reporting to the user on the system configuration, factory testing and inspection results;
 - 2) Preparing the pre-delivery inspection and acceptance outline;
 - 3) Providing list of the testing instruments and equipment for the acceptance;
 - 4) Conducting the tests specified in the acceptance inspection outline.
- d) In the pre-delivery inspection and acceptance process, the user shall be mainly responsible for:
 - 1) Discussing, reviewing and modifying the pre-delivery inspection and acceptance outline, and finalizing the pre-delivery inspection and acceptance outline;
 - 2) Supervising and reviewing the pre-delivery acceptance tests.
- e) At the end of mainly pre-delivery inspection and acceptance, the pre-delivery acceptance summary shall be signed by and between the supplier and the user, and the pre-delivery acceptance results shall be evaluated. If the equipment still has defects, the treatment suggestion and completion deadline shall be proposed in the acceptance summary and the defects shall be treated by the supplier.

8.2 Inspection of the equipment appearance, software/hardware configuration and technical documents

8.2.1 Inspection of the equipment appearance

8.2.1.1 The equipment surface shall be free from any obvious pits, scratches, cracks, deformation and contamination. The surface coating and plating shall be uniform and free from bubbling, fracturing, peeling and wearing. The metal spare parts shall be tightly fastened and free from any mechanical damages.

8.2.1.2 The installation and internal connection of the internal components shall be correct, firm and tight. The operations of the keyboards, switches, buttons and other control components shall be flexible and reliable. The layout and internal wiring of the wiring terminals shall be reasonable, tidy and legibly marked.

8.2.2 Inspection of software/hardware configuration

8.2.2.1 Inspect the hardware configuration of the equipment. Its quantity, model and performance shall comply with the provisions of the technical specifications for the inspected product, and the hardware shall be reasonably laid out.

8.2.2.2 Inspect the equipment's hardware configuration, documents and its carriers, which shall comply with the provisions of the technical specifications for the inspected item.

8.2.3 Inspection of the equipment technical documents

The technical documents related to the equipment (including the outsourced supporting equipment) shall be complete, detailed, uniform and valid.

8.3 Function and performance tests

8.3.1 Data collection and processing function test

8.3.1.1 Analogue data collection and processing function testing requirements:

a) Analogue data collection function test

The analogue data includes the AC current, AC voltage, DC current, DC voltage, temperature signal and water level signal, relevant to the LCU, the relay protection device and the DC power supply system in the hydropower station.

The corresponding analogue signal generator shall be connected through the analogue input terminal, to change the output of the analogue signal generator, and calculate the error of the ana-

logue data collection, shall comply with the provisions of the technical specifications of the inspected product.

b) Analogue data processing function test

The correctness of the analogue display and the off-limit records shall be checked. Its off-limit alarm start value and man-machine interface display contents shall be consistent with the provisions of technical specifications for the inspected product.

8.3.1.2 Digital data collection and processing function testing requirements:

a) Digital data collection test

The digital data includes the position signals and the status signals relevant to the LCU, relay the protection device and the DC power supply system in the hydropower station.

The corresponding digital signal generator shall be connected through the digital input terminal, and shall be subjected to input signal shift testing according to the specific measuring point requirement. The display and the relevant records shall be inspected through the man-machine interface of the monitoring system and shall be consistent with the actual input and the technical specifications for the inspected product.

b) Digital data processing function test

The correctness of the digital data shift display and the event sequence record shall be checked. The shift display, event record sequence and man-machine interface display contents shall be consistent with the provisions of the technical specifications for the inspected product.

8.3.1.3 Calculated data collection and processing function testing requirements:

a) Current working conditions of the water-turbine generator, transformer and connection circuit, the action times, running time and overhaul time of the main/auxiliary equipment, power and the electric energy are calculated data.

b) The input conditions shall be simulated according to the digital model of the measuring point specified in the technical specifications for the inspected product, to inspect the correctness of data collection and processing, which shall comply with the provisions of the technical specifications for the inspected product.

8.3.2 Output channel test

8.3.2.1 The digital outputs include the digital output of the LCU, the tripping and alarm output of the relay protection device and the alarm output of the DC power supply system. The digital output

channel test requires that:

- a) The output terminal of the digital output channel shall be connected to a multi-meter for monitoring the output status;
- b) The digital output shall be set to “0” or “1” at the man-machine interface or debugging terminal of the monitoring system;
- c) The external multi-meter shall be connected to the output terminal to inspect the correctness of output channel actions.

8.3.2.2 The analogue output shall include the current, voltage, power, temperature and water level signals which are transmitted at 4 mA to 20 mA or 0 V to 5 V. The analogue output channel test requires that:

- a) The testing instrument with accuracy at least one level higher than the requirements of the technical specifications of the inspected product shall be connected to the output terminal of the analogue output channel;
- b) The set value of analogue output shall be changed at the man-machine interface or the debugging terminal of monitoring system;
- c) The accuracy of the analogue output calculated as per the measured value with the external instrument shall comply with the provisions of the technical specifications for the inspected product.

8.3.2.3 Other data processing functions including the accident review function and other functions specified in the technical specifications for the inspected product shall be tested so that:

- a) Its starting conditions shall be simulated to inspect the processing correctness according to the provisions of the technical specifications for the inspected product;
- b) The display and the relevant records shall be inspected through the man-machine interface of the monitoring system, which shall be consistent with the actual input and the technical specifications for the inspected product.

8.3.3 Relay protection function and performance test

The relay protection of the hydropower station shall include the relay protections for the connection circuit, main transformer and hydro turbine generator as well as the emergency control of the voltage frequency. The relay protection performance test requires that:

- a) All signals relevant to the relay protection shall be inputted through the leading-out terminal of

the cabinets;

- b) The protective current and voltage shall be provided by the relay protection testing instruments, and the correctness of the relay protection function and performance shall be tested;
- c) The display and the relevant records shall be inspected through the man-machine interface of the monitoring system and shall be consistent with the actual input and the technical specifications for the inspected product.

8.3.4 DC System function and performance test

The following functions and performance shall comply with the requirements of the technical specifications for the inspected product:

- a) Accuracy of the voltage regulation and current regulation;
- b) Storage battery capacity;
- c) Charging-discharging test requirement;
- d) DC bus voltage regulation function;
- e) DC bus and outgoing feeder insulating property.

8.3.5 Man-machine interface function inspection

The following man-machine interface function shall comply with the requirements of the product technical specifications:

- a) Correctness of the image display and copy;
- b) Correctness of the image dynamic display by changing the data and status imputed from the production process interface;
- c) Correctness, uniqueness and reliability of the control command;
- d) Correctness and reliability of the parameters and status setting or modification;
- e) Correctness of the alarm, prompt, audio, voice, logging in and authority;
- f) Correctness of the various report forms and printings;
- g) Correctness of the historical data query;

- h) The system shall not make a mistake or crash when the undefined key is operated;
- i) Inspect the other man-machine interface functions specified by the technical specifications for the inspected product.

8.4 Test of the power supply adaptive capacity

When any parameter of the voltage, frequency and waveform of the external power supply under normal test atmospheric conditions is at the extreme value stipulated in the technical specifications for the inspected product (while the others are at rated values), the inspected system shall work reliably, and its function and performance shall comply with the provisions of the technical specifications for the inspected product.

8.5 Insulation resistance test

According to the rated insulation voltage of the tested circuit, the insulation resistance between the live parts of the device which is not earthed directly and the non-live metal parts as well as the enclosure, and between the circuits which are electrically disconnected shall be tested with the tramegger. The test requires that:

- a) The insulation resistance of the circuits to ground as well as that between the AC circuit and the DC circuit shall not be less than 100 M Ω ;
- b) The connection of the circuits to ground as well as that between the AC circuit and the DC circuit shall be able to sustain the test with 50 Hz/60 Hz, 2 kV (effective value) AC check voltage for one minute, and shall be free from flashover or insulation breakdown;
- c) The connection of the communication interface to ground shall be able to sustain the test with 50 Hz/60 Hz, 500 V (effective value) AC check voltage for one minute, and shall be free from flashover or insulation breakdown.

8.6 Continuous-current test

In accordance with the provisions of the technical specifications for the inspected product, the product shall be subjected to continuous-current testing for no less than 72 hours after being tested for the other inspection and acceptance items. In the inspection process, the optional test or inspection shall be carried out at a fixed interval (such as every 12 hours). The test shall be suspended in a timely manner if any product quality problem is found, and resumed after the problem is solved.

8.7 Pre-delivery inspection and acceptance

When the technical specifications for the inspected product requires pre-delivery inspection and acceptance before delivery, the user and the supplier shall test in accordance with the inspection and

acceptance outline jointly prepared by both parties. The tests specified in the inspection and acceptance outline include the full or partial contents of the pre-delivery tests and inspections.

9 Site acceptance

9.1 Environmental conditions for the site testing and acceptance

Unless there are special provisions for environmental conditions for the environmental tests or in the technical specifications for the inspected product, the other tests mentioned in this document shall be carried out under the following conditions:

- a) Ambient temperature: 15 °C to 35 °C ;
- b) Relative humidity: 45% to 75% ;
- c) Atmospheric pressure: 86 kPa to 106 kPa.

When the test could not be carried out under standard atmospheric conditions, the actual conditions shall be filled out on the test report.

9.2 Site test and acceptance rules

9.2.1 The site tests and acceptance shall be jointly carried out by the user (including the supervisor, the same below) and the supplier for the installation and commissioning after the product is delivered to the site. See Appendix A for the site testing and acceptance items.

9.2.2 The responsibilities of the supplier and the user shall be clarified in the site testing and acceptance process:

- a) Responsibilities of the supplier
 - 1) Preparation of the site testing and acceptance outline;
 - 2) Relevant inspection and commissioning tests of the product on site;
 - 3) Submission of the site commissioning test report.
- b) Responsibilities of the user
 - 1) Discussing and modifying the site testing and acceptance outline, supplementing the contents relevant to the on-site equipment and safety as well as reviewing and approving the site testing and acceptance outline;

- 2) Coordinating for the site commissioning test, and completing the safety measures for the potential hazards threatening the main and auxiliary equipment and personal safety on site;
- 3) Organizing and supervising the site commissioning work.

9.2.3 When any defects which make the equipment fail to comply with the technical specifications of inspected equipment are detected during the site commissioning test, the requirements for the treatment and the deadline shall be proposed in the intermediate site acceptance summary, and the defects shall be treated by the supplier.

9.2.4 If the site testing and acceptance are carried out in stages, the intermediate site acceptance summary shall be signed by and between the supplier and the user after the equipment passes the testing and acceptance inspection at each stage; at the end of all site tests and acceptance inspections, the final site acceptance document shall be signed by and between the supplier and the user.

9.3 Inspection of the equipment appearance, software/hardware configuration and the technical documents

9.3.1 Inspection of the appearance

Same as the corresponding section of the inspection of the equipment appearance in 8.2.1.

9.3.2 Inspection of the equipment software/hardware configuration

Same as the corresponding section of the inspection of the equipment software/hardware configuration in 8.2.2.

9.3.3 Inspection of the equipment technical documents

Same as the corresponding section of the inspection of the equipment technical documents in 8.2.3. Meanwhile, it is necessary to provide the equipment delivery inspection certificate.

9.4 Site unpacking, installation and wiring inspections

9.4.1 Site unpacking inspection

After the equipment (including the technical documents) within the supply scope arrives at the destination, the user shall be responsible for inspecting whether the goods container is damaged and inspecting the quantity of the arrived goods. When unpacking the container for inspection before the installation, the user shall give advance notice to the supplier, and the latter shall come to the site or entrust the user to count and accept the packing, appearance and quantity of the goods after receiving such notice.

9.4.2 System internal wiring inspection

The correctness of the wiring between the devices in the monitoring system shall be inspected, which shall be consistent with the design and construction drawings.

9.4.3 Site installation and external wiring inspection

The correctness of the installation of the monitoring system on site as well as the connection of the monitoring system to the on-site working process, the power supply system and the earthing system shall be inspected, which shall be consistent with the design and construction drawings.

9.5 Function and performance tests

9.5.1 Data collection and the processing function test

Same as the section on the data collection and processing function test in 8.3.1.

9.5.2 Output channel test

Same as the section of the output channel test in 8.3.2.

9.5.3 Relay protection test

Relay protection test requirements:

- a) Current and voltage for the test shall be provided by the relay protection testing instrument. All the voltage and current signals relevant to the relay protection shall be inputted through the leading-out terminal of the cabinets;
- b) Corresponding circuit breaker shall be controlled directly with the protective action outlet;
- c) The display and the relevant records shall be inspected through the man-machine interface of the monitoring system and shall be consistent with the actual input and the technical specifications for the inspected product.

9.5.4 Synchronization test

Synchronization test requirements:

- a) Current and voltage for the test shall be provided with the relay protection test instrument. All the voltage signals relevant to the synchronization operation shall be inputted through the leading-out terminal of the cabinets;

- b) Corresponding circuit breaker shall be directly controlled with the synchronizing outlet;
- c) The display and relevant records shall be inspected through the man-machine interface of the monitoring system and shall be consistent with the actual input and the technical specifications for the inspected product.

9.5.5 Power regulation function test

9.5.5.1 Active power regulation test requirements:

- a) Inspect the limit values and the protective parameters relevant to the active power regulation, which shall be error-free;
- b) Quit the automatic regulation process of the active power and the reactive power;
- c) Execute the “electricity generating” process of the hydro turbine generator unit to start the hydro turbine generator unit and connect it to the power grid;
- d) Initiate the active power regulation process;
- e) Under the premise of avoiding the vibration region, change the given value of the active power by 10% or its integer multiples until the maximum possible variation value occurs in the operation process, change the active power regulation parameter and make the active power regulation quality meet the site operation requirements;
- f) Monitor and manually regulate the reactive power of the hydro turbine generator unit in the testing process so as to meet the operation requirements.

9.5.5.2 Reactive power regulation testing requirements:

- a) Inspect the limit values and the protective parameters relevant to the reactive power regulation, which shall be error-free;
- b) Quit the automatic regulation process of the active power and the reactive power;
- c) Execute the “electricity generating” process of the hydro turbine generator unit to start the hydro turbine generator unit and connect it to the power grid;
- d) Initiate active power regulation process;
- e) Under the premise that the operating conditions of the hydro turbine generator unit so permit, change the given value of the reactive power by 10% or its integer multiples until the maximum possible variation value occurs in the operation process, change the reactive power regulation

parameter and make the reactive power regulation quality meet the site operation requirements;

- f) Monitor and manually regulate the active power of the hydro turbine generator unit in the testing process so as to meet the operational requirements.

9.5.6 Automatic generation control (AGC) function test (optional)

9.5.6.1 Requirements for testing of the AGC functions in “Station” mode:

- a) Set the AGC working mode to “Station” and “Open-loop” to test the correctness of the load distribution operation and the start-up/shutdown directions of the AGC in different control modes;
- b) Set the AGC working mode to “Station” and “Closed-loop” to test the effectiveness of the load distribution, power regulation and start-up/shutdown operation of the AGC in different control modes.

9.5.6.2 Requirements for testing of the AGC functions in “Dispatch” mode:

- a) Set the AGC working mode to “Dispatch” and “Open-loop” to test the correctness of the various functions of the remote AGC (such as modification of the voltage curve and the set value of the total active power of the entire station from the dispatching side);
- b) Set the AGC working mode to “Dispatch” and “Closed-loop” to test the execution correctness of the various functions of the remote AGC.

9.5.7 Automatic voltage control (AVC) function test (optional)

9.5.7.1 Requirements for testing of the AVC functions in “Station” mode:

- a) Set the AVC working mode to “Station” and “Open-loop” to test the correctness of the load distribution operation of the AVC in different control modes;
- b) Set the AVC working mode to “Station” and “Closed-loop” to test the load distribution and power regulation execution effects of the AVC in different control modes.

9.5.7.2 Requirements for testing of the AVC functions in “Dispatch” mode:

- a) Set the AVC working mode to “Dispatch” and “Open-loop” to test the correctness of the various functions of the remote AVC (such as modification of the voltage curve and setting of the total reactive power or the whole station);
- b) Set the AVC working mode to “Dispatch” and “Closed-loop” to test the execution correctness of the various functions of the remote AVC.

9.5.8 Real-time performance index inspection and test

9.5.8.1 Real-time performance index inspection shall include the inspection of the data collection cycle as well as the setting value of the parameters of the AGC and the AVC relevant to the execution cycle; the results shall comply with the provisions of the technical specifications for the inspected product.

9.5.8.2 Requirements for testing of the real-time performance index:

- a) Test of the time when the analogue input signal is suddenly changed to the data display on the image;
- b) Test of the time when the digital input is shifted to the image block on the image or the data display is changed, or the alarm information or sound is sent;
- c) Test of the time from the sending of the command to the execution of the control output by the LCU;
- d) Test of the man-machine interface response time:
 - 1) Response time for calling new image;
 - 2) Real-time data refresh time on the displayed image;
 - 3) Time from the generating of the analogue data event to the display of the alarm information on the image and the making of the sound;
 - 4) Time from the generation of the event sequence record to the display of the alarm information on the image and the making of the sound;
 - 5) Time from the generation of the calculated data event to the display of the alarm information on the image and the making of the sound.
- e) Test of the dual-machine switchover time: When quitting the main machine manually, the spare machine shall be put to work automatically and the switchover time shall be measured; in the switchover process, no error or crash of the system shall occur;
- f) Other real-time performance indices shall be tested according to the technical specifications for the inspected product; The real-time performance indices shall comply with the provisions of the technical specifications for the inspected product.

9.5.9 External communication function test

9.5.9.1 According to the provisions of the technical specifications for the inspected product, the function of communication between the inspected system and the various dispatching as well as the other external systems and equipment (such as the water regime, information management system of the hydropower station, automatic devices and intelligent instruments) shall be tested by simulating the PC communication offside or by directly using the real equipment in accordance with the communication protocol, which shall comply with the provisions of the technical specifications for the inspected product.

9.5.9.2 For the channel with the redundancy configuration, the spare channel shall be automatically put to work if the working channel is quit manually and no error of crashing of the system shall occur in the switch-over process.

9.5.10 Application edit function test

The application edit functions (such as the modification, addition and deletion of the images, measuring point definition, tables and control processes) of the inspected product shall be tested according to the provisions of the technical specifications for the inspected product, which shall comply with the provisions of the technical specifications for the inspected product.

9.5.11 System self-diagnosis and self-recovery function test

The following items should be tested:

- a) Power on or restart the system, and inspect whether the system could be started normally;
- b) Simulate the failure of the application system, and inspect whether the system is self-recovered;
- c) Simulate the failures of the various functional modules, peripheral equipment and communication interfaces, and inspect whether the corresponding alarms and records are correct;
- d) For equipment with the hot standby redundancy configuration (such as the main machine, network and LCU), simulate the failure of the working equipment, inspect whether the standby equipment could be activated as the working equipment, whether the data is consistent after switching over and whether the tasks are continuously executed; the system shall not crash.

9.5.12 CPU load rate performance index test

As for the system with clear provision for the CPU load rate, the indices such as the CPU load rate,

memory occupancy and magnetic disk use rate shall be displayed and recorded through the command or operating system interface on the computer, and their maximum values shall be worked out through statistics.

10 Nameplate, packing, transportation and storage

10.1 Nameplate

The materials and printing method of the nameplates shall ensure that the texts are not obliterated during the entire service period, and the following information shall be marked:

Supplier name, equipment name, equipment model, product number and delivery date.

10.2 Packing

10.2.1 The packing container shall be manufactured according to the packaging drawing. The following information shall be marked on the outside of the container:

- a) Consignee and address;
- b) Supplier and address;
- c) Equipment model, name and number;
- d) Equipment net weight, gross weight, centre of the gravity line of the packing container, position of the slings and overall dimensions of the packing container;
- e) Wordings and marks like “Handle with Care”, “Keep Away from Moisture” and “Do not Put Upside Down”.

10.2.2 Rain-proof, damp-proof, mould-proof, dust-proof, anti-vibration and salt-spray-proof measures shall be taken for the equipment packing according to the different requirements for the equipment and the transportation modes.

10.2.3 Before packing, the following preparations shall be made:

- a) Inspect whether the equipment appearance gets damaged and whether there is dust on the surface;
- b) Remove the fragile and vibration-sensitive components and meters, and pack them separately;
- c) Get the spare parts, compliance certificate and relevant technical documents ready along with

the equipment, wrap them properly and affix in the proper position.

10.2.4 Name and quantity listed on the packing list shall be consistent with the material objects and the drawings in the container.

10.2.5 The packing of the equipment for export shall comply with the of the relevant countries' provisions concerning inspection and quarantine.

10.3 Transportation

The supplier shall designate the applicable transportation tools and transportation requirements for the equipment. The transportation and the handling shall be implemented according to the marks on the packing container. The number of packages, the number of cases, markings, the delivery time and the train number shall be notified by the supplier to the consignee upon delivery.

10.4 Storage

The packed equipment shall be stored in the warehouse with an ambient temperature of $-25\text{ }^{\circ}\text{C}$ to $+55\text{ }^{\circ}\text{C}$ and relative humidity of not more than 85%; the warehouse shall be free from any acid, alkali, salt, corrosive or explosive gases and strong electromagnetic fields, and be shall protected from dust, rain and snow. The supplier shall ensure that the equipment shall not be rusted or the accuracy shall not be reduced due to improper packing under the above storage conditions within 12 months from the date of delivery.

11 Installation and training

11.1 Installation

11.1.1 Installation guide

The supplier shall be responsible for the site installation, testing and commissioning of the equipment to the user's satisfaction and the supplier shall assign technicians to work at the site.

11.1.2 Installation specifications

Installation shall be carried out as per this document as well as relevant the standards and specifications.

11.1.3 Installation test records

After installation, the user and the supplier's technicians shall comprehensively test the equipment and formulate complete test records.

11.2 Training

11.2.1 The supplier shall organize training on aspects of the equipment operation, daily maintenance and malfunction treatment for the user.

11.2.2 Reasonable training plan shall be formulated and training documents shall be properly prepared for the user training.

11.2.3 The user training shall be carried out in stages and preferably in three stages:

- a) Pre-delivery training: Before the equipment is delivered, the user shall assign personnel to participate in the delivery inspection of the equipment at the supplier's premises and receive systematic training on aspects of theory and practice;
- b) On-site training: After the equipment arrives at the installation site, the user shall assign personnel to participate in the site installation, testing and commissioning of the equipment, and receive operational training;
- c) Operational training: After the equipment is put into operation, as required, the user shall assign personnel to receive hands-on operational training at the power plant or the real time digital simulator at the supplier's premise or in some institute having such a facility.

12 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 on which the 72-hour trial operation is completed, 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
(Normative)
Inspection, acceptance tests

Table A.1 Inspection, acceptance tests and test items

No.	Inspection items	Factory inspection	Site acceptance
1	Inspection of the product appearance, software/hardware configuration and the technical documents	√	√
2	Test of the analogue data collection and the processing function	√	√
3	Test of the digital data collection and the processing function	√	√
4	Test of the calculated data collection and the processing function	√	√
5	Test of the digital output channel	√	√
6	Test of the analogue output channel	√	√
7	Test of the other data processing function	√	√
8	Test of the relay protection function and performance	√	√
9	Voltage and current stabilization test of the direct current system	√	√
10	Inspection of the storage battery capacity	√	√
11	Charge-discharge test	√	√
12	Test of the DC bus voltage regulation function	√	√
13	Test of the DC bus and the out going feeder insulating property	√	√
14	Test of the man-machine interface function	√	√
15	Test of the power supply adaptive capacity	√	√
16	Insulation resistance test	√	√
17	Continuous-current test	√	√
18	On-site unpacking, installation and wiring Inspections		√
19	Synchronization function test	√	√
20	Power regulation function test	√	√
21	Automatic generation control (AGC) function test	√	√
22	Automatic voltage control (AVC) function test	√	√
23	Real-time performance index inspection and testing	√	√
24	Communication function test	√	√
25	Test of the application edit function	√	√
26	Test of the system self-diagnosis and self-recovery functions	√	√
27	CPU load rate, memory occupancy performance index test	√	√
28	Other functional tests	√	√