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

Part 3: Technical Renovation

SHP/TG 005-3: 2019



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Technical Guidelines for the
Development of Small Hydropower Plants
MANAGEMENT

Part 3: Technical Renovation

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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-Management

Part 3: Technical Renovation

1 Scope

This Part of the Management Guidelines specifies the basic principles, contents, methods and requirements for the technical renovation of an small hydropower (SHP) station.

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 60060-3-200, *High-voltage Test Technique—Part 3: Definition and Requirements for On-site Testing*

IEC 61439, *Low-voltage Switchgear and Controlgear Assemblies*

IEC 62006:2010, *Hydraulic Machines—Acceptance Tests of Small hydroelectric Installations*

IEC 62208, *Empty enclosures for low-voltage switchgear and controlgear assemblies—General requirements*

IEC 60609-1, *Hydraulic Turbines, Storage Pumps and Pump—Turbines—Cavitation Pitting Evaluation—Part 1: Evaluation in Reaction Turbines, Storage Pumps and Pump-turbines*

IEC 60609-2, *Hydraulic Turbines, Storage Pumps and Pump—Turbines—Cavitation Pitting Evaluation—Part 2: Evaluation in Pelton Turbines*

ISO/DIS 5208, *Industrial Valves—Pressure Testing of Metallic Valves*

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 SHP/TG 001 apply.

4 General

4.1 The technical renovation of the power station shall eliminate the safety hazards, ensure work safety, improve the power generation efficiency, shall bring cost effectiveness to the works and shall improve the operation and maintenance.

4.2 The existing facilities or equipment shall be fully utilized, and the matured new technologies, new processes, new equipment and new materials shall be actively used to improve the technical functional and financial aspects of the hydropower station and meet the energy conservation and environmental protection requirements in the obsolete technologies shall not be used.

4.3 If the facility or equipment has serious defects, and their safety could not be ensured even after several repairs or the renovation cost is predicted to be higher than 60% of the cost for new equipment, it should be scrapped and replaced with new equipment/components.

4.4 Before the implementation of the renovation, the status analysis and evaluation shall be performed first; the safety detection shall be performed for the equipment and facility when necessary; and the feasibility study may be implemented to determine the technical renovation scheme.

4.5 The cooperation of the cascade hydropower stations in the same river basin shall be taken into account, or if flows or generating have impacts from one station on another station.

4.6 Attention shall be paid to the social and environmental impacts, particularly the discharge of ecological flow and environmental protection. The fish pass structure shall be installed according to the actual situation of the power station.

4.7 The renovation scheme shall meet the provisions of the national as well as the local regulations for the project.

5 Status analysis and evaluation

5.1 For the technical renovation of the power station, the following data shall be collected:

- a) Engineering design, completion and operation data and the overhaul records over the years;
- b) Hydrological and sediment data;

- c) Safety detection and performance test or evaluation data;
- d) Other relevant data.

5.2 Before technical renovation of the power station, the equipment or facility including the hydraulic structure, electromechanical equipment and the hydromechanical structure shall be analysed from the aspect of performance and safety according to the preventive test report, performance testing result, safety detection results, and the operation and overhaul data; and whether the facility and equipment of the power station should be renovated shall be evaluated from the point of view of performance and safety.

5.3 Analyze the operation data and maintenance data of the power station according to the river planning and hydrologic data, study the change rules of the upstream and downstream water level, water head, flow, sediment concentration, and demonstrate the necessity and feasibility of the renovation. Whether the capacity of the power station should be uprated or derated shall be evaluated, and the evaluation shall include the following contents:

- a) The available runoff and the design flood shall be reviewed when necessary, if any flooding has occurred since the operation of the hydropower station or if the hydraulic structures are to be uprated to increase the water diversion volume or to increase the weir/dam height. The impact of climate change shall also be checked for the safe spillway capacity;
- b) The runoff shall be rechecked when the hydropower station is renovated by uprating or derating the capacity;
- c) The conditions which may increase or decrease the flow and may increase or reduce the working head;
- d) Usable abandoned water;
- e) Conditions for reducing the head loss and the reduced flow loss;
- f) Ecological flow review.

5.4 The possible social and environmental impacts of the hydropower station renovation shall be evaluated.

6 Detection and evaluation

6.1 Before the power station is renovated, the hydraulic structures should be inspected, and the appearance, structural safety, operation and management conditions, and the project quality should be evaluated. Hydraulic structures with abnormal conditions identified through on-site inspection and

safety monitoring should necessarily be checked.

6.2 The comparison test should be performed for the performance of unit before and after the technical renovation; the test data is the important basis for assessing the effects and the economic indices of the technical renovation of the power station. It is recommended to perform performance tests before and after the renovation with same method and same set of instruments and meters.

6.3 The turbine performance test shall be performed according to the specific situation, or carried out in accordance with the relevant provisions of IEC 62006:2010.

6.4 With regard to the hydropower station with the main electromechanical equipment exceeding the design service life or subject to an abnormal condition influencing safe operation, the main structural members shall be inspected or detected for corrosion, deformation and cracks; and their strength and rigidity shall be reviewed and evaluated.

6.5 For the penstock, specials gate and hoist, the deformation, twisting, cracks, corrosion or abrasion of the main structural members, and the welds with defects shall be detected through non-destructive testing; and their strength and rigidity shall be reviewed and evaluated.

6.6 The performance test of the main electrical equipment of the power station may employ the preventive test results or the current test results before renovation, and the test may be performed in accordance with IEC 60060-3:2006.

6.7 The detection and evaluation results shall be used as the basis for determining the necessity and renovation scheme for the technical renovation of the power station, and for assessing the effects of the technical renovation.

7 Renovation contents and requirements

7.1 General provisions

7.1.1 In any of the following cases, the technical renovation shall be performed:

- a) Existing and foreseeable potential for a safety hazard;
- b) The parameters of the upstream and downstream hydrological characteristics change significantly;
- c) The utilization of the water power resource is unreasonable, especially if the head and flow is not used properly and is in conflict with the utilization of other water power resources.
- d) The quality of the civil engineering construction, equipment manufacture or installation is poor,

the equipment performance lags behind and the technical condition is poor;

- e) The geological conditions have changed significantly;
- f) The ecological environment is seriously and negatively impacted;
- g) Other situation requiring renovation.

7.1.2 The usable part of the existing facility and equipment shall be reviewed and calculated as necessary; the corresponding technical treatment shall be performed when necessary.

7.1.3 The power station with a great abundance of water may be renovated by uprating the capacity; the hydropower station with low annual utilization hours, lower head or decreasing flow may be renovated by derating the capacity.

7.1.4 For the hydropower station to be renovated by uprating the capacity, the scale of the installed capacity shall be re-determined and following contents shall be reviewed:

- a) The water intake, head loss, structural strength and hydraulic transient and equipment as well as the facility for diversion system (including the water intake, diversion tunnel and penstock) shall be reviewed.
- b) The tunnel and channel discharge capacity should be rechecked.
- c) The project class, structure grade and flood standard shall be reviewed.
- d) The regulating guarantee parameters of the unit and water conveyance system shall be verified.

7.2 Hydraulic structures

7.2.1 The technical renovation of the hydraulic structure shall meet the following requirements:

- a) The potential safety hazard is eliminated;
- b) The inundation loss is small;
- c) The construction is convenient.

7.2.2 The following technical renovation measures may be taken for the scientific utilization of the water power resources:

- a) To lead the water from different zones in the same basin into the reservoir or forebay by channelling or tunnelling under the premise of meeting the ecological flow requirement;

- b) To increase the power generation head and the regulation storage with the method of increasing the dam height under the premise of minimizing the influence on the submersion, so as to improve the power production;
- c) On the premise of not affecting flood control safety, add rubber dams, flap gates or controllable gates, and other facilities on the spillway. Combining with the water regime forecast, the sluice can store water at the end of the flood season to enhance the water head and the storage capacity, thus increasing the generating capacity;
- d) To flush out the river channel sedimentation, and reduce the tailwater level of the unit on the premise of meeting the turbine static suction head.

7.2.3 The following measures may be taken for the technical renovation of the water diversion system:

- a) To improve the sediment removal and the flushing and trash cleaning facilities at the head of the water diversion system, including improving the layout of the water intake, and renovating the hydraulic structure which otherwise did not meet the smooth flow rule for water flow and to try to establish the streamline form;
- b) To improve the structure of the trash rack, install additional trash cleaning equipment or add the trash holding and ice discharging facilities, including adjusting the spacing between the trash rack bars, and improving the structure of the trash rack and the shape of the bars to reduce the clogging of trash;
- c) To increase the flow cross-section and to improve the roughness factor;
- d) Dredging and anti-seepage treatment are performed on the forebay, tunnel and channel of the diversion structure;
- e) To clear the barrier and desilt the tailwater, and to improve the water flow regime of the tailrace.

7.2.4 The technical renovation of the powerhouse shall meet the following requirements:

- a) The flood control installation shall be improved to meet the flood control requirements;
- b) With regard to the updated renovation hydropower station, the strength of the generator pier and the crane beam shall be reviewed, and the strength of the floor slab with the load increase shall also be reviewed;
- c) The requirements for the safe operation, maintenance and overhaul of the electromechanical equipment shall be met;

d) The appearance of the powerhouse shall be harmonious with the ambient environment.

7.2.5 In the cold region, the frost resistance facilities such as the ice retaining bar and the ice holding rack shall be established for the hydraulic structure and the hydro mechanical equipment.

7.2.6 The technical renovation of the gates and hoists shall meet the following requirements:

- a) With regard to all kinds of gates with corrosion, deformation, vibration and serious water leakage as well as the hoist which cannot operate flexibly, the technical renovation shall be performed to eliminate the defects;
- b) With regard to the gate with excessive hoisting capacity due to corrosion or deformation, new supporting materials shall be used in precedence, or the supporting form of the gate or hoist equipment may be improved;
- c) With regard to the power station with the diversion system renovated or the dam height increased, the existing gate or hoist shall be reviewed or reinforced.

7.2.7 For the emergency bulkhead gate at the water intake of the unit and the tailwater bulkhead gate, the water filling and pressure balancing facilities should be established, and it is strictly prohibited for the tail lock to use the upstream high pressure water for water filling and pressure balancing.

7.2.8 The hoist for the flood discharge gate shall be equipped with reliable standby power.

7.2.9 The technical renovation of the penstock shall meet the following requirements:

- a) The water-stop ring for the expansion joint which seriously leaks water and has aged shall be replaced;
- b) The steel pipe shall be replaced if it is seriously corroded or damaged;
- c) The anchor blocks and the supports with differential settlement shall be reinforced;
- d) The reinforced concrete pipeline which has seriously aged shall be replaced;
- e) If the pipe diameter of the penstock is too small, more pipelines shall be used or the pipe diameter shall be increased to reduce head losses.

7.2.10 The safety monitoring system of the reservoir dam shall be improved.

7.3 Turbine and its accessory equipment

7.3.1 The technical renovation of the turbine shall be performed in line with the following principles:

- a) For advancement, it is necessary to select the efficient runner with advanced performance and matured technologies; during the type selection and design, it is necessary to collect as much information as possible on the various kinds of runners (usually at least 3) from the research department and the manufacturers for comparison and selection.
- b) For rationality, it is necessary to closely combine and handle the limiting conditions of this hydropower station which cannot be changed or should not be changed.
- c) For economy, it is necessary to increase the annual energy output, and to improve the economic benefit of the power station.
- d) For particularity, it is necessary to improve the operating conditions of the turbine under special water quality conditions such as excessive sediment and to take the comprehensive treatment measures for the sediment and abrasion resistance.

7.3.2 The technical renovation of the turbine shall meet the following requirements:

- a) The turbine runner selected shall be advanced in the energy index, have excellent cavitation characteristics and have good operation stability;
- b) When the main parameters of the turbine are selected, the dimensions and installation elevation of the diversion system and the turbine flow passage of the hydropower station as well as the parameters of the generator shall be considered so that the turbine can operate in the stable and efficient zone, and the static suction head meets the requirement;
- c) The turbine shall be adaptive to the changes in head and flow to improve the operating conditions and to enhance the operational stability and efficiency;
- d) With regard to the high sediment-carrying water at the hydropower station, the sediment abrasion of the turbine shall be evaluated and analysed, the technical renovation parameters shall be reasonably selected and abrasion resistance measures such as the silt resistive turbine material or coating shall be selected. With regard to the hydropower station with high sediment passing through the turbine, the turbine should operate under cavitation-free conditions.

7.3.3 The technical renovation of the turbine shall be carried out with the following methods according to the specific conditions of the hydropower station:

- a) New runner with higher performance shall be adopted, the new runner shall be matched with the turbine flow passage; the profile and structure of the passage parts may be improved upon technical demonstration, when necessary;
- b) With regard to the power station with small changes in the head and flow compared to the original design condition, but with old turbine equipment of low efficiency, the turbine performance

shall be improved;

- c) With regard to the power station with head and flow higher than the original design conditions, the rated power output shall be improved;
- d) With regard to the power station with head and flow lower than the original design conditions, the rated power output shall be reduced;
- e) With regard to the power station with high sediment contents, the hydraulic and structural design of the turbine shall be improved according to the volume of sediment passing through the turbine and the characteristics of the sediment, and the abrasion-resistance material and protective coating shall be used;
- f) If the unit has a serious potential safety hazard or its damage meets the scrap conditions, it shall be scrapped and replaced with a new unit.

7.3.4 The turbine runner and guide blade should be machined with a numerically-controlled machine tool.

7.3.5 The technical renovation of the thrust bearing shall meet the following requirements:

- a) The structural style should be improved or the cooling effect should be strengthened for thrust bearings with a relatively high temperature during power generation. Units with the rated speed of 1 000 r/min or less should use elastic metal-plastic thrust bearings.
- b) For the design of the capacity enhancement of the unit, the maximum axial thrust of the unit, the bearing capacity of the thrust bearing and the bearing capacity of the foundation shall be calculated and reviewed.

7.3.6 The radial bearing of the horizontal shaft may employ the anti-friction bearing or the sliding bearing; the sliding bearing may employ the Babbitt bearing shoe or other appropriate bearing shoe. The guide bearing of the vertical shaft turbine should be a parabolic structure to prevent the bearing shoe from being scratched.

7.3.7 The technical renovation of the hydro turbine governing system shall meet the following requirements:

- a) The characteristic parameters such as the work capacity of the governor shall be reviewed according to the turbine parameters when the head, flow or runner diameter changes;
- b) The renovated hydro turbine governing system shall meet the requirements for start-up and shutdown, fast synchronization, load increase/decrease and emergency shutdown;

- c) The hydro turbine governing system should be renovated to employ the microcomputer-based full-automatic governor or the manipulator with the energy storage equipment;
- d) The hydro turbine governing system after the technical renovation may provide the pressure oil source for the automatic braking device under the premise of meeting the operating work requirement;
- e) When the unit requires black start, the governor shall be equipped with the fully manual operating system.

7.3.8 The technical renovation of the main valve of the turbine shall meet the following requirements:

- a) When the water leakage is significant, the sealing form of the main valve shall be improved or it shall be replaced with a new main valve;
- b) The valve shall be equipped with the mechanical limit protection device;
- c) The valve should be equipped with the automatic operating mechanism;
- d) The hydraulically-operated valve should be equipped with the hydraulic device having the energy storage equipment.

7.4 Auxiliary equipment

7.4.1 The auxiliary equipment of the hydraulic machinery shall be correspondingly replaced or renovated according to the requirements for the technical renovation of the unit equipment.

7.4.2 The technical renovation of the technical water supply system shall meet the following requirements:

- a) The renovation of the technical water supply system shall satisfy the water requirement after the renovation of the power station;
- b) With regard to the hydropower station designed to be unattended during operation (attended by fewer persons), the technical water supply system shall be equipped with the automatic water filter, the automatic control valve and the flow indicating signal device;
- c) The seepage drainage system should employ the self-priming pump for drainage, or the submerged pump or the deep-well pump;
- d) The pipeline which has been seriously corroded or has leakage or with an undesirable pipeline diameter shall be replaced.

7.4.3 The technical renovation of the compressed air system shall meet the air demand after the renovation of the unit; with regard to the governor oil pressure device equipped with the bladder type hydro-pneumatic accumulator, the corresponding compressed air system may be omitted.

7.4.4 The technical renovation of the oil system shall meet the following requirements:

- a) The turbine oil system shall be laid in the simplified pipeline, and the oil should be supplied and drained through the hose;
- b) The oil tank for the insulating oil system should be omitted (considering the insulating oil of the SHP is mainly used for the transformer, and there is usually no need to charge or discharge the oil, and the oil can be filtered online).

7.4.5 The hoisting equipment that fails the test shall be refurbished or replaced.

7.4.6 For the design of the hydropower station renovated by upgrading the capacity, the hoisting equipment and its supporting structure in the plant shall be reviewed for the weight of the heaviest part plus the weight of the lifting device. When the hoisting weight is more than the rated hoisting capacity of the crane, the crane and its supporting structure shall be renovated or other safety measures shall be taken.

7.5 Generator and the other electrical equipment

7.5.1 The technical renovation of the generator shall match the capacity of the turbine and the other power transmission and transformation equipment.

7.5.2 The technical renovation of the generator may be realized in the following manner:

- a) To improve or replace the cooling system, change the rotor fan, enhance the forced ventilation or change the pipeline ventilation to the sealed air cooler.
- b) To replace the stator winding and the rotor magnetic pole coil; if the insulation of the stator or the rotor winding has aged, the winding shall be replaced, or insulating material of a higher grade shall be used; for example, change the insulation of grade B to insulation of grade F to improve the temperature resistance. With regard to the generator with large capacity enhancement, in addition to the replacement of the winding and the insulation, the length of the stator and the rotor core may be increased to improve the electromagnetic power. With regard to the vertical generator, lifting the rotor out of the generator pit shall not be influenced if the stator extrudes from the ground of the main generator room due to the increase in the core length.
- c) To renovate the generator bearing; it is allowed to adopt plastic thrust pads with low friction, large bearing capacity and without bearing shoe grinding.

- d) To replace the generator; the foundation and embedded parts of the old equipment shall be fully utilized, and new insulation materials and high-quality and high-efficient silicon steel sheets shall be used.

7.5.3 The generator shall be equipped with the temperature measurement components.

7.5.4 The high-voltage generator with low capacity may be replaced by the low-voltage generator, and the updated generator capacity should not exceed 800 kW, otherwise the current will be too great, the cable section will be thickened, and the wiring will be much more difficult, and the investment will increase.

7.5.5 The generator with a large insulation resistance drop of the stator winding after shutdown may be dried with the additional heating and dehumidification device. If the insulation resistance still could not meet the requirements after heating and dehumidification, the insulation shall be replaced or other measures shall be taken.

7.5.6 The technical renovation of the excitation system shall employ the excitation device with the automatic regulating function, and the static excitation or the brushless excitation mode should be adopted.

7.5.7 Technical renovation of the main transformer shall meet the following requirements:

- a) The rated capacity of the main transformer shall meet the requirement of the output capacity of the hydropower station after renovation;
- b) The main transformer with high energy consumption shall be replaced with energy-saving transformer with low energy consumption;
- c) With regard to the power station with the distribution transformer as main transformer, it shall be updated to the boosting transformer.

7.5.8 Technical renovation of the other electrical equipment shall meet the following requirements:

- a) Safe, energy-saving and environment-friendly electrical equipment products shall be selected; the equipment with high energy consumption or with the potential to pollute the environment shall not be used;
- b) Oil-free high-voltage circuit breaker shall be selected;
- c) Selected light-weight closed high-voltage switchgear cabinet shall meet the following requirements:
 - 1) Prevent the circuit breaker from being opened or closed by mistake;

- 2) Prevent the disconnecting switch from being turned on or off with load;
 - 3) Prevent the grounding wire from being connected with power on;
 - 4) Prevent power supply switch from being turned on with grounding wire connected;
 - 5) Prevent the operator from entering the live compartment.
- d) The low-voltage switchgear cabinet shall meet the requirements of IEC 61439 and IEC 62208;
- e) The cables should be laid on the cable racks or treaded through the pipe.

7.5.9 The hydropower station designed for unattended operation (or attended by fewer people) shall be equipped with the reliable operation power supply; the operating power supply for the low-voltage generator unit with a unit capacity lower than 800 kW may be appropriately simplified; UPS meeting the demands for switch tripping and electrical control may be used.

7.5.10 The lightning protection system shall be improved to satisfy the grounding resistance requirements.

7.5.11 In the technical renovation of the power station, the emergency lighting shall be installed. The lighting shall be configured with energy-saving and environmental protection products and be convenient for maintenance.

7.6 Automation

7.6.1 For the automation technical renovation of the power station, the control mode shall be determined according to the characteristics of the hydropower station, the operation mode and the scheduling requirements of the electric power system. The unattended operation with fewer guardians should be selected.

7.6.2 The power station designed for unattended operation with fewer guardians shall meet the following requirements:

- a) Reliable digital protector shall be established. When the protector acts, the machine shall be able to be shut down and the telemetry signal shall be sent;
- b) The functions of one-key start/stop, automatic frequency regulation, automatic voltage regulation and automatic active/reactive power regulation shall be provided;
- c) The remote control operation function shall be provided;
- d) The video monitoring system should be installed and the automatic saving function shall be pro-

vided;

e) The burglar alarm shall be installed.

7.6.3 For the technical renovation of the unit braking system, the automatic braking device should be installed.

7.6.4 Microcomputer-based automatic control and monitoring system selected and provided for the renovation shall be simple and reliable.

7.6.5 For the technical renovation of the power station, the gate monitoring system be established to realize the remote control and monitoring functions; the rapid operating gate also shall have the one-button drop function.

7.6.6 If the conditions so permit, the dam safety monitoring system, and the hydrologic (water regime) automatic observation and reporting system may share data with the microcomputer-based monitoring system of the hydropower station.

7.6.7 With regard to the power station with the low voltage unit, the digital monitoring, protection and excitation all-in-one screen with the simple and reliable structure should be used for the technical renovation of the control equipment.

7.6.8 The protection grade of the electric secondary cabinet shall not be lower than IP42. The lighting and dehumidification device should be installed in the cabinet.

7.6.9 The renovation of the power station shall be equipped with reliable communication equipment. The mobile communication equipment may be installed to monitor the operational situation of the hydropower station.

7.6.10 The renovation of the power station may employ the centralized control mode for a group of power stations.

7.7 Heating and ventilation, fire control and safety

7.7.1 The power station with temperature, humidity and noise levels exceeding the standard shall be technically renovated.

7.7.2 The technical renovation of the fire control shall meet the relevant provisions of the local government, and the fire facilities shall be installed.

7.7.3 The legible safety signs and protection facilities shall be provided at the places which may endanger personal safety.

7.7.4 An additional safety evacuation exit shall be established for the power distribution equipment room which is more than 7 m in length and has only one exit.

7.7.5 Safety protection measures shall be taken for the rotating part of the unit, and legible safety warning signs shall be established.

7.8 Ecological flow discharging facility

7.8.1 With regard to the hydropower station which cannot meet the discharging requirement for ecological flow, the ecological flow discharging facility shall be renovated or a new facility shall be built.

7.8.2 The measures for ensuring the ecological flow shall be taken in line with the principles of adjusting the measures to the local conditions, if it is technologically reasonable and economically practical.

7.8.3 The renovation of the ecological flow discharging facility may be undertaken with the following measures:

- a) Establish the “small unit for the ecological flow” and operate it for a long term to undertake the task of ecological flow discharging;
- b) For the hydropower station with the base load power generation task, the ecological flow may be discharged in the power generation process;
- c) For the purpose of ensuring the ecological flow, build new, or renovate the old diversion, water releasing, desilting and discharging facilities;
- d) Introduce the software and hardware for the joint dispatching of the cascade hydropower station to ensure that the ecological flow in the river channel between cascade power stations meets the requirements.

7.8.4 The online monitoring device for the ecological flow in the river channel shall be established. Once the ecological flow is found to be insufficient, the release gate (valve), if installed, may be opened in a timely manner, or otherwise other measures may be undertaken.

8 Technical performance index

8.1 After technical renovation of the power station, the unit power and the unit efficiency shall meet the following requirements:

- a) The output power of the unit shall reach or exceed the design requirement for the technical ren-

ovation;

- b) Under the rated condition, the unit efficiency shall not be lower than the indices in Table 1, which shall be taken from high to low according to the unit power; the comprehensive efficiency of the impulse turbine generator unit may be appropriately reduced.

Table 1 Unit efficiency index under the rated working condition

No.	Unit power P (kW)	Efficiency index
1	$P \leq 100$	60%
2	$100 < P \leq 250$	70%
3	$250 < P \leq 500$	75%
4	$500 < P \leq 3\ 000$	75% to 85% , where the efficiency of the Francis turbine unit is 77% to 85%
5	$3\ 000 < P \leq 10\ 000$	81% to 87% , where the efficiency of the Francis turbine unit and the bulb turbine unit is 83% to 87%
6	$> 10\ 000$	85 to 88% , where the efficiency of the Francis turbine unit and the bulb turbine unit is 88%.

8.2 The allocation of the electromechanical equipment shall be reasonable; the rate of equipment in good condition shall reach 100% for the part of the technical renovation.

8.3 After the technical renovation, the noise of the turbine and the generator during normal operation shall meet the following requirements:

- a) For the vertical shaft turbine, the noise measured at a position 1 m above the generator pit floor shall not exceed 90 dB(A) and the noise measured at a position 1 m from the manhole of the draft tube shall not exceed 95 dB(A).
- b) For the horizontal shaft turbine, the noise measured at a position 1 m from the main shaft and the draft tube shall not exceed 90 dB(A).
- c) The noise measured at a position 1 m above the outer edge of the cover plate shall not exceed 85 dB(A) for the vertical shaft generator and the noise measured at a position 1 m from the outer edge of the stator shall not exceed 85 dB(A) for the horizontal shaft generator.

8.4 After the main valve is updated, the water leakage shall meet the relevant provisions of ISO/DIS 5208.

8.5 After the updated guide vane is fully closed, the water leakage shall meet the following requirements:

- a) Under the rated head, the water leakage shall not be more than 0.4% of the rated flow of the

turbine when the new tapered guide vane of the reaction turbine is fully closed; the water leakage shall not be more than 0.3% of the rated flow of the turbine when the new non-tapered guide blade is fully closed.

- b) The new nozzles of the Pelton, inclined-jet and cross-flow turbines shall not leak water when they are fully closed.

8.6 The cavitation of the turbine shall meet the relevant requirements of IEC 60609-1 or IEC 60609-2.

