



UNITED NATIONS  
INDUSTRIAL DEVELOPMENT ORGANIZATION



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

**Part 2: Operation and  
Maintenance**

SHP/TG 005-2: 2019



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## ACKNOWLEDGEMENTS

The technical guidelines (TGs) are the result of a collaborative effort between the United Nations Industrial Development Organization (UNIDO) and the International Network on Small Hydro Power (INSHP). About 80 international experts and 40 international agencies were involved in the document's preparation and peer review, and they provided concrete comments and suggestions to make the TGs professional and applicable.

UNIDO and the INSHP highly appreciate the contributions provided during the development of these guidelines and in particular those delivered by the following international organizations:

- The Common Market for Eastern and Southern Africa (COMESA)
- The Global Network of Regional Sustainable Energy Centres (GN-SEC), particularly the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), the East African Centre for Renewable Energy and Energy Efficiency (EACREEE), the Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE) and the Caribbean Centre for Renewable Energy and Energy Efficiency (CCREEE).

The Chinese government has facilitated the finalization of these guidelines and was of great importance to its completion.

The development of these guidelines benefited greatly from the valuable inputs, review and constructive comments as well as contributions received from Mr. Adnan Ahmed Shawky Atwa, Mr. Adoyi John Ochigbo, Mr. Arun Kumar, Mr. Atul Sarthak, Mr. Bassey Edet Nkposong, Mr. Bernardo Cazadilla-Sarmiento, Ms. Chang Fangyuan, Mr. Chen Changjun, Ms. Chen Hongying, Mr. Chen Xiaodong, Ms. Chen Yan, Ms. Chen Yueqing, Ms. Cheng Xialei, Ms. Chileshe Kapaya Matantilo, Ms. Chileshe Mpundu Kapwepwe, Mr. Deogratias Kamweya, Mr. Dolwin Khan, Mr. Dong Guofeng, Mr. Ejaz Hussain Butt, Ms. Eva Kremere, Ms. Fang Lin, Mr. Fu Liangliang, Mr. Garaio Donald Gafiye, Mr. Guei Guillaume Fulbert Kouhie, Mr. Guo Chenguang, Mr. Guo Hongyou, Mr. Harold John Annegam, Ms. Hou ling, Mr. Hu Jianwei, Ms. Hu Xiaobo, Mr. Hu Yunchu, Mr. Huang Haiyang, Mr. Huang Zhengmin, Ms. Januka Gyawali, Mr. Jiang Songkun, Mr. K. M. Dharesan Unnithan, Mr. Kipyego Cheluget, Mr. Kolade Esan, Mr. Lamyser Castellanos Rigoberto, Mr. Li Zhiwu, Ms. Li Hui, Mr. Li Xiaoyong, Ms. Li Jingjing, Ms. Li Sa, Mr. Li Zhenggui, Ms. Liang Hong, Mr. Liang Yong, Mr. Lin Xuxin, Mr. Liu Deyou, Mr. Liu Heng, Mr. Louis Philippe Jacques Tavernier, Ms. Lu Xiaoyan, Mr. Lv Jianping, Mr. Manuel Mattiat, Mr. Martin Lugmayr, Mr. Mohamedain SeifElnasr, Mr. Mundia Simainga, Mr. Mukayi Musarurwa, Mr. Olumide TaiwoAlade, Mr. Ou Chuanqi, Ms. Pan Meiting, Mr. Pan Weiping, Mr. Ralf Steffen Kaeser, Mr. Rudolf Hüpfel, Mr. Rui Jun, Mr. Rao Dayi, Mr. Sandeep Kher, Mr. Sergio Armando Trelles Jasso, Mr. Sindiso Ngwenga, Mr. Sidney Kilmete, Ms. Sitraka Zarasoa Rakotomahefa, Mr. Shang Zhihong, Mr. Shen Cunke, Mr. Shi Rongqing, Ms. Sanja Komadina, Mr. Tareqemtairah, Mr. Tokihiko Fujimoto, Mr. Tovoniaina Ramanantsoa Andriampaniry, Mr. Tan Xiangqing, Mr. Tong Leyi, Mr. Wang Xinliang, Mr. Wang Fuyun, Mr. Wang Baolu, Mr. Wei Jianghui, Mr. Wu Cong, Ms. Xie Lihua, Mr. Xiong Jie, Ms. Xu Jie, Ms. Xu Xiaoyan, Mr. Xu Wei, Mr. Yohane Mukabe, Mr. Yan Wenjiao, Mr. Yang Weijun, Ms. Yan Li, Mr. Yao Shenghong, Mr. Zeng Jingnian, Mr. Zhao Guojun, Mr. Zhang Min, Mr. Zhang Liansheng, Mr. Zhang Zhenzhong, Mr. Zhang Xiaowen, Ms. Zhang Yingnan, Mr. Zheng Liang, Mr. Mr. Zheng Yu, Mr. Zhou Shuhua, Ms. Zhu Mingjuan.

Further recommendations and suggestions for application for the update would be highly welcome.

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## Foreword

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

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

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

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

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

## Introduction

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

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

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

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



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

## Part 2: Operation and Maintenance

### 1 Scope

This Part of the Management Guidelines specifies the basic management requirements for the operation and maintenance of an small hydropower (SHP) SHP station as well as the specific requirements for the operation and maintenance of a hydraulic structure, hydro mechanical works and electrical and mechanical equipment.

### 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.

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 Basic Requirements

#### 4.1 Operation management

4.1.1 Operation management procedures of the hydropower station shall be formulated according to the actual situation and be strictly implemented.

4.1.2 The operator on duty shall strictly perform his responsibilities, and carry out the operation and maintenance of the plant. Operation engineer shall be responsible for the daily management of shifts and the implementation of the daily maintenance schedule.

4.1.3 The operator on duty shall carefully review the work permit and operating permit, and shall return them for archiving in a timely manner at the end of the work.

4.1.4 The operator on duty shall inspect the operating equipment at fixed times and fixed locations on the inspection route according to the requirements of the equipment inspection system.

4.1.5 Any defects in the equipment found by the operator on duty shall be handled according to the requirements of the equipment defect management system. The annual equipment defects elimination rate shall reach 100%.

4.1.6 The operators shall strictly change shifts in accordance with shift regulations for shifting of duties. If any accident happens or the operation is abnormal during the shifting of duties, the shift change shall be immediately stopped; the operator on duty shall organize relevant personnel to handle the abnormal condition, and the relieving personnel shall provide assistance under the instructions of the operator on duty.

4.1.7 Hydropower station operation equipment should be clearly marked with the name, number and colour listed. The mark should be fixed at a visible place during operation.

4.1.8 The control room of the hydropower station shall have the safety manual, operation manual, and maintenance manual, and the water regulation manual and specifications for all the major equipment and a set of important drawings, and these shall be regularly updated.

4.1.9 The following charts and diagrams should be hung in the hydropower station:

- a) Analog board of the main single line electrical diagram;
- b) Message board for safe operation;
- c) Diagram of the oil, compressed air and cooling water system;
- d) Turbine operating characteristic curve;
- e) Route map for daily inspection of the plant;
- f) Layout of the escape routes and firefighting equipment.

4.1.10 The following tables and charts shall be available at the hydropower station:

- a) Parameters of the main equipment;
- b) List of persons in charge, the personnel with the authority to sign and issue work permits and operation permits;

- c) Table of outputs of the relay protection and automatic device;
- d) Table of the normal shut down and emergency shutdown operation sequence;
- e) List of contacts for reporting during an emergency.

4.1.11 The following records shall be kept for the hydropower station:

- a) Shift check schedule;
- b) Shift operation record (log sheets);
- c) Equipment defects and handling record;
- d) Key movement record;
- e) Circuit breaker on/off record;
- f) Tripping of circuit breaker analysis record;
- g) Test record of the storage battery and battery chargers;
- h) Instruction Record;
- i) Start/stop record for the turbine generator unit;
- j) Inspection and test record for the electrical insulating tools and safety appliances;
- k) Work record of the safety activities;
- l) Equipment overhaul and testing record;
- m) Safety and fire drill (Anti-accident exercise) record;
- n) Equipment accident handling record;
- o) Inspection record for the hydraulic structures;
- p) Action record of the automatic device failures of the turbine generator unit;
- q) Action record of the relay protection and automatic device of the circuit breaker;
- r) Commissioning record for the relay protection and the automatic device;

- s) Record of the tools and spare parts;
- t) Record of visitors;
- u) Technical examination record of the operating personnel.

4.1.12 The hydropower station shall be provided with the following management systems, which shall be regularly revised to ensure that the systems are efficient and instructive:

- a) Work permit system;
- b) Operating permit system;
- c) Shift relief system;
- d) Equipment walk-around of the inspection system;
- e) Operation on duty system;
- f) Equipment defect management system;
- g) Normal start-up, synchronization and shut down system for the plant equipment;
- h) Equipment overhaul management system;
- i) Management system for equipment acceptance;
- j) Management system for the hydraulic structures;
- k) Equipment and facility defects and handling management system;
- l) Management system for spare parts;
- m) Safety management system;
- n) Management system for flood control and emergency;
- o) Management system for the emergency equipment;
- p) Management system for firefighting;
- q) Management system for equipment and facility grading;

- r) Other management systems applicable to this station.

## 4.2 Safety management

4.2.1 The work permit and operating permit system shall be strictly implemented. The implementation rate for the work permit and operating permit should be 100%.

4.2.2 The accidents shall be reported in a timely manner, and classified into different grades according to the relevant provisions.

4.2.3 The safety management shall comply with the following requirements:

- a) Flood fighting plan and the emergency response plan shall be prepared and implemented accordingly.
- b) The roads in the plant area shall be kept clean and obstruction-free to meet the flood fighting requirement.

4.2.4 The anti-accident measures shall comply with the following requirements:

- a) Anti-accident organizational measures and technical measures shall be prepared and implemented. Periodic inspections must be carried out to ensure that these are being meticulously implemented.
- b) Anti-accident exercises shall be organized periodically, and the exercises shall be recorded.

4.2.5 Firefighting and safety management of the hydropower station shall meet the following requirements:

- a) Firefighting and safety measures shall be provided as per the regulations of the country. The person in charge of the firefighting and safety system must be trained as per regulations and experienced and shall be responsible for taking action in emergencies as well as ensuring that the proper preventive safety plan is being implemented to avoid such an occurrence.
- b) various types of firefighting equipment shall be placed at the suitable positions as per the plan prepared by experts and be periodically inspected.
- c) Inflammables and explosives shall be stored according to the provisions. Use of flammables and explosives is to be carried out as per the provisions and with the utmost care, if necessary, in the operational area and shall be immediately withdrawn at the end of the work.
- d) The operators and the other staff on duty shall be familiar and proficient in the use of the firefighting equipment.

- e) Safety and security work shall be properly carried out, and the fire alarm system shall be periodically inspected.

**4.2.6** The management of the safety tools and equipment for the hydropower station shall comply with the following requirements:

- a) The safety tools should be placed in special cabinets by number and the management personnel should be confirmed.
- b) The safety tools and equipment shall be periodically tested and shall not be used beyond their service life.
- c) The safety tools and equipment shall be carefully inspected before use, and shall not be used if they are damaged.

**4.2.7** Safety inspection and grading shall be carried out for the equipment and facilities in the hydropower station according to the provisions. The perfectness ratio of the equipment and facilities shall reach 100%; the percentage of equipment and facilities with a perfectness ratio that reaches Grade I standard shall not be less than 80%; see Appendix A.

### **4.3 Overhaul and maintenance management**

**4.3.1** An overhaul plan shall be formulated in accordance with the manufacturer's requirements and the equipment's operating situation in the hydropower station. The overhaul shall be carried out according to the plan, and the gradual transition from periodic overhaul to condition-based maintenance shall be realized.

**4.3.2** The overhaul period shall be reasonably arranged according to the availability of water inflow and the operating mode of the power grid and should be preferably arranged during the dry season.

**4.3.3** The equipment in the hydropower station shall be overhauled by professional technical personnel and with advanced tools/devices equipment overhaul and maintenance specifications or overhaul guidelines shall be prepared for the hydropower station. In the equipment overhaul process, the quality control points for the key working procedures shall be identified and implemented.

**4.3.4** Periodic overhaul shall comply with the following requirements:

- a) Periodic overhaul plan shall be prepared in accordance with the requirements of the manufacturer and the operating situation of the equipment.
- b) Periodic overhaul could generally be divided into routine inspection with minor repairs, say daily checks, weekly inspection, and monthly inspection, quarterly and half yearly inspections; annual inspection and overhaul; capital or major overhaul; renovation and modernization.

- c) Prior to overhaul, it is necessary to examine the operating equipment on site, fully acknowledge the existing problems and analyse the causes and prepare the overall plan to provide the basis for the overhaul.
- d) Periodic overhaul shall be identified by specific category, the overhaul process flow shall be prepared and then be implemented after being approved by the competent authority.
- e) Overhaul quality shall comply with the requirements of the relevant specifications.
- f) The overhauled equipment shall be inspected and tested, and put into operation after it passes the acceptance inspections.
- g) Technical data relevant to the overhaul, inspection and tests shall be properly recorded and archived.

**4.3.5** The emergency repair shall comply with the following requirements:

- a) Emergency repair mechanisms and emergency response mechanisms shall be established and implemented to ensure that the emergency repair and restoration could be rapidly organized when accidents happen to the equipment and facilities in the hydropower station.
- b) Emergency repair plan for typical accidents and breakdowns shall be formulated according to the practical circumstance, and should be submitted to the competent authority for review and approval. Upon approval of the emergency repair plan for typical accidents and breakdowns, the emergency repair work shall be assigned to some competent agency as per the rules and regulations and the agency's responsibilities shall be clearly defined.
- c) The tools, devices and illumination equipment used for the emergency repair shall be kept and maintained at the power station, and shall be periodically inspected and tested.

**4.4 On-the-job training management**

**4.4.1** On-the-job training management shall comply with the following requirements:

- a) Annual training plans shall be formulated. The training programme shall be implemented under the supervision of the station head or the professional agency.
- b) The employees shall be organized to receive professional technical training and learn the relevant specifications for the plant equipment, operational procedures, safety related issues, hands on training in handling the fire-fighting equipment and other relevant work practices.
- c) If possible, the operating and maintenance personnel must be trained on the Real Time Digital Simulator whenever it is possible in order to have hands-on training for the operation of the

plant equipment and handling abnormal conditions during plant operation.

- d) Concerned personnel shall be trained before using the new equipment, new technologies and new processes. The operation and maintenance personnel shall receive comprehensive training for the optimal performance of the plant and equipment of the hydropower station at least once a year.

**4.4.2** The personnel training shall meet the following requirements:

- a) Acquire knowledge of the working condition of the plant and equipment.
- b) Acquire knowledge of the technical parameters and layout of the plant and equipment.
- c) Acquire knowledge of the wiring and operating modes of the primary and secondary electrical equipment.
- d) Acquire knowledge of the layout and operating modes of the oil, air and water systems.
- e) Acquire knowledge of the equipment maintenance, overhaul technologies and safety requirements.
- f) Acquire knowledge of the switching operation method and precautions.
- g) Acquire knowledge of the operation, maintenance, overhaul technologies and safety requirements of the hydraulic structure and hydro mechanical equipment.
- h) Acquire knowledge of the emergency plan for accidents, emergencies, natural calamities and the tasks to be executed.
- i) Acquire knowledge of the safe operation of the plant and equipment and the relevant management systems.
- j) Acquire knowledge of the procedures for the overhauling, testing and setting of the control and relay protection system.
- k) Acquire knowledge of the hydro mechanical equipment, and its operating procedures.
- l) Acquire the capability of analysing and judging the condition of the equipment according to the operational situation and inspection results. Acquire the capability of analysing equipment defects and taking remedial measures.
- m) Acquire the capability of correctly judging the cause of the failure or accident according to the instrument, signal indication and abnormal situation of the equipment, and responding rapidly



and properly.

#### 4.5 Archive management

4.5.1 Archive management systems shall be established and implemented at the hydropower station. All kinds of operation, maintenance, overhaul, inspection records, test reports and other technical data shall be sorted and analysed in a timely manner, and shall be archived in a timely manner. All records regarding abnormal operating conditions, failure of equipment, accidents, emergencies and natural calamities shall be archived in a time manner.

4.5.2 The archives management shall comply with the following requirements:

- a) The archives shall be stored in a dedicated room and file cabinet; the archives room shall satisfy the requirements for archive management.
- b) The archives shall be arranged, and stored as per the classification; the archives shall be inspected annually by the station head.
- c) When the archives are managed by computer, the backup archives shall also be kept.

4.5.3 The following technical archives and data shall be provided:

- a) Design reports and a complete set of drawings.
- b) Completion report of the construction work and a complete set of as-built drawings.
- c) Specifications, drawings and quality certificates for the equipment.
- d) Equipment installation drawings, installation records and relevant data.
- e) Commissioning test report and relevant data.
- f) Preventive maintenance and test report for the electrical equipment over the years.
- g) Equipment defect management archives.
- h) Equipment preventive maintenance, overhaul, capital maintenance, renovation and modernization records and test reports.
- i) Specific analysis reports on equipment accidents, failures and operation.
- j) Classified report on safety management over the years.

- k) Observation and analysis report on the water diversion structure, intake structure and the water conductor system over the years.
- l) Hydrological and flood observation data over the years.
- m) Training and examination data of the operating personnel.

#### **4.6 Civilized production management**

**4.6.1** The plant area shall be properly afforested and beautified, the pavement in the plant area shall be level, the illumination lamps shall be complete and intact, the water drainage shall be unobstructed and the retaining walls shall be intact and free from weeds.

**4.6.2** Enclosures or fences shall be erected for the switchyard and warning signs shall be erected. The inspection accesses shall be clean and unobstructed, the equipment marks shall be clear and the names shall be accurate.

**4.6.3** The plant shall be neat and free from water leakage; the doors and windows shall be intact and the equipment shall be clean.

**4.6.4** The tools, data, books and records shall be kept in the dedicated cabinets or stored on the dedicated stacks as per their classification, and shall be neatly placed.

**4.6.5** The charts shall be neatly hung, and all the kinds of panels, cabinets and desks shall be clean and intact.

**4.6.6** The cable ducts shall be clean, and the cover plates shall be complete and intact.

**4.6.7** The activities that are irrelevant to production shall be barred at important places such as the control room and the machinery hall.

**4.6.8** The operator on duty shall be dressed in a uniform, and wear on-duty marks. It is strictly prohibited to wear slippers, high-heeled shoes or skirts on duty. The operators with long hair shall put their hair up and wear work caps.

**4.6.9** The poultry and livestock shall not be raised in the plant area.

## **5 Hydraulic structures**

### **5.1 Diversion structures**

**5.1.1** Safety assessments of the structures shall be carried out regularly.

5.1.2 The items to be monitored and the number of times the various measurements are to be taken shall meet the design requirements. The results shall be promptly analysed and recorded in the files.

5.1.3 Hydraulic structures shall be regularly inspected and checked for defects by staff. The record of inspections and checking shall be maintained for identification of problems and timely remedial measures.

5.1.4 The inspection for the diversion structures shall include the following:

- a) Check whether the release structure has cracks, leakage, or seepage and whether the dam foundation has abnormal leakage or unusual displacement.
- b) Check whether the earth and rockfill dam slope is stable, the dam crest and slope are smooth, and whether cracks, sinking, bulges, ants' nests or animal burrows that affect the structural stability or seepage flow safety exist; whether the slope surface has complete slope protection and whether it has partial deficiencies like looseness, sinking or slumping, cushion slippage or hollow slope protection; whether the downstream surface and the dam toe have leakage pools, sinking areas, piping, abnormal plant growth and backwashing; whether the seepage water is muddy.
- c) Check whether the concrete dam body has denudation, abrasion or water seepage, the adjacent monoliths have unequal settlement; the expansion joints and sealing work normally, any cracks that affect the structure or seepage safety and whether the changes in uplift pressures are normal.
- d) Check whether the overflow structure is intact, the flood-relief channels are broken, whether abnormal cracks, settlements and water seepage exist on the base plates and side walls of flood spillways and tunnels, the side walls and their inner surfaces, and whether the energy dissipation devices are damaged.
- e) Check whether the auxiliary facilities of the water retaining/release structures are intact and work normally.

5.1.5 Maintenance for the diversion structures shall be implemented based on the relevant rules. The maintenance shall meet the following requirements:

- a) Dam crest, slope, parapet and observation facilities shall be intact; drains shall be cleaned frequently in order to keep them clear.
- b) Materials shall not be stacked on the dam crest, slope or berm. The dam surface shall not be used as a transfer dock, and the crest, slope and dam toe shall not be used as water conduits.
- c) On the dam and in the upstream and downstream range that may affect the project safety, activ-

ities that are harmful to the project including digging pits, building fish ponds and drilling wells shall be forbidden.

- d) On the dam surface, there shall be no plants and crops, grazing, and spade turf, and no removal of the sand and stones used for slope protection and the seepage diversion facilities.
- e) Erosion and scouring of the dam surface by rainwater shall be avoided; filtering facilities of the dam body and pressure relieving devices behind the dam shall be maintained in order to ensure normal operation.
- f) For silt-laden water, the reservoir flushing facilities shall be opened regularly; for cold areas, ice prevention measures shall be undertaken.
- g) The concrete weirs with hydraulic self-acting flap gates shall not only meet the relevant requirements for concrete dams, but also have to ensure the smooth opening and closing of the flap gates.
- h) The deflating devices of rubber dams shall be safe and reliable; the dam bag shall be intact and shall meet the requirements for flood discharging. Electromechanical devices and water (air) filling pipes shall work properly.
- i) The structure of the discharge structures is intact. If the base plates and side walls have abnormal cracks, settlement and water seepage, and if the energy dissipation facilities are destroyed, discharging shall be stopped to allow for emergency repairs. For those that cannot temporarily meet the conditions, an alternative discharging scheme shall be used in order to prevent accidents and create conditions for emergency repair.
- j) Discharge structures shall keep their discharge conduits clear. During discharging periods, upstream drift material shall be promptly salvaged and wooden rafts and shipping shall be strictly forbidden from getting close to the entrance of the structures.
- k) The auxiliary facilities of the discharge structures shall be in normal operation. The discharging sluice and valve shall be intact with normal hoisting and reliable operating power.
- l) If retaining structures have any dangerous defects such as abnormal cracks, distortion or water seepage, these shall be dealt with promptly.

## 5.2 Intake structures

5.2.1 The lowest operational water level (forebay level) of the pressure intakes shall be maintained to meet the submerged depth requirements of the intake.

5.2.2 Maintenance for the intake structures shall meet the following requirements:

- a) The side slope of the intake (outlet) shall be stable.
- b) The air vent of the intake shall be kept unobstructed.
- c) The hoisting chamber shall be free of debris.

### 5.3 Water conductor system( tunnel, open channel or combination of both)

5.3.1 The water conductor system structures shall be regularly inspected, especially during the rainy season for hill side slopes that easily give rise to geological hazards. Checking and inspection shall have the following requirements. Any identified problem should be processed in a timely manner.

- a) Check whether the tunnel has cracks, distortion, leakage, erosion, abrasion, cavitation, carbonization, loss of sealing filling, or other phenomena. Check whether the unlined tunnel has serious rockfall or water seepage and whether the lined tunnel has serious concrete spalling or water seepage. Check whether instability or water seepage occurs on the slope at the tunnel intake (outlet).
- b) Check whether heavy materials are stacked at the top of the open-air culvert or non-pressure tunnel where the top rock thickness is less than three times the tunnel diameter.
- c) Check whether the canal main body and side slopes are stable and whether soil-rock collapse or bank failure occurs. Check whether silt deposits exists inside the canal and whether the canal surface has abrasion, liner damage or serious water seepage.
- d) Check whether the aqueduct body and piers are stable and whether any tilting, cracks, damage or serious water seepage exist on them.
- e) Check whether the surge tank has uneven settlement, seepage, cracks, serious weathered abrasion, and damaged linings. Check whether the surge tank (tower) with cover ventilates smoothly.
- f) Check whether the base plate of the pressure forebay, overflow weir and retaining wall have distortion, water seepage or side slope collapse. Check whether the overflow and drainage facilities and sand flush openings are intact.

5.3.2 Maintenance and repair of the water conductor system structures shall meet the following requirements:

- a) The auxiliary facilities of the surge chamber shall be secure; the water level observation facilities shall be normal and reliable.

- b) The tunnel shall be emptied for inspection and overhaul as well as regularly cleared under expert supervision and as per regulations.
- c) The average flow velocity of the channel under design flow shall not exceed the permissible velocity for the facing materials; the velocities in the channel shall meet the requirements for no deposits or no scouring under sediment-laden conditions.
- d) If the aqueduct has been damaged, has cracks, erosion or aged sealing, it shall be restored or refurbished. If the base of the pipe has cracks or distortion, it shall be repaired or reinforced.
- e) If the water conductor system structures have breaches and water leakage that affect the mountain stability, they shall be promptly dealt with.

#### **5.4 Powerhouse and substation(or switchyard)**

**5.4.1** The powerhouse and substation(or switchyard) shall be regularly inspected. The inspection shall comply with the following requirements. Any identified problem should be processed in a timely manner.

- a) Check whether the powerhouse structures and their ancillary facilities are intact.
- b) Check regularly whether the concrete beams, plates and pillars of the powerhouse have cracks and whether the cracks develop. Check whether the concrete pedestals for the turbine generator unit have cracks or are damaged.
- c) Check whether the hill slopes behind the powerhouse are stable or whether they collapse.
- d) Check whether the booster station base and structure are stable.

**5.4.2** Maintenance and repair of the powerhouse and substation(or switchyard) shall comply with the relevant rules. They shall meet the following requirements:

- a) If the components of the powerhouse have serious distortion, damage, cracks or water seepage which threaten the safety of the staff and equipment, and the mountain has signs of a landslide, it shall be promptly dealt with.
- b) If the flood control criteria of the powerhouse do not meet the requirements, engineering measures shall be adopted to promptly solve the problems.

## **6 Hydro mechanical works**

### **6.1 Penstock**

**6.1.1** The penstock shall meet the following requirements:

- a) The inner surface of the penstock shall be provided with anti-corrosive coating having even thickness.
- b) It shall be ensured that the penstock is free from distortion, cracks or water seepage.
- c) It shall be ensured that the penstock glides freely along the axis in the expansion joint.
- d) The manhole and the penstock expansion joints shall have the desired compression so that they remain leak-proof.
- e) The penstock shall be regularly inspected.
- f) The saddle supports and anchors for the penstock shall be intact and stable and without cracks, damage, displacement or settlement.

**6.1.2** Maintenance of the penstocks shall satisfy the following requirements:

- a) The surface of the penstock shall receive anti-corrosive treatment regularly.
- b) If there is any corrosion, cracking or instability, it shall be promptly repaired or replaced.
- c) If the gap between the buried pipe and the concrete as well as the rock, jointly bear the internal pressure increases, then grouting of the joints shall be carried out to treat the problem.
- d) Dampening measures shall be adopted if the exposed pipe is vibrating.

## **6.2 Gates and hoists**

**6.2.1** Normal operation of the gate shall meet the following requirements:

- a) The gate shall be stable and reliable, and no distortion or corrosion, the seals shall be intact, the pulleys shall be in smooth working order and all the bearings, bushings and ropes shall be duly greased.
- b) If the main components of the gate including the boarding, girder and edge beam and the radial gate arms have corrosion, a structural inspection shall be promptly carried out, the strength and hardness shall be checked and remedial measures promptly taken.
- c) Buried components of the gate shall be inspected regularly; those with seriously eroded tracks or over 2 mm of un-repairable joint dislocation or that are seriously corroded shall be replaced. If over 30% of the gate components need to be replaced, the entire gate shall be scrapped and replaced.

**6.2.2** Normal operation of the lifting device shall meet the following requirements:

- a) The lifting device shall have reliable standby power.
- b) The electrical operating devices and ancillary facilities of the lifting device shall be safe and reliable.
- c) Outdoor lifting devices shall have protection covers installed and the electrical operating devices shall be locked.
- d) The wire ropes of the gate lifting device shall not have distortion, collapse, aberration and broken strands. The wire, strand and core of wire ropes shall not be squeezed out. The wire ropes shall be kept lubricated.
- e) The operation of the hoist shall be safe and reliable.
- f) The noise level of the hydraulic lifting device shall not be over 85 dB .
- g) Electrical screw lifting devices shall have reliable electrical and mechanical over-load safety protection devices.
- h) Both electrical and manual operative screw lifting devices or manual screw lifting devices shall have safety shaft handles installed; when the manual device of the electrical-manual operative lifting device is connected to the machine, it shall have safety measures that can switch off the entire electrical circuit.

**6.2.3 Maintenance of the gate shall satisfy the following requirements:**

- a) Regular clearing of aquatic growth, weed and filth on the gate and gate slot.
- b) Keeping the rotating components of the gate lubricated.
- c) Fastened joints shall be reliable without sloughing.
- d) During the frozen season in cold areas, measures shall be adopted to avoid or decrease the ice load on the gate.
- e) Replacing of worn out, ripped and aged water seals in a timely manner.
- f) Regular greasing and replacing of the broken bearing/bushes of the gate wheels.

**6.2.4 Maintenance of the lifting device shall meet the following requirements:**

- a) Electrical portion of the lifting device shall be kept in good condition all the time.



- b) Regularly inspection and maintenance of the decelerator and gears and regular filtering and replacing of the hydraulic oil shall be ensured.
- c) Braking wheels and the brake scotches surfaces shall be kept clean and the brake shoe gap shall be kept normal. Worn brake scotches shall be promptly replaced.
- d) If the setting values of the variable pump, overflow valve and pressure gauge are abnormal, they shall be reset.
- e) Wire ropes and pulley blocks shall be oiled frequently for corrosion protection.
- f) Height indicators and load limiters shall be checked and reset regularly.

### 6.3 Trashrack

6.3.1 Trash facilities of the intake shall be safe and reliable.

6.3.2 Trash facilities should ensure an adequate overflow area. Silt and dirt should be removed in a timely manner.

## 7 Electro-mechanical equipment

### 7.1 Turbine

7.1.1 The following requirements shall be met for normal operation of the turbines:

- a) Turbines shall operate continuously and for long periods according to the relevant design parameters.
- b) Turbines shall not be run when the bearing oil temperature is lower than 5 °C. Cooling water supply shall be stopped when the bearing/governor oil temperature is lower than 10 °C.
- c) The temperature of the thrust bearings using metal bushings should not exceed 60 °C (maximum limit is 70 °C). An alarm is set at 65 °C, and the tripping of the unit is set at 70 °C. The temperature of thrust bearings using elastic metallic plastic bushings should not exceed 55 °C.
- d) There shall be normal operation of the bearing cooling water, without leakage of the water, and no abnormal noise. The cooling water temperature should be within 5 °C to 30 °C, and the cooling water pressure should be within 0.15 MPa to 0.3 MPa.
- e) When a turbine generator unit is shut down, the oil level in various the bearings shall be ensured to be normal and the oil quality shall meet the required standard.

- f) There shall be normal operation of the guide vanes, guide vane linkages and shearing pins.
- g) There shall be no serious water leakage in the main shaft sealing and shaft-sleeves of the guide vanes.
- h) There shall be no leaking and clogging in the oil, air and water pipes.
- i) There shall be normal operation of the vacuum valve.
- j) Runout and vibration values of all the turbine generator unit components shall be kept within the allowable range.
- k) The governor should be kept in automatic control operation mode. Manual control is to be adopted if special conditions occur such as unstable working or malfunctioning of the governing system.
- l) Operation shall be prohibited under the following conditions:
  - 1) Excessive fluctuation of the up-stream and down-stream water levels or under excessive pulsating pressure in the draft tube.
  - 2) Excessive runout and vibration of turbine generator unit components and the shearing pin is broken.
  - 3) Oil pressure of the oil pressure units drops to the value set for low oil pressure due to malfunctioning.
- m) For a turbine generator unit with a regulating valve, the coordinated motion of the regulating valve and the governor should function normally.
- n) It is to be ensured that all the instrument meters show correct indications.
- o) Checking and recording of the turbine generator unit operating conditions should be done on hourly basis.
- p) Hot standby units shall be regularly inspected as operating units. Irrelevant operations should not be carried out.

7.1.2 The following requirements shall be met for normal starting operation of turbines.

- a) Reaction turbine:
  - 1) Ensure that the opening and closing of the guide vanes is normal and the air release valve of

the spiral case functions normally.

- 2) Ensure that the water leakage from the guide vanes in the closed position is within the limits and shall not hinder normal shutdown of the turbine generator unit.
- 3) Ensure that the opening and closing of the runner blades of the Kaplan turbine is as per the Alpha-Beta setting.

b) Impulse turbine:

- 1) Ensure that there is no water leakage in the needle in the fully-closed position. For a turbine with a nozzle air release valve, ensure that the nozzle air release is working normally during start-up of the turbine generator unit.
- 2) Ensure that the deflector is working normally, and is positioned accurately.
- 3) Ensure that the brake sub-nozzle is working normally.

**7.1.3** To start the turbine generator unit, the following criteria shall be met:

- a) Ensure that the main valve is fully-open, the regulating valve is fully-closed and the penstock is full.
- b) Ensure that the governor is in the fully-closed position and is locked; oil pressure in pressure accumulator is normal and the power source for the oil pump is switched on.
- c) Ensure that the oil level of all the bearings of the turbine generator unit is normal and that the oil colour is normal and there is no oil leakage.
- d) Ensure that the electric protection, mechanical protection and A.C/D.C operating power sources are functioning normally.
- e) Ensure that the electrical system is normal and ready to be put into operation.
- f) Ensure that the brake device of the turbine generator unit is functioning normally and is at its closing position.

**7.1.4** The following inspections should be carried out for newly-installed turbine generator units or units that are put into operations after maintenance, and all work permits should be returned. New units can be put into trial operation after being inspected and when it is ensured that there are no persons working inside the turbine generator unit.

- a) Ensure that there shall be no debris in the water conductor system and the flow passages inclu-

ding the penstock, spiral case and air pipe.

- b) Ensure that the brake device works normally and is in its closing position.
- c) Ensure that the guide vane mechanism is normal, with no damage to the guide vanes or loose shearing pins.
- d) Ensure that no debris or tools shall be left inside the generator; the spring pressure of the carbon brush in the collecting ring shall be normal without blocking and loosening conditions.
- e) Ensure that the automation device of the turbine generator unit shall be normal.
- f) Ensure that all the sealing devices of the turbine shall be in good order.
- g) Ensure that the operating mechanism of the turbine's main valve, regulating valve and stroke switch shall work normally.
- h) Ensure that the oil, air and water systems shall be normal.
- i) Ensure that the governor shall function normally.
- j) Security isolation fences around the unit should be removed.
- k) Ensure that the rotor jacking up work shall be completed.
- l) Ensure that all the electrical tests, turbine generator unit over speed and load rejection tests are done and comply with the relevant standards and are recorded as per the norms.
- m) Ensure that for newly-installed turbine generator units 72-hour of continuous full load test run shall be done. If due to the non-availability of sufficient discharge or grid problems, the turbine generator unit is unable to take up its rated load then the 72-hour continuous operation test shall be carried out under as large a load as possible according to the conditions at that time.

**7.1.5** For maintenance and fault treatment of the turbine, the following requirements shall be satisfied:

- a) Regular inspection and maintenance of the turbine shall include the following operations:
  - 1) Measuring and recording of the turbine's main shaft swing, shaft voltage and the shaft current of the turbine generator unit;

- 2) Switching of the auxiliary equipment and accessory system between the main and stand-by systems;
  - 3) Filling or changing of the lubricating oil and lubricating grease according to the oil usage conditions of the various bearings and lubricated parts;
  - 4) Inspection and adjustment of the main shaft sealing gap to an appropriate intermediate value, and inspection of the water quality of the sealing water;
  - 5) Cleaning and back flushing of the filter for clean water supply;
  - 6) Water release and dirt draining for all the air and water separators;
  - 7) Inspection of the guide vane opening for evenness and checking of the vertical side and end side gaps;
  - 8) Inspection and checking of the turbine labyrinth gap;
  - 9) Jacking up of the rotor once prior to restarting the turbine generator units for a 72 hours shut down. For thrust bearings using elastic metallic plastic bushings, starting of the turbine generator unit without jacking up of the rotor by high pressure oil is allowable.
  - 10) Regular cleaning of the surfaces of the equipment should be ensured.
- b) Maintenance and treatment of the turbines under operation shall satisfy the following requirements:
- 1) If there is abnormal noise during turbine operation, then the turbine generator unit shall be shut down for inspection;
  - 2) When over speed occurs, the guide vanes shall be closed immediately to find the cause of the same and relevant maintenance and remedial measures shall be taken;
  - 3) When the guide vane shearing pin is sheared, the turbine generator unit shall be stopped and the shearing pin changed;
  - 4) When the bearing temperature rises abnormally, checks are to be carried out for oil leakage in all parts, the oil level being normal, oil colour being normal, and the water supply for the bearing being normal, any increase in turbine generator unit vibration, swing or abnormal noise inside the bearings. Regular bearing temperature monitoring shall be done. If the problem still persists, the machine should be shut down for detailed checking and for taking re-

medial measures;

- 5) If the bearing bushing temperature exceeds 65 °C and continues to rise after being processed, the turbine generator unit should be shut down for inspection;
- 6) When the oil level in the bearing drops, the turbine generator unit shall be immediately shut down and the relevant measures taken;
- 7) When water leakage occurs in the bearing cooler, the turbine generator unit shall be immediately shut down for changing or repairing the cooler, and a pressure test shall be carried out;
- 8) When the cooling water in the bearing is blocked or stopped, the turbine generator unit shall be shut down and an inspection carried out;
- 9) When the vibration and swing value exceed the allowable values, the unit shall be shut down to check for the cause of the problem;
- 10) If the unit without braking device, it shall be renovated. The manual braking method using wood pad or stick shall not be adopted;
- 11) Other faults that could possibly endanger personal and equipment safety shall be dealt with.

## 7.2 Generator

7.2.1 The following requirements shall be met for normal operation of the generator:

- a) The generator should be operated continuously for a long duration, the operating parameters should be kept within the prescribed limits set by the manufacturer.
- b) The air temperature for air-cooled generators should be within the prescribed limits. Air shall be clean, dry and non-corrosive.
- c) The highest allowable temperature rise and temperature of the stator winding, rotor winding and iron core shall not exceed the manufacturer's specifications.
- d) Voltage fluctuation under constant power output is less than  $\pm 5\%$  of rated value, with the maximum not exceeding  $\pm 10\%$  of the rated value and the excitation current then shall not exceed the rated value. Minimum operating voltage is determined by the requirements for power grid stability and should not be lower than 90% of the rated value, and the stator current then shall still not exceed 105% of the rated value.

- e) When the frequency fluctuations do not exceed  $\pm 0.5\text{Hz}$ , operation may take place under the rated capacity. Rotor current shall not exceed the rated value when the frequency is less than 49.5 Hz. The frequency fluctuation range of the turbine generator unit may be extended as appropriate for isolated small power grids.
- f) Incomplete phase operation shall not be allowed. Under fault conditions, short time over-current is allowed. The limits of over current of the stator winding and its corresponding allowable time duration shall be maintained as per the manufacturer's instructions and the occurrence of over-current lasting for the allowable time duration should not exceed 2 times a year.
- g) During operation, if the turbine generator unit is required to operate at leading PF, it shall be ensured that the stator and rotor currents are not exceeding their prescribed limits.
- h) It is to be ensured that during starting the brakes are off and during shut down of the unit they are closed at only 20% to 35 % of the rated speed, the duration of braking should not exceed 2 min. The brake air pressure shall be within the normal range as prescribed by the manufacturer (0.5 MPa to 0.7 MPa). It is to be ensured that the machine comes to a standstill within the prescribed time after the brakes are applied. Long-term creeping of the turbine generator units at low speed shall be avoided. When sub-nozzle inverse water flushing or jetting is used for the Pelton turbine generator units, the maximum brake duration shall not exceed 5 min, and the monitoring and control devices for the switching brake water flushing or jetting on and off shall work normally.

7.2.2 The following criteria shall be met for normal starting, paralleling, load increasing and stopping of the generator:

- a) Operation of normal starting of the turbine generator units shall be carried out by the authorized operator after receiving clearance of all the work permits. Operation of normal shutdown will be done after receiving clear instructions from authorized personnel.
- b) Stand-by units and their auxiliary systems/equipment shall be in good condition and be able to start immediately at all times.
- c) When the generator speed reaches about 50% of rated speed, the vibration and contact condition of the carbon brushes on the collecting ring shall be inspected, as well as whether the sound of all parts of the turbine generator unit is normal or not. If anything abnormal occurs, the causes shall be found and resolved.
- d) After the turbine generator unit speed basically reaches the rated value, the voltage build up process should be started by switching on the excitation system. The voltage should be slowly increased to its rated value.
- e) The following items shall be inspected during the process of increasing the generator voltage:

- 1) For generators with silicon-controlled excitation, there shall be an appropriate number of laps of the potentiometer for regulating the excitation;
  - 2) The three phase stator current shall be equal to zero. If current exists in the stator circuit, the de-excitation switch shall be shut off immediately and the turbine generator unit shut down to inspect whether or not there is a short circuit in the stator circuit or the grounding wire has been removed;
  - 3) Inspect whether the three phase stator voltages are balanced;
  - 4) Inspect the insulation resistance of the rotor circuit of the turbine generator unit;
  - 5) Under no load rated voltage, check whether the rotor voltage and current exceed the no load rated value or not. If they do, the turbine generator unit shall be immediately shut down and the excitation main circuit shall be inspected for faults.
- f) If one of the following conditions exists, the parallel/synchronizing breaker shall not be allowed to be closed:
- 1) Rotation of synchroscope pointer is too fast;
  - 2) Pointer stops when close to the synchronous mark;
  - 3) If the pointer is fluctuating;
  - 4) Failure of the synchroscope;
  - 5) Operator is in a nervous state and his/her four limbs are trembling.
- g) The following requirements should be satisfactory for disconnecting the turbine generator unit from the power grid and shutting it down:
- 1) Reduce the load of the turbine generator unit and bring it close to zero after receiving the order to shutdown the unit;
  - 2) Then turbine generator unit circuit breaker shall be switched off;
  - 3) For generators with silicon controlled excitation, the de-excitation shall proceed by reduction in the continuous current flow;
  - 4) Disconnect the disconnecting switch;
  - 5) If the duration of the shutdown of the turbine generator unit is scheduled for a long dura-



tion, the insulation resistance of the rotor and stator circuits shall be measured and recorded.

**7.2.3** After a major or minor overhaul, the turbine generator unit shall have qualified acceptance prior to putting it into operation. Items of acceptance shall satisfy the following requirements:

- a) Temporary grounding line, signage cards and guard blocks are removed; no persons are to be working on the relevant equipment and no miscellaneous items and tools are missing.
- b) Insulation resistance of the stator winding and the rotor circuit is proper.
- c) Conditions of the primary and secondary circuits are normal.
- d) Excitation circuit is normal, and manual and automatic excitation transfer switches are at the cut-off position.
- e) The disconnecting switch, circuit breaker and de-excitation switch of the generator are in the shut-off position.
- f) Rotor jacking up completed for the vertical turbine generator units.

**7.2.4** The following requirements for normal monitoring and maintenance of the generator shall be met:

- a) Changes in all the meters on the centralized control board and electrical panels shall be recorded once every hour.
- b) The temperature of the stator winding, stator core, outlet water from the air cooler, inlet and outlet air and bearings shall be recorded once every hour.
- c) Readings of all the meters provided on the various unit panels and control panels shall be recorded once every hour and the rotor insulation and balance condition of the stator three phase voltages shall be inspected.
- d) For power stations with microprocessor monitoring, records should be made every hour.
- e) Sounds, vibration and the smell of the rotating parts of the generator and excitation system shall be monitored, and if any abnormal conditions are discovered, timely recording and reporting shall be made so that remedial measures are ensured in a timely manner.
- f) Inspect whether heating and colour changes exist in any connection parts of the primary and secondary circuits, whether abnormal noises exist in the potential and current transformers, and whether the oil level and oil colour in the oil circuit breakers are normal or not.

- g) Regular inspection of the generator and its accessories shall be done, at least once every shift.
- h) Regular preventive tests for the generator shall be done.

7.2.5 The following requirements for the measurement of the insulation resistance and the drying of the generator shall be satisfied:

- a) For a generator that has been shutdown for more than 3 to 10 days, the insulation resistance of the stator and the rotor circuits shall be measured prior to the start of operation according to the actual environmental weather conditions at the power station.
- b) For high voltage turbine generator units with generator outlet voltages of 6.3 kV and over, the insulation resistance of the stator circuit is to be measured by a 2.5 kV mega-ohmmeter. The measured figure shall be converted to the value at 75 °C for the sake of comparison. Measurement of the insulation resistance of the stator winding may include the power cable; in the case of generator-transformer connections, the low voltage winding of the transformer may be included.
- c) For turbine generator units with generator outlet voltage of 400 V, the insulation resistance of the stator and rotor may be measured by a 500 V mega-ohmmeter, which shall be over 0.5 MΩ.
- d) The insulation resistance of all the excitation systems, measured with a 500 V mega-ohmmeter, shall be over 0.5 MΩ.
- e) When the insulation resistance does not meet the requirements due to the effect of dampness, generator drying must be carried out by the following methods:
  - 1) Natural air cooling on no load rotation or drying by passing hot air;
  - 2) DC current drying;
  - 3) Electric lamp drying;
  - 4) Electric oven baking;
  - 5) Short circuit drying.

7.2.6 Under fault conditions, short time overload is allowed for the generator, and the allowable duration of overload shall meet the requirements specified in Table 1. When the generator stator current exceeds the allowable value, the duration of the allowable excess value of the generator power factor, voltage and current shall be inspected. Reduction of the excitation current causes the generator stator current not to exceed the maximum allowable value. If decreasing the excitation current cannot satisfy the requirements, a report shall be sent to the load dispatch centre for decreasing the

active load until the allowable current is reached.

**Table 1 Allowable duration for generator short time overload**

Overload current/rated current	1.1	1.12	1.15	1.2	1.25	1.5
Allowable continuous during (min)	60	30	15	6	5	2

**7.2.7** The following requirements shall be met for the maintenance and fault removal of the generator:

- a) When the generator is overloaded, the reactive load shall be reduced upon coordination with the load dispatch centre; if the stator current cannot be reduced to the rated value by decreasing the excitation current, then the active load of the generator must be reduced. If there is any fault in the power system, the overload requirement for the generator shall be observed and the stator winding temperature shall be strictly monitored.
- b) When the excitation system is grounded at one point, the turbine generator unit shall be shut down for remedial measures.
- c) When the generator temperature is abnormal, the temperature measurement device and the components shall be inspected to see whether they are normal or not.
- d) When the potential transformer circuit malfunctions, the secondary circuit fuses shall be inspected and replaced if found to be blown; if the fault still persists, shutdown of the turbine generator unit for remedial measures shall be requested.
- e) When the generator output in kW/MW meter disappears, the following shall be inspected to:
  - Ensure whether the fuses of the operating circuit are blown or not;
  - Ensure whether the electrical connection of the monitoring relay in the operating circuit is intact or not; Ensure whether the operating coils of the generator circuit breaker are okay or not;
  - Ensure whether the subsidiary contact points are having poor contact;
  - Take remedial action wherever required; If the fault still persists then shut down the turbine generator unit for detailed inspection and removal of the fault.
- f) When generator circuit breaker trips automatically, the stator winding shall be inspected to ensure if it is having a phase-to-phase short circuit or a phase-to-ground short circuit.

When there is a generator terminal, bus bar or line short circuit; or faulty action of the relay

protection device or circuit breaker operating mechanism or contact by the operator by mistake, the de-excitation switch of the generator shall be immediately tripped and the manual/automatic excitation control switch turned to the cut-off position. Causes shall be identified and remedial action taken.

- g) When the low voltage over-current protection is activated, the generator circuit breaker trips. At the same time, the main transformer and line circuit breakers also trip due to over-current, indicating that it was all caused by a line fault. The operator should start the unit and keep the unit at no load position so that it may be synchronized as soon as the line fault is attended to and clearance is given by the load dispatch centre.
- h) When differential protection is activated,
- The turbine generator unit shall be shut down immediately and de-excited;
  - Checking of the fault indications, the differential circuit, relay protection circuit will be done to ensure whether these are in order or not;
  - Phenomena of arc light, smoke and fire caused by a puncture of the internal insulation of the generator shall be checked for;
  - Short circuit and grounding of the equipment within the differential protection area shall be inspected;
  - Phase-to-phase and phase-to-ground insulation resistance of the generator windings shall be measured with a 2.5 kV mega-ohmmeter;
  - If a fault point is not discovered and the insulation resistance is good, a report to the load dispatch centre may be delivered for raising the voltage from zero and special attention shall be paid to the conditions during the process, with immediate shutdown of the turbine generator unit upon the emergence of any abnormal condition;
  - Prior to detection of the causes of differential switching off, the starting of the turbine generator unit and forced synchronization with the grid is absolutely not allowed.
- i) When the overvoltage protection action occurs, check the overvoltage tripping cause, resolve the faults and arranged maintenance according to the situation.
- j) If there is faulty action of the generator circuit breaker, the generator excitation and rotation speed shall be immediately regulated to the no load position and the causes of the fault ascertained. If no abnormality is found, the unit should be immediately synchronized with the grid.
- k) During non-synchronous parallel operation, the insulation resistance of the generator stator

winding shall be checked for any damage at the generator terminals. If so, and the remedial action is taken and all the other components of the unit are found to be normal, then the unit is restarted and synchronized with the grid.

- l) When the increasing of the generator voltage fails, the power source of the excitation system and the contact condition of the excitation circuit shall be checked.
- m) For a double winding shunt reactance excitation device fault, the turbine generator unit shall be shut down, the items shall be inspected one by one and the faults resolved.
- n) When the following conditions emerge, the turbine generator unit shall be shut down for treatment:
  - 1) Voltage build-up for the brushless excitation system fails;
  - 2) Voltage build-up for the silicon controlled self-excitation system fails;
  - 3) Generator loses excitation;
  - 4) Smoke, fire or a charring smell appears in the generator stator and the rotor;
  - 5) Strong sparks in the slip ring brush appear and the remedial action fails;
  - 6) Faults occur in the electrical parts and cables, and recovery is not possible;
  - 7) Foreign substances such as metallic matter have dropped into the generator.
- o) When generator vibration increases, the generator excitation current is increased, and the load is also appropriately reduced to recover synchronism. Even after this, if the synchronism between the entire power plant and the power system is lost 2 minutes later, the power plant shall be disconnected from the power grid and suitable remedial action shall be taken.
- p) When the indication values for the stator or the rotor measuring meter suddenly disappear, the values for the other measuring meter can be used, and check whether the measuring meter is damaged or the secondary circuit is disconnected. Resolve the faults by taking measures.
- q) If the generator catches fire, the generator circuit breaker shall be immediately tripped; the guide vane opening shall be reduced, and the turbine generator unit shall not be shut down by braking, but it shall be shut down if it is confirmed that the internal insulation of the generator has been burnt. Fire protection measures shall be adopted to reduce damage. Attendants shall extinguish the fire using non-conducting fire extinguishers according to the requirements; fire extinguishing devices using water may be used to put out the fire once it is confirmed that the power source has been disconnected.

### 7.3 Hydro turbine governing system

7.3.1 The following requirements shall be met for normal operation of the governor:

- a) Stable operation of the governor, normal indications and no abnormal vibration and blockage.
- b) No abnormal trembling of the main distribution valve and auxiliary servomotor of the properly-controlled governor, and no loosening and dropping off of any levers and pin axles in the control cabinet.
- c) No oil leakage in any oil pipe or connection point in the governor.
- d) Regular cleaning of the oil filter and inspection of the oil level and colour in the governor.
- e) Normal operation of the oil pump and electrical circuits in the governor, capable of starting and stopping within the range of specified oil pressure.
- f) Reliable action of the safety valve and check valve.
- g) All instrument meters of the pressure oil tank shall indicate normal operation; the pressure meter of the filter shall indicate that the operating pressure of the hydraulic pressure control circuit of the governor is normal.
- h) The pressure meter for controlling the starting and stopping of the oil pump works normally.
- i) The oil pump motor shall work normally.
- j) The oil level of the pressure oil tank and return oil tank is normal.
- k) The visible oil level meter of the pressure oil device is in good condition.
- l) The pressure oil device with an intermediate air supply tank shall supply air to the normal pressure and satisfy the oil-air ratio requirements.
- m) The pressure set value of the safety valve of the oil pump shall be up to standard.
- n) The uni-directional valve of the high oil pressure governor operates normally. The electric motor must not rotate in the reverse direction when the pump shuts down.

7.3.2 The hydraulic system and the governor shall meet the following requirements:

- a) The servomotor lock shall be pulled out during operation.

- b) The servomotor action shall be normal during mechanical manual and electrical manual operation, and phenomena such as servomotor twitching and vibration shall not occur.
- c) No oil leakage surrounding the hydraulic pressure valve, and no defects in the sealing ring of the valve body.
- d) The governor closing time shall be set and be up to standard, and loosening and alteration of the position of the adjustment mechanism shall be prevented.
- e) The manual dead band of the servomotor during on-load operation shall be set reasonably.
- f) The electrical feedback device of the servomotor shall be normal, and faults of “feedback line breaking” shall not emerge.
- g) The servomotor shall be locked after the turbine generator unit shuts down.
- h) The no load opening shall be reasonably set in accordance with the control parameters of the turbine generator unit.
- i) For turbine generator units deployed with a regulating valve, the combined action of the governor and the regulating valve shall be normal.

**7.3.3** The governing system shall be taken out of operation when one of the following faults emerges:

- a) Fault in the pressure meter with the electrical contact point used for the stop control of the oil pump.
- b) Fault in the oil pump.
- c) Fault in the safety valve.
- d) Incomplete phase operation of the electric motor.
- e) Fault in the visible oil level meter on the pressure oil tank.
- f) Fault in the regulation of the closing time of the governor.
- g) Feedback line broken.
- h) Fault in the turbine generator unit frequency.
- i) Oil leaks out around the hydraulic pressure valve.

**7.3.4** Inspection, repair and maintenance of the governor system shall be comprised of the following contents:

- a) Inspect the components of the pressure oil device, including the pressure meter with electrical contact point, the oil pump, oil pump electric motor, safety valve, emergency shutdown electro-magnetic valve and the emergency shutdown time regulation mechanism, the visible oil level meter of the pressure oil tank, visible oil level meter of the oil return tank, and the main oil valve and the oil pump control panel.
- b) Inspect the oil pressure control parts including the central filter core of the oil filter, the pressure meter of the oil filter and the oil leakage of the oil pressure valve body.
- c) Regular oil filling for the governor key shaft.
- d) Frequently inspect whether the oil-air ratio of the governor oil pressure tank is normal or not.
- e) Observe the operating condition of the electrical parts and components of the governor.
- f) Inspect the external operating circuit.
- g) Inspect the outside appearance.

#### **7.4 Excitation system**

**7.4.1** The following contents shall be included for normal operation of the excitation system:

- a) The panel and cabinet shall be clean and tidy with no dust accumulation.
- b) The wire connection shall be in good order, with no abnormal ageing of the wire and the wire connections shall be firm.
- c) No damage to the parts and components.
- d) Normal operation of the air ventilation.
- e) Carbon brushes shall be intact and in good condition, without jumping and overheating.
- f) All limit functions of the excitation regulator shall be normal and in operation.

**7.4.2** The excitation system shall be taken out of operation if the following faults emerge:

- a) Evident temperature rise of the device or equipment, and the temperature still exceeds the allowable value after measures have been taken.



- b) System insulation has decreased, and normal operation cannot be maintained.
- c) Contacts of the de-excitation switch, circuit breaker of the magnetic field or other AC/DC switches overheat.
- d) Fault in the rectifier power cabinet, so that continuous generator operation at the rated load and rated power factor cannot be ensured.
- e) Fault in the cooling system which cannot be rectified within a short time.
- f) Fault in the automatic unit of the excitation regulator, and the manual unit cannot be put into operation.
- g) Automatic channel cannot operate normally for a long time.

**7.4.3** The overhaul and maintenance of excitation systems shall include the following contents:

- a) Any dust accumulating in the cabinet, panel and rectifying components shall be cleaned up.
- b) Inspection of the operating circuit of the excitation system.
- c) Inspection of all the switch mechanisms.
- d) Inspection of the over voltage protection, limits and other auxiliary function units of the excitation system.
- e) Inspection of the integral performance of the input and output, and the phase shift range of the excitation regulator.
- f) Remedial actions are taken for the operational defects.

**7.4.4** Systematic tests shall be carried out after overhaul for the excitation system.

## **7.5 Main valve and overhead crane**

**7.5.1** The name plate of the main valve shall be placed at an appropriate position.

**7.5.2** The main valve shall meet the following criteria prior to opening:

- a) Drain valve of the spiral casing shall be fully closed.
- b) Governor shall be at the fully-closed position.

- c) Mechanical lock of the main valve shall be at the insertion position.
- d) Water pressure at the front and back of the valve shall be basically in equilibrium.

7.5.3 The following requirements shall be met for closing the main valve:

- a) Control circuit of the main valve should be in working condition.
- b) Main valve shall have back-up protection function.
- c) Main valve should be closed after the turbine generator unit shuts down.
- d) When the guide vane could not be fully closed due to a fault, the main valve shall be able to close under flowing water within 5 minutes. Hydraulically-operated sliding valves and butterfly valves, and electrically (manually) operated butterfly valves and sliding valves shall be able to close under flowing water within 5 minutes after the electricity is shutoff.
- e) The mechanical lock shall be put into effect after confirming closure of the valve.

7.5.4 The following requirements shall be met for the operation and maintenance of the main valve:

- a) Regular inspection of the valve and its control device should be carried out regularly and ensure these are in good working condition.
- b) Inspect whether there is water leakage in the main valve, extended section, expansion joint, and connection flange.
- c) Inspect all the pressure switches and pressure meters to see whether their indication is normal.
- d) Inspect whether the position of the valve on the by-pass passage is correct and its action is normal.
- e) Inspect whether the operation of the air valve is normal.
- f) Inspect whether the sound of the opening and closing of the main valve is normal.
- g) Inspect whether the valve is able to close within the specified time under flowing water.
- h) Inspect whether the operation of the stroke switch is normal and the position of the opening indicator is correct.
- i) Inspect whether the operation of all the signal devices is normal.

- j) Inspect whether the operation of the operating power source and the electrical control device is normal.
- k) The drive mechanism shall be regularly filled with lubricating oil and grease.

**7.5.5** The following requirements shall also be met for the operation and maintenance of hydraulically-operated main valves:

- a) The oil level of the oil pressure device shall not be lower than 1/3 above the bottom line of the oil mark. Pressurized oil shall be filtered once every 3 months. The oil tank shall be regularly cleaned and inspected.
- b) The pressure of the filled gas in the pressure accumulator is to be inspected regularly. Nitrogen shall be filled to the set value when the filled gas pressure is lower than the set value.
- c) Inspect whether the oil and water pipe lines are intact, and there should be no leakage from any joint.
- d) Inspect whether the position of the operating servomotor of the main valve is normal and that there is no leakage from any joint.
- e) Inspect whether the pressure oil pump and circulating oil pump are normal during operation and that the manual oil pump is able to open the valve normally.
- f) Inspect whether the position of the operating servomotor of the main valve is correct, there should be no leakage from any joint.
- g) Inspect whether the operation of the locking device is normal.

**7.5.6** The following requirements shall be met for normal operation of the crane:

- a) Ensure that the working of the automatic brake device is normal.
- b) The micro-regulating control system of the bridge crane is reliable.
- c) It shall be ensured that the metallic structures and outer casings of all the electrical equipment are reliably grounded.
- d) The cable insulation shall be reliable.
- e) Ensure that the fire protection equipment is normal and that the rubber insulation cushion in the operator's cabin is effective.

- f) The balancing weights are not to be disturbed by the removal or addition of the load.
- g) The starter shall be returned to its original resting position and then the power source switch shall be turned off once the electricity is shut off during operation, and in the case that there is a braking device for the crane, it shall be brake tight.
- h) The terminal buffer of the rail shall be reliable.

**7.5.7** Repair and maintenance of the crane shall meet the following requirements:

- a) The crane should be inspected once a year and the pulley block can be maintained once every 2 to 6 years.
- b) When maintenance and repairs are carried out on the rails, both ends of the maintenance and repair locations shall be fixed by steel rail clamps.
- c) When work stops, the power source shall be cut off and the track clip firmly installed.
- d) For newly-installed cranes, or for cranes just after major repair, static and dynamic load tests for the crane shall be carried out according to the relevant regulations prior to commissioning.

**7.6** Water, oil and air systems

**7.6.1** The following requirements shall be met for normal operation of the water supply system equipment:

- a) The flow and pressure of the water supply system shall satisfy the requirements.
- b) The pressure at the rear of the pressure reducing valve shall be within the range of the design value.
- c) The filter works normally.
- d) During cleaning of the filter, the water supply shall not be interrupted. The sedimentation device and silt release device shall be able to operate reliably.
- e) The water quality of the bearing lubricating water and the main shaft sealing water shall meet the design requirements.
- f) The electro-magnetic or electrical valve shall be able to act normally without any blockage and resistance.
- g) The water supply pump works normally and the stand-by pump shall be able to start at all times.

7.6.2 Water supply equipment shall be withdrawn from operation when the following faults emerge:

- a) Abnormal pressure occurs at the rear of the pressure reducing valve, or the pressure is higher than the design value when the water is shut off.
- b) The automatic filter is not able to clean normally.
- c) There is blockage or resistance in the electro-magnetic or electrical valve.
- d) The pressure transducer is not working normally.

7.6.3 The following requirements shall be met for the repair and maintenance of the water supply system equipment:

- a) When the rear pressure of the pressure reducing valve is not stable, it shall be replaced if it still could not reach the requirements after repair.
- b) If the filter is seriously blocked, it shall be dismantled and the filter core shall be repaired or replaced.
- c) The electro-magnetic valve shall be replaced in case of blockage or be replaced by an electrical valve.
- d) The pressure transducer shall be replaced in case of inability to transmit data.
- e) The lubricating oil of the water supply pump and electric motor should be replaced once every year.
- f) If the water supply pump is seriously corroded and faults occur frequently, it shall be replaced.
- g) If the water supply pipe is seriously corroded, it shall be replaced.
- h) The colour of the pipes shall be uniform and distinct.

7.6.4 The following requirements shall be met for the normal operation of the drainage system equipment:

- a) There should be no leakage in the drainage system pipework.
- b) The water pump shall start and operate normally with no abnormal sounds.
- c) The level sensor and annunciator of the wet sump shall operate normally.

d) The non-return flow valve of the drainage pipework shall be normal.

**7.6.5** The water drainage pump shall be replaced in case of the following faults.

- a) Serious fault in the water drainage pump.
- b) Fault in the level sensor and annunciator of the wet sump.
- c) Fault in the water flowmeter and the annunciator.

**7.6.6** The following requirements shall be met for the repair and maintenance of the water drainage system equipment:

- a) Lubricating oil for the water drainage pump and the bearing of the electric motor shall be replaced once every year or as per the manufacturer's recommendations.
- b) The water drainage pump shall be repaired or replaced in case of abnormal operation.
- c) The water level sensor and the annunciator shall be replaced or repaired if an abnormal indication emerges.
- d) The water drainage exposed pipes shall be replaced in case of serious corrosion.
- e) The colour of the pipes shall be uniform and distinct.

**7.6.7** The following requirements shall be met for the normal operation of the oil system equipment:

- a) The oil system equipment and pipes shall be installed as per the design requirements.
- b) The storage volume of the oil should be 110% of the maximum oil utilization in the system.
- c) A suitable oil filtration machine shall be arranged and kept at an appropriate place in the power station.
- d) The fire protection devices shall meet the design requirements.

**7.6.8** The oil system equipment shall be withdrawn from operation under the following faults:

- a) Oil system pipes gets corroded or blocked up.
- b) Fire protection devices do not meet the requirements.

7.6.9 The following requirements shall be met for the repair and maintenance of the oil system equipment:

- a) Oil system pipes shall be replaced in case of corrosion or blockage.
- b) When the storage volume of the oil is less than 110% of the maximum oil utilization equipment in the oil system, sufficient stand-by oil volume shall be added.
- c) Regular examination and maintenance of the fire protection devices shall be carried out.
- d) Pipe colour shall be uniform and distinct.

7.6.10 The following requirements shall be met for the normal operation of the air system equipment:

- a) Compressed air systems should have main and stand-by compressors with the required pressure with an automatic switch over system and the system should always remain in normal working condition.
- b) Sufficient spare parts should be available.
- c) The compressed air tanks (including the safety valve and dirt and the condensate draining valve) shall be examined and shall be in normal and safe working mode.

7.6.11 The air system equipment shall be withdrawn from operation when the following faults emerge:

- a) Abnormal pressure output from the air compressor.
- b) Air leakage in the compressed air tank. Blockage at the dirt and condensate drainage opening and a fault in the safety valve.
- c) Oil-water separator is unable to work normally.

7.6.12 The following contents shall be included for the repair and maintenance of the air system equipment:

- a) Air compressor: Record the number of start-up times of the air compressor. When the pressure output from the air compressor is abnormal, the stand-by air compressor may be started for use and the faulty equipment repaired.
- b) Compressed air tank: Frequently inspect whether the compressed air tank has air leakage or not. Open the dirt draining exit to regularly drain the dirt. The safety valve of the air compressor and

the compressed air tank shall be checked for normal working once every year.

- c) The colour of the pipes shall be uniform and distinct.

## 7.7 Transformer

7.7.1 The following requirements shall be met for the normal operation of the transformer:

- a) After repair of the transformer and a long (over half a month) shutdown time, the insulation resistance between each winding and between the winding and the outer case shall be measured prior to being put into operation. The Tan  $\delta$  and the absorption ratio ( $R_{60}/R_{15}$ ) of the transformer shall be measured, if the insulation resistance drops to 50% of the original value, an oil sample shall be taken for testing.
- b) The current and voltage of the transformer shall be kept within the rated range.
- c) The temperature rise of the transformer and the oil temperature shall be normal.
- d) The off-load tapping switch of the transformer shall not be regulated under load. Before shifting of the tapping, the power source at the high and low voltage sides of the transformer shall be disconnected. The voltage fluctuation range shall be kept within  $\pm 5\%$  of the tapping rated voltage.
- e) Under temperature rise conditions, the transformer may be operated within the allowable range, the allowable value is determined by the cooling criteria and temperature conditions of the transformer.
- f) Ensure normal working condition, the winding and oil temperature shall be recorded once every shift.

7.7.2 The following checks shall be done daily as routine inspection of the transformer:

- a) Inspect whether the oil temperature is normal, there is no oil seepage and leakage and a normal oil level in the conservator tank.
- b) Inspect whether the oil level in the bushing is normal, there is no damage and cracks on the outside part of the bushing, no serious greasy dirt and no trace of electrical discharge and other unusual behaviour.
- c) Inspect whether the sound of the transformer is normal.
- d) Check whether the cooling system is normal.



- e) Check that the silica breather is in good condition and the colour of the silica gel is normal.
- f) Check that the cable joints, cables and bus have no overheating indication.
- g) Pressure vent and the Bulchoz relay safety gas channel are in good condition.
- h) The tap position of the tapping switch and the indication of the power source is normal.
- i) No gas shall be present in the Bulchoz relay.
- j) All the control cabinets and secondary terminal boxes are to be tightly closed and there is no dampness there.
- k) The outer surface of dry type transformers shall have no dirt accumulation.
- l) There shall be no water leakage in the transformer room, and the doors, windows and lighting shall be in good condition, with good air ventilation and normal temperatures.
- m) The outer casing of the transformer and all the parts shall be kept clean.
- n) The transformer fan and heat radiation shall be in good condition.
- o) There shall be proper grounding of the outer casing of the transformer.

**7.7.3** The following requirements shall be met for abnormal operation and fault treatment of the transformer:

- a) When abnormal phenomena such as oil leakage, oil level insufficiency in the oil conservator, excessive rise of oil temperature or abnormal sound emerge in the transformer, timely action shall be taken and recorded in the shift log book and defect register and reported in a timely manner.
- b) Shutdown should immediately take place when one of the following conditions emerges in the transformer:
  - 1) Abnormal noise from the interior of the transformer, with uneven and explosive sounds;
  - 2) Abnormal transformer oil/winding temperature and there is a rising trend even after load reduction.
  - 3) Serious oil leakage;
  - 4) Oil spurts from the oil conservator or the explosion proof pipe;

- 5) Breakage or serious electrical discharge from the bushing;
  - 6) Smoke rises up from the transformer and it catches fire.
- c) When the transformer oil temperature exceeds the allowable value, the causes shall be identified and measures taken to reduce it. When an internal fault is identified in the transformer, the load shall be immediately reduced until operation is stopped.
  - d) When obvious reduction of the oil level in the transformer is discovered, its causes shall be immediately identified and a sufficient amount of oil shall be added to make up the deficiency.
  - e) When the transformer automatically switches off due to overload and external short circuit or secondary circuit fault of a protection device, operation may be restarted after removal of the faults and inspection of the transformer's exterior.
  - f) Following action is to be taken if the transformer's differential protection operates:
    - 1) Inspect in detail whether there are short circuit or grounding conditions for the main transformer, circuit breaker, current transformer, busbar, power cable and insulators within the range of the differential protection;
    - 2) Measure the insulation resistance of the transformer and the equipment connected to it with a mega-ohmmeter, and a charging switch-on test may be carried out for the transformer to ensure the health condition of the transformer.
    - 3) When a charging switch-on test is carried out, if the circuit breaker switches off again, the causes shall be identified;
  - g) Following action shall be taken if Bucholz relay acts:
    - 1) Check whether the action of the Bucholz relay was caused by the inlet of air, oil leakage, too low an oil level or faults in the secondary circuit;
    - 2) If abnormal phenomena are not discovered through external inspection and analysis, the nature of the gas stored in the gas relay shall be checked for to identify the causes of the faults.
  - h) If the action of Bucholz relay was not caused by the faulty action of the relay protection or of the secondary circuit, the transformer shall not be put into operation before identification of the causes.
  - i) If switch-off of the transformer was caused by the action of the differential protection or confirmed, Bucholz relay operation shut down of the transformer shall take place and the core shall

be lifted out for detailed inspection.

- j) When a transformer catches fire, its power source on both the high and low voltage sides shall be disconnected, and the automatic water spraying fire extinguishing system or fire extinguishers shall be used to put out the fire.

**7.7.4** The following stipulations shall be implemented for transformer overhaul and maintenance. The following items shall be included for the transformer's major overhaul:

- a) Lifting out the core for overhaul.
- b) Overhaul of the winding, leading wire and magnetic shielding device.
- c) Overhaul of the tapping switch.
- d) Overhaul of the iron core, core thrust bolts, yoke beam, stamp nail and grounding slice.
- e) Overhaul of the oil tank, bushing, heat radiator, safety air channel and oil storage tank.
- f) Inspection and testing of the protection devices, measuring devices and operation control cabinet.
- g) Transformer oil centrifuging, dry out and breakdown voltage testing shall be done.
- h) Overhaul of the protection devices for the transformer oil.
- i) Replacement of the seal liner.
- j) Cleaning of the interior of the oil tank, and rust removal and painting of the outer casing of the oil tank.
- k) Dry of transformer insulation, if necessary.
- l) Carrying out all the prescribed measurements and tests.

**7.7.5** Preventive tests shall be carried out for the transformer according to the requirements.

## **7.8 Switchgear installation**

**7.8.1** The following requirements shall be met for normal operation of the switchgear installation:

- a) External appearance of the switchgear installation shall be complete and in good condition. Performance of the operating mechanism shall be able to meet the relevant requirements, without

blockage and resistance.

- b) The phase sequence of the switchgear installation for the same electrical circuit shall be identical and shall have obvious colour distinction. The outer casing of the switchgear installation shall be reliably grounded.
- c) The disconnecting switch, circuit breaker, busbar and other equipment of the system in operation shall be inspected twice every shift. For equipment under high temperature and high load and with existing defects, the cyclical inspection shall be strengthened. Immediate shutoff for inspection shall be carried out, if it is found that the safety of people and equipment is in danger.

**7.8.2** The following contents shall be included for operational maintenance of the vacuum circuit breaker:

- a) The normal items of each inspection tour of the vacuum circuit breaker:
  - 1) Indication of the off and on indicators shall be correct and shall conform with the actual operating condition at the time;
  - 2) Supporting insulators shall have no cracks and damage, and have a bright and clean surface.
  - 3) No abnormality in the vacuum arc extinguishing chamber, and the colour of the observable shielding cover shall be checked for evident variation;
  - 4) No serious corrosion and deformation in the metallic frame or the base stand;
  - 5) Connecting bolts of the observable parts shall not be loose and the shaft pins are not dropping off or deformed;
  - 6) Grounding in good condition;
  - 7) No excessive heat phenomenon in the contact parts of the cable connections or the temperature indicating parts, and the pre-sag of the jumpers conductor shall be moderate;
- b) Maintenance items for the vacuum circuit breaker:
  - 1) In combination with the preventive test, clean up the stored ash and dirt materials on the surface of the elements such as the vacuum arc extinguisher, insulating rod and supporting insulators;
  - 2) In combination with the preventive test or the scheduled maintenance and repair of the mechanism which shall be carried out after on and off switching operation occurs

2 000 times, all the fasteners shall be inspected to see whether these are loose. Components that have fairly serious wear and tear shall be replaced in a timely manner, and moving parts shall be well greased/lubricated in a timely manner;

- 3) For vacuum arc extinguishing chambers with glass outer casing, the colour of the metallic shielding cover should be observed to see whether there is evident change, and the degree of vacuum shall be inspected, if there is any doubt about it;
- 4) The variation of the contact stroke of the contactor in the vacuum arc extinguishing chamber shall be inspected. This directly reflects the amount of contact wear. The vacuum arc extinguishing chamber shall be replaced when the contact wear exceeds the technical specification for the product;
- 5) Inspect the service life of the vacuum extinguishing chamber; it shall be replaced in a timely manner, if its life expectancy has already passed.

**7.8.3** The following checks shall be required for operation and maintenance of SF<sub>6</sub> circuit breakers:

- a) Normal checks of the SF<sub>6</sub> circuit breakers are as follows:
  - 1) Supporting insulators shall have no cracks and damage, and have a bright and clean surface;
  - 2) The pressure meter indication (or density controller with indication) shall be observed and compared with the temperature-pressure curve, and shall be within the specified range. Pressure and temperature values shall be regularly recorded;
  - 3) The on/off position indicator shall give correct indications and the on/off position shall be precise;
  - 4) Integrated fasteners shall not be loose and dropping off;
  - 5) The interior of the energy-storage motors and circuit breakers shall have no abnormal sound;
  - 6) On/off switch windings shall have no smoke or burnt smell phenomena;
  - 7) The grounding of the outer casing and the frame shall be in good condition;
  - 8) The outer casing and the operating mechanism chamber shall be intact, and without corrosion;
  - 9) All components shall have no damage, deformation and rust phenomena.

b) Maintenance points for SF<sub>6</sub> circuit breakers:

- 1) Anti-corrosive treatment and supplementary painting shall be carried out for rusty and corroded parts of the outer casing of the circuit breakers every year;
- 2) Rotating and drive parts of circuit breakers shall be lubricated once every half year and after 3 times of normal operation occurrences;
- 3) Qualitative leakage inspection for all the sealing surfaces of the circuit breakers shall take place once every two years, and the annual leakage rate shall not exceed 1% ;
- 4) Testing of the micro moisture content of the SF<sub>6</sub> gas is to take place once every year, and the test result shall not exceed 300 ppm (20 °C) compared with the moisture-temperature curve.

**7.8.4** The following checks shall be included for the operation and maintenance of the disconnecting switch:

a) Normal checks during operation and maintenance:

- 1) Check contact parts of the disconnecting switch. These should not be overheated;
- 2) Check the insulators for damage, cracks and traces of electrical discharge.
- 3) Inspect whether the locking device of the disconnecting switch knife blade is in good condition.
- 4) Check that all the fasteners are tight and intact.
- 5) Check that all the jumper conductor connections are tight and not loose.

b) Maintenance items of the disconnecting switch:

- 1) Clean dust on the surface of porcelain elements, check whether the surface of the porcelain elements has the glaze dropping off, damage, any cracks and traces of sparks, and whether the insulator binding parts of the iron and porcelain are firm. Replacement shall be carried out in case of serious damage;
- 2) Inspect whether the knife blade surface is clean and has any mechanical damage, traces of oxidation or overheating and deformation;
- 3) Inspect whether the contact points or accessories of the knife blades are complete and have any damage;

- 4) Inspect whether the leading wire connecting the disconnecting switch to the busbar and the circuit breaker is firm and has any overheating;
- 5) Inspect whether the soft connecting components have any phenomena of twist damage and strand breaking;
- 6) Inspect and clean the operating mechanism and drive parts, and lubricate these.
- 7) Inspect whether the distance between the drive parts and the electrified parts is normal, whether the positioner and the brake device are firm and the operating movement correct;
- 8) Inspect whether the pedestal of the disconnecting switch is in good condition and grounding reliable.

7.8.5 The operation and maintenance of the alternating current metallic closed switch boards shall be carried according to the product technical requirements.

7.8.6 The following checks shall be carried out for inspection of the outer parts of other primary circuit equipment:

- a) The supporting porcelain of the busbar shall be complete and all the joint parts shall be firm and reliable.
- b) The current and potential transformers shall be in good operating condition.
- c) Ensure that there is no dirt and water in the cable ducts.
- d) Appearance of all the cable heads and cables shall be intact, without overheating.
- e) Fuses shall be complete and the contacts in good condition.
- f) Measures for preventing the entry of small insects, lizards and rats shall be provided.

7.8.7 Switchgear installations having one of the following conditions shall be shut off for remedial measures:

- a) Outer casing and insulation pipes broken.
- b) Wire connection head and cable head are overheated, and seriously discoloured to the point of meltdown.
- c) Having the possibility of oil and gas leaks.

- d) Fire in the internal parts or the emission of an offensive odour and smoke.
- e) Sparking and electrical discharge between the winding and the outer casing or the leading wire.

7.8.8 Regular preventive tests for the switchgear installation and equipment refurbishment shall be carried out.

## 7.9 Relay protection and monitoring system

7.9.1 The following requirements shall be met for the operation management of the relay protection:

- a) Nobody shall change the pre-set values and connections of the relay protection.
- b) After overhaul and examination of the relay protection, inspection and acceptance shall be done jointly with the authorized engineer for the present shift. Records of overhaul and examination and the settings of relays are properly done as per the relevant standard.
- c) Good records shall be made whenever the relay protection goes into action. If the protection acts in error, the original conditions shall be maintained as far as possible or the process of the wrong action shall be recorded in detail. The causes shall be identified and dealt with in a timely manner.
- d) The cross section of the secondary circuit cable and the earthed insulation resistance shall satisfy the design requirements.
- e) Relay protection under operation shall be inspected every shift, and shall include the following contents:
  - 1) Overheating, noise, location of the press plate, secondary fuses and corrosion of the secondary circuits of the modules;
  - 2) Conditions of damage, twisting, change of colour, loosening and strand breaking;
  - 3) Inspect the conditions of the buzzers, alarms, annunciations, status display and indicating lamps.

7.9.2 The following requirements shall be met for the utilization management of the monitoring system:

- a) The central control room and control desk shall be kept clean and tidy.
- b) Operation by non-authorized staff shall not be allowed.



- c) Attendants shall not change any equipment's set values and limit values, interlocks at will, and shall not amend the relevant procedures and records at will.
- d) During operation monitoring shall ensure whether the communication is smooth and the transmitted data is correct.
- e) Regular maintenance of the computer, on-line communication and back-up data storage of the power station shall be carried out.

7.9.3 Regular inspection and normal functioning of the relay protection and the monitoring system shall be meticulously carried out.

## 7.10 Direct current(DC) system

7.10.1 The following requirements shall be met for the operation and maintenance of the charging devices:

- a) Regular inspection of the charging devices shall take place to see whether various meter indications of AC input voltage, DC output voltage, and DC output current are correct, the operating noise is abnormal, all the protection signals are normal, and whether the insulation condition is good.
- b) When the AC power source shuts off, the battery will provide electricity to the DC bus without interruption and shall regulate the control bus voltage in a timely manner to ensure a stable value. If the supply capacity of the battery reduces to 20% of its rated capacity and above, then, after the AC power source is restored, the battery charging device shall be manually or automatically started immediately to charge the battery according to the normal charging method stipulated by the manufacturer. Alternatively, battery charging could be carried out according to the constant current limited voltage or the constant voltage or the floating charging methods.
- c) Batteries of different age, degrees of newness and different capacity should not be mixed together in use. The outer casing of the battery shall not be cleaned with organic solvent; over-charging and over-discharging of the battery are strictly prohibited; the battery shall be charged up in a timely manner after discharging, and it shall not be left uncharged for more than 2 hours; during battery maintenance, the operator's face should not directly face the top part of the battery and he shall keep a certain distance away at a certain angle.

7.10.2 For on-line monitoring devices of the insulation under operation, the indicated values of the device shall be checked to ensure whether they conform to the actual measured values.

7.10.3 The following checks shall be carried out regularly for the battery operation and maintenance:

- a) Whether the connecting plates of the battery have any phenomena of loosening and corrosion, the casing body has any leakage and deformation, and whether they are clean or not.
- b) Whether there is any acid vapour spilling out around the electrodes and safety valves.
- c) Whether the insulation resistance has decreased.
- d) Whether the bolts of the primary connection line are loosened or corroded and polluted; if loosened, they shall be screwed tightly to the specified torque, and if corroded, they shall be replaced in a timely manner.
- e) Battery capacity should be checked regularly to ensure reliable DC power supply.
- f) For the battery room, the ventilation, lighting, temperature regulation equipment and fire protection devices shall be inspected regularly.

**7.10.4** The following requirement shall be met for the operation and maintenance of the microprocessor monitoring devices for direct current power sources:

- a) For the microprocessor monitoring device for DC power sources under operation, inspection of the relevant functions and parameters shall take place through the operation of the switchover of the push buttons, and the setting of the value of its various parameters shall be subject to authorisation limits and supervision measures.
- b) When a microprocessor monitoring device has a fault, back-up charging devices shall first be put in, if available and the faulty device taken out of operation. If a back-up charging device is not available, manual operation shall be started and regulated to the required operating mode and the monitoring device shall be taken out for maintenance and put into operation again after inspection and repair.

## **7.11 Lightning protection and grounding**

**7.11.1** The power station shall have reliable lightning protection devices. The protection scope of the lightning rod and lightning line shall be able to cover the area to be protected and be reliably grounded.

**7.11.2** The surface of the lightning arrester shall be neat, acting reliably and counting correctly.

**7.11.3** The connection between the lightning protection device and the grounding body shall be intact.

**7.11.4** The grounding resistance of the grounding device shall meet the design requirements for power stations.

7.11.5 The grounding resistance of the power station shall be regularly measured; if unable to meet this requirement, reduction of the grounding resistance may take place through other methods such as offsetting an artificial grounding body underwater, a leading external line, and deep well grounding.

7.11.6 In areas with a high soil resistance rate, when the required grounding resistance value of the grounding device is unreasonable, the grounding resistance shall be determined by the design calculation. The grounding resistance value shall be implemented to a standard which may be satisfied by the design calculation under the condition of ensuring the safety of persons and equipment.

7.11.7 Preventive tests of the lightning protection device of the power station shall be carried out regularly on a yearly basis.

## 7.12 Communication

7.12.1 Maintenance and inspection of the equipment shall regularly take place, and problems that affect the quality of communication shall be resolved in a timely manner, ensuring that the technical performance of the equipment meets the requirements, keeping the communication among power stations and higher level departments of flood protection, dispatching and the automated dispatching system running smoothly.

7.12.2 Great importance shall be paid to the lightning protection for the communication system.

7.12.3 Start up and stopping of the operation and overhaul of the communication system shall be arranged in a unified manner after approval from the authorized engineer/manager.

## 8 Optimized operation

### 8.1 Basic requirements

8.1.1 Power stations shall draw up the optimized operation plan for the power generation as per the grid regulation and the availability of water, making the most of the benefits of comprehensive utilization. The power station shall submit their proposal for yearly, monthly and daily power generation plans in a timely manner to the power dispatch organization as per the dispatching agreement under the interconnected grid and shall automatically transmit relevant real time operation data from the turbine generator units, power station and reservoir to the power dispatch organization and ensure the accuracy and prompt timing of the information; submit the design data for the power station, the statistical data from operation and the summary reports of operation to the power dispatch organization.

8.1.2 For implementation of the power station's optimized operation, the power station shall consistently apprise its management and ensure the safe and reliable operation of the hydraulic

structures and the electromechanical equipment. The following essential requirements shall be met:

- a) Strengthen the operation management and maintenance and repair of the power stations facilities and equipment and devices, and improve the rate at which the equipment is in good condition.
- b) For power stations on silty rivers, measures such as sand release, silt prevention and corrosion prevention shall be adopted to maintain the capability of regulation and storage and to reduce equipment erosion/corrosion.
- c) Strengthen the management of the power generation water conductor system, the tail water system and their auxiliary equipment to reduce seepage and water head loss.

**8.1.3** Optimized operation of the power station shall meet the following requirements, and shall not be changed at will.

- a) Optimized operation of the power station shall be implemented according to the design requirements, the optimized operation plan or the stipulations of other special documents.
- b) Optimized operation of the power station shall be carried out in accordance with engineering design data such as the reservoir's characteristic water level, etc..

**8.1.4** The water utilization and generation shall meet the following requirements:

- a) Power stations shall do their best at forecasting the water regime, and reasonably dispatch operation under the prerequisite of satisfying the flood protection requirements so as to achieve less water wastage and more electricity generation.
- b) Power stations shall be able to master at any time the conditions like the forecasting of the inflow water, water storage and water consumption for electricity generation, so as to strengthen the planned water utilization.

**8.1.5** Power stations should enable the turbine generator units to operate in the high efficiency region.

**8.1.6** Power stations shall review and revise in a timely manner the relevant data for the project's characteristics, dynamic performance of the turbine generator units, the dynamic performance of the power station, and consistently raise the optimized operation level.

**8.1.7** Power stations shall establish technical archives of operations, regularly train the operation and maintenance staff, and gradually realize the modernization of the power station.

## 8.2 In-plant optimized operation

8.2.1 Power stations shall draw up the operation strategy for in-plant optimized operation according to the availability of water, the water head stable grid and the dynamic performance of the turbine generator units.

8.2.2 Optimal generation of the active and reactive power of the turbine generator unit shall be realized in in-plant operation. For optimal load sharing of in-plant optimized operation among the turbine generator units, the micro incremental rate method or the dynamic planning method may be adopted in combination with the turbine generator unit characteristics.

8.2.3 Computerized real time monitoring should be adopted for in-plant optimized operation; for power stations with no large load variation, it may also be realized according to the operation strategy for in-plant optimized operation.

## 8.3 Optimized operation of cascade power stations

8.3.1 Optimized operation of the cascade power stations shall seek the maximum benefit of total electricity generation of the entire cascade.

8.3.2 For cascade power stations implementing optimized operation, the turbine generator unit performance characteristic and other relevant design aspects shall be implemented; a computerized real-time monitoring system or in-plant optimized operation strategy shall be strictly followed.

8.3.3 Cascade power stations shall transmit real-time operation data to the power dispatching organization, which shall meet the relevant stipulations. The electric power dispatching organization shall issue timely orders of the operation plan to various power stations. For some cascade power stations, one key power station may be selected to establish a central control centre, if the conditions are suitable.

**Appendix A**  
**(Informative)**

**Grading of the equipment and facilities for the hydropower station**

**A.1 Scope and unit division for grading**

**A.1.1** All the equipment and facilities related to electricity generation in the hydropower station are subject to grading.

**A.1.2** The unit division shall comply with the following provisions:

- a) Each turbine, generator (including the exciter), governor (including the permanent magnetic generator PMG) and valve is regarded as one unit;
- b) Each of the oil, water and air systems is regarded as one unit;
- c) Each transformer, electric reactor and power capacitor is regarded as one unit;
- d) Each indoor panel or cabinet is regarded as one unit (main console is regarded as one unit);
- e) Each group of circuit breakers and disconnecting switches is regarded as one unit;
- f) Each group of voltage transformers, current transformers, different transducers, sensors and high voltage fuses is regarded as one unit;
- g) One busbar and one framework are regarded as one unit;
- h) Each group of lightning arresters is regarded as one unit;
- i) One lightning rod and one grounding device are regarded as one unit;
- j) Each power cable, control cable, communication system, storage battery and rectifying device is regarded as one unit;
- k) Each dam, power house, water conveying tunnel, penstock, surge shaft, flood and sediment discharge structure, diversion canal, tailrace, gate, trash rack and cleaning equipment and hoist is regarded as one unit;
- l) Each of the other buildings (structures), cable ducts, lifting devices, illumination and ventilation is regarded as one unit;

The equipment and facilities not included herein above shall be determined by the contractor according to the actual situation.

**A.2 Grading method**

A.2.1 The grading of the equipment and facilities is an important work for the hydropower station, and shall be carried out every year.

A.2.2 The grading of the equipment and facilities of one unit shall be determined according to the comprehensive technical status of the individual equipment and the facility in the unit. If the equipment and the facility in one unit simultaneously belong to Grade I, Grade II and Grade III , they will be classified into Grade III; if the equipment and the facility in one unit simultaneously belong to Grade I and Grade II , they will be classified into Grade II; the equipment and facility in Grade I and Grade II are regarded as intact equipment and facility.

A.2.3 The perfectness ratio of the equipment and facility shall be calculated as per the formula (A.1):

$$P = \frac{A + B}{A + B + C} \times 100\% \quad \dots\dots\dots(A.1)$$

where

*P* is the perfectness ratio of the equipment and facility;

*A* is the number of units containing Grade I equipment and facility;

*B* is the number of units containing Grade II equipment and facility;

*C* is the number of units containing Grade III equipment and facility.

**A.3 Principle for equipment and facilities grading**

A.3.1 Grade I: The equipment and facility have a good technical status, and are defect-free; the installation, construction, overhaul and maintenance quality and process level meet the provisions of the specifications, and could ensure them to operate safely, economically and reliably.

A.3.2 Grade II: The equipment and facility have a favourable technical status; although they have minor defects, but the defects will not directly influence safe operation.

A.3.3 Grade III: The equipment and facility have major defects; the installation, construction, maintenance and overhaul quality does not meet the provisions of the specifications, and safe operation

is seriously threatened.

#### A.4 Standards for electrical and mechanical equipment and facilities for grading

##### A.4.1 The grading of the turbine shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) The component is capable of continuously reaching the nominal output mentioned on the nameplate or the output approved by the higher authorities. The component is able to operate normally under various working conditions and load conditions;
  - 2) The vibration and runout of the turbine meet the standard; the stability is good and the unit is free from any rust or corrosion. The bearing temperature and oil quality on various components meet the standard specified in the operating specification;
  - 3) When operating within the parameter scope specified by the manufacturer, the unit is free from serious cavitation, abrasion or efficiency reduction;
  - 4) Vacuum gauge, pressure gauge and temperature gauge installed according to the provisions, the parts are intact, the actions are flexible and the indications are correct;
  - 5) Runner, spiral case, sealing ring, main shaft, end cap and bearing meet the designed and installation process requirements, and are free from any oil or water leakage.
- b) The components shall be classified into Grade III if they fall into any of the following cases:
  - 1) The turbine could not ensure the output indicated on the nameplate when the water head and the flow reach the designed values;
  - 2) Various components of the main body leak water, oil or air, the corrosion and abrasion/erosion are serious, the guide vane could not be tightly closed and the turbine rotates at low speed when the vane is fully closed;
  - 3) The cavitation is serious, and the vibration and runout of the turbine exceed the allowable values;
  - 4) The bearing temperature exceeds the specified value.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

##### A.4.2 The grading of the governor (including PMG) shall comply with the following provisions:



- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) The parameters of the governor (including PMG) meet the design requirements, and the working conditions could satisfy the requirements of the operating specifications;
  - 2) The governor could rapidly control the turbine and resume normal speed when the turbine speed increases due to sudden load rejection;
  - 3) The automatic device and the signal device are intact, and the actions are accurate;
  - 4) The actions of the pressure annunciator under emergency shutdown meet the design requirements when the oil pressure falls to the lower limit;
  - 5) The automatic air compensation equipment and the oil compensation system of the oil pressure unit and the oil level sensors, the pressure accumulator pressure gauges shall operate accurately and reliably;
  - 6) The PMG, if provided, operates normally and provides reliable DC output.
  
- b) The components shall be classified into Grade III if they fall into any of the following cases:
  - 1) The governing system has serious swing, vibration, jamming, abrasion or oil leakage, and could not normally be put into operation;
  - 2) The oil is seriously degraded and the equipment is seriously rusted, which threaten the safe operation;
  - 3) The over-speed protection device is unreliable or the turbine protection fails;
  - 4) Oil pressure device, oil compensation, air compensation systems or other equipment could not work normally, which threatens the safe operation;
  - 5) The PMG is defective and could not provide reliable DC power;
  - 6) The components are under the influence of other elements threatening the safety.
  
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.3** The grading of the main valve shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) The main valve could be closed tightly and rotate flexibly and reliably;

- 2) The protective coating is intact and does not peel off; the component is free from corrosion, cavitation and abrasion;
  - 3) The bypass valve operates normally;
  - 4) With regard to the main valve operated with oil pressure, the oil pressure device operates normally, and is free from any oil leakage; with regard to the main valve operated electronically, the electrical circuit shall work normally and reliably.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) Main valve seriously leaks water;
  - 2) Main valve is jammed when being opened and closed;
  - 3) The corrosion and cavitation seriously threaten safety;
  - 4) The operating circuit has major defects;
  - 5) The components are under the influence of other elements that threaten safety.
- c) The components shall be classified into Grade II if they do not belong in Grade I and Grade III.

**A.4.4** The grading of the generator (including exciter) shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The generator could reach the output indicated on the nameplate or approved by the higher authorities for a long time, and could be put into operation at any time;
  - 2) The vibration and runout of the generator unit comply with the standard, the sound is normal and the noise level meets the provision of the specification;
  - 3) The parts are intact and complete, the coils on the stator end are free from oil stain, carbon dust or deformation, the cushion block and the binding are tight, and the stator core, rotor forging, hoop and binding wires are in good condition;
  - 4) The insulation of the stator and rotor windings is free from obvious aging, the test data meets the specified value, the temperature of the stator core meets the provision, and the measurement is accurate;
  - 5) The cooling system is perfect and the cooling effect is good.

- 6) The exciter and the accessories are intact and could satisfy the normal operation requirement of the generator unit, the carbon brush is intact, in good contact and free from jumping or overheating, the commutator and the collecting ring are level and smooth, and free from carbon dust, and the spark grade meets the provision;
  - 7) The bearing and the sealing device operate normally and are free from any oil leakage; the temperature is in the specified scope;
  - 8) The fittings of the rotor magnetic poles, damping device and fan lead are fixed and free from cracks and deformation; the ventilating ducts are free from rust deposit and blocking.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The generator could not reach the outputs indicated on the nameplate or approved by the higher authorities;
  - 2) The insulation of the stator and the rotor windings is defective or seriously aged, and the voltage withstands standard declines;
  - 3) The DC resistance value of the three-phase stator is seriously unbalanced or significantly different from the data provided by the manufacturer, which threatens safe operation;
  - 4) The exciter and accessories have serious defects which influence the generator outputs;
  - 5) The bearings seriously leak oil or shed oil; there is heavy greasy dirt on the end of the stator;
  - 6) The brake system is defective;
  - 7) The generator has other major defects impacting safe operation.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.5** The grading of the oil system shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The pipeline settings meet the requirements, and the pipelines are free from vibration or deformation;
  - 2) The pipeline accessories and gauges are normal and reliable;
  - 3) The pipelines and valves are not cracked or corroded;

- 4) The valves and flanges are tightly sealed, rotate flexibly and reliably and are free from oil leakage;
  - 5) Oil pressure and oil quality meet the operating requirements;
  - 6) Pipeline welding quality meets the requirement;
  - 7) Pressure oil pump and oil filter meet the design requirement and work reliably;
  - 8) Oil storage tank is free from cracks or leakage, and the gauges are accurate;
  - 9) The appearance is clean, and the marks are intact and correct.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The pipeline settings do not meet the requirements, or the vibration and deformation exceed the provision of the specification;
  - 2) The safety accessories of the pipeline are abnormal, or the gauges/meters are inaccurate;
  - 3) The valves or the flanges seriously leak, the valves could not be flexibly rotated or tightly closed;
  - 4) The pipeline and the valves are damaged or seriously corroded;
  - 5) The oil pressure could not satisfy the operating requirement, and the oil is seriously degraded;
  - 6) The welding quality is below the standard and threatens safety;
  - 7) There are serious defects threatening the safety of the pressure oil pump and the oil filter;
  - 8) The oil storage tank leaks seriously;
  - 9) The components are under the influence of other elements threatening safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.6** The grading of the water supply and the drainage systems shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:

- 1) The setting of the pipeline meets the requirements, the pipeline is free from vibration or deformation and the pipeline and the valves are free from damages or corrosion;
  - 2) The pipeline accessories and gauges/meters are normal and reliable, the valves and flanges are tightly sealed, and the water pump rotates flexibly, operates reliably and is free from water leakage;
  - 3) The filter operates normally, and the water quality and water pressure meet the requirements;
  - 4) The water source and water taking equipment could meet the operation requirements of the unit;
  - 5) The firefighting water is reliable and meets the firefighting requirements;
  - 6) The welding quality of the pipeline meets the requirement;
  - 7) The appearance is clean, and the marks are intact and correct.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The setting of the pipeline does not meet the requirement, the vibration or deformation exceeds the provision of the specification, or the pipeline and the valves are damaged or seriously corroded;
  - 2) The safety accessories of the pipeline are abnormal, the gauges/meters are inaccurate, the valves and the flanges are not well-sealed, the water pump could not rotate flexibly and seriously leaks water;
  - 3) The filtering effect of the filter is poor, and the water quality could not meet the requirement;
  - 4) The water source and the water taking equipment are not reasonably configured and could not meet the operating requirements of the unit;
  - 5) The welding quality of the pipeline does not meet the requirement and threatens safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.7** The grading of the air system (including air compressor) shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:

- 1) The setting of the air system meets the requirements;
  - 2) The pipeline and the accessories are free from cracks and corrosion, the valves could be tightly closed and rotate flexibly;
  - 3) The welding quality of the pipelines meets the requirement;
  - 4) The air compressor could operate continuously and reach the output indicated on the nameplate; at rated output, the operation temperature does not exceed the provisions of the specification;
  - 5) The pressure gauge is intact, accurate and in good contact, the protection and automatic devices pass the inspections, and the actions are reliable;
  - 6) The accessories are intact and in good condition, the reducing valve and the safety valve meet the provisions, and the environment for the equipment and air compressor is neat and clean;
  - 7) The appearance is clean and the marks are intact.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The setting of the air system could not satisfy the operation requirements of the unit;
  - 2) The safety accessories of the pipeline are abnormal, the gauges/meters are inaccurate or the pipelines and the valves are damaged or seriously corroded so that safety is under threat;
  - 3) The welding quality of the pipelines does not meet the requirement and threatens safety;
  - 4) The air compressor could not reach the output indicated on the nameplate; the ratio of the high pressure of compressed air to the low pressure could not satisfy the requirements;
  - 5) The components are under the influence of other elements threatening safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.8** The grading of the main transformer (arc suppression coil) shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The transformer could continuously reach the output indicated on the nameplate or the out-

put approved by the higher authorities;

- 2) The components of the transformer are intact, the shell is not corroded, the surface is smooth and free from any dirt, there is no crack on the porcelain insulators and the lead connectors are in good contact and free from overheating phenomenon;
  - 3) The temperature rise of the oil and winding, the oil level in the conservator tank are as per the values specified by the manufacturer or the value approved after testing;
  - 4) The transformer is installed according to the technological requirements, and is fundamentally free from any sinking, tilting or damage phenomena;
  - 5) The coils, bushings and electric insulating oil (including the bushing oil) are tested according to the specifications and meet the specified requirements;
  - 6) The electrical and mechanical performance of the tapping switch is good, the indicating signs are correct and the actions are flexible and reliable;
  - 7) The gauges and meters are accurate, and the components are intact;
  - 8) The appliances such as the gas relays are intact, and the actions are verified to be reliable and accurate;
  - 9) The explosion-proof equipment, breather, conservator and oil dipstick are intact;
  - 10) The oil level of the transformer and the oil filled bushing meets the provision, there is no leakage phenomenon, the overall cleanliness of the transformer and the bushing is maintained, and the paint is intact;
  - 11) The cross section of the grounding wire meets the provision, the grounding wire is in good contact and is firmly and reliably connected;
  - 12) The transformer has been periodically subjected to overhaul, minor repair and preventive tests, the repair and test records are properly kept and the test results meet the requirements.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The coils, bushings and electric insulating oil (including bushing oil) fail the test;
  - 2) There is an abnormal noise or the light gas protection often acts but the causes have not been found;

- 3) The coil insulation is seriously aged and could not ensure safe and economical operations;
  - 4) The creepage distance of the bushing in the polluted areas does not meet the requirements, nor are any effective measures taken;
  - 5) The electrical or mechanical performance of the tapping switch for the transformer is unfavourable, and could not ensure safe operation;
  - 6) The transformer and the oil-filled pipes seriously leak oil;
  - 7) The output of the transformer is affected or the operational instruments are inaccurate due to the defects of the accessories;
  - 8) The components are under the influence of other elements threatening safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.9** The grading of the electric reactor shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The components are periodically tested according to the provisions and comply with the requirements of the specification; the parameters comply with the actual operational requirements;
  - 2) The coils are not deformed, the concrete columns are free from any cracks and the porcelain parts are not damaged;
  - 3) The body is clean, the paint is intact and the marks are correct and clear.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The components are not periodically tested as required or fail the periodic test;
  - 2) The coils are deformed, the concrete columns are cracked or the porcelain parts are damaged.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.10** The grading of the circuit breaker shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:



- 1) Rated voltage, rated current and cut-off capacity of the circuit breaker could satisfy the operational requirements;
  - 2) The parts of the circuit breaker are in good condition, the operating mechanism acts flexibly and the protection action is reliable;
  - 3) The circuit breaker shall be overhauled and tested according to the provisions of the specifications, and the records are properly kept; the contact situation and the main technical and electrical performance indexes comply with the requirements;
  - 4) The circuit breaker is in good condition, the indications are clear and correct, the overall cleanliness of the equipment is kept and the paint is intact;
  - 5) The porcelain parts pass the insulation test and are free from defects such as cracks and damages.
  - 6) The grounding measures for the body and support are firm and reliable.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The parameters could not satisfy the operation requirements;
  - 2) The protection actions of the operating mechanism are not reliable;
  - 3) The creepage distance of the bushing in the polluted areas does not meet the requirement of the specification, nor are any effective measures taken;
  - 4) The main body fails the insulation test;
  - 5) The equipment has serious defects, and the oil level indication is not clear;
  - 6) There are cracks or damages on the porcelain parts;
  - 7) The components are under the influence of major defects threatening the safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.11** The grading of the disconnecting switch and the high voltage fuse shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) Rated voltage, rated current and cut-off capacity meet the operation requirements;

- 2) The switches could be operated flexibly, and the actions of the locking device are correct and reliable;
  - 3) The electrical contact is in good condition, and the contact resistance meets the requirements of the specification;
  - 4) The porcelain parts pass the insulation test, and are free from defects such as cracks or damages;
  - 5) The periodic test results comply with the provisions of the specifications;
  - 6) The high voltage fuse is free from electro-corrosion.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The equipment parameters could not satisfy the operation requirements;
  - 2) The equipment is seriously overheated, and their safe operation could not be ensured;
  - 3) There are cracks or damages on the porcelain parts;
  - 4) The switches could not be operated flexibly, the switches could not be tightly turned on, the locking device is imperfect, the actions are unreliable and the equipment corrosion is relatively serious;
  - 5) The electro-corrosion of the high voltage fuse is serious.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.12** The grading of the voltage transformer and current transformer shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The parameters meet the demand of the technical conditions for operation;
  - 2) The components are intact, the porcelain parts and insulation part of the body are not damaged and free from dirt or dust, the electric test meets the provisions of the specification;
  - 3) The oil insulation is good and the test results meet the requirements of the specification;
  - 4) The oil level is normal, and there is no oil seepage or overheating phenomenon;

- 5) The overall cleanliness of the component is maintained, the paint is intact and the marks are correct and clear;
  - 6) The wiring is correct, and the grounding measures for the shell and the secondary side are firm and reliable.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) Grade of mutual inductor and ratio of transformation could not meet the operational requirements;
  - 2) The components have not been periodically tested or failed the tests;
  - 3) There is abnormal noise or overheating phenomenon inside;
  - 4) There is oil leakage or serious corrosion phenomenon;
  - 5) The components are under the influence of other defects that threaten safe operation.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.13** The grading of the power capacitor shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The parameters indicated on the nameplate meet the operational requirements;
  - 2) The components are periodically tested according to the provisions, and meet the requirements of the specification;
  - 3) The porcelain parts are intact, free from dirt and dust and undamaged;
  - 4) The sealing is tight and the shell is free from oil seepage, greasy dirt, deformation or corrosion.
  - 5) The paint of the shell is intact.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The parameters indicated on the nameplate could not meet the operational requirements;
  - 2) The test results do not meet the requirements of the specification;

- 3) Fire protection, anti-explosion and ventilation facilities for the capacitor installed indoors are dysfunctional, which influences its safe operation;
  - 4) The capacitor seriously leaks oil or the oil tank is expanded;
  - 5) The components are under the influence of other elements threatening safe operation.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.14** The grading of the various panels and cabinets shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) All kinds of microcomputer protection, comprehensive automation devices, relays, instruments and signal devices in the panel/cabinet are properly installed, and are firm and clean, the enclosure is properly sealed and is marked with the name;
  - 2) The wiring is proper and meets the standard, the cables and terminals are properly numbered and the cross-section of the conductor and the cable meets the provisions of the specification;
  - 3) The screws on the terminals of the subassemblies and components are reliably, and the standby subassemblies and conductors are electrically neutral;
  - 4) The insulation of the subassemblies, components and secondary circuits meets the provisions of the relevant specification, and the enclosures are grounded on two positions;
  - 5) The circuit connection is reliable, and the installation wiring diagram meets the actual situation;
  - 6) The errors of the inspection and test characteristics of the subassemblies and components meet the provision of the specification;
  - 7) The primary equipment in the panel/cabinet is intact in appearance, passes the test, acts reliably and meets the operational requirement;
  - 8) The actions of the full group of various devices are correct and reliable in the tests.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) All kinds of relays, comprehensive automation devices, instruments and signal devices in the panel/cabinet are not properly and firmly installed, or the name marks are unclear;

- 2) The wiring is irregular, the cables and terminals are not numbered or the cross-section of the conductor does not meet the provisions of the relevant specification;
  - 3) The insulation of the subassemblies, components and secondary circuits does not meet the provisions of the relevant specification,
  - 4) The screws on the terminals of the subassemblies and components are not reliably fastened;
  - 5) The checks and test characteristics of the subassemblies and components do not meet the provisions of the specification;
  - 6) The appearance of the primary equipment in the panel/cabinet is damaged, the equipment has not been tested according to the provisions or fails the test, the actions are not reliable and the operation requirement could not be met;
  - 7) The actions of the complete group of various devices are not reliable in the tests.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.15** The grading of the lightning protection and the grounding device shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The configuration and installation of the lightning protection facilities meet the requirements of the design and installation specifications, and the lightning protection components are complete and intact;
  - 2) The installation and the grounding resistance of the grounding device meet the provisions of the specification;
  - 3) The lightning protection device and the grounding device are periodically tested and the results meet the provisions of the specification;
  - 4) All the safe grounding positions are in good contact, firm and reliable;
  - 5) The signs and marks are correct and complete.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The configuration of the lightning protection facilities does not meet the requirements, and the lightning protection device fails the periodic tests;

- 2) The grounding resistance fails the inspection;
  - 3) The grounding wire is not reliable or has other major defects endangering safe operation;
  - 4) The signs and marks are not correct or complete.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.16** The grading of the power cables shall comply with the following provisions:

- a) The cables, cable laying and termination shall be classified into Grade I if all of the following conditions are met:
- 1) The technical specification could meet the operational requirements, and the cables and termination are free from overheating phenomenon;
  - 2) The installation and the layout meet the provisions of the specification, and the protective measures for entering/leaving the ground, bending radius, threading process, arrangement position and height difference and fire prevention measures meet the requirements;
  - 3) The periodic test results meet the requirement of the specification;
  - 4) The components are free from any mechanical damages threatening safe operation;
  - 5) The cable heads and fittings are properly sealed, and free from any obvious oil seepage; the porcelain bushing is intact and undamaged;
  - 6) The laying route, intermediate head and cable core are legibly and properly marked.
- b) The cables, cable laying and termination shall be classified into Grade III if they are in any of the following cases:
- 1) The parameters of the cable could not meet the operational requirements;
  - 2) There is obvious oil seepage, drying or serious overheating signs on the cable head and fittings;
  - 3) The components fail the test or are under the influence of other elements threatening safe operation.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.17** The grading of the control cables shall comply with the following provisions:

- a) The control cables, laying and termination shall be classified into Grade I if all of the following conditions are met:
  - 1) The control cable meets the design provision;
  - 2) The insulation is good, and the tests meet the provision of the specifications;
  - 3) The cable number as well as the signboards indicating that the cable model, number of cores, cross-section, voltage and places are correct and intact;
  - 4) The inlet and outlet of the cable duct are properly sealed;
  - 5) The fixing and the bracket of the cable are intact;
- b) The control cables, laying and termination shall be classified into Grade III if they are in any of the following cases:
  - 1) The technical parameters of the cables do not meet the requirements of the specifications;
  - 2) There is no obvious and correct mark on the cable head and the intermediate head;
  - 3) The components fail the tests or are under the influence of other elements threatening safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.18** The grading of the communication system shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) The equipment is installed according to the provisions of the specification;
  - 2) The performance meets the provisions of the specification and the manufacturer's requirements;
  - 3) Reliable standby power supply is provided;
  - 4) The tone quality and volume meet the technical requirement.
- b) The components shall be classified into Grade III if they are in any of the following cases:
  - 1) The installation does not meet the provisions of the specification;

- 2) The performance could not meet the provisions of the specification or the manufacturer.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.19** The grading of the rectifying device and the DC system panel shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) The characteristics of the rectifying device are as per the specification, the parameters meet the operational requirements and the relay protection and on-off action requirements could be satisfied under normal and fault conditions;
  - 2) The voltage regulator and the voltage stabilizing transformer operate without abnormal noise or overheating phenomenon;
  - 3) The switches and components are firmly and properly installed, the connection points are in good contact and are not heated;
  - 4) The actions of the protection, signal devices and indicating instruments are reliable, and the indications are correct;
  - 5) The wiring is neat, the components are properly marked and numbered, and the practical wiring diagram is provided.
- b) The components shall be classified into Grade III if they are in any of the following cases:
  - 1) The characteristics of the rectifying components could not meet the operational requirements; the relay protection and on-off action requirements could not be satisfied under normal or accident conditions;
  - 2) The installation of the switches and components does not meet the requirement, the connection points are not in good contact and are over-heated;
  - 3) The actions of the protection, signal devices and indicating instruments are unreliable, and the indications are incorrect;
  - 4) The wiring and the marks do not meet the provisions of the relevant specifications.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.20** The grading of the storage battery shall comply with the following provisions:



- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The capacity of the acid (maintenance-free) storage battery reaches the parameter indicated on the nameplate; although the capacity of the used storage battery could not reach the parameter indicated on the nameplate, it is properly maintained and could meet the requirement for on-off action;
  - 2) The electrolyte passes the test;
  - 3) The pole plate is not bent or otherwise deformed, the colour is normal, the shell is intact and not tilted and there is no serious sediment;
  - 4) The storage battery is neat and clean, correctly and clearly marked, and the insulation meets the provisions of the specifications;
  - 5) The fittings are firmly and reliably connected, and not corroded;
  - 6) Acid proofing, sunlight proofing, heating, ventilation and anti-explosion facilities are in good condition.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The capacity could not meet the requirements indicated on the nameplate;
  - 2) The electrolyte fails the test;
  - 3) The pole plate is bent or otherwise deformed, the colour changes and there is a lot of sediment in the shell;
  - 4) The fittings are unreliably connected or seriously corroded;
  - 5) Acid proofing, sunlight proofing, heating, ventilation and anti-explosion facilities do not meet the requirements.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.21** The grading of ventilation and illumination shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The indoor/outdoor illumination and emergency illumination are as per specification and could satisfy the demands for normal operation and emergency illumination, the wiring is neat, the return circuits are in good condition and it is convenient for operation and main-

tenance;

- 2) The intensity of illumination meets the requirement, and no glare is noted in front of the master control room screen (panel);
  - 3) The control room, storage battery room and capacitor room are equipped with good ventilation facilities, the temperature in the general control room does not exceed 35 °C and the temperature of the outgoing air in the storage battery room and the capacitor room does not exceed 40 °C.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The indoor/outdoor illumination could not satisfy the demands for normal operation and emergency illumination;
  - 2) There are serious defects in the ventilation of the control room, storage battery room and capacitor room;
  - 3) The illumination facilities are highly insufficient, the lines are seriously damaged or there are other major defects threatening safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.4.22** The grading of the busbar and the framework shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The thermal stability and dynamic stability of the busbar meet the requirements, and the connections are not over-heated;
  - 2) The technical parameters meet the operation requirements;
  - 3) The components are intact, the porcelain parts are not damaged and are free from traces of discharge, and the framework is properly grounded;
  - 4) The framework is intact and is free from tilting, foundation sinking, and corrosion of the iron parts, rebar exposure or cracks.
  - 5) The marks are complete and correct.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The thermal stability and dynamic stability of the busbar are relatively poor, the

connections of the busbar are over-heated;

- 2) The framework is tilted severely, the phenomena like foundation sinking, corrosion, rebar exposure and cracks are serious;
  - 3) The components are under the influence of other defects threatening safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

## **A.5 Grading standards for buildings and hydro mechanical structures**

**A.5.1** The grading of the earth-rock fill dam shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) The components shall ensure safe operation under design standard conditions;
  - 2) The earth-rockfill dam is free from cracks, seepage, collapse pits and upheaval, the pavement on the dam crest is level and the elevation meets the design requirements;
  - 3) The slopes are intact, and free from loose masonry, collapse, bedding loss, cavity or turf damage;
  - 4) The dam is free from any injurious insect and harmful animal burrows;
  - 5) The junctions between the earth-rockfill dam and both banks, the downstream dam toe and the outlet of the embedded pipe below the dam are free from abnormal leakage phenomenon;
  - 6) All parts of the earth-rockfill dam are free from thick weeds, dregs, rubbish and sundry materials or other unsightly phenomenon.
- b) The components shall be classified into Grade III if they are in any of the following cases:
  - 1) The components could not reach the design standards, and there are defects at some parts influencing safety and normal electricity generation;
  - 2) There are serious damages such as loose slopes and masonry, collapse, bedding loss or cavity;
  - 3) There are injurious insects and harmful animal burrows on the dam threatening safety;

- 4) The seepage of the earth-rockfill dam is serious and threatens safety;
  - 5) The turf slope and rock fill slope are seriously damaged or rolled, resulting in scouring damage to the dam;
  - 6) The components are under the influence of other elements threatening the dam's safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.2** The grading of the concrete and masonry structures (such as the concrete dam and the surge shaft) shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The structure, shape, strength and foundation of the structures meet the design requirements;
  - 2) The reserved expansion joints on the gate dam are free from sundry materials and the fillers are free from any loss;
  - 3) The surface of the gate dam is free from abrasion, scouring, weathering, denudation or cracks;
  - 4) The foundation, the expansion joints and the structure body are free from serious leakage or bypass seepage;
  - 5) The drain holes on the structure body as well as the adjacent drainage ditch, drain pipe and water-collecting well are unobstructed;
  - 6) The forebay shall ensure the intactness of the overflow and drainage facilities and the flushing sluice;
  - 7) The surge shaft (tower) meets the design requirement as a whole, the structure is safe and reliable and could satisfy the requirements for water flow stability and surge when the load changes suddenly. The surge shaft (tower) with top cover is well-ventilated.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The structures could not meet the design standard, and there are serious defects at some parts;
  - 2) There are sundry materials in the reserved expansion joints on the gate dam and the filler are lost seriously;

- 3) The surface of gate dam suffers serious abrasion, scouring, weathering, denudation or cracking;
  - 4) The drain holes on the structure body as well as the adjacent drainage ditch, drain pipe and water-collecting well are obstructed;
  - 5) The foundation of the structure suffers relatively serious water seepage;
  - 6) The lining of surge shaft (tower) walls is in poor contact, the consolidation grouting is of poor quality and there are serious fracturing and leakage phenomena;
  - 7) There are serious defects on the overflow and drainage facilities and the flushing sluice;
  - 8) The components are under the influence of elements threatening building safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.3** The grading of the water conveying tunnel (culvert) shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The inlet of the water conveying tunnel (culvert) is free from scouring, cavitation or freezing-thawing damages;
  - 2) The water conveying tunnel (culvert) is free from any damages caused by over-pressure, negative pressure or water hammer;
  - 3) The water conveying tunnel plug (choke plug) as well as the unused sub-tunnel and grout pipe are free from water leakage;
  - 4) The tunnel body is free from seepage;
  - 5) No weight shall be stacked and no building shall be erected on the top of the non-pressure culvert pipe or the non-pressure tunnel with a thickness of rock mass less than three times the tunnel diameter;
  - 6) Head loss at the inlet of the water conveying tunnel and the frictional head loss have not exceeded the design requirements.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) There are serious defects at the inlet to the water conveying tunnel (culvert);

- 2) There is serious damage deprecation caused by over-pressure, negative pressure or water hammer;
  - 3) The tunnel body and other positions suffer serious seepage;
  - 4) Head loss at the inlet to the water conveying tunnel or the frictional head loss exceed the design value.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.4** The grading of the steel penstock shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The steel plates and the welds are free from cracks or water seepage;
  - 2) The steel rivet holes and the riveted seams are free from leakage, and the rivet head is not damaged;
  - 3) The concrete buttress and the anchor blocks are free from cracks and looseness;
  - 4) There are no barriers influencing the movement of the bearing ring between the bearing ring and the buttress concrete blocks;
  - 5) The sealing of the rolling or cranking support shield is in good condition;
  - 6) The expansion joints are free from water leakage;
  - 7) The protective coatings on the inner and outer walls of the pipeline are intact, and free from obvious corrosion.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The steel plates and the welds are cracked and suffer water seepage;
  - 2) The rivet holes and the riveted seams seriously leak, and the rivet head is damaged;
  - 3) There are cracks on the concrete buttress and the anchor blocks;
  - 4) The movement between the bearing ring and the buttress concrete block is abnormal;
  - 5) The sealing of the rolling or cranking support shield is seriously defective;

- 6) The seepage of the expansion joints is serious;
  - 7) The components are under the influence of other elements threatening safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.5** The grading of the reinforced concrete penstock shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) The reinforced concrete penstock is free from any cracks or seepage;
  - 2) The bell and the spigot joints of the penstock are intact, and free from cracks or seepage;
  - 3) The reinforced concrete penstock is free from exposed rebar or denudation;
  - 4) The concrete buttress and the anchor blocks are free from cracks, sinking or deformation.
- b) The components shall be classified into Grade III if they are in any of the following cases:
  - 1) The reinforced concrete penstock is cracked and seriously leaks;
  - 2) The bell and the spigot joints of the penstock are damaged, cracked or seriously seep;
  - 3) The rebar of the reinforced concrete penstock is exposed or the denudation is serious;
  - 4) There are cracks, sinking or serious deformation on the concrete buttress and the anchor blocks.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.6** The grading of the flood discharge and sand draining structures shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) The foundation is of good quality, the structure is stable and the drainage, seepage-proofing and water stop facilities for the foundation work normally;
  - 2) The lining and overflowing surfaces are level and smooth, and could satisfy the anti-scouring requirement;
  - 3) The flood discharge and energy dissipation facilities are reliable, and free from any potential

hazards which might threaten the safety of the dam foundation, other structures and downstream areas;

- 4) The mountains on both banks at the inlet/outlet of the structures are stable, and free from any landslide or collapse threatening safety;
  - 5) External observation facilities for the safe operation of the structures are equipped, have good performance and work reliably.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The foundation quality is poor, which seriously impacts safe operation;
  - 2) The lining and the overflowing surfaces of the structures could not satisfy the anti-scouring, wear-resistance, anti-freezing or seepage-proofing requirements;
  - 3) The flood discharge and the energy dissipation are seriously unbalanced, which influences the safety of the structures and the downstream area;
  - 4) The mountains on both banks at the inlet/outlet are unstable, and suffer from serious landslide and collapse risks threatening the safety;
  - 5) The components are under the influence of other elements threatening the safety.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.7** The grading of the powerhouse structure shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) The foundation is good and the deformation meets the design standard. The seepage-proofing and drainage facilities work normally;
  - 2) The powerhouse is of stable structure, and free from obvious cracks, deformation or water seepage;
  - 3) The flood fighting, firefighting, ventilation and illumination facilities are as per the design standards and in normal working condition.
  - 4) The observation data on the safe operation of the powerhouse is available, the performance of the observation facilities is good, and the observed results could reflect the engineering practice and meet the requirements;



- 5) The equipment foundations are intact, the indoor/outdoor stationary barriers are perfect and the marks are complete.
- b) The components shall be classified into Grade III if they are in any of the following cases:
    - 1) There are defects influencing the safety of the foundation and the structure of the powerhouse;
    - 2) The flood fighting, drainage, seepage-proofing, water stop, ventilation, firefighting, and illumination facilities are highly imperfect;
    - 3) The powerhouse leaks water or the doors/windows are seriously damaged;
    - 4) The components are under the influence of other elements threatening safe operation.
  - c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.8** The grading of the diversion canal and the tailrace shall comply with the following provisions:

- a) The diversion canal and the tailrace shall be classified into Grade I if all of the following conditions are met:
  - 1) The diversion canal and tailrace are of good quality and could meet the seepage-proofing, anti-freezing, anti-scouring, anti-corrosion and flood fighting requirements;
  - 2) The diversion canal and the tailrace are free from scouring, the tail water level reaches or is close to the design value, and the water flow is unobstructed;
  - 3) The lining quality of the diversion canal and the tailrace is good, and the slope is stable;
  - 4) There are no sundry materials or weeds in the diversion canal and the tailrace.
- b) The diversion canal and the tailrace shall be classified into Grade III if they are in any of the following cases:
  - 1) The diversion canal and the tailrace are of poor quality and suffer from serious scouring and sedimentation;
  - 2) The slope of the diversion canal and the tailrace is collapsed and the water flow is influenced;
  - 3) The water level in the diversion canal and the tailrace could not meet the design requirement, and the diversion canal and the tailrace suffer from serious damming and water bloc-

king phenomenon.

- c) The diversion canal and the tailrace shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.9** The grading of the gate, hoist, trashrack and cleaning equipment shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) Gate and hoist are safe and reliable, and could be flexibly opened/closed; and the stroke meets the requirement;
  - 2) Gate and hoisting equipment are free from deformation, water trapping and oil leakage;
  - 3) The trashrack and cleaning equipment work reliably, and the trashrack is not blocked;
  - 4) The protective coating for the gate and hoisting equipment and the trash rack and cleaning equipment is intact, and is not peeling; the parts are free from corrosion.
- b) The components shall be classified into Grade III if they are in any of the following cases:
  - 1) Gate and hoist and the trash rack and cleaning equipment are seriously deformed or corroded or have other major defects;
  - 2) The trashrack is seriously blocked;
  - 3) The stroke of the hoist could not reach the design requirement;
  - 4) The gate leaks seriously after being closed.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.10** The grading of the lifting device shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
  - 1) The lifting frame and column are free from cracks or deformation;
  - 2) The power supply (including standby power supply), and the power machinery are in good working condition, and may be started at any time;
  - 3) Safety protection facilities and instruments are intact;

- 4) The lubricating oil at the rotating parts of the machinery is sufficient, and the oil volume at the high speed parts (such as the gear box) meets the requirements of the specification;
  - 5) The traction equipment works normally, the steel wires are free from corrosion or broken strands, and the lifting hook is not bent or cracked;
  - 6) The bumper, stopper and limit switches are reliable, and the frame could accurately move to the lifting position.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The lifting frame and column are seriously cracked or deformed;
  - 2) The power supply is unreliable and could not be started as per the requirement;
  - 3) The protection facilities are improper;
  - 4) The lubricating oil at the rotating parts of the machinery is insufficient, and the rotation is not flexible;
  - 5) The steel wirerope is seriously corroded or ruptured, or the lifting hook is damaged, which threatens safety;
  - 6) The components are under the influence of other elements threatening safe operation.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.

**A.5.11** The grading of the other buildings (structures) and the cable ducts shall comply with the following provisions:

- a) The components shall be classified into Grade I if all of the following conditions are met:
- 1) Other buildings and structures are stable, and their strength, deformation, earthquake prevention, flood fighting and drainage and firefighting meet the requirements of the specification and for the production;
  - 2) The access shall meet the operational, maintenance and overhaul requirements;
  - 3) The framework is intact and is free from sinking or tilting; the iron parts are not corroded;
  - 4) The cable ducts are intact and clean, the cover plate is neat and complete, and the water drainage is unobstructed. The intersection between the cable duct, the drainage way and vehicle roads shall be reinforced;

- 5) The indoor and outdoor ground shall be level, and the water drainage shall be unobstructed;
  - 6) The enclosures, fences, gate and indoor/outdoor stationary barriers are intact;
  - 7) The firefighting facilities are perfect, the firefighting equipment is intact and reliable. Safety drills and training of staff are regularly carried out.
  - 8) Emergency oil drainage system is provided.
- b) The components shall be classified into Grade III if they are in any of the following cases:
- 1) The buildings or structures have serious structural defects which threaten the safety of the equipment and personnel;
  - 2) The access is narrow and could not satisfy the operational, maintenance and overhaul requirements;
  - 3) The framework is damaged, sunken or tilted; the iron parts are seriously corroded;
  - 4) The cover plate of the cable duct and the drainage way are seriously damaged, collapsed and threaten personal safety;
  - 5) The indoor and outdoor ground is uneven and a lot of water is trapped on the ground;
  - 6) The enclosures or the fences are tilted or damaged; the gate and the indoor/outdoor stationary barriers are seriously damaged;
  - 7) The components are under the influence of other elements threatening safe operation.
- c) The components shall be classified into Grade II if they do not belong to Grade I and Grade III.
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