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

Part 11: Report Preparation

SHP/TG 002-11: 2019



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

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Foreword

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

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

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

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

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

Introduction

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

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

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

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

Technical Guidelines for the Development of Small Hydropower Plants-Design

Part 11: Report Preparation

1 Scope

This part of the Design Guidelines stipulates the principles, contents, requirements and outlines of different reports required for small hydropower (SHP) projects at the pre-feasibility study and feasibility study stages.

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 Report compilation principles

4.1 National laws and local regulations shall be used as the legal basis for the compilation of the report.

4.2 The data and information cited shall be authentic, accurate, reliable and effective.

4.3 Technical contents shall be consistent with the relevant regulations and requirements of SHP/TG 002.

5 Guidelines of the pre-feasibility study report

5.1 The pre-feasibility study report shall include:

- a) The basis and reasons for proposing the project;
- b) Reasons for site selection, including site characteristics, potential problems and solutions;
- c) A general framework of the proposed investment project;
- d) Technical and economic analysis and evaluation of the proposed investment project.

5.2 The contents of the pre-feasibility study report shall meet the following requirements:

- a) To demonstrate the necessity of engineering construction, and determine the scope and sequence of engineering tasks and comprehensive utilization of resources.
- b) To collect topographical data of rivers and surrounding areas, and preliminarily demonstrate the rationality of site selection.
- c) To preliminarily determine the main hydrological parameters and results according to the analysis and calculation of basic hydrological data.
- d) To preliminarily investigate and analyse the geological conditions and main engineering geological problems in the project area.
- e) To preliminarily determine the scale and development mode of the project.
- f) To preliminarily select the construction sites (dam sites, intake sites and power plant site) of the main structures, and to preliminarily formulate the overall layout of the project and the basic types of the main structures.
- g) To preliminarily select the type, quantity, and layout plan of units.
- h) To work out the main electric connection scheme, selection plan and layout plan of other electromechanical equipment.
- i) To preliminarily select the hydro mechanical structure and layout plan.
- j) To preliminarily formulate the construction diversion mode, construction scheme of main works, external traffic scheme, general construction arrangement and total construction period.

- k) To preliminarily evaluate the social and environmental impact of engineering construction.
- l) To estimate the project investment.
- m) To evaluate preliminarily economic cost-effectiveness and provide financial evaluation.

5.3 The pre-feasibility study report shall be prepared in accordance with the outline provided in Appendix A.

6 Guidelines of the feasibility study report

6.1 The feasibility study report shall demonstrate the technical feasibility and economic rationality of the project on the basis of the pre-feasibility study report. The report shall include the following contents:

- a) Review the conclusion of the pre-feasibility study phase.
- b) Provide applicable plans, countermeasures and drawings for the project implementation.
- c) Provide relatively accurate quantities and costs of the project.
- d) Further evaluate the project value from the perspective of resource allocation and provide the economic appraisal.
- e) Further evaluate project profitability from the perspective of investors and carry out a financial evaluation.

6.2 The contents of the feasibility study report shall meet the following requirements:

- a) To collect relevant policies of the national government, as well as the support provided by social organizations for the project.
- b) To review and determine the project tasks and scale, project operation principles and modes; to re-check the design parameters of ground motion and the corresponding seismic design intensity.
- c) To review and determine hydrological parameters and results.
- d) To ascertain the geological conditions of the reservoir and project area, and to evaluate any geological problems of the project.
- e) To determine the design flood standards and the general layout of the project, as well as the rel-

ative position, structural type, control size, control elevation and work quantity of the selected structures.

- f) To select the type, quantity, basic parameters and layout plan of the turbine. To select the type, quantity, main technical parameters and layout plan of the turbine accessory equipment and auxiliary systems;
- g) To determine the power transmission voltage level and transmission scheme, and to select the main electrical connection scheme, and the type, specifications, main technical parameters, quantity and layout plan of the electrical equipment.
- h) To select the type, quantity, main technical parameters, dimensions and layout of various types of gates, trash racks, valves and hoisting equipment.
- i) To review the construction diversion mode; to determine the structural design of the diversion structures, the construction scheme of main works, the general layout of construction sites and the controlled construction period, and to propose the basis for preparation of construction conditions.
- j) To review the social and environmental impact of engineering construction and determine the design of environmental protection measures.
- k) To prepare the design estimates for the engineering part; to put forward the general design estimate for the project.
- l) To review the economic appraisal indicators.

6.3 The feasibility study report shall be prepared in accordance with the outline given in Appendix B.

Appendix A
(Normative)
Outline of the pre-feasibility study report

Chapter 1 Overview

1. The project geographical location, river planning results and approval opinions and the compilation process of this document.
2. Briefly describe the results or conclusions of the site selection report.
3. Briefly describe the results of the pre-feasibility study.
4. Briefly describe the investment environment and project background (if necessary).
 - a) Collect relevant policies of domestic industries, enterprises, taxation and investment, as well as the role of non-governmental organizations in the small hydropower industry, and analyse the regional investment environment of the project.
 - b) Provide the project background information and relevant information of potential investors.
5. Conclusions and recommendations.
6. The attached drawings and tables mainly include:
 - a) Project position schematic diagram;
 - b) Hydropower development status and planning schematic diagram (plan, cascade longitudinal plan) of the river (section) where the project is located;
 - c) Table of project features.

Chapter 2 Project construction necessity and tasks

1. Demonstrate the necessity of the project from the aspects of resource conditions, social economy and development planning.
2. Demonstrate the tasks and the order of engineering construction.

Chapter 3 Construction conditions and site selection evaluation

1. Briefly describe the topography, landform and traffic situation of the preliminarily selected site.
2. Hydrology
 - a) Briefly describe acquisition conditions, methods of obtaining hydrological data and the quality of the data.
 - b) Analyse the data of runoff, flood and sediment, and provide preliminary results.
 - c) Attached drawings and tables mainly include:
 - 1) Drainage system and hydrological network distribution diagram;
 - 2) Annual runoff or rainfall results table and frequency curve chart;
 - 3) Design storm or flood peak frequency curve chart.
3. Engineering geology
 - a) Briefly describe the regional geological conditions and major geological problems of reservoir areas and main project structures.
 - b) Put forward geological conclusions and suggestions.
 - c) Attach a regional geological map or structure outline map.
4. Preliminarily evaluate site construction conditions.

Chapter 4 Characteristic water level and installed capacity

1. Preliminarily determine the reservoir characteristic water level according to the river basin conditions and technical and economic analysis.
2. According to the tasks, hydro-energy conditions, or load status and planning objectives of the power station in the system, preliminarily determine the installed capacity of the power station and calculate corresponding electric energy indexes.
3. Attach reservoir stage-area-volume curve diagram (table)

Chapter 5 General layout and main structures of the project

1. According to the project scale, determine the design flood standard and preliminarily establish the earthquake fortification criterion.
2. Preliminarily select the project sites (dam site, gate site and plant site).
3. Preliminarily determine the general layout of the project according to the site conditions and development modes of the power station.
4. Preliminarily determine the basic layout, structural type, control elevation and main dimensions of the main structures.
5. Attached drawings and tables mainly include:
 - a) General layout plan of the project;
 - b) Plans and sections of the main structures;
 - c) List of major work quantities.

Chapter 6 Electromechanical equipment and hydro mechanical structures

1. Preliminarily determine the turbine type and unit capacity, select corresponding main and auxiliary equipment, draw up the layout plan and put forward preliminary calculation results of unit regulation guarantees according to the installed capacity, unit operation mode, traffic conditions, equipment costs and other factors.
2. Preliminarily determine the power supply voltage level, main electrical connections, main electrical equipment, monitoring and protection mode and layout of the main electrical equipment.
3. Preliminarily determine the types, parameters and layout of various gates, trash racks, valves and hoist equipment.
4. Attached drawings and tables mainly include:
 - a) Main electromechanical equipment layout plan;
 - b) Main electrical wiring diagram;
 - c) Summary of work quantities of the main hydraulic machinery and equipment for the electrical

and hydro mechanical structures.

Chapter 7 Engineering construction

1. Briefly describe the construction conditions, and preliminarily determine the construction diversion scheme, main project construction scheme, construction layout and construction progress.
2. Attached drawings and tables mainly include:
 - a) External traffic schematic diagram;
 - b) Construction progress chart (table);
 - c) Major quantity summary sheet.

Chapter 8 Social and environmental impact assessment

1. Briefly describe the natural social and economic status quo of the project area and its affected areas and evaluate the social and environmental baseline.
2. Predict impacts of the project on society and the environment, including impacts on society, the water environment, ecological environment, atmospheric environment and acoustic environment.
3. Preliminarily determine the social and environmental protection measures.
4. Estimate the investment in social and environmental protection measures.

Chapter 9 Project investment estimation

1. Briefly describe the compilation principle, basis and price level year of investment estimation; analyse and determine the main basic unit price and the unit price of main works; estimate the total project investment and static total investment.
2. Attached tables mainly include:
 - a) Table of total project investment estimate;
 - b) Table of estimate of auxiliary works;

- c) Table of estimate of construction works;
- d) Table of estimate of electromechanical equipment and installation;
- e) Table of estimate of hydro mechanical equipment and installation;
- f) Table of independent cost estimate.

Chapter 10 Economic appraisal

1. Briefly describe the national policies of the power industry and taxation.
2. Preliminary economic cost benefit evaluation of the project.
3. Preliminary financial evaluation of the project.
4. Attached tables mainly include:
 - a) Economic benefit cost flow table;
 - b) Financial cash flow table.

Chapter 11 Conclusions and suggestions

1. Put forward the conclusions on comprehensive evaluation of the project and suggestions on the work in the next stage.

Appendix B
(Normative)
Outline of the feasibility study report

Chapter 1 Comprehensive description

1. Briefly describe the project geographical location, river planning results, pre-feasibility study results, approval opinions and compilation process of this document.
2. Extract the feasibility study results, comprehensive description and conclusions.
3. Attached drawings and tables mainly include:
 - a) Project feature table;
 - b) Schematic map of river basin and project location;
 - c) General project layout plan and sections of main structures;
 - d) Geographical connection diagram of the power system connecting to the hydropower station;
 - e) General construction layout plan;
 - f) Map of reservoir inundated area;
 - g) General table of design estimates.

Chapter 2 Investment environment and project background

1. Provide relevant policies on domestic industries, enterprises, taxation and investment, as well as the role of non-governmental organizations in the SHP industry.
2. Provide project background information.
3. Information of the project sponsor.

Chapter 3 Hydrologic analysis

1. Briefly describe the physical geography of the river basin, basin and river characteristics, distribution and observation of meteorological (hydrological) observation stations, and the regional meteorological characteristics.
2. Review results of runoff, flood, sediment, evaporation and ice regime.
3. Review results of the design section stage-discharge relation.
4. Attached tables mainly include:
 - a) Statistics of hydrological characteristic values over the years from the reference stations on which the design is based;
 - b) Annual (monthly) runoff and rainfall series;
 - c) Daily average flow series;
 - d) Rainstorm volume and flood peak volume series;
 - e) Typical flood and design flood hydrograph table;
 - f) Table of main section stage-discharge relation curve outcomes.
5. Attached drawings mainly include:
 - a) Watershed system and hydrological network distribution diagram;
 - b) Interpolation charts for runoff, flood, and rainstorm;
 - c) Annual rainfall and annual runoff frequency curve;
 - d) Daily average flow duration curve;
 - e) Storm and flood peak volume frequency curves;
 - f) Typical flood and design flood hydrograph table;
 - g) Main design section stage-discharge relation table.

Chapter 4 Engineering geology

1. Describe the main conclusions and review opinions of engineering geological investigations at the pre-feasibility study stage.
2. Briefly describe the overview of supplementary geological investigation work at this stage and all survey workload up to date.
3. Describe conclusions of basic geological conditions, regional tectonic stability and seismic parameters in the project area.
4. Put forward engineering geological conditions, reservoir seepage, immersion and reservoir bank stability in the reservoir area are described and the relevant treatment suggestions.
5. Describe engineering geological conditions of structures, evaluate engineering geological problems of the structures, and determine physical and mechanical parameters and hydrogeological parameters of the main rock and soil mass of the structures.
6. Describe types, quantities and quality of various natural construction materials for the project and put forward the investigation results at this stage.
7. General conclusions and suggestions.
8. Attached drawings and tables mainly include:
 - a) Comprehensive geological map of reservoir area;
 - b) Engineering geological maps of dam site and other structures area;
 - c) Geological map of bed rocks (including contour map of bed rocks) of the dam;
 - d) Engineering geological profile of the dam site and other structures area;
 - e) Seepage profile of the dam anti-seepage lines;
 - f) Distribution chart of natural construction materials production places;
 - g) Engineering geological profile of any specific areas of potential problems;
 - h) Typical borehole histogram;
 - i) Summary of test results of rock, soil and water.

Chapter 5 Water energy and project scale

1. Briefly describe water energy calculation results and approval opinions at the previous stages.
2. Analyse or review the water energy output and related energy indexes of the project site.
3. Review project scales, including selection of normal storage water level and dead water level, runoff regulation calculation, installed capacity selection, unit rated water head and unit capacity selection; review design values of ground motion parameters and corresponding seismic design intensity.
4. Analyse reservoir operation, including determination of reservoir operation mode, reservoir sediment deposition analysis, sediment parameters and backwater calculation.
5. Attached drawings mainly include:
 - a) General project layout;
 - b) Reservoir stage-area-storage curve;
 - c) Curve of guaranteed rate of power generation;
 - d) Reservoir sedimentation longitudinal section and backwater curve;
 - e) Reservoir operation and dispatching graph.

Chapter 6 Project layout and structures

1. Review the design flood standard, and describe technical standards and main design allowable values on which the design is based.
2. Compare and determine the general layout scheme of the project, based on pre-feasibility study results.
3. Determine the type, quantity, layout scheme and main dimensions of the structures and conduct structural calculation and stability analysis.
4. Determine the project permanent traffic plan, building structure and comprehensive utilization plan.
5. Determine project safety monitoring items and layouts.

6. Attached drawings and tables mainly include:

- a) Site layout plan;
- b) Layout comparison and profile of main structure types;
- c) General project layout plan and main structure arrangement plan and section of recommended scheme;
- d) Project safety monitoring layout plan;
- e) Results of stability and stress calculation for major structures;
- f) Work quantity summary sheet.

Chapter 7 Electromechanical, hydro mechanical structure, ventilation and heating

1. Select basic parameters, such as turbine type, quantity and unit capacity; select the turbine type and installation elevation; and select the form, quantity and arrangement of the auxiliary equipment and system of the turbine.
2. Review the calculation for regulation guarantee of the unit.
3. For a hydropower station with high sediment concentration in flow passing through the turbine, the anti-corrosion measures for major flow passage components are determined.
4. Determine the voltage level, the number of transmission lines, and the connection point and distance of the lines and the power system.
5. Select the main electric connection scheme, station service power supply scheme, specifications, quantity and layout of electrical equipment; determine the monitoring, relay protection, excitation, operation control power supply, communication and other design schemes.
6. Select the type, quantity, technical parameters, dimensions and layout of hydro mechanical structure gates, trash racks, valves and hoisting equipment; and select the corrosion, clogging and freezing prevention schemes and measures for hydro mechanical structures.
7. Select the heating, ventilation and air conditioning scheme, and equipment form, quantity and layout; and select the firefighting design scheme, power distribution design and firefighting equipment layout.
8. Attached drawings and tables mainly include:

- a) Layout plan of electromechanical equipment in the main and auxiliary powerhouses;
- b) Comprehensive characteristic curve of the turbine operation;
- c) Chart of oil, air, water, and hydraulic monitoring systems in the hydropower station;
- d) Geographical connection diagram of the power system connecting to the hydropower station;
- e) Main electrical wiring diagram;
- f) Auxiliary power and dam area power supply system diagram;
- g) Monitoring and communication system structure and layout diagram;
- h) General layout of hydro mechanical structure of the project;
- i) Short circuit current calculation results table;
- j) Summary sheet of hydraulic machinery equipment;
- k) Summary sheet of electrical equipment;
- l) Hydro mechanical structure summary sheet;
- m) Summary sheet of heating, ventilation and air conditioning equipment;
- n) Firefighting and automatic fire alarm equipment list.

Chapter 8 Construction organization design

1. Briefly describe construction conditions, including natural conditions, water supply, power supply, communication, traffic, material organization and on-site access.
2. Preliminarily determine the natural material borrow area, and mining, processing and transportation schemes.
3. Determine the construction diversion and closure scheme, construction scheme of main works, layout of construction workshops, construction transportation, construction overall layout and general construction progress.
4. Attached drawings and tables mainly include:

- a) General construction layout plan;
- b) Construction diversion procedures and project layout plans at each phase;
- c) Diversion works structure chart;
- d) General construction schedule;
- e) Construction plant facilities, scale of production and quantity list of major machinery and equipment.

Chapter 9 Environmental protection design

1. Briefly describe the natural social and economic status of the project area and it's affected areas and evaluate the environmental baseline.
2. Briefly describe the environmental assessment criteria.
3. Predict the social and environmental impact of the project, including inundation, migration, water environment, water ecology, terrestrial ecology, atmospheric environment, and noise.
4. Briefly describe the general situation of land acquisition and resettlement, and analyse the impacts on the living standards, infrastructure, community reconstruction, religious or ethnic customs, cultural relics, landscape and other aspects of resettled residents.
5. Put forward social and environmental protection measures and countermeasures; design environmental protection facilities and social impact compensation measures; put forward environmental monitoring programmes and social and environmental protection budget estimates.
6. Attached drawings mainly include:
 - a) General layout of environmental protection design;
 - b) Design plans for various environmental protection measures;
 - c) Layout of environmental monitoring points.

Chapter 10 Project cost estimation

1. The project cost estimation includes compilation instructions, principles and basis, and a summary of estimate results.

2. Attach tables mainly include:

- a) Estimate table;
- b) Construction project estimate table;
- c) Estimate table for electromechanical equipment and installation;
- d) Estimate table for hydro mechanical equipment and installation;
- e) Estimate of temporary construction works;
- f) Project unit price summary sheet;
- g) Material estimate summary sheet.

Chapter 11 Economic appraisal

1. Evaluate the project economic cost benefit.

2. Carry out the project financial evaluation.

3. Describe the financing plan, financial evaluation conclusion and economic appraisal conclusion.

4. Attach drawings and tables mainly include:

- a) Construction investment estimate table;
- b) Total investment utilization plan and financing table;
- c) Total cost estimate table;
- d) Profit and profit distribution table;
- e) Cash flow statement of financial plan;
- f) Cash flow statement for project investment;
- g) Schedule for repayment of capital with interest;
- h) Project break-even analysis chart;

- i) Project sensitivity analysis chart.

Chapter 12 Conclusions and suggestions

1. Summarize the concluding opinions of the feasibility study report, explain the main differences between concluding opinions and the approval opinions in the pre-feasibility study stage, and put forward suggestions for future work.
-