SYLLABUS AND
TEACHERS' REFERENCE

RURAL HYDROPOWER CIVIL ENGINEERING

Decentralised schemes up to 500 kW

European Union

german cooperation
DEUTSCHE ZUSAMMENARBEIT

USAID
FROM THE AMERICAN PEOPLE

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Rural Hydropower Civil Engineering

Syllabus & Teacher's Reference for a 120-hours training course for civil engineers
3nd Edition • March 2017
Developed in pursuit of conformity with the Nigerian Competency Standards for Clean Energy | Release 2016 in the domain "Rural Hydropower Civil Engineering (Micro hydropower schemes up to 500 kW)"

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Content

ABOUT

This document seeks to guide trainers on the delivery of the training course Rural Hydropower Civil Engineering. The topics and subjects contained are a result of the needs expressed by the clean energy private sector in Nigeria conducted in 2014 and Competency Standards evolved together with the industry in 2015 and 2016. This document is expected to be reviewed periodically to reflect changing needs of the Nigerian market.

Course objective	Enable civil engineers to plan, design and commission civil works for rural hydropower projects up to 500 kilowatts (kW), supervise construction and provide related advisory services – in conformity with the requirements of the **Nigerian Competency Standards for Clean Energy**	Release 2016 in the domain *"Rural Hydropower Civil Engineering (Micro hydropower schemes up to 500 kW)"*.
Target group	**Civil engineers**
Entry criteria	Minimum Higher National Diploma (HND) or university degree in civil engineering recommended with 2 years' of relevant experience
Duration	120 hours recommended (equivalent to 15 days at 8 hours per day)
Class size	14-18 trainees recommended
Expected tasks and duties	▪ Plan and design civil engineering works for micro hydropower schemes ▪ Provide advisory services ▪ Plan maintenance schedule ▪ Supervise construction
Teaching methods	▪ Discussions ▪ Lectures (presentations and videos) ▪ Group work (homework, role plays and presentations) ▪ Pop-quiz ▪ Field trips ▪ Hand outs ▪ Demos
Assessment methods	▪ Written examination ▪ Oral examination ▪ Group projects

1.1. USING THE SYLLABUS

The content of each course module is broken down to topical levels. Key information guides the trainer on the following:

- **Competency level** that the student is expected to attain at the end of the module. There are 5 levels of competency detailed in this document
  - Skills and competencies required by the trainee for knowledge purposes only are classified as "**To know"**. This is the simple most level.
  - Skills and competencies required for explaining to third parties are classified as "**To understand"**.

  - Skills and competencies required for day-to-day work on an as-is basis in respect of the handbook are classified as "**To use"**. Training on practical examples, for instance, is essential to attain this.
  - Skills and competencies for day-to-day work which need to be adapted to practical contexts are classified as "**To apply".** This level is the most demanding and requires application in areas beyond what has been learned.
- Appropriate **teaching techniques** and methods for effective delivery of contents.
- **Activities** to aid effective knowledge transfer.
- **Materials and equipment** required for training activities.
- **Key resources** for trainers to study to ensure the depth and breadth of their knowledge exceeds that of the Course Handbook.

1.2. COURSE DURATIONS

The recommended contact hours for delivery of this course is **120 hours**. This would translate into 15 days of training for a fulltime delivery of 8 hours per day.

For effective delivery, the course is designed in modules, each with recommended duration of delivery. The recommended amount of time to be spent by the students in specific learning environments is suggested in the following groups:

- **Classroom:** Duration suggested in a classroom setting where techniques such as discussions, role plays, and interactive sessions, exercises presentations are deployed to *engage* the students apart from traditional teaching.
- **Lab/workshop, field trips:** Duration suggested for engaging in practical aspects. This could be field trips, site visits, laboratory experiments or any other form of engagement *practical* in nature.
- **Spare time:** Contingency kept aside to use at discretion of the trainer. The trainer decides what environment to use the spare time for based on the response of the class to course content.
- **Additional self-study:** Duration the student is expected to engage in self-study and research complementing classroom and practicals time.

1.3. ACTIVITIES

Various activities are required for the successful delivery of the course. These include:

- **Demo:** Concepts or aspects are being demonstrated to students.
- **Exercise:** Activities that require the student to solve problems in the classroom.
- **Experiment:** Carry out practical exercises in a controlled environment, usually the laboratory.
- **Interactive session:** Sessions where students are engaged in open discussions to share their views with the class, thus sparking intellectual debates.
- **Role play:** Students to perform roles they are expected to assume or encounter in the workplace.
- **Site visit**: Field trips that serve as a means of buttressing the point made in class by providing the students with tangible evidence/experience of concepts taught.
- **Video:** For introduction and support of concepts taught in class.

SPECIAL SYMBOLS

⌘ Indicates *material* available in softcopy in the package folder.

♦ Indicates *resources* available in softcopy in the package folder.

1.4. MATERIALS AND FACILITIES

To successfully deliver this training course – particularly in view of the skills acquisition, certain materials and equipment are required. A careful review of this section is warmly recommended well ahead of the delivery of the course to ascertain availability, verify operating status, initiate procurement or repairs and provide alternatives wherever the originally recommended item is unavailable. The success of this training course vitally depends on practice on such material and equipment encompassing:

- Access to sites with hydropower potential
- Theodolite or dumpy level
- Altimeter
- Conductivity meter
- Handheld global positioning system (GPS)
- Common salt
- Measuring tape
- Stopwatch
- Topographical maps
- Water level tube
- Laptops

Minimum requirements for class of 18 students	*Quantity*	*Approx. unit cost*	*Approx. total cost*
Computer per participant	Lot	Students to bring their own device	
Cardboard strips	Lot		
Pin board	1		
Laptop	1		
Projector	1		
Whiteboard	1		
Whiteboard markers	Lot		
Pins/thumb tacks	Lot		
Loud speaker	1		
Water level tube (8 metre length)	4	3,000 Naira	12,000 Naira
Altimeter - "Hand held" Barometer Huger EB 833 H	4	25,000 Naira	100,000 Naira
Hand held GPS - Garmin GPSMAP64	4	62,500 Naira	250,000 Naira
Dumpy level/ theodolite	1	237,000 Naira	237,000 Naira
Measuring tape – 30 metre	4	2,500 Naira	10,000 Naira
Conductivity meter (Lutron CD-4301)	1	37,500 Naira	37,500 Naira
Weighing scale – kitchen top model	4	10,000 Naira	40,000 Naira
Common salt (2 kg)	1	5,000 Naira	5,000 Naira
Stopwatch (included feature in the altimeter)	4	3,000 Naira	12,000 Naira
Topographical sheets of 1:20,000 scale of sites	Lot	75,000 Naira	
Internet access for students			

Prices are as at February 2016

1.5. TRAINING COURSE OVERVIEW

Module 1. Components and structures	***16 hours***
Content	Introduction 1.1 System components 1.2 Types of hydropower schemes 1.3 Turbine selection
Recommended time allocation	15 hours Classroom 0 hour Lab/workshop, field trip 1 hour Spare time +4 hours Additional self-study
Learning outcomes	At the end of the module, the learner is able to: ▪ Identify and notice the importance of components of a small hydro-power (SHP) system ▪ Describe the functions of components of SHP systems ▪ To locate components in a new scheme

Module 2. Site assessment	***40 hours***
Content	2.1 Hydrology 2.2 Geological aspects Map reading
Recommended time allocation	20 hours Classroom 16 hours Lab/workshop, field trip 4 hours Spare time +4 hours Additional self-study
Learning outcomes	At the end of the module, the learner is able to: ▪ Measure head and flow of a stream ▪ Assess the potential of a site ▪ Assess the geological features of the site ▪ Define the site layout

Module 3. System design and implementation	***48 hours***
Content	3.1 Diversion works 3.2 Storage structures 3.3 Spillways 3.4 Water conveyance systems 3.5 Penstocks 3.6 Maintenance of civil components
Recommended time allocation	20 hours Classroom 24 hours Lab/workshop, field trip 4 hours Spare time +8 hours Additional self-study
Learning outcomes	At the end of the module the learner is able to: ▪ Select an appropriate layout for SHP civil works ▪ Design and plan the civil works and select appropriate materials ▪ Understand best practices and common pitfalls ▪ Supervise construction of rural hydropower civil works

Practice Test – In preparation of national certification *16 hours*

Purpose

At the end of the course, the aptitude of each trainee should be assessed through a practice test in preparation of National Certification. The test should be based on the same benchmark: **Nigerian Competency Standards for Clean Energy** | Release 2016 in the domain *"Rural Hydropower Civil Engineering (Micro hydropower schemes up to 500 kW)"*.

Recommended duration and weightage

Duration	Examination type	Weightage
6 hours	Written examination	40%
2 hours	Oral examination	25%
8 hours	Practical examination/project	35%

Grading

A candidate is deemed to have completed the course successfully (passed) if candidates attains a cumulative average **score of 70% or above**.

Recommended certificate

Certificate of participation

MODULE 1: COMPONENTS AND STRUCTURES

Content	Topics	Methods & materials	Key resources
Introduction (1 hour)			Competency level: To understand
Definition	- Classification of hydro - Sub classification of small hydro	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards **Activities** Interactive session 1.0-1: Teacher uses Metaplan style to recognise the current knowledge base of the students. By asking them to mention what they each understand by hydropower. ⌘Video 1.0-1: Video detailing hydropower in general for introduction to the course (10 mins) ⌘Video 1.0-2: Video showing a 15 kW micro hydro scheme.	1. ♦*Micro hydro power scout guide* • German Technical Cooperation (GTZ) 2. ♦*Layman's guidebook on how to develop a small hydro site* • European Small Hydropower Association (ESHA) 3. *Micro hydro design Manual* • ITDG (now Practical Action)
General characteristics of SHP	- Strengths - Weaknesses - Opportunities - Threats		
1.1 System components (6 hours)			Competency level: To apply
General layout	- List all components	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards **Activities** Interactive session 1.1-1: Teacher plays Video 1.0-2 and asks students to identify the system components. ⌘Interactive session 1.1-2: Teacher plays Video 1.0-2 and discusses with students the role individual components play. Also discussing the scenarios in the absence/ presence of the components.	1. ♦*Micro hydro power scout guide* • German Technical Cooperation (GTZ) 2. ♦*Layman's guidebook on how to develop a small hydro site* • European Small Hydropower Association (ESHA) 3. *Hydro-electric handbook* • William P. Creager & Joel D. Justin 4. *Micro hydro design manual* • Adam Harvey & others 5. *Irrigation engineering and hydraulic structure* • Santosh Kumar Garg 6. *Water power engineering* • M.M. Dandeker & K.N. Sharma
Reservoir	- Purpose - Different types - Suitability		
Different types of dams	- Purpose - Foundation criteria - Suitability		
Diversion/ intake	- Purpose - Side intake - Drop Intake - Suitability		
Spillways	- Purpose - Different types		
Desilting	- Purpose - Main criteria		

Content	Topics	Methods & materials	Key resources
Headrace	- Purpose - Different types - Location - Sizing - Leakage - Intake screen	⌘Exercise 1.1-1: Teacher engages students with critical thinking sessions to test their ability to apply knowledge gained.	7. *Feasibility studies for small scale hydro power additions: A guide manual* • US Army Corps of Engineers 8. *Civil engineering guidelines for planning and designing hydro electric developments* • American Society of Civil Engineers (ASCE)
Power intake/ forebay	- Purpose - Location - Surge - Bypass gates		
Penstock	- Purpose - Design aspects - Support and anchorage - Expansion joints - Sizing		
Powerhouse	- Purpose - Design aspects - Location criteria		
Tailrace	- Purpose - Design aspects - Location criteria		
Transmission	- Design aspects - Earthing		
1.2 Types of hydropower schemes (2 hours + 2 hours of exercise)			Competency level: To know
Power calculations	- Head - Flow - Efficiency	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards **Activities** ⌘Exercise 1.2-1: Students are given numerical exercises to calculate the theoretical power output on different hydropower schemes. The students use these results to classify the schemes.	1. *Teachers manual hydropower engineering* • Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee 2. ♦*Manuals and guidelines for micro hydropower development in rural electrification - Volume I* • Japan International Cooperation Agency (JICA)
Classification	- Flow condition - Head - Load - Interconnection		
Based on flow condition	- Run of river - With dam storage - Pumped storage		
Based on head	- Low - Medium - High		
Based on load	- Base-load - Peak load		
Based on interconnection	- Grid connected - Isolated		

Content	Topics	Methods & materials	Key resources
1.3 Turbine selection (2 hours + 2 hours exercise)			Competency level: To apply
Turbine types	- Impulse - Reaction - Design aspects - Selection criteria	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards **Activities** ⌘Exercise 1.3-1: Students are given numerical exercises where they have to select turbines for hydropower schemes using the examples in exercise 1.2-1. Students use turbine selection worksheets to make selections. Demo 1.3-1: Students are shown, where possible, actual turbine types. Otherwise, pictures are used.	1. ♦*Micro hydro power scout guide* • German Technical Cooperation (GTZ) 2. *Basics of mechanical engineering and hydropower* • Khanna Publishers
Specific speed	- Definition - Impulse and reaction type		
Impulse turbines	- Characteristics - Types		
Reaction turbines			

MODULE 2: SITE ASSESSMENT

Content	Topics	Methods & materials	Key resources
2.1 Hydrology (8 hours class + 8 hours site visit)			Competency level: To apply
Introduction	- Definition - Surface water - Ground water	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards Meteorological data, Altimeter, Water tube, Theodolite, GPS unit, Measuring tape, Conductivity meter, Common salt, Weighing scale, Stopwatch **Activities** Demo 2.1-1: Teacher to demonstrate to students how to collect and interpret rainfall data. Demo 2.1-2: Teacher shows the students how to use the various measurement instruments and how to use them. ⌘Exercise 2.1-1: Students interpret data using worksheets to develop (a) hydrograph and (b) flow duration curve (FDC). ⌘Site visit 2.1-1: Students are taken to a stream/river and they take measurement of (a) flow and (b) head of the site.	1. ♦*Micro hydro power scout guide* • German Technical Cooperation (GTZ) 2. *Concise hydrology* • Dawei Han 3. *Fundamentals of hydrology* • Tim Davie 4. *How to compile rainfall data – Training module SWDP-11 – Training module* • Hydrology Project by World Bank and Netherlands 5. *Irrigation water resources and water power engineering* • P.N. Modi 6. *Guide on how to develop small hydropower plant* • European Hydropower Association (ESHA) 7. *Civil engineering guidelines for planning and designing hydro electric developments* • American Society of Civil Engineers (ASCE)
Precipitation	- Measuring rainfall - Interpretation - Graphical analysis - Regional analysis		
Run-off and stream flow	- Catchment area - Runoff - Stream flow data - Different types of measurement - Flow characteristics - Flood run-off - Flow duration curve (FDC)		
Gross head	- Digital instruments - Dumpy levels and theodolites - Maps - Altimeters - Hand held GPS		
2.2 Geology (8 hours + 8 hours site visit)			Competency level: To apply
Introduction	- Definition - Importance	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards	1. *Essentials of geology* • Stephen Marshak 2. *Engineering geology* • N. Chenna Kesavulu 3. *Preparation of projects and engineering geology – PWD handbook GOM* • R.B. Gupte & L.G. Godbole
Geological structures	- Geo engineering properties - Outcrops - Strike and dip - Faults - Unconformity		
Stability of slopes	- Land slides - Slope stability		

Content	Topics	Methods & materials	Key resources
Siting the dam	- Case studies - Considerations in the selection - Geo-structural features	**Activities** Interactive session 2.2-1: At the beginning of the class, the teacher uses Metaplan style to asking students to list geological features that they know (max. 15 minutes). Site visit 2.2-1: Students go on a field trip to observe of geological formations.	4. *Water resources engineering – Principles and practices* • C. Satyanarayana Murthy
Reservoirs	- Capacity - Preventing leakages - Silting		
Map reading (2 hours + 2 hours exercise)			Competency level: To apply
	- Interpreting maps using contour lines - Determining the catchment area - Defining geological features	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards Topographical maps, transparent graph sheet **Activities** ⌘Demo 2.0-1: Students are guided on how to interpret maps using contour lines (scale - 1: 50,000). Teacher uses one worked example. Exercise 2.0-1: Students are given topographical maps on which they practice map reading skills. Students calculate (a) catchment area (b) siting of components (intake, canal, forebay, penstock, power house and tailrace).	

MODULE 3: SYSTEM DESIGN AND IMPLEMENTATION

Content	Topics	Methods & materials	Key resources
3.1 Diversion works (6 hours classroom)			Competency level: To understand
Storage head works	- Definitions	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards **Activities** Exercise 3.1-1: Students conduct numerical calculations.	1. ♦*Micro hydro power scout guide* • German Technical Cooperation (GTZ) 2. *Civil engineering guidelines for planning and designing hydro electric developments* • American Society of Civil Engineers (ASCE) 3. *Irrigation water resources and water power Engineering* • P.N. Modi 4. *Irrigation engineering and hydraulic structures* • Santosh Kumar Garg 5. *Water resources engineering – Principles and practices* • C. Satyanarayana Murthy 6. ♦*Wetlands engineering handbook* • US Army Corps of Engineers 7. ♦*Small dams and weirs in earth and gabion material* • Food and Agricultural Organisation (FAO)
Diversion head works	- Temporary works - Permanent works - Weirs and barrages - Layout		
Types of weirs	- Classification methods - Vertical drop - Rock-fill weir - Concrete weirs - Other types		
Design considerations of weirs	- Hydraulic - Structural		
Hydraulic design of weirs	- Data required - Design for flood discharge - Shape of the weir - Discharge over weir - Water way - Energy dissipation - Causes of failure - Head regulator - Structural design considerations		
3.2 Storage structures (6 hours classroom)			Competency level: To understand
Storage structures	- Introduction	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards	1. ♦*Micro hydro power scout guide* • German Technical Cooperation (GTZ) 2. *Civil engineering guidelines for planning and designing hydro electric developments* • American Society of Civil Engineers (ASCE) 3. *Irrigation water resources and water power engineering* • P.N. Modi
Classification of dams	- Storage dams - Diversion dams - Detention dams - Based on shapes - Based on materials		

Content	Topics	Methods & materials	Key resources
Selection of type of dam	- Topography - Geology and foundation conditions - Construction materials - Spillway and its location - Environmental considerations - Earth quake zone - General consideration		4. *Irrigation engineering and hydraulic structures* • Santosh Kumar Garg 5. *Water resources engineering – Principles and practices* • C. Satyanarayana Murthy 6. ♦*Wetlands engineering handbook* • US Army Corps of Engineers 7. ♦*Small dams and weirs in earth and gabion material* • Food and Agricultural Organisation (FAO) 8. *Small hydroelectric engineering practice* • Bryan Leyland
Site selection	- Type and characteristics - Reconnaissance - Preliminary investigation - Final investigations		
Gravity dam	- Data required - Examples - Structural stability - Conditions on stability		
Embankment dams	- Earthen dams - Rockfill dams - RCC dams - Failure of dams - Safety of dams		
3.3 Spillways (2 hours)			Competency level: To apply
	- Introduction - Design flood	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Meta-plan cards, Metaplan pin boards	1. ♦*Micro hydro power scout guide* • German Technical Cooperation (GTZ) 2. *Civil engineering guidelines for planning and designing hydro electric developments* • American Society of Civil Engineers (ASCE) 3. *Irrigation water resources and water power engineering* • P.N. Modi 4. *Irrigation engineering and hydraulic structures* • Santosh Kumar Garg
Types of spillways	- Free overfall spillway - Overflow spillway - Side channel spillway		
Energy dissipation	- Stilling basins - Bucket type		

Content	Topics	Methods & materials	Key resources
			5. *Water resources engineering – Principles and practices* • C. Satyanarayana Murthy 6. ♦*Wetlands engineering handbook* • US Army Corps of Engineers 7. ♦*Small dams and weirs in earth and gabion material* • Food and Agricultural Organisation (FAO)
3.4 Water conveyance system (2 hours)			Competency level: To understand
	- Introduction - Conduits	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards **Activities** ⌘Exercise 3.4-1: Students perform sizing calculations using Excel spreadsheet.	1. ♦*Micro hydro power scout guide* • German Technical Cooperation (GTZ) 2. *Irrigation water resources and water power Engineering* • P.N. Modi 3. *Irrigation engineering and hydraulic structures* • Santosh Kumar Garg 4. *Water resources engineering – Principles and practices* • C. Satyanarayana Murthy 5. ♦*Wetlands engineering handbook* • US Army Corps of Engineers 6. ♦*Small dams and weirs in earth and gabion material* • Food and Agricultural Organisation (FAO)
Power canals	- Alignment - Design - Lining - Flumes - Surges - Sediment control - Cross drainage works - Catch water drains - Slope protection		
Water hammer	- Resonance - Channel surges - Surge tanks		
3.5 Penstocks (2 hours)			Competency level: To apply
Penstocks	- Classification - Materials - Jointing - Buried or embedded - Design criteria - Number of penstocks - Economical diameter - Anchor blocks - Forces on anchor blocks	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards **Activities** ⌘Exercise 3.5-1: Students perform sizing calculations using Excel spreadsheet.	1. ♦*Micro hydro power scout guide* • German Technical Cooperation (GTZ) 2. *Irrigation water resources and water power Engineering* • P.N. Modi 3. *Irrigation engineering and hydraulic structures* • Santosh Kumar Garg

Content	Topics	Methods & materials	Key resources
			4. *Water resources engineering – Principles and practices* • C. Satyanarayana Murthy 5. ♦*Wetlands engineering handbook* • US Army Corps of Engineers 6. ♦*Small dams and weirs in earth and gabion material* • Food and Agricultural Organisation (FAO)
3.6 Maintenance of civil components (2 hours)			Competency level: To apply
Maintenance	- Weirs - Intakes - Overflows and spillways - Channels - Silt tanks, forebay tanks and reservoirs - Penstocks - Valves	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards	1. *Irrigation water resources and water power Engineering* • P.N. Modi 2. *Irrigation engineering and hydraulic structures* • Santosh Kumar Garg 3. *Water resources engineering – Principles and practices* • C. Satyanarayana Murthy 4. ♦*Wetlands engineering handbook* • US Army Corps of Engineers 5. ♦*Small dams and weirs in earth and gabion material* • Food and Agricultural Organisation (FAO)
End of course project (24 hours) Students are divided into three groups to work on one narrative for a hydropower scheme. At the end of the exercise (16 hours), each group makes a presentation to the rest of the class and answers questions on their design process (8 hours).			

FURTHER SUGGESTIONS

- Enhancing the course with opportunity for engagement with rural communities;
- Additional exercises;
- Make supplied resource material available to trainees.