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MINI-GRID TECHNICAL GUIDELINES

Operation Manual Ref: Annex 4

DEPARTMENT OF RURAL DEVELOPMENT,

MINISTRY OF AGRICULTURE, LIVESTOCK AND IRRIGATION

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ABBREVIATIONS AND ACRONYMS

AC	Alternating Current
BOS	Balance of Systems
DRD	Department of Rural Development
ELC	Electronic Load Controller
ESE	Electricity Supply Enterprise
FS	Feasibility Study
HH	Households
IEC	International Electrotechnical Commission
IECEE	IEC System for conformity testing and certification of electrotechnical equipment and components
IFC	International Finance Corporation
IGC	Induction Generator Controller
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
LED	Light Emitting Diode
LV	Low voltage (400V)
MoEE	Ministry of Electricity and Energy
MV	Medium voltage (11-33kV)
MW	Megawatt
NEP	National Electrification Project
PMO	Project Management Office within DRD
Pre-FS	Pre-Feasibility Study
PV	Photovoltaic
RoR	Run-of-River
VEC	Village Electrification Committee
Wp	Watt-peak

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1 INTRODUCTION

The Off-Grid Component of the National Electrification Project (NEP) is supporting the development of mini-grids using one or a combination of energy generation technologies for pre-electrification.

The generation source shall be decided based on assessment of various resources at the potential site. Candidates include, but are not limited to, solar photovoltaic (PV), micro hydropower, biomass, wind, diesel or any combination (hybrids) of these technologies. Mini-grids up to one megawatt (MW) effective generation capacity are eligible for assistance through this program, and larger systems may be considered on a case-by-case basis.

This document outlines the minimum technical specifications that must be followed in development of mini-grid plants under the NEP framework.

1.1 Definition of Mini-grid Project

A mini-grid is the combination of distribution network and embedded generation facilities; usually small in capacities, operating at low (distribution) voltage in most cases, which provides electricity to one or more nearby communities which are isolated from the national grid network. Common generating sources include solar, hydro, biomass, wind and diesel or hybrid generators of two of these technologies. Mini-grids typically fall within a few archetypal operator models: the utility operator model, in which the national or regional electricity utility is responsible for all mini-grid operations; the private operator model, in which a private entity plans, builds, manages and operates the mini-grid system; the community-based operator model, in which local communities own, operate and manage the system and provide all services for the benefit of its members; and the hybrid operator model, which combine different aspects of the three aforementioned models[1]. The NEP mini-grid program supports the private operator model, the community-based operator model and the hybrid operator model.

1.2 Purpose

These technical guidelines are drafted with the purpose of maintaining acceptable quality standards of the projects developed under the NEP mini-grid program in order to ensure the safety and sustainability of projects.

The role of a mini-grid project developer is to ensure that contractors, equipment suppliers and associated service providers involved in the mini-grid project development provide components and services which meet or exceed the guidance and standards described in this document.

1.3 Structure of the Technical Specifications

The technical specifications described here have been classified into four sections for clarity and ease of reference. In each section, there are sub-sections based on different technologies predominantly used in Myanmar for mini-grids. Based on the proposals received from village

[1] Source: *Mini-Grid Policy Toolkit*

communities and/or project developers, new technologies may be added to this document whenever it is required.

The main sections of this document are listed below:

- General Requirements
- Civil works
- Power Generation systems
- Distribution system

Departure from specifications: If the developer believes that project can be developed in such a way so as to perform better and safer than if a strict adherence of this document were followed, prior approval from the NEP Project Management Office (PMO) at the Department of Rural Development (DRD) may be sought to depart from these specifications. In the event that a departure is approved and real-world findings validate the initial claims, a revision for these specifications may be issued to ensure that the most cost-effective approach is followed for future projects.

Disclaimer: Whilst the PMO has made every effort to ensure that information presented here is correct and up-to-date for safe and effective performance of mini-grid projects, all parties must rely upon their own skills and judgments when making use of this document.

The PMO shall review the technical design and equipment in proposal submissions and shall reserve the right to modify specifications and/or requirements for any equipment or component in order to improve reliability, functionality, longevity of a project design or to remove ambiguity.

2 GENERAL REQUIREMENTSOF NEP MINI-GRID

2.1 General Requirements

(a) Pre-Feasibility Study (Pre-FS) Proposals and Feasibility Study (FS) Reports should include all of the technical and non-technical aspects listed in **Support Doc. 16:** *Pre-Feasibility and Feasibility Study Components*. Due attention needs to be given to non-technical requirements which are usually the most critical in assessing the viability and sustainability of the mini-grid project.

(b) Technical and operational aspects of the propose mini-grid project must comply with prevailing statutory requirements at both the Union and State/Regional levels. At the Union level, the 2014 Electricity Law [2] is the current governing legislation for the off-grid electricity space.

(c) Prospective developers are required to utilize the standard documents such as demand assessment forms (**Support Doc. 13**), instructions on selection of distribution line layout and design (**Support Doc. 7**), bills of quantity formats and financial analysis formats (**Support Doc. 8**), etc. provided on the DRD website[3].

2.2 Design Parameters

(a) The project life is expected to be up to 15 years to satisfy the pre-electrification requirement, as mandated by the NEP. When assessing the demand and evaluating the financial performance of a potential mini-grid site, a project period of 15 years should to be taken into account.

(b) Mini-grids in which the load demand growth is expected to mature slowly or only after several years must be designed for **phased implementation**. Such project phasing may entail installing smaller generation plant initially and designing a second phase as demand increases. Mini-grid systems designed in a phased manner take full advantage of the modular and expandable nature of different generation and distribution technologies.

(c) When designing the mini-grid distribution system, alternating current (AC) should be used irrespective of generation technology or capacity of the system. Voltage, frequency and other electrical parameters of the AC distribution network should be compatible with that of the national electricity grid in Myanmar.

(d) Depending on the type and capacity of loads and/or depending on the plant capacity, a system may require a 11kV medium voltage (MV) network in combination with a low voltage (LV) network of either single-phase (230V) or three-phase (400V) configuration. Special care must be exercised in the three-phase mini-grid systems so as to balance the loads evenly across each phase.

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[2] Pyidaungsu Hluttaw Law no. 44/2014

[3] http://drdmyanmar.org/index.php

(e) Additional studies such as geological analysis, environmental analysis, hydrological study, test certificates from suppliers, etc. may be requested from the relevant authority by the PMO.

2.3 Operation and Maintenance

(a) An Operation and Maintenance manual for the mini-grid system must be provided to the DRD at the time of project commissioning, along with a clear plan for training of the village personnel for basic tasks and to ensure safe long-term usage of system. The manual must include a section on troubleshooting and contact details of equipment suppliers for requisite repairs and the provision of spare parts.

(b) Full time plant operator is compulsory for the NEP mini-grid project. In addition, Developer needs to appoint a project manager responsible for the mini-grid project, who is responsible for the successful operation of the project and needs to communicate with VEC and DRD regularly.

(c) As the engineering, procurement and construction representative of the mini-grid project, the developer should also provide applicable warranty certificates from manufactures and suppliers at the time of project commissioning.

(d) It is recommended that the developer and/or the Village Electrification Committee (VEC) obtain suitable insurance coverage for the project, taking into account circumstances that may lead to costly repair or replacement obligations within the project lifetime.

3 CIVIL WORKS - GENERAL REQUIREMENTS

All civil works developed under the NEP mini-grids program should be in line with the prevailing national building code: *Myanmar National Building Code (Part 1-5):2016.*

3.1 Durability

The design life of mini-grid civil structures should be 20 years. Adequate and safe structures should be achieved while minimizing unnecessary costs for the community and other stakeholders.

3.2 Construction Material

The following concrete mixtures should be used for their respective purpose as described below:

- For base (screed) concretes: 1:3:6 (Grade 15)
- For water-bearing structures such as the forebay tank, weir and channel of a hydropower facility: 1:2:3 (Grade 25)
- For foundations and other structures: 1:2:4 (Grade 20)

3.3 Metal and Coarse Aggregate

Metal used for concrete should be ¾" size. Crushed rock is the preferred aggregate but gravel is also permitted in case there are no other options.

3.4 Formwork

Concrete formwork should be preferably done with metal sheets or with plywood of minimum 15 mm thickness or with similar wood sheeting. A lubricating layer of concrete form release agent (typically oil) should be applied before casting with formwork in order to maintain good quality of surface finish.

3.5 Tor Steel

Tor steel or rebar used for construction should comply with *BS 4449-2005* and bends should comply with *BS 8666*.

3.6 Mild Steel for Structural Components

All steel sections should conform with *BS 4360:1979*. For solar systems, the minimum thickness of steel PV mounting sections should be 6 mm and actual thickness should be designed based on the loading conditions of the PV panels e.g. gravitational loads, wind loads and other loads applicable at a particular site location.

All structures made of steel should be galvanized appropriately or wire brushed to prevent rusting. Wherever galvanization or wire brushing is not possible, two coats of anticorrosive paint should be applied. Furthermore, it is advisable to sandblast any steel components in contact with water before painting if they have not been adequately galvanized.

4 POWERHOUSE CONTRUCTION OF A MINI-GRID

(a) **Layout:** The mini-grid powerhouse should be located above the maximum 25-year flood levels as observed by local residents near the site. The floor area of the powerhouse should be sufficient to safely place the equipment and carry out routine maintenance work conveniently. Adequate spacing and easy access to the electrical and electromechanical equipment from all sides should maintained for ease operation and maintenance.

(b) **Insulation and ventilation:** Window areas of the powerhouse shall be equivalent to at least 10% of the powerhouse floor area to ensure adequate passive ventilation in the absence or failure of automatic temperature control equipment. All metallic roof sheets must be insulated from the inside using double size insulation glass wool or similar insulating material of minimum 25mm thickness. Roof ventilation should be achieved through the use of whirly-bird passive air extractors and ventilation gaps must be rodent resistant.

(c) **Roofing:** The minimum height between floor and ceiling should be 3 meters or 10 feet. Roofing material should be made of fire-resistant materials such as tile or corrugated sheets. In case of corrugated sheets, the minimum thickness should be 0.47mm. The roof should be watertight and should extend at least 1 meter or 3 feet over walls to prevent water for entering through window portals. The power house door shall be designed with adequate spacing for easy installation and removal of equipment. For safety reasons, the door should be outward-opening (i.e. able to open from the inside).

(d) An appropriate lifting mechanism such as a gantry crane should be provided for the convenience of operation and maintenance in case the system components are unwieldy or otherwise difficult to access safely.

(e) A toolbox including any required specialized tools should be available and upkept with any consumables needed for routine maintenance. Operation and maintenance log books should be regularly updated (i.e. on a daily basis) with accurate performance records.

(f) Workers' room, an extension of the powerhouse, with basic facilities such as bathroom/washroom and essential living furniture should accompany the powerhouse design as it is necessary for an operator to be present all the times during normal system operation.

(g) All exposed trenches such as the cable ways of solar projects and main valve pits of hydro projects should be covered with checkered steel plates or another suitable cover made of steel. Wherever it is impossible to cover these trenches, a safety railing should be affixed during construction.

(h) Fencing & drainage: Proper fencing with foundations suitable for the slope of the land, drainage system and main gate is compulsory for NEP mini-grid systems.

5 CIVIL STRUCTURES OF MINI AND MICRO HYDRO

Run-of-River (RoR) hydropower projects with installed capacity of 1 MW are considered under the NEP mini-grid program. Civil structures in mini- and micro-hydropower (MHP) projects should be designed in such a way to maximize the utilization of locally available human resources and material, which can be considered as in-kind contribution of the community beneficiaries. Large excavations which can potentially affect the environment should be avoided as much as possible.

5.1 Location of components (Site selection):

(a) A place with shortest river width, with an exposed bedrock or where depth to the bedrock is minimum along with considerable upstream storage for a project with a considerable dry season (deep flow duration curve), should be selected as the weir location.

(b) Intake should be selected such that minimum debris will enter the system during flooding period.

(c) In case the layout is long, a shorter headrace channel with higher slope connecting to the settling tank and channel section with mild slope from there to the forebay should be incorporated for efficient filtering purpose.

(d) Forebay and settling tank (if any), should be located near the natural gulley whenever possible to facilitate safer and low-cost spillway arrangement of diverting spill water back to the stream.

5.2 Weir and Intake

(a) Maximum height of weir in mini grid hydro projects should be 2m from the deepest point in normal case. Upstream inundation area for 100-year flood should be calculated and presented in the feasibility study. If there is a threat to upstream inhabitants and/or cultivations, NEP PMO may ask to revise the proposed weir height to safer value.

(b) Construction material of weir can be concrete or rubble and masonry or mixture (rubble masonry interior jacketed with concrete layer). Selection of material will be based on the weir height, flowrate and power output of the plant.

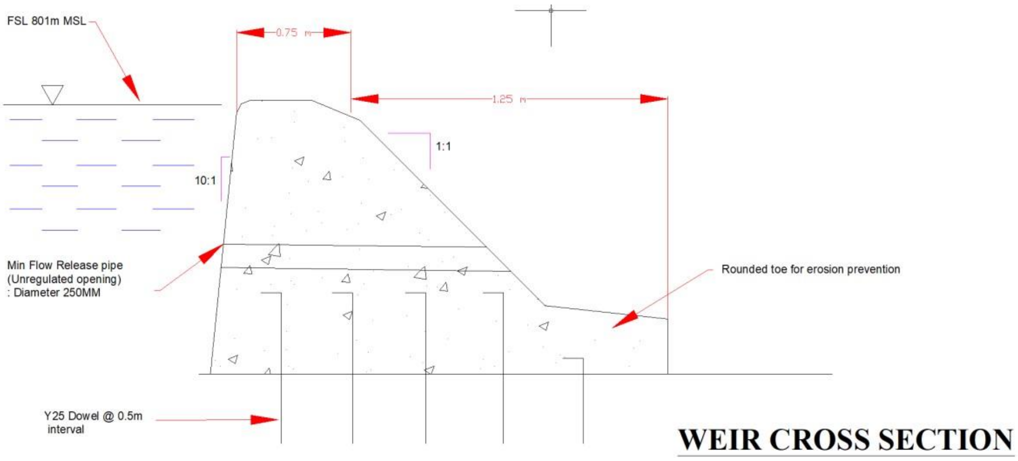
(c) Intake should be equipped with a **trash rack** to prevent clogging; a **control gate** to control the water flow to the channel and **flood barrier** wall to make the control gate operations possible during high flow periods. Trash rack should have preferably iron rods or flat irons; welded with a gap decided based on the turbine supplier's recommendation; rod orienting upward (vertical) direction without cross bars, making it easy for the plant personnel to clean efficiently with a rake. It should have a locking mechanism to prevent unauthorized access. Rod spacing should not be too small which can cause rapid blockage and resulting an operational problem.

(d) **Flood barrier** should be designed with consideration of 100-year flood level calculated with hydrological model.

(e) Location of the intake, specially the intake gate should be done such that it can be accessed during high flood period.

(f) Unregulated **environmental flow releasing pipe**, of which diameter and location (height from the top of weir) determined by the National Environmental authority or PMO, must be placed to release environmental flow (E_{flow}) to safeguard the downstream ecosystem.

Figure 1- Weir cross section for hydro plant



(g) Flush gate, designed based on the maximum silt load of the stream needs to place at the lowest point of the weir with a proper controlling mechanism.

(h) Erosion and deepening of downstream riverbed (due to scouring action) of weir and spillways should be considered in design phase and should be protected with suitable mechanism/ structures incorporated in weir design.

5.3 Channel

(a) Rectangular concrete channel build with Grade 25 reinforced concrete is the prefer selection for MHP projects. For extreme case like very low plant capacity with relatively higher channel length, earth, rubble masonry, cement and mortar channels, pipe or combination of different types can be considered.

(b) **Freeboard allowance** of 30% should be kept when designing the channel dimensions.

(c) **Maximum channel velocity** to avoid erosion, in different types of channel should be conform to the specifications below. In case of silty water, channel velocity should be maintained at the **minimum velocity** of 0.3 m/s to prevent clogging of the channel.

Table 1- Maximum channel velocity of different types of hydro channels

Type of channel	Maximum velocity (m/s)
Concrete channels with no internal plaster	2
Rubble and masonry channel with smooth plaster	1.8
Clay channel	1.5
Earth Channel	0.7

(d) **Channel crossing and drain outlets underneath** should be placed in appropriate places (e.g. gulley crosses the channel path if it is not being diverted to the channel) at intervals of at least 20m. This will ensure safe flow of water across the channel (i.e. transverse flow across channel) from embankment to the river down. Interval of drain outlets will depend on nature of surface water flow in the project area. Drain outlet can be an embedded construction to a channel or a pipe line.

5.4 Forebay and settling tank

Purpose of the forebay tank is to provide a constant head (water pressure) to the turbine. In mini hydro projects under the NEP framework, combined forebay with settling section is advisable, unless it is necessary to have a separate settling tank, at the midway point of the channel for layouts with relatively long channel.

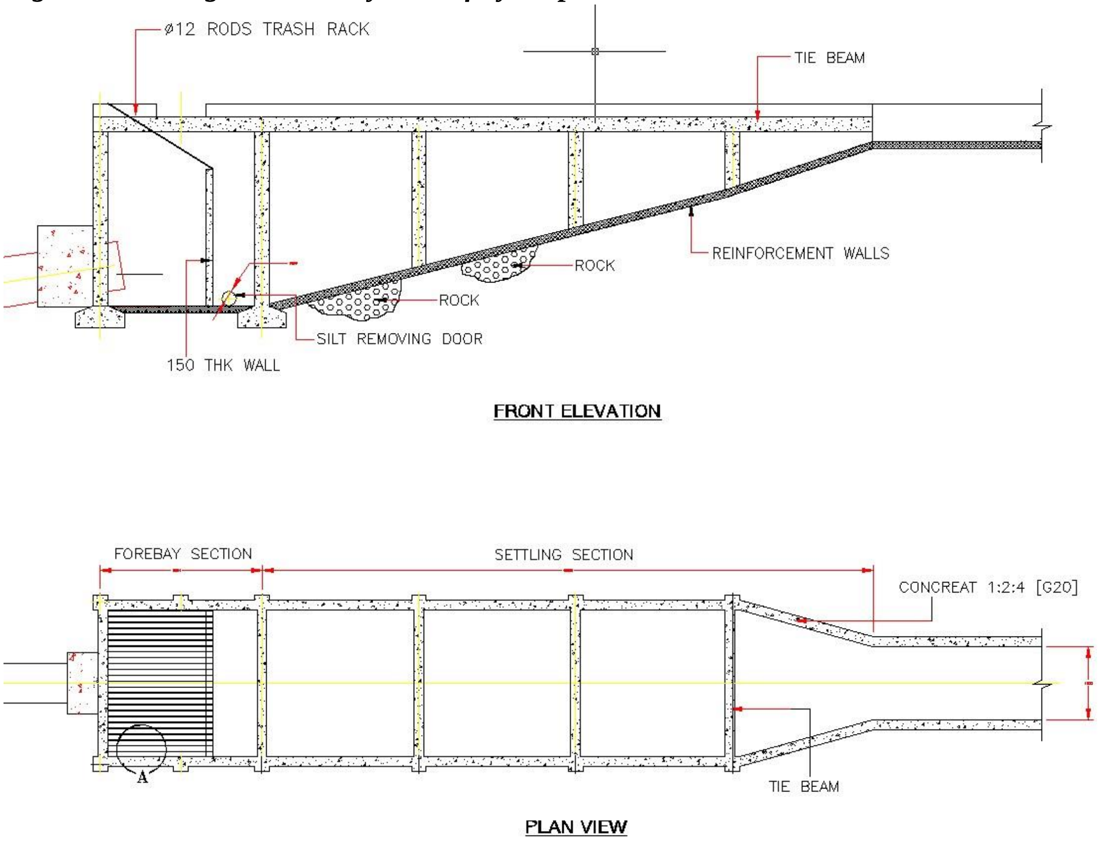
(a) Settling Tank section: Settling tank will settle the particles which otherwise could damage the turbine casing and runner over a period of operation due to wear (abrasion) and cavitation. MHP projects under NEP should settle and filter **particles above 0.3 mm** unless the turbine manufactures instructed to filter even finer particles.

(b) In reaction turbines, the manufacture will state the maximum sand particle allowed in the water and same should be honored to get the cavitation guarantee offered by the supplier.

(c) **Flush gate** (sluice gate) and **spill way** operating manually should be incorporated to the settling section to flush the silt collected from time to time. In most instances, one spillway is adequate to cover the safe passage of spill water in settling and forebay sections.

(d) **Trash rack** is compulsory in the forebay section and the rod spacing can be decided to match the weir intake trash rack.

Figure 2: Settling and Forebay tank of hydro plant



Gantry (steel or concrete beam), **climbing ladder** and **handrails** should be fixed for the safety of the operators during the cleaning of the forebay trash rack.

(e) A thumb rule which can be used during reconnaissance study **for determining the height of forebay section** is to make it minimum four times of the penstock diameter to prevent vortex formation in the full flow operation of the turbines. In detailed engineering design this water height should be selected to be greater than [1.5 x $(V_{penstock})^2/20$]. V is the velocity of water in the penstock.

(f) Bell mouth (or penstock itself in smaller systems) should be positioned at least 150mm above the forebay tank floor to prevent silt and small stones from entering the penstock.

(g) **Vent pipe** with a sufficient diameter should be fixed to the penstock or bell mouth section to prevent damage due to surge. It will prevent inward collapse of penstock due to surge pressure.

5.5 Penstock and supports

Purpose of the penstock is to draw water to the turbine from the forebay tank. Penstock path should be selected such that number of bends are minimum, and length is shortest, making the construction safe and cost effective.

(a) Penstock should have constant gradient in each section; i.e. straight from one anchor to the next. In some projects an air release valve should be fitted to highest point if air is likely to trapped due to the layout of the penstock.

(b) **Material** that can be used in MHP projects and design characteristic which should be followed in selection of different parameters are tabulated in the table below:

Table 2- Penstock Material and design criteria

Type of penstock	Maximum velocity (m/s)	Safety factor	Corrosion allowance	Finishing
uPVC	3	3	n/a	Exposed parts to should be painted to prevent deterioration due to sunshine
Steel	3	3	1.5 mm	<50 kW- two coats of anticorrosive paint after wire brush > 50 kW epoxy paint to 150um thickness after sand blast
Glass Reinforced Pipe (GRP)	3	3	n/a	No painting requires

Notes-

- Safety factor should be calculated considering total pressure, which is the accumulation of statics pressure and surge pressure.
- In the events where slow closing flow control valves and/ or jet deflector arrangement are presented, safety factor of 2 should be considered.

5.5.1 Design factor

(c) For NEP mini grid hydro MHP projects of smaller capacity, uPVC pipes (uPVC Class E; 1.5 MPa satisfies to *BS 3505:1968*) can be used as penstocks for heads up to 100m provided required diameters are available. Depending on the turbine and governor mechanism proposing, the selection should be checked against the minimum safety factor stated in table 2 above.

(d) Penstock loss due to internal friction and local losses like, bend losses, contractions losses, expansion losses etc. calculated for 110% of the rated flow of the plant should be below 5% of the gross head.

(e) If the steel pipes are fabricated locally, all the pipes should be **pressure tested** to the 150% of the static pressure of the system.

(f) Penstocks laid above ground should be supported at every 6m intervals with a **slide block** or **support block**. In the event of support blocks, minimum of 120 deg of the penstock circumference should be firmly in contact to the support block. These supports and slide blocks can be made with concrete, rubble and masonry; if the height is less than 2m a combination of concrete and rubble and masonry or steel.

(g) In all bends, an **anchor block** made of reinforced concrete and/or concrete with 20% plums and/or rubble and masonry with concrete jacket should constructed to counterbalance the forces occurs due to cause by change of momentum of water. Possible penstock failing scenarios like toppling, sliding, sinking/lifting forces should be considered when sizing the anchor blocks. *Annexes 2* and *3* drawings of typical slide block, anchor block and support block are provided for reference.

(h) **Underground** steel and PVC penstocks should be buried at least 300mm beneath the ground and should be on a sand bed. No slide or supports blocks apart from anchor blocks at the bends are required in underground penstocks. In GRP penstocks, even this requirement of having anchors at bends can be minimized.

(i) Underground steel penstocks should be painted with epoxy liquid coal tar (bitumen) to a minimum paint thickness of 150 um.

(j) **Thermal expansion and Expansion joints**: rubber sheets or tar sheets (graphite asbestos sheet) of minimum thickness of 3mm must be placed between penstock and supports to prevent abrasion due to thermal expansion and contraction.

Expansion joints are required in **steel penstocks** just below anchor blocks and forebay tank to minimize the stress created due to thermal expansion and contraction.

In case of **uPVC penstock pipes**, spigot joint can accommodate the thermal expansions. If glued socket connections are used in over ground uPVC penstocks, at least one spigot joint is recommended between anchors or expansion joint can also be used.

5.6 Tailrace and electro/mechanical foundations

(a) Tailrace of NEP hydro project should be constructed with G25 reinforced concrete and should create a safe passage of water back to the stream. Steps or rock protuberance should incorporate to break the water speed and to minimize erosion. Whenever possible, tailrace should be built up to the stream/river to allow safe water exit from the turbine.

6 POWER GENERATION SYSTEMS

Mini-grid generation system is confined to power generation equipment, controlling/ governing/ monitoring equipment, energy storage equipment if applicable, system safety equipment and power distribution panels and accessories. Distribution systems are discussed separately

6.1 Quality of electricity in general

Myanmar has no grid or voltage standards, so mini-grids should follow *IEC 60038:2009 (IEC standard voltages*). Irrespective of type of generator, the mini-grid should meet the following criteria for the electricity supplied to the consumers.

Nominal generating voltage (Vn)	- 400/ 230 V
Maximum voltage at distribution bus bar	- 110% of Vn
Frequency	- 50Hz

6.2 Electrical system in general

(a) Generation voltage of the mini-grid plant can vary depending on the type of generation source. To transmit or distribute this electricity, it is required to convert this to single or three phase alternating current (AC) @ 50 Hz. No-load powerhouse voltage can be set to maximum 110% of the nominal voltage if required to maintain the voltage drop at the farthest consumer premises.

(b) The power factor should not drop below 0.8 in synchronous generator systems, while this should not drop below 0.95 in induction generator systems. 0.95 to retain frequency control. If required, pf correction device must be added to achieve the pf specified above.

(c) All major equipment such as generators, inverters, solar panels, batteries etc. should have clear name plate; fitted by manufacture; which displays the manufactures name, serial and model numbers, date of manufacture wherever required and technical specification of the components etc.

(d) All electrical installation must comply to standards specifications of *British Standards Institution, Regulation for Electrical Installation issued by Institute of Electrical Engineers, London (IEE Wiring Regulations) 17th edition* or *IEC 60364 Electrical Installations for Buildings.*

(e) Power cables which can be copper or aluminum shall comply to *IEC60227* and *IEC 60502 Power cables with extruded insulation*; *IEC 60228 Conductors of insulated cables* or *BS 6004/BS 6346*.

(f) Enclosures of electrical accessories, joint boxes should comply to *BS 4662*. Live surfaces and points of cables and other parts should be shielded from human contact.

Proper jointing method which are durable, strong and serving the purpose must be used. In case of joining conductors with different material, bi-metallic connectors must be used.

(g) Distribution board in powerhouse: should have appropriately rated isolators, ELCB (or RCD) and MCB for each line complying with *IEC 61008: Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs), IEC 60898: Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations* and/or *IEC 60947: Low-voltage switchgear and control gear*, as applicable.

(h) Protection at powerhouse to safeguard end-users: Over and under voltage and frequency protection should added to control panels at powerhouse if required to safeguard the users and domestic and industrial equipment and appliances use.

(i) All metal enclosures including casing of electrical generators, casing of turbines, cable trays etc. and surge protection devices (SPD), Residual current devices (RCD), lightening arrestors at powerhouse and load points should have earthing system complying to the relevant part of *IEC 60364*: Low-voltage electrical installations standards. Each distribution line starting form powerhouse should have one ELCB with a maximum leakage current rating of 300 mA.

(j) Copper rod with diameter not less than 35/50 sq.mm or copper strip of dimensions not less than 20mm x 3mm or Cu conductor of minimum cross section of 25mm2 should be used as earthing. Earth resistance of 2 Ω (ohm); on dry day, should be maintained at the powerhouse and consumer points.

(k) Lighting arrestors: lighting protection installation in NEP mini-grid projects should be comply with *IEC 62305: Protection against lightning* or British Standards C.P.326 standards. Roof conductor and down conductors shall be soft annealed copper type of size not less than 20mm width and 3 mm in thickness. In case of bare conductor are is for distribution line, spark gap type lightening arrestors and associated earthing system should be installed to cover each 500 m radius of line and end user points.

(l) IT and Control cabling: All the control and IT cables should be appropriately laid and conform to *IEC 11801: Information technology - Generic cabling for customer premises* and *IEC 14763-2: Information technology - Implementation and operation of customer premises cabling* standards to ensure proper control and monitoring of system.

(m) Monitoring and controlling: Irrespective of the technology used, following electrical parameters should be monitored at powerhouse control panels.

Table 3- List of minimum electrical parameter to measure

	Number	
Electrical parameter/ panel meter	Single phase	Three phases
Frequency/ Frequency meter	1 No.	1 No.
Voltage/ Voltmeter (village)	1 No.	3 Nos.
Voltage/ Voltmeter (ballast)	Depend on ballast partitions	
Amperage/ Ammeter (village)	1 No.	3 Nos.
Amperage/ Ammeter (ballast)	1 No.	3 No.
Energy/ Energy meter (kWh)	1 No.	1 No.
Power factor	One phase	Each phase

(n) Labels and Diagrams: All electrical components should have labels describing their function, in English and Myanmar language. Block diagram which shows overall system and single line diagram (circuit diagrams) for each panel and controllers should be included. Illustrated Warning signs in Myanmar language should be fixed at all places which poses a threat for operators, community and/or end users.

7 SOLAR PV MINI-GRID GENERATION SYSTEM COMPONENTS

Solar based mini-grids offer opportunity for standardized approach to design and implementation which is less dependent on site-specific resources than other mini-grid technologies. The standardized approach can enable a more rapid development process and roll-out. However, there are specific design considerations which are critical to ensuring viable and sustainable mini-grid operation.

However, key considerations most critical to viability of solar-based mini-grids are

- Assessment of the load demand characteristics, especially: initial uptake, load growth and allowances for growth, seasonality of loads, day time loads versus nighttime loads.
- Variability of solar resource from day to day, and seasonally
- Solar mini-grid configuration options best suited to match load characteristics with resource characteristics.

In general, solar mini-grids for rural villages will always comprise of at least the following components, also illustrated in figure below.

- Distribution network
- Storage batteries
- DC-AC inverter or power conditioner for providing useful power to the loads
- Solar arrays
    - DC-coupled charging batteries directly, or,
    - AC-coupled providing power direct to AC day-time loads, and optionally charging battery through the bi-directional inverter charger
- Optional back-up diesel generator
- Water supply arrangement for regular cleaning of PV arrays.

Solar PV or Solar PV Hybrid Mini-grids must follow *IEC 62257, Recommendations for Small Renewable Energy and Hybrid Systems for Rural Electrification*, which provides guiding principles for design and other system characteristics of such systems.

7.1 Solar PV Modules

Solar modules in NEP mini-grid projects can be polycrystalline, monocrystalline or thin film. In one project, modules from same category with same rating should be installed.

7.1.1 Standards and certifications

All PV modules shall be certified to conform to the following minimum standards.

(a) **Compulsory Standards:** Solar modules shall conform to the following standards form the International Electro-Technical Commission (IEC).

- *IEC 61215 Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval.*

- *IEC 61730 Photovoltaic (PV) modules safety qualification – Requirements for construction and requirement for testing.*

(b) **Recommended standards:** In special case of salty environment (installation near the sea), additional standard of *IEC 61701 Salt mist corrosion testing of photovoltaic modules* should satisfy.

(c) **Laboratory accreditation:** Solar PV Modules must be tested by laboratory in accordance with *ISO/IEC 17025*. Manufacturer of modules accredited by ISO and should have an EN-ISO certificate, JCRC-ISPRA 503, PV-GAP, UL listing 1703, NEC 2008 compliant or equivalent quality type approval from an internationally accredited laboratory.

(d) For the delivery of the solar modules the transport standard *IEC 62759-1: Photovoltaic (PV) modules - Transportation testing - Part 1: Transportation and shipping of module package units* (or equivalent) must be fulfilled.

(e) **Warranties:** All PV modules installed in the NEP mini-grid should have following product warranty levels.

- ***Manufacturing warranty*** (material and workmanship): must have ten-year warranty on physical manufacture of module itself, i.e. the frame, encapsulant, glass, module junction box etc.
- ***Power output warranty:*** twelve years 90% and 25 years 80% output warranty.

(f) Mini-grid project Developer should be responsible for on-site warranty - i.e. transporting back and forth and get the modules repaired or replaced in case such a claim is required.

7.1.2 General requirements

(a) **Minimum Module rating**: individual module should preferably rate over 250 Wp.

(b) **Temperature coefficient** rated power of -0.45%/°C or lower.

(c) Modules should be able to withstand **wind load** of 5,400 Pa.

(d) **Bypass diodes** should be installed in each module to prevent hot-spots in modules, which occur often because of partial shading of modules. The NEP mini-grid project developer shall ensure that every module in a series string of more than 24V nominal voltage, shall include bypass diodes in the module terminal-connection box. The diodes should be replaceable without replacing the module or module junction-box.

(e) **Modular junction box, cable and Connector**: should have water and dust tight junction (IP65) box mounted at the back of the panel with minimum of 1 m ;4 mm^2 output cables connected with male and female (quick) connectors.

(f) **Label of PV panel**: label of the PV module should have the following details. Name of the manufactures and website; model number, serial number, peak current, peak voltage, power rating of panel at standards test condition; open circuit voltage, short circuit current.

(g) Developer should provide **I-V curve** with the Feasibility at AM 1.5 and STC, Temperature coefficients dV/dT, dI/dT, etc

7.2 PV Inverters / battery inverters and MPPT

Distribution grid is a main component of mini-grid which distinguishes mini-grid from an isolated home power generation. Inverters in solar PV mini-grid will convert Direct Current (DC) power produced in PV arrays or stored in batteries to Alternating Current (AC) to distribute efficiently direct to loads. Some PV arrays may charge batteries directly. PV mini-grids rely on sophisticated electronic control components to operate silently and efficiently. This section addresses these main components which are functionally described below:

- **PV inverter:** converts solar DC power directly to AC electricity which can be supplied directly to the distribution network for consumption. Arrays electrically connected this way are commonly referred to AC-coupled solar arrays.
- **Charge controller MPPT:** converts solar power into DC energy comparable with charging batteries directly. Charge controllers are used to connect DC coupled solar arrays.
- **Bi-directional inverter or battery inverter:** supplies energy from the battery to the AC distribution network as needed, and conversely can charge DC batteries from the AC distribution network or AC-coupled solar arrays.

7.2.1 Standards and certifications

(a) **<u>Safety standards</u>:** Inverters and electronics used for mini-grids are required to meet minimum safety standard set by

- *IEC 62109-1 (Safety of Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements).*
- *IEC 62109-2 (Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters*
- *European Union (CE) or Underwriters Laboratory (UL 1741)* for compliance

(b) Particular standards for **PV inverters** which must comply with the following or similar

- *IEC 61727: Photovoltaic (PV) systems – Characteristics of the utility interface*
- *IEC 62116: Test procedure of islanding prevention measures for utility interconnected photovoltaic inverters*
- *DIN VDE 126-1-1 or VDE 126 or similar (frequency and voltage disconnection limits) Automatic disconnection device between grid parallel power generating system and the public low voltage grid*

- *G83/1-1, EA Engineering Recommendation G83/1-1: Amendment 1-June 2008, Recommendation for the connection of small-scale embedded generators (up to 16 A per phase) in parallel with the public low-voltage distribution networks.*
- *AS 4777.2-2005: Grid connection of energy systems via inverters– invert requirements:*
- *EN 50438, Requirements for the connection of micro-generators in parallel with public low-voltage distribution networks*
- *UL1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources*
- *IEEE 1547: Standard for Interconnecting Distributed Resources with Electric Power Systems*
- *IEC 61683: Photovoltaic System-Power Conditioners - Procedure for Measuring Efficiency*
- *IEC 61000-4-2: Electromagnetic compatibility (EMC) Testing and measurement techniques – electrostatic discharge immunity test*
- *IEC 61000-4-3: Electromagnetic compatibility (EMC) Testing and measurement techniques - radiated, radio frequency, electromagnetic field immunity test*
- *IEC 61000-6-2; IEC 61000-6-4; Electromagnetic compatibility*

(c) Particular standards for **Bi-directional Battery inverters** must in addition comply with comply with

- *IEC 61000-3-2, IEC 61000-3-3, IEC 61000-6-1, IEC 61000-6-2, IEC 61000-63: Electromagnetic compatibility,*
- *IEC 60335-2-29: Household and similar electrical appliances - Safety - Part 229: Particular requirements for battery chargers*

(d) Particular standards for **MPPT/ Charge controllers**

- *IEC 61683: Photovoltaic System-Power Conditioners - Procedure for Measuring Efficiency*

(e) **Warranties of inverters:** ***Manufacturing and Performance warranty***: must have five-year warranty period and mini-grid project developer should be responsible for transporting back and forth and get the inverter repaired or replaced in case such a claim is required.

7.2.2 Labelling and data

Each inverter device must be labelled with the minimum information:

- Manufacturer name and model
- Serial number
- Input and output voltage and rated power
- Battery type compatibility (if applicable lead-acid and type (OPzV etc.), or Li-ion and type (LiCoO2 LCO, LMO, NMC, LFP, NCA, LTO)]

The supplier is required to provide for each conversion device offered the following data:

- System rating (kW/kVA) with temperature de-rating curves/tables
- Input Voltage (DC) range
- Output Voltage (AC)
- Efficiency versus Power output graph, for various input voltages
- Certificates and compatibility with country standards applicable
- Warranty
- Product brochure

7.2.3 Guidelines for Inverter Selection

(a) Inverter should produce output electricity to match the quality requirement stated in 7.1 in this document.

(b) PV Inverters should have at least one maximum power point trackers (MPPT). If the mini-grid capacity above 25 kW; multi string i.e. Inverter with multiple MPPTs is preferred.

(c) In general, modular and expandable inverters / bi-directional inverter units are preferred, which can be used in multiples in parallel to increase power. Centralized systems which are not expandable to account for future load growth are not preferred.

(d) PV Inverter or charge controller should be able to handle 125% of array short circuit current.

(e) Efficiency of PV inverter should be above 95% over 75% of the power range. Efficiency of bi-directional inverter should be more than 90% over 75% of the power range.

(f) Total harmonic distortion should be below 3%.

(g) Inverter should have protection for incorrect polarity; over temperature and excessive DC voltage.

(h) Inverters located inside the powerhouse should operate between -25°C to 60°C with derating and should have an Ingress Protection rating of at least IP 54.

7.3 Batteries

7.3.1 General requirements

(a) **Batteries of the following types are allowed** for the NEP solar mini-grid projects:

- Lead-acid: the following are acceptable:
    - OPzV: deep cycle tubular gel valve regulated (VRLA)
    - OPzS: deep cycle tubular flooded electrolyte battery

- Li-iron batteries: The following are acceptable o **Lithium Iron Phosphate:** LFP or Li-Fe-phosphate
    - o The following may be acceptable subject to meeting all certification criteria;
    - ✦ **Lithium Nickel Manganese Cobalt Oxide:** NMC (NCM, CMN, CNM, MNC, MCN similar with different metal combinations))
    - ✦ **Lithium Nickel Cobalt Aluminum Oxide:** NCA or Li-aluminum
    - ✦ **Lithium Titanate:** LTO or Li-titanate

    o The following are not generally acceptable
    - ✦ **Lithium Cobalt Oxide:** LCO or Li- cobalt
    - ✦ **Lithium Manganese Oxide:** LMO or Li-manganese

(b) **Expected cycle life** of the batteries shall be as follows when tested to the life-cycle test standards below:

- lead-acid OPzV or OPzS: not less 1,500 Cycle @ 70 % DOD
- *Li-ion* LFP with Cycle performance: not less 3,000 Cycle @ 80 % DOD

7.3.2 Standards

(a) The standards Cycle life of lead acid batteries**:**

- *IEC 60896-21 and 22 Ed 1(2004); Stationary lead-acid batteries - General requirements and test methods: Valve regulated types (clauses 6.13 and 6.17)*
- *IEC 61427-1 (Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 1: Photovoltaic off-grid application*

(b) The safety standard for Valve Regulated lead acid batteries:

- *IEC 60896-21 and 22 Ed 1(2004); Stationary lead-acid batteries - General requirements and test methods: Valve regulated types*
- *IEC 61056-1 (2012): General purpose lead-acid batteries (valve-regulated types) - Part 1: General requirements, functional characteristics - Methods of test.*

(c) Standards for Cycle life endurance for li-ion batteries:

- *IEC 61960; Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications OR*
- *IEC 62620; Secondary cells and batteries containing alkaline or other non-acid electrolytes. Secondary lithium cells and batteries for use in industrial applications*

(d) Safety standard for lithium-ion cells and batteries:

- *IEC 62619; Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and 7 batteries, for use in industrial applications*

7.3.3 Design requirements

(a) **Battery autonomy:** when calculating the required storage an autonomy of about 1 day of mature nighttime load demand should be considered if the configuration has a diesel backup generator i.e. hybrid system solar PV with diesel genset. In general battery autonomy will be optimized using simulation software.

(b) Batteries shall be suitable for operation at 35ºC, and safe up to 45ºC without risk of thermal runaway. Derating of battery capacity, performance and cycle life for high temperature conditions, lower charge voltage conditions etc., is to be carefully considered.

(c) In general, lower voltage battery banks (48V) are preferable due to their modularity, expandability, safety and compatibility with wider range of electronic components due to standardized voltage.

(d) High voltage battery banks (>48V and with multiple cells in series) shall include additional safety protections, as well as any necessary battery management system for cell monitoring / state-of-cell supervision. High-voltage lead-acid battery banks shall be ensured with necessary routine equalization.

(e) **Warranties:** All batteries to be warranted to at least 5 years under the operational conditions on site, to 80% of original rated capacity.

7.3.4 Labelling and data

Each battery/cell shall be engraved with the supply date

For each battery type, the battery must be labeled indicating at minimum ○ Manufacturer, Model Number, Voltage and Capacity. ○ Type of the battery [lead-acid and type (OPzV etc), or Li-ion and type ($LiCoO_2$ LCO, LMO, NMC, LFP, NCA, LTO)] ○ Battery Voltage, Battery Capacity@C20

The supplier is required to provide for each Battery type the following **general data**

- ○ Battery discharge performance versus Temperature
- ○ Battery cycle life versus depth of discharge
- ○ Battery cycle life versus battery temperature
- ○ Product brochure
- ○ Warranty information

The supplier is required to provide for each Battery type the following **test data**

- ○ Battery discharge performance curves at C10 and C50, at a minimum
- ○ Safety test compliance against *IEC 60896-2* for VRLA batteries
- ○ Battery cycling curves against *IEC 60896-11* or *IEC 60896-2*, or against *IEC 61427*.

7.4 Data-logging and Monitoring

Solar mini-grid system data-logging and monitoring shall cover the following aspects:

- Power generation side

- Utility network (Quality Assurance Framework)
- Customer metering
- Regular monthly reporting

7.4.1 Power generation side

Generation plant monitoring system, logging, functionality and remote access are described below.

System Parameters such as solar PV electricity generated, diesel genset generation and run hours, battery voltage and SoC, and energy sent-out from powerhouse, at a minimum shall be recorded hourly with automated data logging equipment. This shall be retained in hourly data format, but also cumulated into daily, weekly and monthly reports.

The logging system shall have capability to upload to internet via mobile carrier or other means. Connection to internet for data upload must occur at least once per month to transfer if no mobile network in available at site. All of the data for the previous month must be uploaded but a more frequent upload interval is preferred.

A live-interactive online system which can see individual components is natural preferred (i.e. each PV inverter, each battery inverter, each battery bank).

Time of occurrence and duration of service interruption events (power failures) to be logged (either automatically or manually) and reported monthly;

The monitoring system must conform to

- *IEC 61724 Ed 1: PV System Performance Monitoring Guidelines for measurement, data exchange and analysis*
- *IEC 61557*: *Electrical safety in low voltage distribution systems up to 1000 V a.c. and 1500 V d.c. - Equipment for testing, measuring or monitoring of protective measures* except electricity metering equipment that complies with *IEC 62053-21, IEC 62053-22* and *IEC 62053-23*

All of the above shall be summarized into monthly performance report for the site.

Multiple meters must be installed in such a manner that all generation and outgoing energy is effectively monitored for clear understanding of system performance.

Table 4- Metering Equipment and locations

Metering Point	**Type of meter**	**Accuracy Class**	**IEC Standard**
DC output of Charge controller (if installed)	DC Energy Meter	0.5 or 1 Accuracy Class	

AC output of PV Inverter (if installed)	AC Energy Meter	0.5 or 1 Accuracy Class	*IEC 62053-22* or *IEC 6205321* and *IEC 62052-11*
Genset output (if installed)	AC Energy Meter	0.5 or 1 Accuracy Class	*IEC 62053-22* or *IEC 6205321* and *IEC 62052-11*
Outgoing Feeders	AC Energy Meter	0.5 or 1 Accuracy Class	*IEC 62053-22* or *IEC 6205321* and *IEC 62052-11*
Biomass generation	AC Energy Meter	0.5 or 1 Accuracy Class	*IEC 62053-22* or *IEC 6205321* and *IEC 62052-11*
Hydro generation	AC Energy Meter	0.5 or 1 Accuracy Class	*IEC 62053-22* or *IEC 6205321* and *IEC 62052-11*

Meters conforming to *IEC 62056* - the DLMS/COSEM suite: smart metering standardization framework are preferred.

Standards

IEC 62052-11: Electricity metering equipment (a.c.) - Particular requirements - Part 11: Electromechanical meters for active energy (classes 0,5, 1and 2)

IEC 62053-21: Electricity metering equipment (a.c.) - Particular requirements - Part 21: Static meters for active energy (classes 1 and 2)

IEC 62053-22: Electricity metering equipment (a.c.) - Particular Requirements - Part 22: Static meters for active energy (classes 0,2 S and 0,5 S)

Note: More meters may be required and must be installed if multiple interface of generation or outgoing point exist in the system, it is the responsibility of developer to install meters such that a complete energy balance is effectively monitored.

Installation of household meters: household energy meters needs to have the ability to see at least the remaining balance available & energy usage. Energy meter is expected to be installed inside the house (or other load point) but if it is installed in the service pole due to any reason, interface with display should be given to each load points to see the above minimum information on their electricity usage and to facilitate the recharging, if applicable.

7.4.2 Utility network monitoring (QAF)

The developer agrees that monitoring of the distribution network according to the Quality Assurance Framework for Mini-grids **QAF)*[4] shall be granted on request by DRD, and the developer shall facilitate such access on monitoring.

QAF is a recently established framework monitoring of the "level-of-service" promised versus that delivered in the field – a kind of "truth in advertising" compliance approach. Key variables include: (i) power quality, (ii) power availability and (iii) power reliability, with many sub variables – all aligned with the more widely known Multi-Tier Framework (MTF) for energy access. QAF is purely output-based, which requires considerable measurement and reporting, over a period of years.

Time of occurrence and duration of service interruption events (power failures) to be logged (preferably automatically or manually) and reported monthly.

7.4.3 Customer

Consumer level consumption data including average daily Watt-Hour consumption and peak power demand (Watts or Amps) to be measured and recorded for inclusion in monthly reporting. This shall cover individual usage and payments, as well as groups of consumers as per monthly reporting.

7.4.4 Monthly reporting

System performance reporting on a monthly basis to DRD shall cover the following aspects, and standard spreadsheet report shall be used.

- kWh generated by solar, total solar insolation
- kWh generated by diesel, diesel run hours, diesel liters used, diesel engine starts
- kWh sold, to each consumer category (households, PEU, Community, streetlights, own usage)
- Qty customers in each consumer category (households, PEU, Community, streetlights)
- Typical total load profile for that month, and for each consumer category (kWh in each hour).
- Hours of no supply and fault report.
- Social issues reported and resolved.

All records are for inclusion in monthly reporting format for the same is described separately.

[4] Quality Assurance Framework for Mini-Grids, NREL, US DoE and Global Leap (2016): https://www.nrel.gov/docs/fy17osti/67374.pdf

7.5 Balance of System in solar mini-grid

Variety of other components such as DC/AC Cables, disconnectors/isolators, protection devices, mounting structures, combiner boxes and monitoring devices are usually called as balance of systems (BOS) in PV industry.

The Switches/Circuit Breakers /Connectors used must comply with *IEC 60947 part I, II, III: Low-voltage switchgear and control gear - ALL PARTS and EN 50521.*

All the Junction Boxes /Enclosures for Inverters/Charge Controllers/Luminaries must have ingress Protection of IP 54(for outdoor)/ IP 21(for indoor) as per *IEC 60529: Degrees of protection provided by enclosures (IP Code)* standards.

SPD should be installed on both AC and DC side conforming to *IEC 61643-11: Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods*.

7.5.1 Cable in Solar PV Mini-grid:

7.5.1.1 General

All external wiring, cabling, insulation material and junction boxes must be UV-resistant and terminals protected against dust and moisture.

The wiring installation shall be both physically robust against bumping and tugging, and electrically robust. All wiring and connectors should have a design lifetime of 20 years.

Double insulation (i.e. insulation comprising both basic and supplementary insulation, and appropriate barriers and separation of parts must be applied to all systems with an open circuit voltage of more than 120VDC Class II insulation on the DC part of PV system, even if less than 120VDC is strongly recommended.

7.5.1.2 Wiring losses

Wire gauges shall be selected to minimize energy losses or system performance problems through wire degradation. Wire shall be derated for climatic conditions.

Source circuit losses shall be limited to 1.5% loss in general and includes each of:

- Array to Array DB:
- DC-DB to DC busbar:
- Battery to DC busbar
- Inverter AC DB to Main AC DB

7.5.1.3 Wiring Standards

Cables use for NEP mini-grid which can be copper or aluminum, should comply to *IEC 60227: Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V* and *IEC 60502: Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV)*; relevant part of *IEC 60228: Conductors of* *insulated cables* or *BS 6004/BS 6346*. PVC insulated cables for working voltage up to and including 1100 V and UV resistant for outdoor installation should be used wherever required.

PV1-F double-insulated cable UV resistant cable is to be used for high voltage DC PV arrays, Flexible DC copper wiring of 4/6mm^2 should use for inter-array cabling, up to inverter/combiner box conforming to:

Relevant part of *IEC 60332: Tests on electric and optical fiber cables under fire conditions, IEC 60216-1: Electrical insulating materials - Thermal endurance properties*

IEC 60811-403: Electric and optical fiber cables - Test methods for non-metallic materials -

Part 403: Miscellaneous tests - Ozone resistance test on cross-linked compounds

IEC 60228: Conductors of insulated cables

IEC 61034 I, II: Measurement of smoke density of cables burning under defined conditions IEC 60754: Test on gases evolved during combustion of materials from cables

DC cable of appropriate size should be used for interconnecting all equipment at site including but not limited to batteries, inverter, combiner box etc. to ensure AC and DC losses to less than 2% respectively. Calculations of the current rating of the cables should be according to *IEC 60287*: Electric cables - Calculation of the current rating

7.5.1.4 Wiring installation

Every core of cable shall be identifiable by color and/or lettering/numbering at its terminations. In the special case where there is no possibility of confusion, e.g. where cables are pre-fitted with purpose made polarized plug and socket connectors (+,-), then additional cable color/alphanumeric identification may be omitted.

All wiring must be neatly done and secured by means of appropriate fasteners at regular intervals.

Wiring lengths shall be sufficiently looped to allow ease of connection and disconnection in the case of component replacement, and for maintenance.

Any wiring connections whether internal, external, high voltage or low voltage shall be inside accessible junction boxes. No visible connections. The double insulation nature of the cables shall be maintained.

Conductor lugs should be used to terminate all DC wiring. Lugs and connectors should be crimped or soldered, and mechanically and electrically sound. No connections shall be made using terminal blocks. DC connections shall be ferruled. All DC electrical connections to be treated with corrosion inhibiting paste, substantially equivalent to DENSAL paste.

7.5.1.5 Under-ground wiring requirement

All external cabling which is routed underground, shall use approved Steel-wire-armoured (SWA) cable. All underground cabling shall be buried at 0.6m below ground level and labelled at each end. Cables crossing roads or driveways shall be protected by steel pipes buried in the ground. Any underground cable interconnections shall be approved water-tight corrosion resistant types.

7.5.1.6 Certification of powerhouse and generation plant wiring

All AC and DC wiring shall be as per the requirements of the electricity standards of Myanmar, being British Standards.

7.5.2 Mounting structure:

Mounting structure used for the solar panels should be made of corrosion resistant material such as aluminum alloy or: hot dip galvanized steels (Hot dip galvanized: ≥ 80-micron galvanization thickness). Minimum thickness of the structural material which is used for mounting structure should be 2mm. Bolts, nuts, fasteners, panel mounting clamps including joining the sections of structure should be with galvanized or stainless-steel bolts (Stainless steel SS 304) or by welding.

In case of a welding structure, galvanization should be done after the fabrication work. All aluminum shall be anodized any damage shall be treated. Any contact between unlike materials shall be avoided by using insulation between any aluminum and galvanized sections. Any surface damage to galvanizing shall be treated with approved cold-galvanizing treatments. Life of the mounting structure to be 20 years.

The structure assembly shall accommodate such cable trucking and any array junction boxes as may be required to meet the specification requirements for module interconnection in similar corrosion resistant materials.

- Mounting structure needs to be designed to withstand *wind speed* of 25 m/s.
- *Orientation* of the panels should be facing true south and tilting 15-25 ^{0} from horizon.
- Location of the PV array should not have *shading* from 6 am to 6 pm throughout the year.

This mounting structure should be fixed to **reinforced concrete foundations**; deigned based on loads (self-weight, wind load etc.) and bearing capacity of the soil. Foundation should have a footing of 1 m SQ; minimum 300mm thickness and shaft of minimum underground depth of 300mm for dens gravel or medium dense sand and gravel with bearing capacity of (200-600) kN/m^2 as per *BS 8004*; code of practice for foundations.

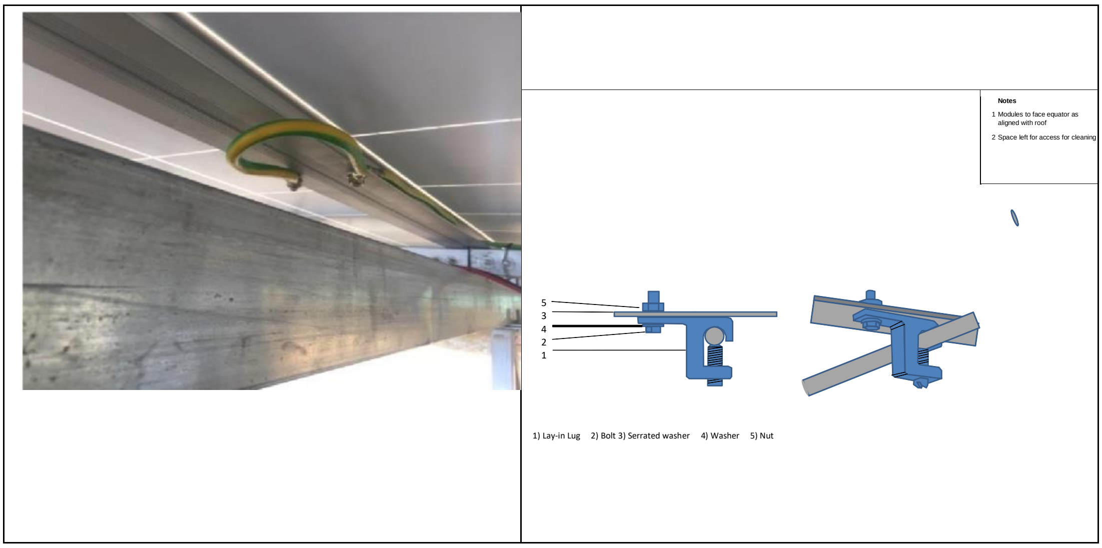
(a) **Cleaning of PV panels**: in the event where solar panels are mounted at a height where a person cannot access safely for cleaning purpose, a gantry which can be permanently fixed to ground or movable is required to include to the design.

(b) **DC/AC Isolator**, rated to suite the system should be installed between PV combiner box and inverter. Suitable AC isolator is requiring after the inverter. They must follow the appropriate standards mentioned above.

7.5.3 Module bonding to array structure

PV module frames and array structures shall be properly earthed. Each array and module must be earthed. For ease of installation and testing, the best practice approach for earthing modules together is to use separate *earth frame flange grounding* using stainless bolts, onto earth conductors providing earth continuity.

- Examples of acceptable bonding for non-coastal environments:
  ○ Use stainless steel mounting bolts for arrays to frame, with serrated washers to ensure good contact through galvanization (if galvanized steel) or aluminum oxide layer (if aluminum). ○ Separate earth bonding cables with lugs (left)
- For corrosive coastal environment, separate *earth frame flange grounding* using stainless bolts, onto earth conductors providing earth continuity.



Note that the following methods are NOT considered acceptable in the corrosive salt environment.

- Lugged cable between each module and array frame, with array frames providing earth continuity: Combination of copper crimp lug, aluminum and zinc plated "tek" screws are not acceptable
- Rely on metallic contact between module clamps and frames to provide earth contact, with array structure providing earth continuity: Contact may be lost over time due to corrosion
- Special earth clamps "bite" in to each module providing earth contact onto array structure, with array structure providing earth continuity: Contact may be lost over time due to corrosion

7.5.4 Distribution boards, bus-bar enclosures, switchgear and fuses

The general requirement for system configuration and enclosures is non-prescriptive. This section elaborates on the various enclosures and switchgear recommendations.

- Array junction box (typically on roof area or on array structure)
- Array DB (typically in powerhouse)
- DC DB / DC Busbar
- Battery bank with fuse
- Inverter AC DB
- Main AC DB or cluster box

All enclosures shall include standard din-rail mounting for breakers, isolators and meters. Enclosures to be surface mount, with bottom cable entries, (with receptacle for module DC connectors inlet and outlet) and gland seals. All unused slots to be blanked off to prevent access. All external enclosures to be IP65. All DB's and individual components within DB's to be clearly labeled. All external enclosures shall be made of corrosion resistant material.

Enclosures to be either dedicated either for AC or DC use. Mixed use enclosures are not allowed unless there is clear physical separation between AC and DC compartments with requisite labelling.

7.5.4.1 Array junction box

Usually located on the array structure, Array Junction Box is used to combine PV arrays. It contains an isolating switch for each sub-array as specified, and on outgoing switch. These shall be double pole circuit breakers rated for DC operation.

All junction boxes shall be rated to IP65 and Class II. Any junction boxes used externally shall have bottom entry panel receptacles for string connector connections - glands/, and with drip loop installed externally. They shall be located to facilitate inspections with sufficiently long wiring loops internally.

7.5.4.2 Array DB

Usually located within the powerhouse, Array DB isolates high voltage DC-coupled arrays from their respective DC MPPT charge controllers.

Array DB would also optionally isolate any AC-coupled DC arrays from grid tie inverter inputs, if these inverters were located indoors. For array structure mounted grid-tie inverters this is not necessary, or they would have in-built switch-gear.

Switches in Array DB to be double pole circuit breakers rated for DC operation.

7.5.4.3 DC DB / DC Busbar

DC Busbar Enclosure is required in systems with large battery banks and multiple parallel DC coupled arrays and MPPT's, and /or multiple parallel AC-DC battery chargers or parallel DCAC inverters. The DC busbar provides safe and protected interface between the batteries and these paralleled devices. The following are requirements for protection:

- Busbar rated for maximum current of all electronic devices
- Suitably rated 2 pole isolator for each electronic device. These are preferably CB not fuses.

- Battery bank isolator for each battery bank, for both positive and negative poles and negative. CB preferred, rated to maximum discharge capacity of battery or to enable single battery bank to interface with all electronic devices. • Labelling of each component as necessary • Safety covers.

7.5.4.4 Battery bank with fuse

In general batteries shall be installed within protective enclosures or entirely separated battery room. Battery inter-cell connectors shall be supplied with the battery, and they shall be professional quality, corrosion resistant. In case of batteries in the open in the power house, then all terminals shall be un-exposed and behind covers.

All battery banks that are not physically inside the DC Busbar Enclosure shall have separate battery fuses or circuit breakers on both positive and negative terminals, close to battery, to protect against cable short circuits.

Each battery/cell shall be labelled with a unique number numbered from negative to positive. Appropriate danger/caution signage shall be put in place, especially in the case of high voltage banks (greater than 48Vdc).

7.5.4.5 Inverter AC DB

The inverter AC-CB is for paralleling of outputs of grid-tie inverters, and usually located inside the powerhouse. The inverter AC DB shall normally contain the following

- AC over-current CB from each inverter, either 2 pole or 4 pole.
- Busbar of relevant rating and poles
- Outgoing overcurrent CB

7.5.4.6 Main AC DB or multi-cluster box

The purpose of this DB is to interconnect all AC connected devices. Typical inputs and outputs include:

- Outgoing feeders to the load
- Feeder with CB from grid tie inverters (inverter AC DB)
- Feeders to each DC-AC inverter (off-grid inverters)
- Feeders with CB to each AC-DC charger (or bi-directional inverter charger
- Generator set change-over switch or interface panel, allowing parallel diesel generator operation with inverter/chargers, or complete change-over to generator supply only to load.
- Relevant lighting protection devices
- Metering and logging devices for power generation side.

7.5.5 System grounding

7.5.5.1 Array frame earthing

The array structures requires grounding. The systems shall be provided with a separate array ground where the PV array metal structure and the roof structure if metal are connected to an earth electrode via insulated stranded copper earth wire 16 mm^2 minimum) using the shortest practical direct route downwards that directs the cable away from sensitive electronic equipment and shall not enter the building. In cases where the array structure is separate from a metal roof, insulated stranded copper earth wire is connected to both the array and the roof structure and terminated at the same earth electrode. The maximum allowable earth cable resistance between array frame and earth electrode shall be 1.7 Ohms. See earth electrode for its requirements.

7.5.5.2 System equipotential bonding

Equipment bonding shall be used to tie together casings of all equipment and enclosures, including all electronic equipment casings (inverters, chargers, MPPT, genset), array DB, AC DB, DC DB, DC busbars and DC enclosures, with minimum 6 mm^2 earth cable, and connected via an insulated stranded copper earth wire (10 mm^2 minimum) to their own earth electrode. The maximum allowed bonding resistance (between the metal parts of the devices and metal parts of the consumer earth terminal) is 1.7 Ohms (Note: this excludes the earth electrode earth impedance). See earth electrode for its requirements.

7.5.6 System electrical earth

7.5.6.1 AC conductor earthing

The earthing of the electrical system shall be comparable with TN-C-S and TT earth system compatible required (see diagram). All equipment to be TN-C-S and TT compatible, and this is non-negotiable.

System electrical grounding shall only occur on the AC side of a system, where the AC neutral conductor is connected to the consumer earth conductor, at one and only location on the site only. This would usually be within the Main AC DB or Multi-cluster. This requires an AC side N-PE bridge, and is not negotiable! It shall be clearly labelled and also marked on SLD.

The maximum allowable earth fault impedance (Ze) between consumer and earth terminal to earth electrode shall be 1.7 Ohms and shall use able of same size as the main conductors. See earth electrode for its requirements.

7.5.6.2 DC conductor earthing

The DC conductors shall never be earthed directly, as earthing complicates the protection and inspection requirements significantly.

- DC conductors shall always fully floating if galvanically isolated from AC side.
- Virtually earthing bond is allowed only via AC side in one location, if particular equipment is not galvanically isolated from AC side (i.e. certain transformer less Grid tie inverters). This shall be clearly marked on SLD if relevant, and in the equipment.

7.5.6.3 Earth electrodes

All earth electrodes used shall be bare copper plated earth rods, of length at least 1.5m. The spikes shall be driven vertically into the ground till buried to a depth of 300mm.

The maximum earth electrode earth impedance target is 5 ohms on a dry day each electrode. This figure is sufficient to fulfill functions of (i) array lightning surge earth path, (ii) system bonding earth path and equipment protection, and (iii) system electrical earth if required, for the entire system.

In sites with high earth contract resistances, then the following additional steps shall be taken towards this target:

- Electrodes shall be lengthened
- Electrodes to be buried with activated charcoal or salt to improve contact resistance
- Up to three electrodes may if necessary be inter-connected (OR increased in length) to minimize the earth contact resistance.

7.5.7 Lighting protection design

7.5.7.1 Lightning conductors

Lightening conductors used for protection in non-solar mini-grid projects shall comply with *British Standards C.P.326*. Roof conductor and down conductors shall be soft annealed copper tape of size not less than 20mm in width and 3mm in thickness to the required length. In case of bear conductor is used for distribution line, spark gap type lightening arrestors and associated earthing system should installed to cover each 500m radius of line and end users.

7.5.7.2 Surge protection on key cables

In general lighting surge protection is to be included on all cables incoming towards electronic equipment, to protect that equipment from induced surges, and to route the surges towards ground instead.

Lighting arrestors are to be located as follows:

- Externally mounted PV inverters: own Class 2 or 1 as standard internally, on AC cables, to own earth electrode.
- Incoming AC cables from PV inverters: Class 2 protection on all phases plus neutral, located within Inverter AC DB, direct to nearest earth electrode and not entering building.
- Outgoing AC cables to load: Class 2 protection all phases plus neutral located within Main AC DC.
- Incoming AC cable from generator: can be combined with above in Main AC DB
- All underground cables AC or DC cables: Class 2 protection at power house incomer JB, on all conductors plus N, direct to earth electrode. In general, avoid underground cables and use cable trays to keep cables above ground-induced surges.

Lightning surge arrestors to specification as follows: are required as follows:

- Class 2 protection lightning surge arrestors with visual fault indication, 40kA (8/20) according to IEC 61643-1 for sensitive electronics, clamping voltage to less than 1,500V.

- Class 1 and 2 combined protection may be installed later if required for sites with direct strike risk.

Note: For solar PV plant, it is generally advisable to install no lighting conductors on site or near the site, to avoid bringing surges towards the site and to electronics. Lightning should be rather directed away from the site.

8 GENERATION SYSTEM OF HYDRO MINI-GRID

NEP mini-grid program targets projects with capacity of 1 MW or less hence MHP specifications will relevant only for off the projects. Advanced controlling mechanism such as hydraulic flow controlling or remote operation etc. that uses in large project considered here less suitable unless specific arrangement for operation and maintenance is designed in the first stage itself.

8.1 Micro / Mini Hydro Turbines

Function of a hydraulic turbine is to transform the potential energy of water at the forebay tank in to mechanical energy. ***Impulse*** and ***reaction*** turbines are the two main categories of turbines.

Each category has number of turbine types. The site specific *Head* (Hn) and *flowrate* (Q) will determine the suitable turbine type. Typically micro / mini hydropower projects implemented under NEP will be owned and operated by the village community, therefore relatively simple designs that rely on manual control and operation are more likely to ensure long term sustainability of the project.

8.1.1 Turbine runner material:

Cast Iron runners can be used for heads below 100 m. Cast steel, Cast Bronze and Stainless steel should be used for fabricated or casted runners where the operating head exceeds 100m. Runners must be statistically and dynamically balanced and should be easily removable at the site.

Minimum runaway speed of the turbine should be 1.8-time of the rated speed. It should be able to operate at least 2 hours at this speed without mechanical failure.

8.1.2 Adaptor / Manifold

The adaptor connects the turbine to the penstock pipe. It must be designed to ensure a maximum water velocity of 3 m/s whereby minimizing head losses.

8.1.3 Manifold valve

Manifold valve (usually called main inlet valve-MIV) is requiring in all cases to enable the cut off of flow to the turbine. This enables maintenance work to be carried out on the turbine without the need to drain the penstock. For small capacity Pelton turbines with branch valves or jet deflectors and Crossflow/ Francis / Kaplan turbines with guide vanes that are able to shut off flow entirely, the manifold valve is not compulsory for operational purposes. Where a manifold valve is not installed, the penstock must be drained (normally flow into the intake is closed off) when carrying out maintenance on the turbine.

The Main valve should be slow closing (operated via a gearbox if required) **gate or butterfly valve** with a pressure rating exceeding the total pressure of system including a a satisfactory safety factor. A bypass valve of (1.5”-2”) is required in parallel with the main valve to equalize pressure on both sides to ensure easy opening.

8.1.4 Hydro Turbines

Function of a hydraulic turbine is to transform the potential energy of water at the forebay tank in to mechanical energy. ***Impulse*** and ***reaction*** turbines are the two main categories of turbines.

Each category has number of turbine types. *Head* and *flowrate* will determine the suitable turbine type. In NEP mini grid mini-grid projects, village community will ultimately owns and will operate the project and hence manual or semi-automatic; less complicated designs will ensure long term sustainability of the project.

8.1.5 Turbine runner material:

Cast Iron runners can be used for heads below 100 m. Cast steel, cast bronze and stainless steel can be used as fabricated or casted runners for high heads. Runners should be statistically and dynamically balanced and should be easily removable at the site.

Minimum runaway speed of the turbine should be 1.8-time of the rated speed. It should be able to operate at least 2 hours in this speed without a mechanical failure.

8.1.6 Manifold

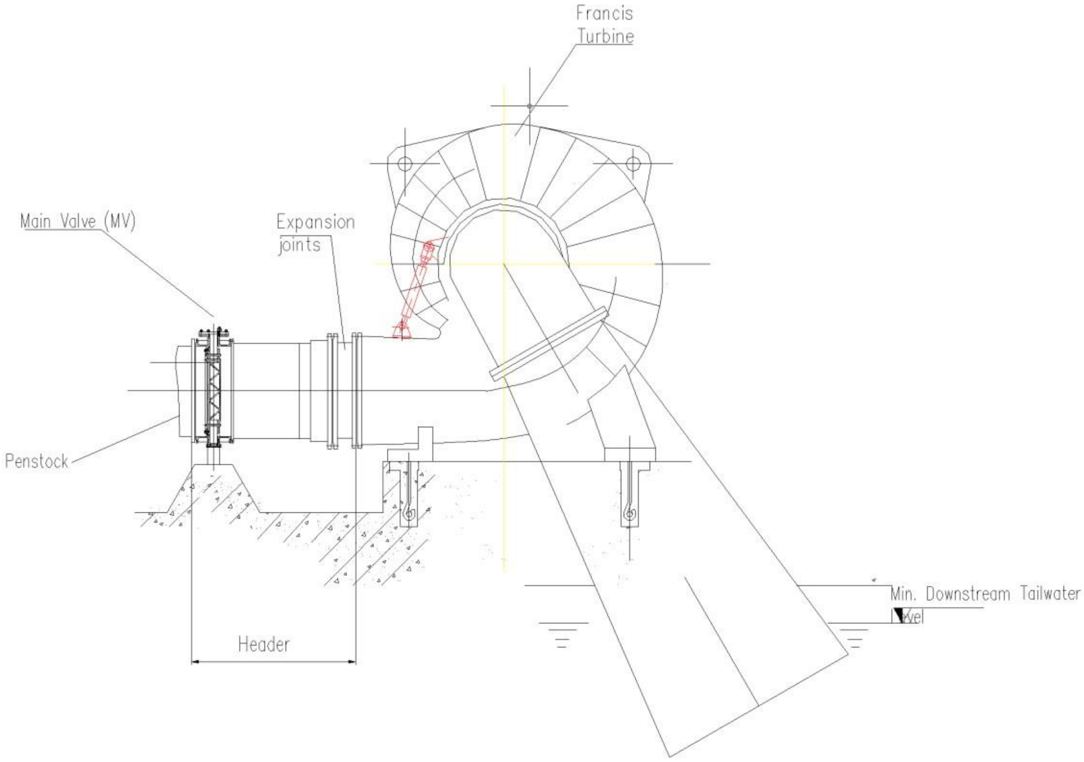
Manifold (which takes water from penstock and carries to the runner) and/or branch pipes must maintain maximum velocity of 3 m/s in order to reduce the head loss due to pipe friction and local losses.

8.1.7 Manifold valve

Manifold valve (usually called main inlet valve-MIV) is requiring in all cases to divert water from the runner and to do maintenance work. For small capacity of Pelton turbines with branch valves or jet deflectors; Cross flow/ Francis/Kaplan turbines with guide vanes that are capable of completely shut down the flow, the manifold valve is not compulsory. (In these cases, for turbine maintenance, it requires to close the flow from intake gate)

Main valve should be slow closing (can be with a gearbox in some instances) **gate or butterfly valve** with pressure rating satisfying total pressure of system. Bypass valve of (1.5”-2”) is requires in parallel with the main valve to equalize pressure on both sides to ensure effortlessness opening.

Figure 3: Turbine, manifold and expansion



8.1.8 Expansion section

Expansion in manifold section is required to absorb slight movement due to pressure changes and expansion due to temperature changes.

8.1.9 Turbine casing

Turbine should be casted with cast iron or fabricated with mild steel with a minimum thickness 6mm. Ribbing should be used wherever necessary to provide additional strength and to reduce noise and vibration. Sand blasting and painting with two coats of anticorrosive paint or galvanizing is required for all metal components of the turbine.

8.1.10 Bearings and Water seals:

Self-aligned spherical bearings with grease lubrication or sleeve bearings with oil lubrication must be used for turbines with capacity of 50 kW or above. Bearings should be capable of continuous operation and have a minimum lifetime of 10 years. Bearing warranty period of 2 year is required for NEP mini grid projects.

The maximum *permissible bearing temperature* should conform to manufacturers operational limits. In most cases this will be below 50 ^{0}C. Under normal operating conditions, it should be possible to touch the bearing housing with the hand. For power plants of 100 kW or more, bearing temperature sensor and associated warning alarms should be incorporated.

Where *axial force* is present, (e.g. turgo turbines or turbines with vertical shaft), angular contact bearing or tapered bearing should be selected.

Irrespective of location of runner, whether centrally mounted or overhung between turbines, a proper *sealing arrangement* is required to seal the water flow along the shaft. Gland packing box (stuffing boxes) is the preferred sealing arrangement for rotating shafts where an operator is able to periodically tighten and / or replace the gland packings easily. A cone arrangement mounted on the shaft and labyrinth seals is also a satisfactory sealing arrangement.

8.1.11 Pressure gauge:

A dial pressure gauge with a minimum 4" diameter dial is must be fitted to the manifold to observe the static and dynamic pressure of the system. A on/off valve should be fitted between the manifold and the pressure gauge enabling the pressure gauge to be isolated as required.

8.1.12 Base frame:

The turbine and generator should preferably be mounted to a single base frame; which can be properly aligned in the workshop prior to being dispatched to the site. In the case of Francis, S-type and bulb turbines, this may not be possible. The base frame should be strong enough that the turbine and generator assembly can be transported, unloaded and moved to its final position without any misalignment taking place. It should have longitudinal and lateral adjustment bolts to facilitate accurate alignment of the generator and tensioning the transmission belt / drive couplings as applicable.

8.1.13 Drive system and couplings:

Belt drive power transmission systems are commonly used for mini hydro projects where standardized turbines are used. This means the turbines are not dimensioned and fabricated specifically to match with standard generator speeds which is the approach followed on larger scale hydro projects. Basic maintenance of such systems can be handled by operators on site without the need for specialist knowhow. The step-up ratio should not exceed 3:1 (large / small pully diameters), Synthetic V belts readily available in the market should be used whenever possible. Taper lock bushes are recommended but not compulsory. Belt size and number of belts required should be designed according to the belt manufactures catalogue/ data sheet for continuous operation. Pulleys should be statically and dynamically balanced but for smaller diameters below 150mm, static balancing only is sufficient.

In configurations where the turbine is coupled directly to the alternator, a ***flexible coupling*** is required. Taper lock couplings are easy to maintain and therefore preferred, however, not mandatory. Couplings should be statically and dynamically balanced.

Guards: in case of belt drive system or direct coupling system, protection guards made of steel, firmly fixed to the base frame or ground is a mandatory requirement.

8.1.14 General aspects of hydro generating system:

Bolts used for both the turbine casing and turbine runner and other internal components that come into contact with water should be stainless steel (SS) or galvanized steel.

All valves used in branch pipes used in Pelton turbines should be flanged typed gate valves or spear valves. In case spear valves or in crossflow turbine guide vane mechanisms a hole for *cleaning and inspection* should be provided to enable easy removal of debris without the need to dismantle the entire turbine. Depending on the governing mechanism selected, these branch valves can be operated manually or automatically.

8.1.15 Tools and special equipment:

Tools and jigs required to dismantle runner and pulleys, eye bolts, chains and D-shackles required to lift the equipment must be provided as part of the standard equipment supply.

8.2 Generator (Alternator) of hydro mini grid:

For micro hydro projects below 50 kW, induction generators (induction motor used as induction generator using capacitor bank) is a suitable option to the conventional synchronous alternator. If this approach is used, it is necessary to oversize the capacity of the induction generator by 20% to compensate the power losses in the capacity bank. Frequency for induction systems can be 50-55Hz, under all load conditions.

Capacitor banks in this system should have an over current device (usually MCB) to disconnect the excitation capacitor bank and stop the generation of excessive voltage and damage to the alternator in the case of turbine overspeed / runaway speed.

Synchronous alternators with brushless excitation can be used for all the mini hydro projects irrespective of capacity. The systems can either be controlled electronically using an Electronic Load Controller (ELC) or with a more sophisticated flow control device. Flow control devises are normally only viable for larger sized projects in excess of 50kW.

(For both IGC and ELC controlled schemes, a reliable ballast tank to absorb any excess power is mandatory. Over/under voltage protection must also be included as function of the IGC or ELC. Ballast tanks should be fitted with an overload protection (usually a bank of appropriately rated MCBs).

Ballast tanks can be water or air and should be able to dissipate 100% plant capacity continually (for example under full load rejection condition).

8.3 Cable size in Hydro Mini Grid:

This refers to the connecting cables from alternator to Electronic Load Controller (ELC) / Induction Generator Controller (IGC), and from the controller panel to the main distribution board and ballast load, cable from distribution panel to the first pole of the distribution (sometimes transmission) line and various sensor cables.

Flexible cables fulfilling *BS 6004* and *BS 6346* should be used for NEP mini grid projects. All cables should be laid as per standards specified in clause 3.3 here. Maximum voltage of all wires/ cables should be 600V.

Log books, Operations and Training manuals are to be provided and training is to be conducted by the developer before commissioning of the project. One copy of these documents is to be handed over to NEP PMO and DRD township office as per the agreement signed with DRD.

9 BIOMASS AND OTHER MINI-GRIDS GENERATION SYSTEM

The Biomass resources can be applied in a wide array of energy conversion technologies to produce thermal or electrical energy. These technologies can be broadly categorized under two system:

- Combustion based Rankine system: The combustion-based systems are most versatile and can utilize all kinds of biomass resources including wastes. Biomass is fired in a boiler to produce steam and the same is used in steam turbine for generation of power.

- Gasification and gas engine-based system: Biomass gasification is the process of partial combustion of biomass under controlled air supply, thus producing a mixture of gases generally called as producer gas which can be burnt in an engine to generate electricity.

Unlike Solar or hydro, vast number of technology configuration can be available in this sector and NEP mini-grid developers are expected to use the latest technologies to ensure optimal conversion.

Management of continuous energy supply and catering to low demand periods (like late night street light illumination) are major challenges for such system and thus require innovative ideas.

No detailed specifications are outlined here due to the novelty of the sectors but developer is expected to follow standards from International Finance Corporation (IFC). The IFC standards should be satisfied for designing and operation of biomass projects under NEP assistance.

- IFC/World Bank: Environmental Health and Safety General Guidelines; 30 April 2007

10 DISTRIBUTION LINE AND WIRING OF END USERS

The NEP mini-grids will require a low-voltage network which carries electric energy from generating station to electricity meters of end customers. Some mini-grids in special circumstances may require a Medium Voltage (MV) network with transformer and the same will be governed by relevant standards not discussed in this document. They may be designed to meet IEC 61968 standards to allow future compatibility with international standards.

In general, the size of the plant, extent of demand and distance to the load points will decide whether medium voltage (MV) transmission line is feasible or not. In all cases losses are to be fully considered.

10.1 MV Distribution line

MV distribution line must be designed to ensure maximum voltage drop of 5 % at the load center. In addition to this the selected voltage must be compatible with the regional/ state distribution line codes. 11m poles complying to ESE standards and an outdoor ONAN hermetically sealed transformer conforming to the IEC 60076, IEC 60616, IEC 60551 and IEC 60437 specifications must be used.

In case of MV distribution line, 11m poles complying to ESE standards and an outdoor ONAN hermetically sealed transformer; satisfying the IEC60076 specifications must be used.

10.2 LV Distribution lines

10.2.1 Pole in LV distribution

Concrete poles of 8 or 9 meter can be used for NEP mini-grid main feeders with insulated conductors. Circular spun poles as per ESE accredited specifications or square poles can be used for mini-grid distribution lines. Sample drawing of a square pole which can be made by villagers (to count as in-kind contribution) is available as an annex to this document. For sub feeders, service poles, concrete poles or wooden poles of 8m can be used. If wooden poles are used, proper treatment is to be done as per next section.

10.2.2 Wooden pole preparation and treatment

Eight-meter wooden poles must have a bottom diameter of 200mm and top diameter of 125mm; it needs to be cut and debarked; let it air dry for 3 months. Then three coats of used engine oil must be done with each coating followed by heating to 70-80 ^{0}C. A gap of 1 week must be allowed between successive coats to ensure adequate penetration and treatment of wood. After installation, it required to periodic inspect and apply oils again up to a height of 2m from bottom.

10.2.3 Layout of electricity lines

Electricity lines should be routed in such a way that it passes through or close to the load centers. Poles should be located such as to provide maximum number of service connections while using minimum number of poles. These lines segment should be straight as much as possible.

1. Poles shall always be planted in a straight line as far as possible.

2. Planting of poles next to roads or streets shall comply with the specifications of the responsible road's authority.
3. LV, MV and street lighting (i.e. electrical services) shall not share a pole with telephone services.
4. Care must be taken so that the required clearances are adhered to as given in this document.

10.2.4 Distribution line diagram:

NEP mini-grid proposal requires the developer to include a distribution line drawing (sketch) with following details:

The spacing of poles shall be as indicated on the layout drawings. Distance of each segment of line, conductor type and conductor size and number of conductors in each segment, location of load points with load details, position of lightening arrestors, positions of poles and disconnector poles (poles with jumpers), position of street lights and poles with cluster load breakers and Residual Current Devises (RCD).

A table showing voltages and voltage drops i.e. distribution network Voltage Regulation should be include with the proposal.

10.2.5 Load Balancing in - phase system

In Mini-grids using a 3-phase distribution network it must be ensure that load is balanced to allow smooth and efficient operation of equipment.

10.2.6 Quality of Electricity:

A table showing voltages and voltage drops i.e. distribution network Voltage Regulation should be include with the proposal. Maximum voltage drop permitted at point of use is 5% of the sending end voltage. Frequency of electricity must be maintained in the range for various systems:

- **Solar Hybrid and Biomass systems**: 49-53 Hz
- **Hydro systems:** 50-55 Hz for systems with induction generator and 50-52.5 Hz for systems with synchronous alternator.

10.2.7 Material of distribution line conductor:

Material of the conductor use for distribution lines can be either aluminum or copper. Cables use for NEP mini-grid should follow international standards given below:

IEC 60889: Hard-drawn aluminum wire for overhead line conductors

IEC 61089: Round wire concentric lay overhead electrical stranded conductors

IEC 62219: Overhead electrical conductors - Formed wire, concentric lay, stranded conductors

IEC 60502: Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV),

IEC 60228: Conductors of insulated cables

IEC 62420: Concentric lay stranded overhead electrical conductors containing one or more gap(s)

IEC TR 61597: Overhead electrical conductors - Calculation methods for stranded bare conductors

IEC 61395: Overhead electrical conductors - Creep test procedures for stranded conductors

10.2.8 Types of distribution line conductor:

Bare conductors, Insulated conductors and Bundle conductors (insulated and bundled together) can be used for the mini-grid transmission/ distributing lines but insulated conductor is preferred due to safety concerns and less maintenance requirement. Additional safety in terms of lightening protection (spark gap type; described in section 7.2.9) is required if bare conductors are used. Service cables needs to insulated with additional protection sheath.

10.2.9 Span of the LV distribution line poles,

Irrespective of line material, distribution line configuration should satisfy the following minimum specifications.

Table 4- Pole spacing respect to the pole type

Conductor type	Maximum span (m)	Minimum pole height (m)
Bare Conductors	30	8 for sub-circuits and 9 for main circuit
Insulated Conductors	30	9

Note: pole height is the length before installation

10.2.10 Distribution line Clearance

Low voltage distribution lines may be located such that distance from lowest conductor to the ground or any structure; with sagging shall not be less than the distances specified below:

Table 6- Clearance of distribution line from structures and ground

Incidence	Bare conductors	Insulated Conductors
Horizontal distance to structure	8ft.	4 ft.
Vertical distance to structure	10ft.	8 ft.
Footpath	15 ft.	15 ft.
Motorable road	19 ft.	19 ft.
Road crossing	19 ft.	19 ft.

10.2.11 Insulators:

Nylon or ceramic bobbing insulators (larger: 96 mm diameter) and (small: 46mm diameter) are to be used for all feeders and service line, in case of bare conductors.

For insulated conductors, nylon or ceramic bobbing insulators or suspension clamps (for straight line section), small angles suspensions/ large angle suspensions (for bends) are to be used. If nylon or ceramic bobbing insulators are used for insulation conductors, insulated wire should be used for binding the cable to the insulator. All the accessories used should be accredited to ESE requirement or international standards IEC 1109.

10.2.12Stay assembly

Stay support using stay assembly is required on first and last pole of feeder along with any pole with distribution line bend of above 5^0. Stay assembly will include stay rod, plate, thimbles and stay brackets and should be made with galvanized steel with a thickness of 80 um. It should be accredited to ESE specifications or follow international standards.

10.3 Load centers

10.3.1 Clustering

If the number of beneficiaries is large (above 100 HH), clustering will help in speedy fault identification in case of faults. In this case an isolator; rated according to the load of the clustered house/ connected loads should be fixed in a waterproofing enclosure on the pole. In case of metal enclosure, proper earthing of the metal casing is required.

10.3.2 Distribution board and load points

The distribution board will include Residual Current Device (RCD) of 20/30 mA/20A rating and over loads fuses or Miniature Circuit Breakers (MCB), selected suitably based on peak power is required for every household. They should be fixed in an enclosure.

10.3.3 House wiring and Appliances

Project proposal should include the cost for house wiring with material including but not limited to protection devices and earthing rod along with installation charges. Two LED bulbs of 10W with min. 400 lumens, one LED tube light of 10 W and one 5 A plug base with 3 pin and 2 pin provisions should be installed in each household irrespective of category, if different categorization exists.

Flexible wires 1/0.044 of brown color code (for phase) and blue color (for neutral) and a green color earth wires of 1 mm^2 should be used for house wiring. All wiring should be done inside conduits, with a minimum of 20mm diameter; fixed firmly with brackets with maximum spacing of 450 mm.

10.3.4 Street lighting

LED Street light of at least 10 W should be installed at least in every other pole and should have a minimum intensity of 800 lumens. It should be mounted 3m above ground with a galvanized bracket. All street light should have IP65 protection with a photo sensor.

10.3.5 House Energy meter and vending machines

The energy meters should be installed in each household and it must be tamperproof, prepayment type meters with maximum self-consumption of 2Wand with non-volatile memory for metering data. Energy meter should be user-friendly and simple, so user can obtain minimal information like the remaining balance, usage etc. It should have a warning system to alert the consumers on low balance or other similar useful events.

It must be capable of having progressive block-rate tariffs (increasing tariffs for increasing consumption) or allow for variable pricing. It is not compulsory to have GSM (mobile data) connection for operation and/or data logging but the same encouraged.

Position of energy meters: Energy meter is expected to be installed inside the house (or other load point) but if it is installed in the service pole due to any reason, interface with display should be given to each load points to see the above minimum information on their electricity usage and to facilitate the recharging, if applicable.

The meters must have Class 1.0 accuracy and conform to *IEC 62053-21*, *IEC 62052-11*, *EN 50470*.

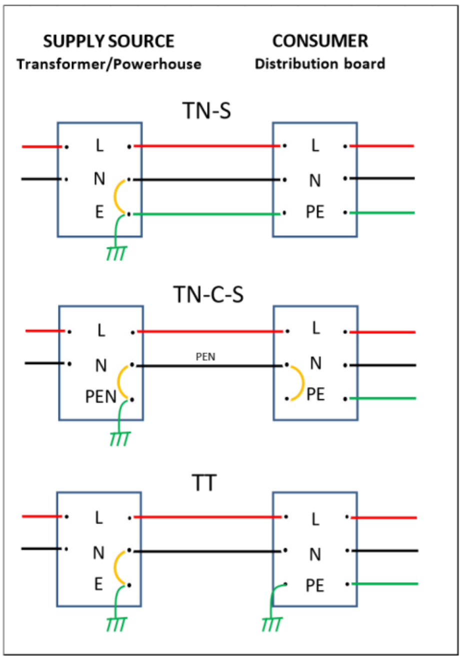
Note: All equipment used in mini-grids projects must meet required national standards wherever available or, in the absence of the same, IEC standards mentioned in this document or other similar document released by DRD. The equipment may follow another equivalent standard such as BS, EN, DIN, ASTM or Australian etc.

10.3.6 Earthing convention: conductor earthing conventions

TN-S requires 3 distribution conductors for single phase system, and 5conductors for 3 phase.

For cost reason, mini-grids may consider following either TN-C-S or TT systems (2 conductor for single phase, 4 conductors for 3 phase). Both these options require N-PEN bond at the powerhouse. At consumer side, both require 3 cable wring in the household. TN-C-S is more cost effective as it does not require an additional earth electrode at each consumer.

As a default condition, the developer should apply the prevailing earthing standards as set out by ESE where such standards exist.



11 Documentation and labelling

A block diagram which shows overall system and *circuit diagrams* for panels and controllers should include:

11.1 Documentation

- Single Line Diagram (SLD)
- Engineer sign-off
- User manual
- Operational manual
- ToC of each

11.2 Labelling SLD and equipment

All electrical components labels describing their function in English and Myanmar language.

- Quality
- Correspondence
- Circuit breakers and equipment

11.3 Signage and safety equipment

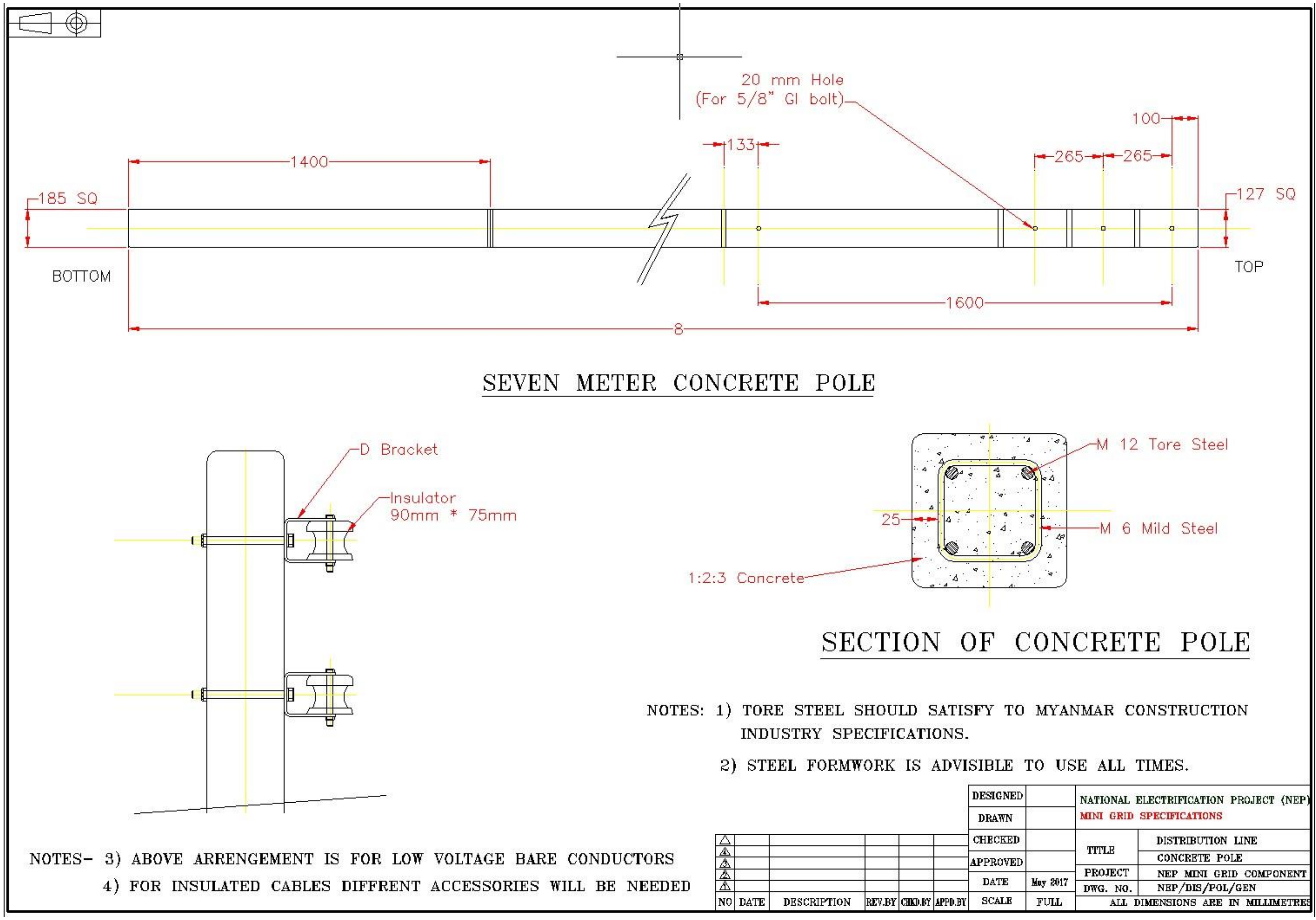
Illustrated *Warning signs* in Myanmar language should be fixed every place it poses a threat for operators and users.

- Standards and language
- Labels
- 1st aid
- Fire extinguishers
- Electric shock signs and processes

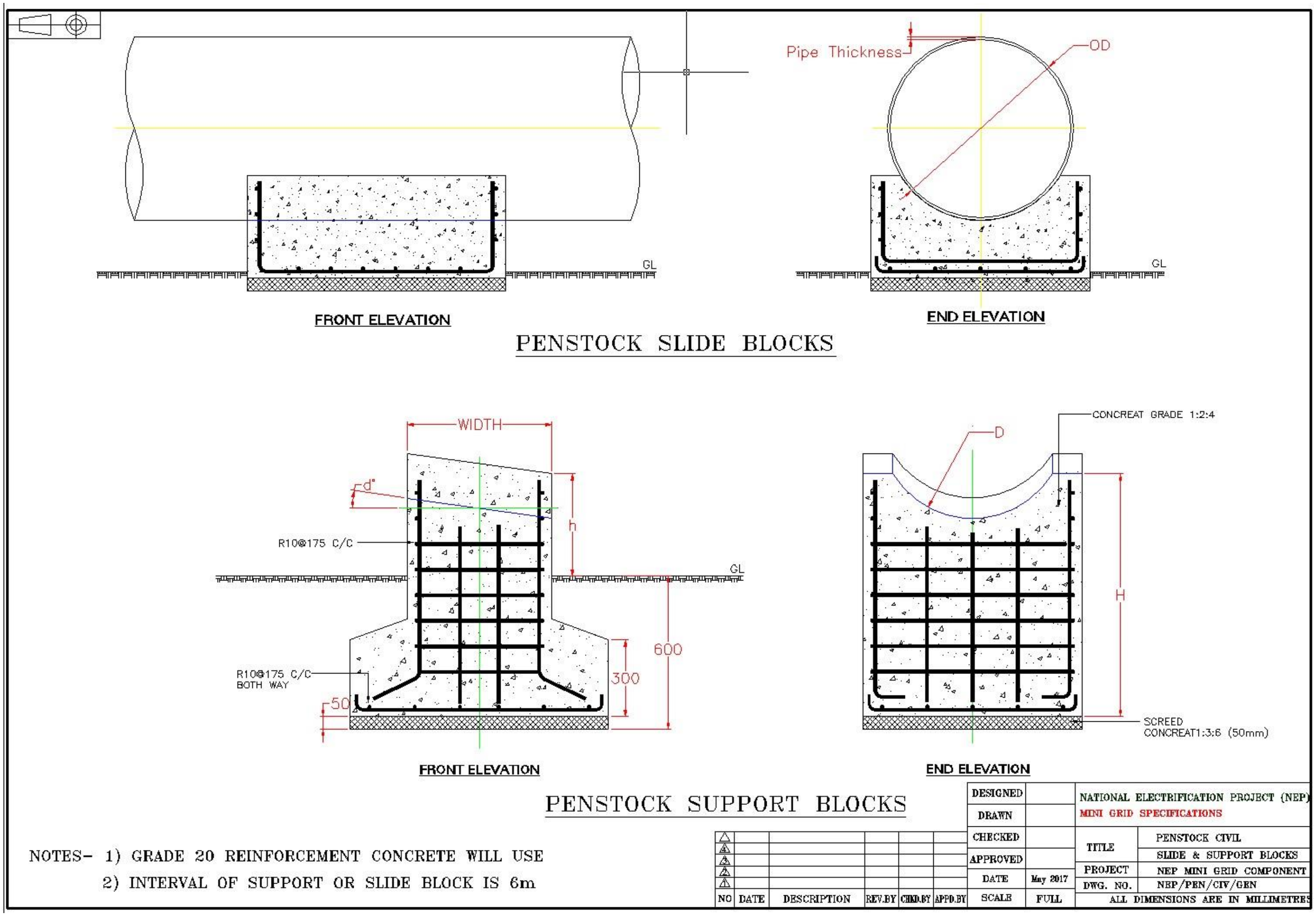
11.4 Warranties

Equipment supplied and installed originally at site with warranty details.

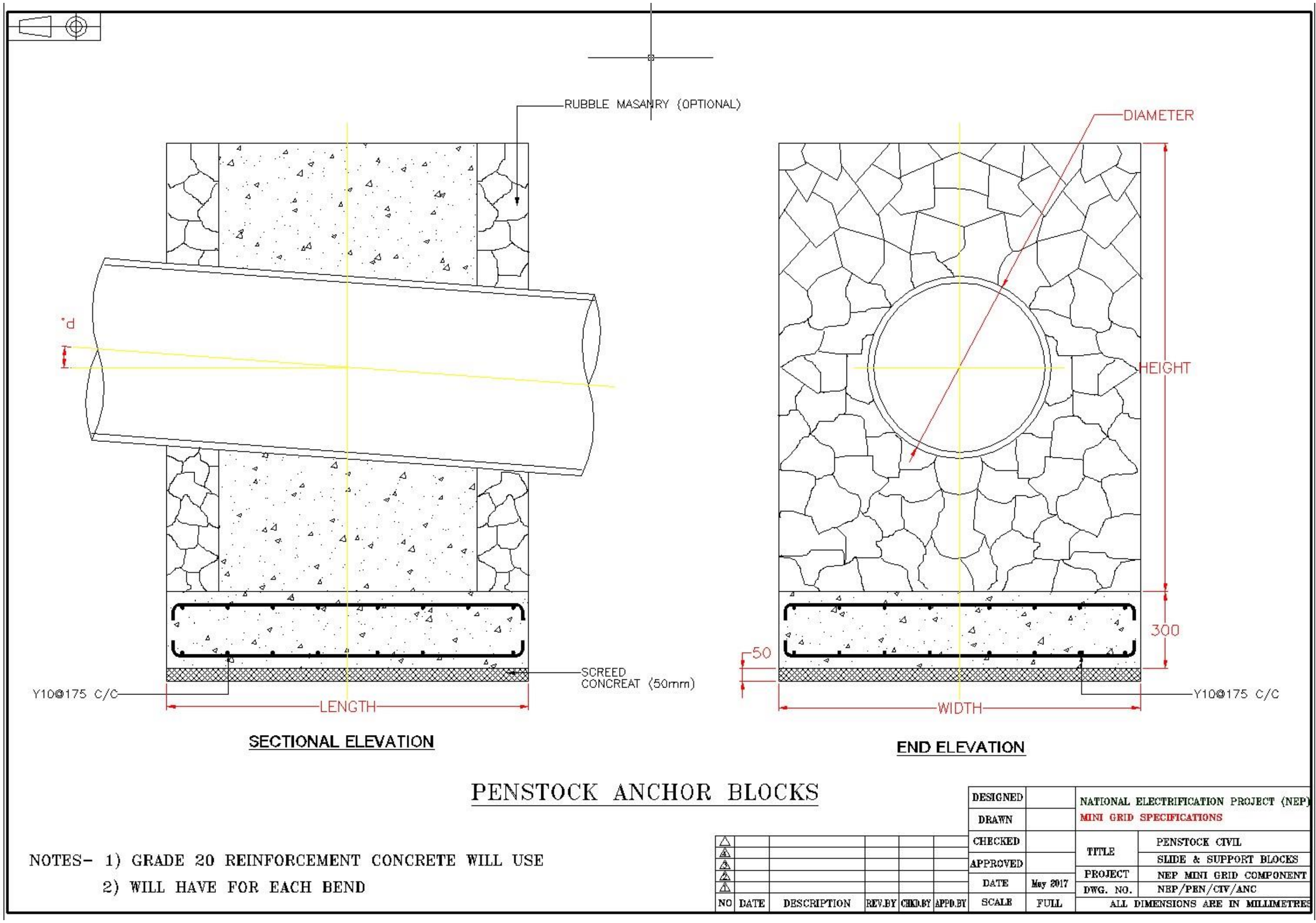
Annexure 1


20 mm Hole
(For 5/8" GI bolt)
100
133
265
265
1400
185 SQ
127 SQ
BOTTOM
TOP
1600
8
SEVEN METER CONCRETE POLE
D Bracket
Insulator
90mm * 75mm
M 12 Tore Steel
25
M 6 Mild Steel
1:2:3 Concrete
SECTION OF CONCRETE POLE
NOTES: 1) TORE STEEL SHOULD SATISFY TO MYANMAR CONSTRUCTION INDUSTRY SPECIFICATIONS.
2) STEEL FORMWORK IS ADVISIBLE TO USE ALL TIMES.
NOTES- 3) ABOVE ARRENGEMENT IS FOR LOW VOLTAGE BARE CONDUCTORS
4) FOR INSULATED CABLES DIFFRENT ACCESSORIES WILL BE NEEDED
NO DATE DESCRIPTION REV.BY CHKD.BY APPD.BY
DESIGNED
DRAWN
CHECKED
APPROVED
DATE May 2017
SCALE FULL
NATIONAL ELECTRIFICATION PROJECT (NEP)
MINI GRID SPECIFICATIONS
TITLE
DISTRIBUTION LINE
CONCRETE POLE
PROJECT NEP MINI GRID COMPONENT
DWG. NO. NEP/DIS/POL/GEN
ALL DIMENSIONS ARE IN MILLIMETRES

Annexure 2


Pipe Thickness
OD
GL
FRONT ELEVATION
END ELEVATION
PENSTOCK SLIDE BLOCKS
WIDTH
d°
h
R10@175 C/C
R10@175 C/C
BOTH WAY
50
300
600
D
CONCREAT GRADE 1:2:4
H
SCREED
CONCREAT1:3:6 (50mm)
FRONT ELEVATION
END ELEVATION
PENSTOCK SUPPORT BLOCKS
NOTES– 1) GRADE 20 REINFORCEMENT CONCRETE WILL USE
2) INTERVAL OF SUPPORT OR SLIDE BLOCK IS 6m
NO DATE DESCRIPTION REV.BY CHKD.BY APPD.BY
DESIGNED
DRAWN
CHECKED
APPROVED
DATE May 2017
SCALE FULL
NATIONAL ELECTRIFICATION PROJECT (NEP)
MINI GRID SPECIFICATIONS
TITLE PENSTOCK CIVIL
SLIDE & SUPPORT BLOCKS
PROJECT NEP MINI GRID COMPONENT
DWG. NO. NEP/PEN/CIV/GEN
ALL DIMENSIONS ARE IN MILLIMETRES

Annexure 3


RUBBLE MASANRY (OPTIONAL)
DIAMETER
*d
HEIGHT
300
50
SCREED CONCREAT (50mm)
Y10@175 C/C
Y10@175 C/C
LENGTH
WIDTH
SECTIONAL ELEVATION
END ELEVATION
PENSTOCK ANCHOR BLOCKS
NOTES- 1) GRADE 20 REINFORCEMENT CONCRETE WILL USE
2) WILL HAVE FOR EACH BEND
DESIGNED
DRAWN
CHECKED
APPROVED
DATE
May 2017
SCALE
FULL
NATIONAL ELECTRIFICATION PROJECT (NEP)
MINI GRID SPECIFICATIONS
TITLE
PENSTOCK CIVIL
SLIDE & SUPPORT BLOCKS
PROJECT
NEP MINI GRID COMPONENT
DWG. NO.
NEP/PEN/CIV/ANC
ALL DIMENSIONS ARE IN MILLIMETRES
NO
DATE
DESCRIPTION
REV.BY
CHKD.BY
APPD.BY