OPERATION & MAINTENANCE (O&M) MANUAL

MINI/MICRO HYDRO POWER

Prepared by

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION (PEDO)

GOVERNMENT OF KHYBER PAKHTUNKHWA

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ABOUT THE OPERATIONAL MANUAL

This operational manual is specifically prepared by PEDO for MHPs operator and local communities. The pressing need of the manual was felt on continued demand from the community and MHPs operator. During preparation of this manual focus have been given to keep it simple, to the point and to respond to the field based lessons learnt. The manual has been categorized to give its audience an overall background of energy crises in the country and need of constructing MHPs. It also highlights the pressing need of electricity of the local deprived communities of Khyber Pakhtunkhwa province.
The core objective of the manual is to enhance the operator capacity in sustainable operation of the MHPs and enable them to cope with the minor problems themselves. This manual covers the normal operational guidelines, emergency switch off standard procedures and detail functions of different sections of the MHPPs. The manual also covers the different parts of the MHPs, its function, maintenance guidelines and minor repair.

MAIN OBJECTIVES/OUTCOMES OF THE O&M MANUAL

The main objectives of this operational manual are as follows,

- This manual would enhance the capacity of operators and local community in step by step operation and maintenance of MMHPPs.
- Define the roles and responsibilities of operators to properly operate and maintain micro-hydropower plants.
- Help operators to efficiently conduct O&M of micro-hydropower plants in strict compliance with the set rules and regulations.
- Enable the operators and local community to know about MHPs components and their respective performance and functions.
- Enable the operators to manage the MHPs in emergency situations.
- Build the operators capacity to inform the incharge of the MHPs prior to possible technical problem if prevails.
- Built the operators capacity in operating and using of different electrical equipment needed for proper transmission of electricity to the local communities.
- Operators will try to prevent any accidents. Preventative measures such as equipment repair and the improvement of the facilities should be implemented as necessary.

BACKGROUND

Proper resource mobilization, either it be human or natural resources, both plays a vital role in the development of any region. It is worth mentioning that in KP there are abundant water resources that can play significant role in the improvement of living standards of under developed population of far flung areas of the province. In many regions of KP the settlements and houses are scattered and population is far away from national grid transmission. Likewise, transport of fuel to these locations is really expensive. The practical option to mitigate these problems is to install micro/mini hydro power plants for the betterment and prosperity of the natives. It has been found over last few decades, that there has been a growing realization in many developing countries like Pakistan that small hydropower schemes have a very important role to play in economic development of the rural population through electrification programs. Small hydropower schemes can provide power for industrial, agricultural and domestic uses through direct mechanical power or coupling of turbine generator. Small scale hydro power potential sites are normally situated in remote isolated areas, with their development expected to serve as an engine towards economic and social development of the remote/local communities.

ENERGY CRISES IN PAKISTAN

Pakistan is going through its worst energy crisis due to the rapid depletion of fossil fuels. A staggering figure of 6000 MW power deficiency has rendered the country handicapped in the economic and political domains. Whereas Pakistan is endowed with a hydro potential of approximately 42,000 MW, most of which lies in KP, Northern areas, Azad Jammu Kashmir and Punjab provinces. The total installed capacity of the hydropower stations in the country is about 7,000 MW. The majority of low head sites are located in remote areas of Pakistan which are off grid and suitable for axial flow turbine conditions. An estimated power production of 1,300 MW can be produced by installing turbines on these micro-hydro sites. Micro Hydro Power being the cheapest source of energy among the conventional energy generation methods, hydropower is 100% environment-friendly. It is imperative to make full use of this hydropower potential in order to meet the country's ever-growing energy demands. Significant proportion of this potential can be utilized with the use of micro-hydro schemes. Operation of diesel stations in the remote isolated systems depends on the expensive imported fuel which is a cost to the national economy.

WHY NEED OF MMHPPs

The above mentioned situation of the country demands to develop small hydro power to supply cheap and environmental friendly electricity to the isolated communities. The recoverable potential of Hydro Electric Power exploited so far constitute of 14 % share of the total energy. Residential and commercial sector is one of the largest consumers of energy accounting for about 25 % of the total energy with a growth rate of 7.4%.

Household incomes in the remote areas of KP are usually a constraint due to low productivity of rain fed agriculture and livestock production and because of lack of off-farm employment opportunities. In terms of income over 80 percent of the households have consumption levels below the province KP poverty level of PK Rs.771 per month. The people in these areas cannot afford to buy expensive electricity generated through thermal power plants, if provided. The only option left behind is of Hydro Power generation through exploitation of locally available endowment. This means the only viable and economical option left is the installation of decentralized power plants to generate electricity at a very low price. It has been widely proclaimed by the government authorities again and again, that electrification of rural areas is the top most priority of the government. It has determined to provide this very basic amenity of life to almost all of these rural areas of the country where electricity is yet to be provided. Government is planning under Medium Term Development Framework (MTDF) to increase the share of Hydro Electric Power from 6.43 MTOE (in 2004) to 38.93 MTOE in (2030). The share of renewable energies is also planned to be increased from almost zero availability to 9.20 MTOE in 2030 under MTDF.

IMPORTANCE OF MMHPPs IN RURAL AREAS OF KP

Mini/Micro Hydro Power plays a vital role in the electrification of rural communities living in remote and far flung mountainous areas of Pakistan. For a fragile and energy deficient National Grid, these rural areas fall in the outreach category when it comes to electrification. The only hope for distant rural communities, to see light and make their way to progress and development, is through Mini/micro hydro power.

Government of Khyber Pakhtunkhwa has launched a project "Construction of 356 Mini / Micro Hydro Power Projects (MHPs) in northern Districts of Khyber Pakhtunkhwa (KP)", with the aim to provide electricity to grid in accessible area. KP government, keeping in view the experience of NGOs selected 6 NGOs through open bids. The implementation of the project through NGO has been adopted to run the MHPs through local community after completion.

HISTORICAL BACKGROUND OF PEDO

The recent concept of PEDO initiated back in 1986 as "Sarhad Hydel Development Organization" with the main objectives of,

- To identify and develop Hydel potential up to 5MW.
- To construct small Hydel stations for isolated load centers.
- To operate and maintain off grid small Hydel stations.

In 1993, it was converted to an autonomous body under the 1993 Act and renamed as Sarhad Hydel Development Organization (SHYDO). In 2013, the name of organization was changed to "Pakhtunkhwa Hydel Development Organization (PHYDO)". Most recently in 2014 PHYDO was renamed as "Pakhtunkhwa Energy Development Organization (PEDO)" through the PEDO Act 2014.

INTRODUCTION TO BASIC COMPONENTS OF MHPs

Following are the main components of MHPs with pictorial details:

INTAKE

The main function of the intake is to allow only rated flow into the headrace channel and as far as possible, to block entry of undesirable solid materials such as stones or wood sticks. For this purpose, either a coarse trash rack or cross-bars are provided at the intake mouth. Usually different types of intake are used for MHP schemes. In most cases, it is a must for an opening constructed in the side of the stream loading to the canal. The down-stream end of the opening may be extended in the form of a partial dam. In another case a proper wall may be constructed in which the intake mouth would be in the form of a Rectangular window.

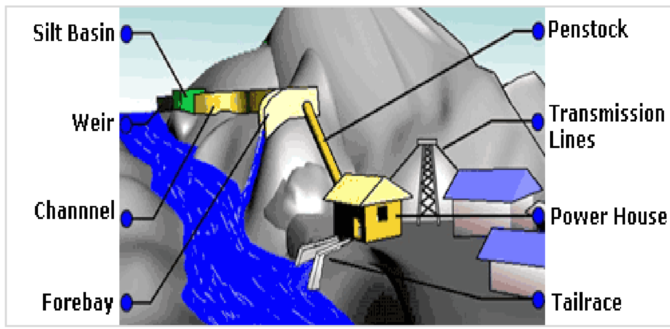

Figure 1. The schematic diagram of an MMHP

The sources of damage for the intake structure are again mainly high floods and flows and boulders, logs or other such heavy objects transported by flow. Additionally, landslides may either damage the structure or block it. The intake structure or adjoining wall may be damaged or get damaged due to high flows, boulders or other heavy solids carried by flowing water. Sometimes, intake mouth may become wider or smaller; or, the trash rack or cross-bars may get damaged; break or-bend. The mouth may also get blocked by the silt deposits. Sometime the whole structure may also get washed away due to extreme conditions. The water turbine is driven by water from the waterway system. If the water flow is shut off by the intake gate or valve, water cannot be fed to the water turbine. In situations where the ability to close the intake gate (or valve) is limited, the water remaining in the penstock flows down by the

Figure 2. Intake of under construction MMHPP

force of its own weight after the opening of the inlet valve (and guide vane), but supplemental air cannot go into the penstock. This lowers the pressure within the penstock. In the worst case scenario, the buildup of air pressure breaks the penstock.

GATES AND VALVES

In every small hydropower scheme some components, for one reason or another (maintenance or repair to avoid the runaway speed on a shutdown turbine etc.) need to be able to be temporarily isolated. Some of the gates and valves suited to the intakes for small hydro systems include the following.

- Stop logs made up of horizontally placed timbers
- Sliding gates of cast iron, steel, plastic or timber
- Flap gates with or without counter weights
- Globe, rotary, sleeve-type, butterfly and sphere valves.

Figure 3. Gate and Valves of an MMHPs

CHANNEL

The channel conducts the water from the intake to the forebay tank. The length of the channel depends on local conditions. In one case a long channel combined with a short penstock can be cheaper or necessary, while in other cases a combination of short channel with long penstock suits better. Most channels are excavated, while sometimes structures like aqueducts are necessary.

Figure 4. The channel of an under construction MHP

To reduce friction and prevent leakages channels are often sealed with cement, clay or polythene sheet. Size and shape of a channel are often a compromise between costs and reduced head. As water flows in the channel, it loses energy in the process of sliding past the walls and bed material. The rougher the material, the greater the friction loss and the higher the head drop needed between channel entry and exit. Where small streams cross the path of the channel a lot of care must be taken to protect the channel. A heavy storm may create a torrent easily capable of washing the channel away. Provision of a drain running under the channel is usually not adequate protection. It will tend to get block with mud or rocks when needed the most. In the long term it is economical to build a complete crossing over the channel.

GRAVEL TRAP

In the absence of a gravel trap, the settling basin must be close to the intake and able to flush the gravel that enters the basin. Gravel traps differ from settling basins in that they handle coarse material that enters near the bed, rather than suspended material that needs to be settled. The main design principle of gravel trap is that the velocity through it should be less than required to move the smallest size of gravel to be removed. The largest size allowed to enter into the intake can be controlled by the spacing of the coarse trash rack bars. In general gravel traps should settle particles larger than 2mm in diameter. Smaller sized particles will be settled and removed in the settling basin.

STANDARD CRITERIA FOR DESIGNING THE GRAVEL TRAP

- To be able to trap particles down to 2mm diameter, the velocity in the gravel trap should be limited to 0.6 m/s.
- If the gravel trap is hopper shaped; the floor slopes should be about 30˚, such an arrangement will facilitate easy flushing of gravel. If it is not possible to construct such a shape, the floor should slope towards the flushing end, with a longitudinal slope of 2-5%.
- The length of the gravel trap should be at least three times the width of the headrace canal, whichever is larger. With this fixed length and a velocity of 0.6 m/s the required width of the trap can now be determined. Note that this is a general rule of thumb, but if a significant bed load can enter the intake, then a longer length may be required. Since studies regarding the movement of gravel in rivers are rare (rare than sediment studies), it is usually difficult to estimate the storage required in a gravel trap. Note that the storage must be provided below the normal flow depth.
- To minimize blockage of the headrace or damage due to abrasion in the headrace, gravel traps should be located as close to the intake as possible.
- Detailed discussion on gravel trap, when and how to clean gravel trap, minor, major inspections etc.

SETTLING BASIN

Suspended sediment that is not settled in the gravel trap is trapped in the settling basin. The basic principle of settling is; the greater the basin surface area and lower the through velocity, the smaller the particles that can settle. A settling basin is assigned larger cross sectional area than the headrace canal and therefore the flow velocity is lower which allows the settling of the suspended materials. A settling basin must satisfy the following criteria:

SETTLING CAPACITY

The length and width of the basin must be large enough to allow large percentage of the fine sediment to fall out of suspension and be deposited on the bed. The sediment concentration passing the basin should be within acceptable limits. The geometry of the inlet, the width of the basin and any curvature must be such as to cause minimum turbulence, which might impair the efficiency.

STORAGE CAPACITY

The basin should be able to store the settled particles for some time unless it is designed for continuous flushing. Continuous flushing mechanisms are however not incorporated in micro hydro schemes due to the complexity of the design and the scarcity of water during the low flow season. Hence, the storage capacity must be sufficiently large so that the basin does not require frequent flushing.

FLUSHING CAPACITY

The basin should be able to be operated so as to remove the strew particles from it. This is done by opening gates or valves and flushing the sediment along with the incoming flow in the basin. The bed gradient must be steep enough to create velocities capable of removing all the sediment during flushing.

Figure 5. The setting basin of an MMHP

FOREBAY TANK

The forebay of a micro hydro scheme serves the following functions:

It allows for transition from open channel to pressure flow conditions. It regulates the flow into the penstock, particularly through the release of excess water into a spillway. It releases the surge pressure as the wave travels out of the penstock pipe. It can also serve as a secondary / final settling basin and trap some particles that enter the head race downstream of the settling basin. Structurally, the forebay tank is similar to settling basin except that the outlet transition is replaced by a trash rack and the entrance into the penstock pipe. The forebay allows for the transition from open channel to flow by providing adequate submergence for the penstock pipe. If the submergence head is not sufficient, the pipe will draw in air and be unable to convey the design flow.

Figure 6. A Fore bay tank of an MMHP

TRASH RACK

The trash rack at the forebay should be placed at 1:3 slop for efficient hydraulic performance and ease of cleaning (such as by racking). To minimize head loss and blockage, the recommended velocity through the trash rack is 0.6m/sec, but a maximum of 1 m/s could be used. It should also be noted that the trash rack bars should be placed vertically since horizontal bars are difficult to clean. The spacing between the trash rack bars should be about half the nozzle diameter for Pelton turbine and half the runner width for cross flow turbines. This prevents the turbine from being obstructed by debris and minimizes the chances of surge. Cleaning of the trash rack can be minimized by fixing it such that it is submerged during the design flow (then the design flow) will be constantly required.

Figure 7. A Trash Rack aerial view of a functional MHP

SPILL WAY

LOCATION OF SPILLWAYS

Spillways are required in headrace canals to spill excess flows during the high flood and incase of obstruction in the canal. Similarly, spillways are also required at the forebay to spill the entire design flow in case of sudden valve closure at the powerhouse. The excess flows that are discharged via a spillway should be safely diverted into the stream or nearby gully such that they do not cause any erosion or damage to other structures. Sometimes, this may require the construction of a channel to the natural watercourse. Locating spillways close to a gully will save the cost of channel construction.

Figure 8. Spill way of an operational MHPs

STANDARD DESIGN STEPS OF SPILL WAY ARE AS FOLLOWS

- Calculate the flow through the intake during high floods. The spillway should be sized such that the entire flood flow can be diverted away from the canal. This is because the micro hydro system could be closed during flood or there could be an obstruction in the canal.
- Choose a spillway profile and determine Cw. In our case a broad, round edge profile is suitable since it is easy to construct.
- Spillway crest level should be 0.05m above normal canal water level. No more than 50% of the freeboard should be used. Therefore, with the designed freeboard of 300mm, the available h overtop is (0.5 x 0.30) – 0.05 = 0.10 m. The required length can then be calculated for the chosen h overtop and flood flow.

POWER HOUSE

The main purpose of the powerhouse building is to protect electrical and mechanical equipment from unfavorable weather and lively creature. Allow only operator and authorized person inside the powerhouse. The following factors should be considered in the location and sizing of the powerhouse structure:

Figure 9. Power house of an operational MHPs

The power house should be safe from not only annual flood but also high flood events. Discussions should be held with the local community members to ensure that floodwaters have not reached the proposed powerhouse site around the past 40 years. It should also be possible to discharge the tail water safely from the powerhouse back to the stream. If possible the powerhouse should be located on level ground to minimize excavation work. If possible; the powerhouse should be located close to the community so that the transportation of the penstock and other equipment is feasible and economical. This will also reduce the transmission line cost. In case the community goes for productive use or public service of the plant, the accessibility and transportation of the goods needs feasibility study.

- Electric Controlling System must be installed inside the power house.
- The structure should be waterproof so that the equipment does not get damaged by rain water.
- Adequate space should be provided for reappearing around the turbine and alternator.
- Adequate lighting and ventilating should be provided.
- The machine foundation should be designed to take into account the short circuit torque.

TAILRACE

After passing through the turbine, the water returns to the river through a short canal called tailrace. The design should also ensure that during relatively high flows the water tailrace does not rise so far that it interferes with the turbine runner. With a reaction turbine the level of the water in the tailrace influences the operation of the turbine and more specifically the onset of cavitation. The level above the tailrace also determines the available net head and low head systems may have a decisive influence on the economic results.

HOW TO TURN ON AND TURN OFF MHP IN NORMAL CONDITION

Pre-operational Check points

Prior to the operation commencement, the following facilities and equipment must be checked by operators to ensure that they are in proper operating condition. Especially for long-term operation, it is of particular importance that the following are checked thoroughly.

- Transmission and distribution lines
- Line and pole damage
- Waterway facilities
- Structural damage
- Sand sedimentation in front of the intake
- Trash rack
- Sand sedimentation in the settling basin and the Forebay

- Turbine, generator, and controller

Start-up of operation is as follows

- Close the flushing gate of the intake weir
- Open the intake gate and intake water into the waterway system
- Open the inlet valve gradually
- If there is a guide vane, open the inlet valve fully, and then open the guide vane gradually
- Use a controller (e.g. ELC) if one exists. Confirm that voltage and frequency or rotating speed (RPM) increase up to the regulated value by guide vane (or inlet valve)
- Turn the load switch on (parallel in)
- Control the inlet valve or guide vane so that voltage and frequency are within the regulated range

Other necessary actions

- **Bearing lubricant condition:** Bearings are delicate parts that maintain stable operation of the units. Periodic application of grease is important for stable and long-term use of the bearings and main units. When lubrication of bearings is insufficient for operations, this means that the bearings have burned out and must be replaced.
- (A-3-2) Cooling water of dummy load for ELC Generator frequency output is controlled by the ELC. The ELC uses a dummy load (a resistance unit) to consume electric power over the necessary load supply at that time. If the dummy load is cooled by water, operators should confirm the water level of the dummy load before operation begins. (The typical cooling methods of dummy loads are water cooling and air cooling.)
- (A-3-3) Protection relays for emergency stop are not activated when a series of failures occurs in the units; protection relays (and automatic cut-off by circuit breakers) are activated for an emergency shutdown of the units. Once the failures are corrected, they can be manually reset by the operators. The excitation current of the AVR system increases the terminal voltage of the generator. When it reaches its approximate rated voltage (and frequency or rotation speed reaches its rated value), operators turn on the load switch (generator circuit breaker) to connect the generator to the transmission (distribution) lines.

Turn off MHP in normal condition

Stopping Operation steps

In order to avoid longer runaway speed of the turbine and the generator, the procedures for stopping operation are as follows:

- Close the inlet valve or the guide vane
- Cut load switch off (load rejection)
- Close the inlet valve and the guide vane completely
- Close the intake gate
- If the load is suddenly cut due to an accident, the operator must close the inlet valve or the guide vane immediately to avoid prolonged periods of the runaway speed of the turbine and the generator

HOW TO TURN OFF MHP IN EMERGENCY CONDITION

Steps prior to turn off the MHP in emergency

During emergency situation the following steps must be followed:

- First of all close the governor/guide van
- Close the main gate value or butterfly value
- Turn off main breaker in the control panel
- Disconnect the transformer links
- Open the spillway gate and shut down the forebay gate
- Close the intake gate if possible
- Use fire extinguisher/sand in fire situation
- Use safety glasses, safety gales, mask, safety shoes etc.
- Use alternate supply for lighting etc.

HOW TO RUN AN MHP SUCCESSFULLY

Steps for successful operation

Following are the stepwise approach for successful running of MHP:

- Control the inlet valve or guide vane so that voltage and frequency are within their regulated range
- Check for equipment and noise vibration, and stop operations if necessary
- Check the temperature of the equipment
- Check the equipment conditions. Stop operation and apply the appropriate(c-5).
- Record operation results and equipment condition

- Operators must always check the condition of facilities and equipment. If trouble is found or an accident occurs, they must inform the person in charge and try to solve the problem.
- Operators must try to prevent any accidents. Preventative measures such as equipment repair and the improvement of the facilities should be implemented as necessary.
- Note the readings of machine time to time
- Record keeping of bills and its follow up
- Patrolling on channel time to time

IMPORTANT PRECAUTIONARY MEASURES TO BE ADOPTED BY OPERATORS

The operators of MHP must maintain control over the equipment so that the supply of quality electricity may be realized in order to maintain equipment conditions and ensure safety factors as follows:

MHP Patrol and Role of Operators

Micro-hydropower plants must be operated and maintained in strict compliance with O&M (Operation and Maintenance). In general, operators of micro hydropower plants should understand the following items.

Role of Operators

- Operators must efficiently conduct O&M of micro hydropower plants in strict compliance with the rules and regulations
- Operators must familiarize themselves with all plant components and their respective performance/functions. Furthermore, they should also be familiar with prompt recovery emergency measures if an accident occur
- The role and features of this manual should be in mind before the start of MHP operation.

INTRODUCTION TO TOOLS AND ITS USAGE IN O&M OF AN MHP

Ampere Meter

An ammeter is a measuring instrument used to measure the current in a circuit. Electric currents are measured in amperes (A) from where the name ampere meter is derived. Instruments used to measure smaller currents, in the miliampere or microampere range, are designated as millimeters or micrometers.

Figure 10. Ampere Meter

Frequency Meter

Frequency meter is an instrument that displays the frequency of a periodic electrical signal. Various types of frequency meters are used. Many are instruments of the deflection type, ordinarily used for measuring low frequencies but capable of being used for frequencies as high as 900 Hz.

Figure 11. Frequency meter

Multi Meter

A multi-meter or a multicenter, also known as a VOM (volt-ohm **meter** or volt-ohm), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current, and resistance.

Figure 12. Multi Meter

Clamp Meter

A clamp meter is an electrical tester that combines a basic digital multimeter with a current sensor. Clamps measure current. Probes measure voltage.

TURBINE AND ITS PARTS

Following are the main parts of a turbine:

- Turbine Adapter
- Turbine Housing
- Guide vane Assembly
- Flanges
- Shaft
- Bearings
- Packing
- Lubrication
- Pressure gauge
- Inspection holes
- Foundation Frame

- Runner
- Oil seals

Figure 13. Brackets for Bearings

Figure 14. Runner of Turbine

TABLE 01. GENERAL MHPs PROBLEM, CAUSE, ASSESSMENT AND SOLUTION

Type of Damage	Causes	Identification/ Assessment	Repairs/Solution
Voltage collapses after releasing push button	Relay not holding	Check relay hold	Tighten connections if loose
	Relay may be faulty	Check relay	Replace if necessary
	Under/over-voltage setting not correct	Check voltage Setting	Adjust voltage as necessary
Sparking/over heating of connector	Loose connection	Check Connections	Tighten loose connections
	Under-size conductors (during repair work, incorrect size may have	Check wire size	Replace with appropriate size
High/low output Voltage	Over/under-voltage trip malfunctioning	Check settings of trip system	Reset the settings Test again Replace a faulty component
	Load variation	Check load through meters	Reduce load if higher on a given phase
	Fuses had blown	Check continuity of fuse by meter	Replace if necessary

ELC EQUIPED UNITS

For units equipped with ELC, the controls and instrument panel usually consist of the following equipment:

- Miniature circuit breaker (MCB) or Miniature coil circuit breaker (MCCB)
- Thyristor (ELC electronic switch)
- Induction gate bipolar transistor IGBT (IGC electronic switch)
- Heat sink (for mounting of thyristor or IGBT switch)
- Heat sink (for mounting of thyristor or IGBT)
- Current transformer (for measuring current)
- Ammeter (for measuring current)
- Voltmeter (for measuring output voltage)
- Frequency meter
- KW meter
- Ballast voltmeter (for ballast load indication)
- Electronic Load Controller or Induction Generator Controller Main Board
- Ballast fuse (to protect ELC, IGC and ballast heaters)

- Push button (voltage/frequency over-ride for startup) Ballast heater (dummy output load for generator control)
- Ballast tank (housing for ballast heaters and water.

TABLE 02. COMMON PROBLEMS AND RECOMMENDED REPAIRS FOR CONTROL PANELS EQUIPPEDWITH LOAD CONTROLLER

Type of Damage	Cause	Identification/Assessment	Repairs
High output voltage and frequency but zero ballast voltage	- Thyristor open circuited (damaged) - Ballast fuse blown (no connection to ballast)	- Check thyristor - Check fuse	- Replace if damaged - Replace with equivalent fuse if necessary
	Defective ballast heater - MCB in off position - No supply to ELC - Defective transformer	Inspect heaters - Check MCB - Check 220 V AC supply to transformer - Check that transformer output is 18-01- 18 V	Replace If necessary - Switch on MCB - Restore supply - If not send for repairs
Generator and ballast voltage rise together	Belt slipping - Generator overloaded - Thyristor short circuited, so that ballast load and consumer load are on generator, causing generator overload	- Check belt tension - Check consumers load - Check thyristors If ballast voltage rises with generator voltage during startup thyristor has short circuited	- Tighten if necessary - Reduce if necessary - Replace if necessary
Speed fluctuation (hunting)	Belt slipping - ELC stability requires adjustment - Incorrect function of AVR (new AVR only)	Check belt tension - Turn 'STAB POT' slowly to check ELC stability	Tighten If necessary - Replace belt(s) - Set proper stability -Take AVR to expert/technician for testing and repairs
Ballast readings unequal when consumer load is not switched ON	Defective meter - Ballast fuse may be blown - Loose ballast heater connection or faulty ballast heater	Check meter - Check ballast fuses - Check connections and ballast heaters	Replace if necessary - Replace if necessary - Replace as necessary
MCB or trip tripping	Load too high - Current limiting or tripping device may be defective, MCB/OVT - Incorrect voltage or frequency - Defective MCB	Check load - Check these devices - Check voltage and frequency meters	Reduce load to within rated limits - Repair or replace as necessary - Adjust potentiometer to correct voltage frequency - Repair or replace as

Connector or wire burnt or sparking	Loose connection - Short between connector terminals - Ventilation to ELC may blocked - Fans not working (if provided in ELC)	Check connections - Check for shorts - Check ventilation holes and screens - Check function of fan	- Tighten connections, - Change connector if damaged - Connections should be tightened periodically - Ensure air circulation during Operation. Clean filters and air inlets and remove obstacle to circulation - Repair/replace
Electric shock from ELC/ballast	Current leakage	Check voltage on metal casing and earth connection, live wire may be touching casing	-Check all live wires including heating elements and housings - Repair/replace as necessary
Indicators do not light	Bulb blown - No supply to indicator bulb - Short circuit	Check bulb - Check supply wires -If MCB/fuse/trip blow immediately after switch on, there may be a short circuit between phases or between phase and neutral	- Replace if necessary - Repair connections to restore supply - Locate short and rewire as necessary
High/low output voltage	Over/under-voltage trip malfunctioning - Load varying - Fuses blown	Check setting of the trip system - Check load through meters - Check fuses with multimeter	Reset settings - Test again - Locate & replace faulty component - Reduce load if high - Replace if damaged

A BRIEF ON TRANSMISSION LINE

LT line

Low voltage overhead lines may use either bare conductors carried on glass or ceramic insulators or an aerial bundled cable system. The number of conductors may be anywhere between four (three phase plus a combined earth/neutral conductor - a TN-C earthling system) up to as many as six (three phase conductors, separate neutral and earth plus street lighting supplied by a common switch).

HT Line

The term high voltage usually means electrical energy at voltages high enough to inflict harm on living organisms. Equipment and conductors that carry high voltage warrant particular safety requirements and procedures

Transformer

Transformer is an apparatus for increasing or decreasing the voltage of an alternating power. Electrical power transformer is a static device which transforms electrical energy from one circuit to another without any direct electrical connection and with the help of mutual induction between two windings. It transforms power from one circuit to another without changing its frequency but may be in different voltage level.

Step up Transformer

A transformer that increases voltage from primary to secondary (more secondary winding turns than primary winding turns) is called a step-up transformer. Conversely, a transformer designed to do just the opposite is called a step-down transformer.

Step down Transformer

A step down transformer has less turns on the secondary coil that the primary coils. The induced voltage across the secondary coil is less the applied voltage across the primary coil or in other words the voltage is “stepped-down”

Insulators

A substance which does not readily allow the passage of heat or sound “Cotton is a poor insulator" A substance or device which does not readily conduct electricity. A series of electrodes separated by insulators. A block of glass, ceramic, or other insulating material enclosing a wire carrying an electric current where it crosses a support.

TRANSMISSION LINE EQUIPMENT & ASSEMBLING

Transmission Lines

Usually, Aluminum Conductor Steel Reinforced (ACSR) is used for transmission and distribution lines. In some cases, armored cables can be used for overhead transmission line if located in a densely populated area or in a snowfall area. Armored cables are also used for underground transmission lines. Damage to the transmission cables as well as poles may be caused by high winds, landslides, over-tightening, breaking or sinking of poles. Sometimes, rains as well as lighting can also damage the cables, in addition to people or animals that may unwittingly shake the poles and make them loose. The conductors may break, sag space between two conductors may become less or they may even touch. Poles may become loose, fall down, sink or break and so on. In order to rejoin a broken wire, it usually becomes necessary to add an extra length because the original length of the wires would be just touching and an additional length is needed for overlapping and joining. In order to make a proper joint, all the strands of each end of the conductor must be opened by about 300 mm and each strand should be twisted once with another strand from the opposite wire and then wrapped around the joint

Joining two cable ends

Leaning poles can be straightened easily by pulling with wires in opposite directions. If the portion in the ground is not damaged or broken; then same poles can be re-erected and earth and stones be compacted well around the pole base so that they stay in position. If necessary, stay wires may also be attached to the poles to keep them in position. If a pole is broken or otherwise damaged; cracked for example, then it is a good practice to replace it. If the insulators on the poles are damaged or broken, they must be replaced.

Connecting wires at the pole with jumper

If the transmission wires pass through a slopping area and a pole has been fixed at a lowest point, then the wires may sometimes get disconnected from the pole and may be hanging in the air; or, the upper portion of a round metallic pole may come out or even the whole pole may be dislodged from the ground. This is actually a design problem; the pole should not have been placed at such a place during installation. However, if such damage happens then the best way to deal with it would be to erect two poles instead of one at little bit higher ground on both sides of the original location, and fixing them properly in the ground using stay wires or foundation bolts if necessary.

Typing wires to insulated stick to control unequal sag

Service lines and connections should be checked about once a year. The main points to be checked are the following,

- Connection between distribution line and service line is not loose or unauthorized
- Insulation of the service line is ok
- The meters or current limiting devices if installed in the houses are properly connected and not by passed
- The meters are calibrated
- The faulty devices are regularly replaced
- Distribution boxes containing connector switches or fuses are also provided where the distribution line branch to go into different streets
- These switches/fuses are checked and replaced if faulty

Lighting Arresters:

Mostly the MHPP's units are installed in the mountains with high rain fall. The thunder charge can damage the unit if it is not properly earthed. Therefore the Lighting arresters are installed to eliminate/reduce the potential hazard.

The lighting arresters includes copper horn, copper wire, and copper plate. The horn will be installed on rooftop of the MHP turbine building and will be connected to the plate through copper wire. The plate will be buried underground.

The earthling resistance of lightning arrestor should be checked to ensure that it is within limits; i.e. less than five ohm (Ω) between the earth plate and another point on the ground about 5m away. At the same time, connections between the buried plate and the wires connected to it. The wire should be checked and if found loose, rusted or damaged, they should be disconnected, surface cleaned with energy paper and rejoined by soldering or using bolts.

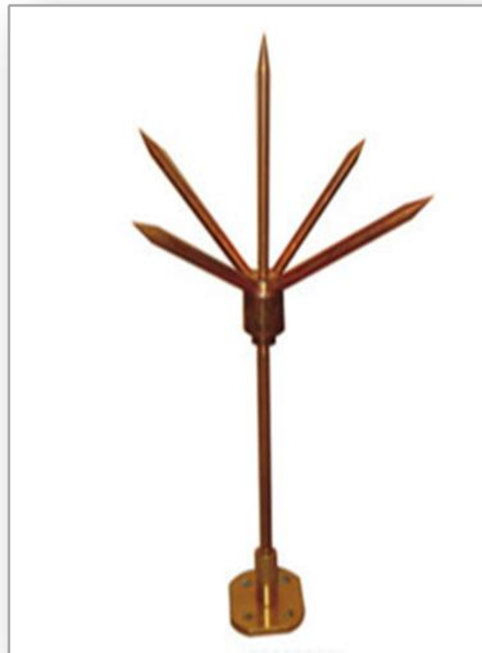

Figure 15. Lighting Arrester

The operator will be provided proper training on TLE in the manufacturing work shop along with skilled workers.

SAFETY PRECAUTIONS IN OPERATING MHP

All maintenance, retrofitting works must be according to regional and local regulations or other national or international applicable electrical standards.

- Use of PPE (Personal Protective Equipment) i.e. non-slip/Insulating gloves, clothes, Helmet, and Goggles with proper insulating equipment must be ensured during installation to prevent direct contact with 400V AC or greater, and to protect your hands against sharp edges.

- Do not allow children or unauthorized persons near the turbine and electric circuits or storage area of modules.
- Ensure availability of sand buckets with proper stand/rack at site. Ensure their proper inspection and stir the sand once a month for loosening the sand particles.

Safety Signs and warnings

Safety signboards as per site requirements will be installed with clear statements in both English and Urdu. Effective safety standard operation procedures (SOP's) must be in place and operators must be familiar with the safety procedures in order to prevent accidents or incidents.

Major safety requirements during MHP servicing include the proper use of PPEs and LOTO (lockout/tag out) procedures for safety. Ensure disconnection of all live circuits during maintenance/Inspection. Following are the MHP-specific system signage and signboards/warnings.

Figure 16. Signboards/Warnings

PPE and Other Safety Equipment

The operator will ensure proper utilization of PPEs during operation and maintenance of the MHP unit. The required PPEs includes arc flash protection, fire rated clothing, heat resistant gloves, Safety shoes, and protective eyewear. PPE is designed to help minimize exposure to inherent system hazards. All personnel working on or near MHP systems should be trained to recognize hazards and choose the suitable PPE to eliminate/reduce those hazards. The floor must be kept dry to avoid the slip/fall potential hazard.

As per OSHA standard requirement, the insulating/heat resistant gloves must be replaced at least once in six months or as per requirement. Proper inspection of the gloves must be carried out before using. Other hand tools required must be with proper Insulated layer for electric shock protection.

Figure 17. Safety Equipment

Safe Operation of Electrical System

System is designed for operation of 16Hrs a day. In case of abnormal situation such as following, a shutdown will be required:

- System failure
- Automatic control is damaged
- Maintenance works

A recommended safety protocol is to follow the left hand rule, which involves standing to the right side of the switch and using the left hand to switch off. This ensures that the worker's body is not in front of the switch if in case an arc flash occur.

Lockout/Tag out

Lockout/tag out (LOTO) procedures are designed to make sure safe working practices and must be strictly followed whenever system is de-energized before servicing.

Lockout/tag out steps includes:

- Notify/Communicate the shutdown reason
- Perform a controlled shutdown
- Verify that the equipment is completely de-energized by testing voltage with a voltmeter
- Lock out for the system switches properly and distribute the keys

Make sure that nobody else has access to the control room while working on the system. Place a note outside of the control room door informing that maintenance is in progress and do not Turn ON the water supply/switches etc. to the turbine.

Figure 18. LOTO Equipment

RECOMENDATIONS FOR FIRST AID FACILITIES AT MHP SITE

PEDO strongly recommends the following first aid facilities at each MHPS:

1. Trainings for the operators
2. Ensuring the provision of First Aid Facility (First Aid Kit) at each individual MHP

The consultants and contractor (Implementing partners) are strongly directed to ensure these facilities provided to the local community operators at each MHP.