Preface

Private or community owned and managed micro-hydropower (MHP) schemes are now accepted as viable and least-cost options for manual under-developed and inaccessible mountain areas of Hindu Kush-Himalayan (HKH) region; where local entrepreneurs and/or community people are likely to initiate, manage, operate and maintain such plants. The technology is simple and low cost and the implementers/surveyors, designers, manufacturers, installers, etc., are usually not fully qualified having expertise of desirable level in their respective fields. Therefore, institutional arrangements and properly designed and implemented inputs are needed for these groups of professionals (both implementers and operators/managers) in the form of training, manuals and guidelines, back-stopping, maintenance/repair facilities and know-how. Without such interventions the performance and viability of many such plants may not be optimal.

Keeping in view the above needs, ICIMOD has endeavored to develop and disseminate a series of five information manuals on; site survey and layout design, manufacture, -installation, management and operation and maintenance and repairs. The manuals have been prepared under a project titled "Capacity Building for Mini- and Micro-hydropower Development in the Selected countries of Hindu Kush-Himalayan Region, Phase 11". The project has been benevolently supported by the Norwegian Government like its predecessor the first phase; and is designed and implemented by ICIMOD in the HKH region of Pakistan, India and Nepal, in collaboration with suitable focal agencies in each country.

The current manual focuses on the installation, commissioning and handing over of such plants to the owner-,managers. Since the educational and technical qualifications of the installers of these plants are likely to be quite low, this manual has been kept simple and short. This approach inevitably leads to a dilemma as to what to cover and to what depth. Nevertheless, an attempt has been made to reach a correct trade off.

The original version of the manual was prepared by DCS-Technology Development Butwal, Nepal; which was extensively revised by me and two short-term consultants, Mr. Ajoy Karki and Mr. Girish Kharel of Kathmandu. The revision is based on recommendations of the Experts' Consultation organised by ICIMOD in February 1998 and also on some suggestions of other experts. DCS did a very good job in collecting the basic information and compiling it in one place; while the consultants rewrote some chapters to improve the contents and cover some additional topics. I myself as well as ICIMOD are grateful to DCS and the consultants for their contribution.

This manual is probably first of it's kind on the subject, While every effort is made to make it useful for the target group, ie; installers or supervisors of installation process; there is always some room for improvement. Therefore, comments are earnestly solicited in due course from experts, implementing agencies and users so that the next edition can be improved.

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ICIMOD, 9' November, 1998

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CHAPTER I

Introduction

Many areas in the Hindu Kush-Himalayan (HKH) region are least developed and inaccessible; and the inhabitants live under difficult conditions involving drudgery, deprivation and degradation of existing resources and environment. Energy, particularly useful forms of energy such as electricity, considered to be the crucial ingredient for development both social as well as economic, is in short supply. To develop such areas, appropriate energy resources and systems, along with improved access would be crucial. Because of difficulties associated with transportation, it is preferable to develop and use local resources of energy which can be initiated and managed/operated by the locals themselves.

Power/energy of flowing or falling water, which is usually available in most remote and under-developed mountain areas, in the micro-hydropower (MHP) range of 0.2 to about 100 kW, can meet the local needs amicably and cheaply; provided appropriate inputs and methodologies are adopted and implemented. Experience in many developing countries has clearly exhibited the viability of this renewable and environment-friendly resource for such areas. However, it has also been learned that properly designed and implemented inputs such as training, manuals on various aspects and back-stopping are vital for the success of such programmes. Another important prerequisite is involvement, infect lead role by the communities/beneficiaries in the whole process of planning, fund raising and decision making; survey; installation and management and operation. Without this complete involvement of the beneficiaries, the chances of success of the plant in the long run are not bright.

1.1 About this Manual

After extensive studies consultations and analysis of the current situation in the HKH region, ICIMOD decided to develop five manuals listed below and three training programmes mainly for the implementing professionals involved in such private MHP schemes at the grassroots level. These manuals mainly cover the following aspects of private/community owned MHP plants in the remote areas.

- Site Survey and Layout Design and Manufacture
- Installation
- Management and Operation
- Repair & Maintenance

This manual is part of the above series and covers all aspects of installation starting from packing and transportation of the equipment to the site, to commissioning and handing over the plant to the owner-manager(s). The intended target group is the private sector installers who may have some experience of installation but by using the current manual they should be able to improve the installation process and deal with the problems and other aspects in a better way. It is expected that such an installer is at least capable of reading and understanding this manual; however, he should preferably have some technical qualification; say, certificate or diploma in a relevant engineering trade.

Obviously, it is impossible to cover all the aspects for all types of different sites and equipment. However, an effort has been made to cover most installation aspects for the micro-sized plants especially up to 50 kW capacity. Some plants may also have agro processing or other equipment within the powerhouse. However, installation of such an equipment has not been covered in this manual since it is a separate subject. Also, instructions are usually provided with such equipment with regard to installation and commissioning.

It is hoped that the information provided in this manual would assist in improving the capabilities of the installers, without having to undergo extensive training; although, there is no doubt that actual and proper training would further enhance their capacities.

In addition to packing and transporting the equipment safely to the site, there are three main components of installation process; ie., civil construction including weir, intake, canal, forebay, powerhouse and tailrace; electromechanical installation of turbine, generator, valve(s) and penstock; and installation of transmission lines. Thus, this manual mainly covers these components and their testing and commissioning.

CHAPTER 2

Planning & Preparations for Installation

Considerable planning and preparations have to be made, information gathered and equipment identified which is to be taken to the site. Most probably, this would not be the first visit of the installers to the site. At least one or more of the team members should have travelled to the site and the main village before, where the team has to stay. Contacts with the local lead persons should also exist. Therefore, travelling to the site should not pose a problem. However, the route for transporting the equipment may be somewhat different than for the personnel; some equipment may have to be airlifted and then manually transported, for example. Also, the time of travel and transportation of equipment has to be given due thought and suitable choices made. Obviously, a rainy season, harvesting time, festival time or very cold/hot season would not be suitable for working at the site. It may also take between two weeks to six months to complete the installation; depending upon the size of the plant, site remoteness, and whether it is an easy or a difficult scheme.

Briefly, the installation process would include the following.

- Packing and transporting equipment and materials to the site and storing it there.
- Finalisation of the sites for weir, intake, power canal and its sub-components (eg., desilting basins, spillways, crossings, etc), forebay, penstock and powerhouse; already demarcated during the surveys.
- Measurement and minor adjustment of locations of some components such as the base of turbine. forebay or intake mouth.
- Construction of all components of civil works including foundations for the turbine, generator, agro-processing equipment, etc; and construct-Ion of support piers, anchor blocks, etc.
- Installation of the penstock pipe and accessories.
- Installation of turbine, generator, agro-processing units (if provided)*' and coupling/drive systems.

- Installation of transmission and distribution wiring systems.
- Testing & commissioning (starting, testing, measuring output, removing defects). Training the managers and operators.
- Handing over the plant and certification.

Sometimes, most of the civil works would have been completed before the arrival of equipment at the site. In other cases, however, it may be convenient to complete the civil works as well as installation of the electromechanical equipment and transmission system simultaneously and in a prescribed sequence.

If for some reason the installation work has to be discontinued, adequate planning would be necessary to prevent damage to the installed/constructed components and to the remaining equipment and materials to be stored, including the cement; which can be easily spoiled due to rain/water or humidity. Similarly, newly constructed civil works such as earthen canal may have to be protected from damage during the monsoon rains or other mishaps.

Usually, two or three persons may travel to the site who collectively possess the requisite expertise. However, all may not stay there all the time. The main expertise needed would be in the field of:

- Site assessment and survey (to assess geophysical features, changes since last survey and some measurements of distances, etc.);
- Civil construction;
- Installation of electromechanical equipment including penstock;
- Laying transmission lines;
- Commissioning and testing.

Information should also be collected and verified regarding availability and costs of skilled and unskilled labour, constriction materials, etc. In addition, locations of a nearest but adequate workshop (say, having welding facilities or other tools), health care centre and communications facilities should also be identified in advance, if possible.

2.1 Tools and Other Materials for the Site

A comprehensive list of tools and instruments to be carried to the site, which may be needed during the installation must be prepared, preferably in the form of a checklist. The list should also include materials to be transported (an indicative check list is given in Annex. 2. 1).

Additionally, all the drawings of the parts/components and their installation instructions must also be carried to the site; for, weir, intake, canal, forebay, penstock route, powerhouse, the mechanical components (eg., trash racks, expansion joints, etc.), plus specifications and construction details for various foundations. The decisions regarding construction materials as to what needs to be carried and what could be acquired a+ the site should also be made in advance (eg., doors and windows, corrugated iron sheets, wooden beams, steel bars, etc.). Some such material can be easily provided or acquired by the communities. In fact, completion of most of the civil works can be and should be the responsibility of the beneficiary communities or the entrepreneur.

It is usual that some land/length measurements may also have to be carried out again; eg., more exact measurement of the length of the penstock. Or, sometimes, adjustment of the penstock length by a few centimeters becomes necessary; for which the base of the turbine or the forebay may have to be raised/lowered; and this can only be done by measuring the length. Similarly, some survey tools such as Abney or Dumpy level would be needed to mark and construct the power canal, intake and the weir.

CHAPTER 3

Transportation of Equipment to Site

Actual transportation of the equipment is usually not the responsibility of the installers. However, they may, sometimes, be called upon to advise. Transportation of the equipment to the site also includes its proper packing and planning the transportation as well as storage at the site till it is properly installed. Packing is an important endeavour to; protect the equipment from weather elements, avoid pilferage/loss/damage during transportation/storage and to make it easy tc) carry. In most instances, the equipment may have to be carried manually, for a few meter distance or quite a few kilometres (eg., in Nepal, it may be a few day's walk). Therefore, the packages have to be of appropriate size and weight. An experienced and trained porter can carry upto 60 kg for long hauls on a mountainous trail; while a horse or mule can carry upto 80 kg. But this would also depend on how difficult or dangerous the trail is (eg., steepness and its width, slipperyness, etc.). Many components (eg. penstock pipe sections) need not be wrapped while in other cases (eg. generator) they have to be wrapped in Polythene sheets or similar material to protect them from rain water. Some smaller items would have to be packed together while others (eg. turbine) may have to be disassembled and packed; otherwise, it may be too heavy to carry manually. The penstock or other long items of more than 3 meter lengths, may also be difficult to carry. All these aspects should be given due consideration while. planning the packaging and transportation. Parts of some items, which have to be assembled latter, may have to be marked so that they are correctly reassembled.

Packing larger units such as a generator & turbine in wooden cartons is usually expensive and inconvenient to carry. However, smaller and delicate items such as electrical instruments, ELC, switches, insulators for transmission, may be packed in card board or wooden cartons, using adequate anti-impact material such as foam and rain protecting material such as plastic sheets. In some countries such as Nepal, the traditional method of carrying a heavy load is on the back; whereas in Pakistan for example, people carry the packages on their head. Therefore, the following maximum dimensions of the package are suggested for each of these methods.

Carrying method	Permissible Dimensions (cm)		
	Length	**Width**	**Height**
On the back	50	50	120
On head	50	50	40

Obviously, packages having more weight and size can be carried on the back if skilled/experienced porters can be found. Sometimes, heavier items can also be carried by two or more persons by fastening them to a wooden pole of appropriate thickness and carrying it on the shoulders. In this way, more heavier loads (upto 100 kg) can be carried by two people. Table 2.1 below, gives the sizes and weights which can be carried by a single person or other transport systems.

Table 2.1 Permissible Weights for Transportation of Goods

Mode of Transport	Carrying Capacity	Remarks
Man	60-80 kg	On back
Horse	60 kg	30 kg each side
Mule	40-60 kg	30 kg each side
Truck	8-10 ton	Up to 5 ton units if crane available for loading
Helicopter	0.5-4	Depends on type
Plane	2-10 ton for hilly areas	Depends on type

3.1 Storage at the Site

Usually, it is necessary for equipment and other materials (eg. cement), which has been transported to the site to be stored there for sometime. For this purpose, an appropriate location has to be found. Some items must be stored indoors under lock and key, while other heavier equipment can be kept outside but properly covered. Items, such as penstock pipe lengths (flanged or unflanged) can be stored outside but preferably covered with waterproof sheets. If possible and safe, the heavier equipment may actually be stored at the site (eg., penstock, turbine, generator, trash racks); while other lighter, more delicate and expensive items should be stored at another place in-doors (eg. ELC/control panel, transmission wires, insulators, etc.) in a house, school, etc. Special attention should be paid to the storage of cement since it can go hard in a few days due to excessive humidity even. Therefore, it should be wrapped properly in plastic sheets during transportation and in-door storage. Other factors to be considered for selecting a storage site and storing the equipment/materials, are the following.

- Adequate space is available both out-doors and in-doors.
- The place is as near to the actual site of installation as possible; to avoid extra expenditure and probability of damage due to repackaging and transportation.
- There is no possibility of pilferage and/or damage by trespassers, rain, snow, animals, falling rocks, landslides, etc.

CHAPTER 4

Civil Construction

4.1 Site Inspection and Preparation

Based on the detailed design, the locations of various MHP structures should be verified and then clearly marked at the site. This includes placing centre line pegs along the headrace and penstock routes and along the boundary of other structures such as the settling basins, forebay, anchor blocks and the powerhouse.

At this stage the layout design should be well finalised and additional changes should be unwarranted. However, a final survey should be carried out to verify that there have been no changes in the site since the design phase to necessitate relocation of structures. The layout should only be changed if there are major geological changes such as landslides along the headrace or penstock routes.

The site preparation should include clearing the route from the intake to the tailrace. Shrubs and other vegetation should be uprooted if they can obstruct the construction work. Similarly, if some structures are located along cultivated fields, such fields should be left barren prior to commencing the construction work. It should be noted that a larger area will be required during the construction phase than the actual area that various MHP structures will eventually occupy. This is because adequate space would be needed for labourers to work freely, for storing construction materials such as stones and sand and for dumping excavated soil.

4.2 Construction Sequence

The construction of the scheme should be started from the most critical location; i.e., where a slight misalignment or improper orientation may result in significant expenditure for remedial measures. Usually the machine foundation in the powerhouse is the most critical location. This is because once the machine foundation anchor bolts are set in concrete, the turbine and the generator locations cannot be readjusted. Therefore, first the machine foundation should be constructed. Then work should commence on the installation of the penstock pipe from the machine foundation to the forebay. Except for their final 300 mm height, support piers can be constructed as the penstock installation work progresses upstream including expansion joints at given locations as per design. The final height should be adjusted once the entire pipe length has been installed which has been supported by temporary stonework, wooden planks, or other similar materials, in order to achieve proper alignment of penstock pipe and avoid bending stresses while reaching the end point in the forebay. The anchor blocks should also be completed after the entire penstock pipe length has been installed. This is because once anchor blocks are constructed, the penstock pipe cannot be readjusted.

The forebay is usually located on an elevated terrace (flat area) at a steep slope above the penstock. Sometimes excavation on the location is required to provide sufficient area for the forebay. Thus, some adjustment is usually possible of the penstock pipe length; if the actual length of the penstock and the distance at the location do not match. Hence, the forebay should be constructed after the penstock pipe reaches this structure.

Once the machine foundation, penstock and the forebay have been constructed, the logical sequence is to continue the construction work upstream until the location of the intake is reached. If the construction work is commenced in this sequence, there will be less chances of misalignment or errors ;.n the elevation of the structures. However, if the survey work has been accurate enough and staff at site are well experienced, some construction work can also commence concurrently. For example, different portions of the headrace canal and the settling basins can be constructed concurrently. However, it should be noted that in this approach if the elevations of the headrace canal do not match and the downstream section is higher, remedial measures will be costly.

Construction work at the intake and specially the diversion weir should normally start when all other structures are completed. This is because the flow can not be diverted for power generation until all other structures are completed. Furthermore, there can be additional risks from floods if the work at the intake and weir is completed prior to the onset of monsoon but other structures are still incomplete. Some retaining work along the intake bank can still be carried out concurrently with other structures, provided that the MHP scheme can be commissioned prior to the onset of monsoon rains.

4.3 Machine Foundation, Powerhouse and Tailrace

4.3.1 Construction of Machine Foundation

The machine foundation should be constructed as follows.

- Demarcate the floor area of the powerhouse and the location of the machine foundation as per the design.
- Excavate the machine foundation pit (as per design) until the required depth is reached and compact the floor using a manual ram. If the pit base is not a rock, then a 250 mm stone soling should be provided above it.
- Excavate the tailrace section inside the powerhouse before commencing the machine foundation concrete work. This prevents any misalignment between the machine foundation and the tailrace. Note that if the tailrace is excavated at a later stage there needs to be a gap of about a week after the construction of the machine foundation for the concrete to cure. Also once the machine foundation and the tailrace section in the powerhouse are completed, work on the powerhouse walls and roof can commence. Due to confined space, it may not be feasible to construct the powerhouse structure, machine foundation and the tailrace section concurrently.
- Place formwork at the periphery of the excavation and arrange the reinforcement and anchor bars for the base frame as specified in the design. Tile threaded ends of the anchor bars should be greased and then covered with clean pieces of cloth or plastic sheets so that they are not damaged while pouring concrete. Sometimes, the base frame can also be welded to the reinforcement bars and cast into the foundation.
- Once the formwork and reinforcement of the machine foundation have been placed, prepare the concrete mix at the required ratio (usually 1:1.5:3) and then pour it up to the generator/turbine base frame level. Concreting work is discussed further in the next section.
- Manually compact/vibrate the poured concrete using long steel rods. Once the required level is reached, place the base frame for the machines on the concrete so that it fits snugly over the anchor bars (holes in the base frame are in line with the anchor bars). Then tighten the anchor bolts. The base frame level should be constantly checked (using a

"spirit level") while tightening the bolts. Note that the level of the base frame can be adjusted only while the concrete is still wet.

- Protect the newly poured concrete structure from direct sun and rain for at least 24 hours.
- 24 hours after the construction of the machine foundation, curing should start by keeping it moist for at least a week. This is usually done by gently pouring water on the concrete structure. An uncured concrete structure will not gain full strength. During hot and dry weather poring water on the concrete structures may be required twice a day (mornings and afternoons) to ensure that they gain full strength.
- Remove the formworks from the machine foundation only seven days after completion of construction. Note that if wood is expensive, dry stone walls can also be used for the formwork. Also unlike wooden formwork, such dry stone walls need not be removed. A typical machine foundation pit with the reinforcement bars is shown below in Figure 4.1

4.3.2 Preparation of Concrete

The quality of cement, sand and aggregates for concrete work should be as follows.

- Cement used for concrete and masonry work should be fresh and preferably less than six months from the date of manufacture. Cement that has been stored over a long period losses strength significantly.
- The sand quality for concrete work should be granular, clean and free from organic materials and soils. Sand mixed with soil and other organic material should be thoroughly washed before use to remove such and other water soluble materials.
- The aggregates required for concrete work should either be collected from quarries, river beds, or prepared by crushing stones. Aggregates need to be hard, angular and non porous.
- Concrete should never be mixed directly on the ground. This should be done on a clean and water tight platform (such as tightly paved stone surface), or some other adequate surface.

The process of mixing concrete is as follows

- Mix dry cement and sand thoroughly till a uniform colour is visible.

- Add the required volume of coarse aggregates on top of the cement-sand pile and mix the entire mass again so that the aggregates are uniformly distributed.
- Finally, gently pour the required amount of water on the dry concrete and turn the mix thoroughly. Ensure that water does not seep away from the mix. Excess water weakens the concrete, produces shrinkage cracks and decreases the density. Therefore, a water cement ratio of 0.5 (25 liters of water per 50 kg of cement) should be used for manually mixed concrete.
- Also note that, the concrete mix should be poured on the structure within a few hours after its preparation. Concrete stored over-night looses significant strength and should not be used at all.

Fig. 4.2 illustrates the correct and wrong methods of pouring concrete or masonry on structures. Cancrete should not be prepared in separate lumps or poured from high above the under construction structure.

4.3.3 Powerhouse Construction

As discussed in the layout design manual, a powerhouse structure should be similar to other local houses in the area, since it would be much easier to construct. The construction of the powerhouse structure is as follows.

- Demarcate the plan of the powerhouse at the proposed site as specified in the design. Then mark the excavation lines for the constriction of the foundation and the walls. This is done by placing pegs at the inside and outside wall edges of the powerhouse. These pegs should then be joined with powdered lime, ashes or thin ropes. Note that to optimize the space in the powerhouse, the length or width should be at right angles to the final length of the penstock pipe.
- Excavate along the lines prepared above for the wall foundation to the desired level (usually 1 in) and compact the ground using a manual ram.
- Construct the three walls of the powerhouse. Generally the back wall involving the penstock should be constructed after the penstock installation is completed so that there is no interference between these activities. Furthermore, it will also be easy to bring in electromechanical equipment such as the turbine and the generator from this open space.

Usually a 450 mm thick stone masonry in mud mortar is used to construct walls of local houses. During the construction phase the walls should often be checked with a plumb to ensure that they are vertical. Doors and windows should be placed at appropriate locations.

- Construct the back wall after the turbine and the generator have been fixed on the machine foundation and the installation of penstock has been completed .
- Once the powerhouse walls have reached the desired height (about 2.5 m), place the wooden trusses and roof as per design; e.g., with corrugated galvanized iron (CGI) sheets.
- Use only seasoned wood for doors, windows and trusses.

4.4 Civil Works for Penstock

4.4.1 Penstock Pipe Installation

The civil works for penstock involves installing the pipe and constructing the support piers and anchor blocks as specified in the design layout. Both of these must be located on original firm soil and not on backfill.' The procedure is as follows

- Clear all vegetation along the penstock route and mark the centre line by fixing a tight string. Also mark excavation lines for the support piers and anchor blocks.
- Fix the turbine along with the manifold and gate/valve (if provided) to the machine foundation.
- Start the installation of the penstock from the machine foundation by connecting the first link of penstock (usually a bend) to the turbine manifold and proceed upstream, which is usually more convenient method. This avoids any misalignment between the penstock and the turbine housing. Since the turbine needs to be firmly fixed to the machine foundation, there is almost no tolerance at this end after the machine foundation has been constructed. Furthermore, the pipe sections below the expansion joints can slide down if installation proceeds downstream from the forebay. Also as discussed earlier, minor pipe deviation can be adjusted at the forebay wall. -however, such adjustment is not feasible at the machine foundation.
- Install the expansion joints at the required locations as specified in the design layout (i.e., downstream of the forebay and anchor block locations). Tightly pack jute (or similar

fibre) inside the expansion joint during the installation process to prevent leakage during the operational phase.

- As the pipe installation work progresses upstream, construct the support piers at the required locations.. However, it is recommended that the last 150 mm to 300 mm height of the pier be constructed only after the entire penstock pipe has been installed. This allows for some adjustment of the pipe till the end. During the installation process, temporary dry stone walls can be used on top of the unfinished support piers.

The construction of the support piers first involves excavating the ground to the required shape as per the drawings. Once the required foundation depth is reached (usually 300 mm at the downstream face and depth varies according to the slope at the upstream face' the earth should be compacted using a manual ram. Then the piers should be constructed in stone masonry in 1:6 cement mortar as discussed below:

4.4.2 Cement Masonry Work

For stone masonry in cement mortar, the following is recommended.

- Stones should be washed and kept immersed in water for a day prior to construction. Dry stones do not adhere well on cement mortar and therefore the masonry will have less strength.
- The ratio of the mortar should not be less than 1:6 cement/sand for the construction of support piers.
- Use good quality sand and cement as described in sections 4.3.1 and 4.3.2. Also follow other relevant instructions in these sections regarding pouring time, protection from sunlight and curing.

4.4.3 Anchor Blocks

As described earlier also, anchor blocks should only be completed once the penstock pipe installation work is completed. The following procedure should be used to construct the anchor blocks.

- Similar to the support pier, first excavate the around as per the design. Once the required foundation depth is reached, compact the earth using a manual ram. Note that the excavation and compaction work should be done as the pipe installation proceeds..
- Prepare the concrete (usually 1:3:6 with 40% plums) by mixing cement, sand aggregates and water at the required ratio as discussed earlier and place the specified size and number of reinforcement bars (usually 3 bars of 10 nun diameter) as shown in Fig. 4.3.. The prepared concrete should be poured at the proposed anchor block location and the plums should be placed evenly around the block. Either wooden planks or dry stone walls can be used for the formwork depending on the availability of wood at site. Once the concrete work has been completed, the blocks should be cured for about a week. It is recommended that a final check be done on the penstock pipes and the expansion joints to ensure that there are no errors before pouring concrete.

4.5 Forebay

Generally the forebay should be constructed after the installation of the penstock is completed including the civil works. The construction of the forebay involves the following.

- At the proposed location, mark the excavation lines for this structure according to the design as discussed earlier.
- Excavate the ground to the required depth and shape. Note that it is important to check the floor elevation after excavation but before construction. If errors are found on the elevation after construction work has commenced (and the forebay is higher than the headrace canal upstream), remedial work can be expensive.
- Compact the earth surface using a manual ram after completion of the excavation work.
- Then construct the structure as per the design. The forebay and other water retaining structures are usually built using stone masonry in 1:4 cement mortar.
- Construction of cement masonry structure was covered earlier.
- I f possible the inside faces (water retaining surfaces) should have dressed stones which minimizes the thickness of the plaster. Note that once the cement mortar has been prepared it should be used within 2-3 hours.
- As the masonry work condenses, install the gates, flush pipes and spillways at the given locations as per the design.

- After completion of the gates and masonry work, plaster the water retaining surface (i.e. inside surface) of the forebay. About 12 mm thick 1:2 cement mortar is recommended for the plaster.
- Once the construction of the forebay is completed it should be cured as described earlier. If there is a delay between the, masonry work and the plaster then the structure should be cured for another 4 days after completion of plaster.

4.6 Headrace Canal

Once the, canal type (or types for different lengths) has been selected and the sizes worked out, the actual construction procedure involves the following stages.

- Setting out of the course of the canal and marking the centre line with pegs
- Preparing the bench for the canal,
- Fixing the excavation lines,
- Excavating the canal,
- Constructing/lining the canal.

4.6.1 Setting Out the Canal

Before setting out the canal, the availability of the equipment and staff need to be ensured. The same equipment that was used for the detailed survey work such as an Abney level or a theodolite and a tape is usually sufficient for the construction and setting the specified slope of the canal bed. A transparent water tube can also be useful in checking the levels of the canal bed at various locations as the construction progresses.

The setting out of the canal is done as follows

- First place pegs along the headrace canal route**.** Depending on the topography, such pegs should generally be driven at 5m to 20 in intervals along the route. Pegs should be placed more closely at bends as well as at other important locations such as drops, beginning and end of crossings, etc.
- Place some intermediate pegs or reference pegs just outside the canal path using a leveling instrument. With the use of this instrument, the differences in elevation between these pegs can be calculated. Such pegs will serve as reference levels for the

excavation work. An alternative to this is to paint marks at exposed rocks just outside the canal path and calculate their relative elevations.

4.6.2 Preparation of the Bench

The bench of a canal is a strip of land of uniform and width and slope. It is like a road of generally constant width and slope at the level of top of the canal. The bench should be prepared as follows.

- Excavate a strip of land of even width along the pegs placed earlier on the canal route.
- If there is a possibility of materials being washed down by rain from the slope above or small land slips being deposited directly in the canal, increase the width of the bench such that it is larger than the finished canal top width. This extra width is called the berm; which stops debris or water coining down the hillside and from entering the canal. Such excess water should be channelised away from the canal through a proper drainage system. If it is not possible or practical to drain all the excess flow away, it may be allowed to enter the canal at a predetermined and properly constructed location such as near a spillway. The berm can also be used as a walkway for people or for workers during construction. Generally, a berm width of 300 mm to 500 mm is sufficient along the uphill side for people to walk and for construction work.
- The slope of the bench should be the same as Line slope of the canal section. Therefore, where there is a change in the canal slope (in the design) the bench slope should also change accordingly. The bed slope of the bench should be verified using a leveling instrument. The elevation of the canal at different locations can be calculated using the intermediate pegs that were placed outside the canal path earlier.

Once the initial elevation at the intake is fixed, the subsequent elevations for the canal route can be calculated based on the distances and bed slopes. The initial elevation can be estimated based on the contour maps of the area or by using an altimeter. Another method is to carry the trigonometric 'points established by the survey department but this may require more time and resources.

The absolute elevation figures need not be very accurate (i.e. the exact elevation from the sea level) but the differences between intermediate pegs should be accurate, since it is these differences that determine the slope of the canal.

An example of an elevation calculation is presented below.

The designer has recommended a slope of 2.0% for a certain canal section. The topographical map of the area indicates that the elevation at the intake is around 1400 m above mean sea level (AMSL).

In this case the first peg that is placed at the intake area can be assumed to be at a level of 1400 m AMSL. If the second peg is to be placed 20 m (horizontal length) downstream, the bench elevation here should be; 20 in x 2.0/100 = 0.40 m down from the intake or 1400 in - 0.40 m = 1399.6 in AMSL.

The subsequent readings between intermediate pegs (i.e. reference points) can be noted in sequence with similar calculations.

4.6.3 Fixing the Excavation Lines

Once the canal bench has been prepared, the excavation lines need to be set out as follows.

- Place pegs along the centerline and the top and bottom widths of the canal (for trapezoidal sections). Note that in case of lined canal, the top and bottom widths should include the side wall thickness as well (i.e., outside edges of the finished canal).
- Join the pegs using thin ropes. Then mark separate lines for the centre line and top and bottom widths (for trapezoidal sections) using powdered lime or ashes so that they are indicated on the ground. Note that for rectangular sections, top and bottom width are equal and three parallel lines are sufficient for the excavation work.

Check the dimensions against the design specifications continuously during this process.

4.6.4 Excavation of the Canal

This consists of excavating the canal having the required shape and slope according to the design as described below..

- ♦ For rectangular canal, start the excavation from the sides down to the required depth.
- ♦ For trapezoidal sections, start the excavation at the central part without exceeding the bottom width lines vertically down to the required depth. Then excavate the sloppy sides without exceeding the top width and meeting the bottom width at the required depth. Thus, the required trapezoidal shape can be arrived at. This method of excavation minimises the use of construction materials and the need to backfill. Also, note that side walls of a trapezoidal cement masonry canal are more likely to crack if constructed on backfill. It is also helpful to prepare a wooden frame matching the cross sectional shape of the canal to check it continuously as the excavation progresses. This involves constructing a wooden frame of the required trapezoidal shape using rectangular sticks.
- ♦ Check the canal bed slope frequently using a leveling instrument. Note that an inaccurate slope can be very costly. If the slope is less than required, the canal will not have the capacity to convey the design flow. Similarly, if the slope is steeper than required,. the velocity. may exceed the maximum value for the canal type and start eroding it.

4.6.5 Construction of the Canal Lining

Once the excavation work has been completed, the construction of the lining of the canal can commence if provided for in the design. If an earthen canal has been chosen, all that is required is to trim the side walls and bottom width at some places where the excavation work has been poor. However, if a masonry lined canal has been chosen, then this will require collecting stones, dressing/sizing them and then placing them at the excavated surface according to the design.

For stone masonry in cement mortar canals, the following is recommended.

- The minimum thickness for bed and side walls should be 150 mm since thinner walls require more stone work of the lining (dressing & sizing) and may not have the required strength. This also applies to stone masonry in mud mortar canals.
- Since this is a water retaining structure, the ratio of the mortar should not be less than 1:4 cement/sand.
- Use 1:2 cement sand mortar for plaster work in the headrace canal. The thickness of .the plaster should be about 12 mm (- 1/2 inch). Plastering is expensive and therefore it should only be applied where really necessary; such as to prevent leakage.
- Other instructions suggested in Sections 4.3. 1 and 4.3.2 for this type of construction should also be followed.

4.7 Settling Basins and Spillways

The construction of the settling basin is similar to that of the forebay. Since the function of the settling basin is to remove the sediment from the flow, more than one of these structures may be required if the headrace canal is long (say more than 300 m) and unlined. The flow in a long unlined canal can erode the bed and side walls and increase the sediment load which then needs to be removed.

General ,y at least two spillways are required for a MHP scheme. The first one should be located immediately after the intake to divert excess flow during the floods. If there are any chances of the headrace canal being blocked by landslides from above, intermediate spillways should be provided along the canal route. One spillway should always be incorporated at the forebay to divert the design flow in case of valve closure at the powerhouse (such as during emergencies). A spillway may also be required at the settling basin if there is a possibility of excess flow reaching this structure during the floods.

Spillways are constructed as part of other structures such as settling basin or the forebay; or, they may be independent structures just for spilling the (excess) flow. They are simply openings (with or without a gate) at the top wall sections of these structures that divert any excess flows.

The construction of the settling basin is sunarized below.

- At the proposed settling basin location, demarcate the excavation lines for this structure according to the design and then excavate the ground.
- Compact the earth surface using a manual ram after completion of the excavation work.
- Then construct the structure as per the design. The settling basin is usually built using stone masonry in 1:4 cement mortar. Construction of cement masonry structure was covered earlier.
- If possible the inside faces (water retaining surfaces) should have dressed stones which minimizes the thickness of the plaster.
- As the masonry work commences, install the gates, flush pipes and spillways at the required location.
- After completion of the gates and masonry work, plaster the water retaining surface using 12 mm thick 1:2 cement- mortar.
- Once the construction of the settling basin is completed, the channel that diverts the flows from the spillway should also be constructed if required.
- Follow other instructions provided in Sections 4.3.1 and 4.3.2 for similar construction.

4.8 Intake Works

At the intake, construction of the flood protection walls and the mouth should commence first according to the detailed drawings. Such work may require diverting the flow towards the opposite river bank. The weir should be constructed only when all other work at the intake is completed. Depending on the design flow and the nature of the weir (temporary or permanent) this too may require temporarily diverting the river flow towards the opposite bank. The construction work is easier when the water level in the river is low and the water temperature is also not too low.

4.9 Retaining Structures and Stabilization

Small potential landslide prone slopes can be stabilized by dry stone walls, masonry walls or gabions. Gabions are usually most suitable and economical for stabilizing slopes on MHP projects. The construction of gabions requires a skilled person who is able to weave the boxes using GI wires. Gabion boxes can be made in different sizes depending on the requirement.

The following wire sizes are recommended for gabion works for MHP.

Mesh size	:	80 mm x 100 mm
Mesh wire	:	9 SWG (3.66 nun)
Selvedge wire	:	6 SWG (4.88 mm)
Binding wire	:	11 SWG (2.95 mm)

The assembled gabion box should be tightly packed with stones. Preferably, dressed stones should be used on the outside surfaces of the gabions. Once the boxes are filled, the cover should be closed and tied using the selvedge wire. Note that gabions should be placed in such a way that the lengths are parallel to the flow.

Table 4.1 along with Fig. 4.4 can be used as a guideline for selecting the width of the gabion wall for the height of soil that it needs to retain.

Table 4.1 Gabion Sections for Retaining Walls

Wall height required, H (m)	**Width, W (m)**
1	1
2	1.5
3	1.5
4	2
5	2
6	2.5

Terracing and plantation are also suitable methods for stabilizing small areas prone to landslides on hillsides at MHP sites. As can be seen in Fig. 4.5, this involves constructing terraces on the landslide area having overall slope of less than 30". The dry stone walls should be used for the vertical face of the terraces as shown in Fig. 4.5. Such dry stone walls retain the soil behind and allow the surface water to drain out.

Terraces also help to reduce the surface erosion since the surface water can be diverted by constructing small. drains. Note that dry slopes are more stable than saturated ones and landslides generally occur on wet slopes.

Planting grass or shrubs that have deep root systems (such as bamboo or Napier grass) on terraces also contribute towards the stability of slopes. However, note that fast growing trees that do not have intense root systems should be avoided since they may fall due to their own weight during storms.

CHAPTER 5

Installing Electro-mechanical Equipment

5.1 Machine Foundations

Depending on the design, separate machine foundations may be constructed for each machine or one foundation platform may be sufficient for all the machines. For smaller electricity generation units a single foundation block is usually built for both the turbine and generator, which are fitted on to a single baseframe. The baseframe is then fitted to the anchor bolts cast in the foundation block.

For MHPs with milling machinery, it is cheaper to have separate foundations for each machine since the machines are more spread out and having a single foundation block for all of them would not be practical. Construction of foundations for the machinery has been described in Chapter 4.

5.2 Machinery Installation

Once the concrete has fully cured the machines should be fitted to the baseframe on the foundation block. The installed machines should be level and be checked by using a spirit level on the machine shaft. If the machine is not level then place shims under the footplates to raise the appropriate part of the baseframe or the machine until it is level.

5.3 Alignment

The power from the turbine is transmitted to the generator or other machinery by direct coupling or belt drives (Figs. 5.1 & 5.2). Before the machines are run, the pulleys (for belt drive) and the shafts (for direct coupling), must be aligned properly.

Incorrect alignment will lead to loss of power, belt slippage, vibration, and reduced life of bearings. In extreme cases, the shaft could also break due to excessive metal fatigue.

5.3.1 Direct drive

For direct drive systems the shafts of the turbine and generator (or other machines) should have minimum positional or angular misalignment (Fig. 5.3).

To adjust the alignment some generators are provided with adjusting screws which can be used to reposition the generator until the required level of alignment is reached.

For the initial alignment a straight edge placed on one of the shafts can be used to check the alignment (Fig. 5.4). Any gaps between the two shafts will indicate how the shafts are misaligned and the machine can be moved in the appropriate direction to achieve alignment.

Adjustments in height are made by adding or removing shims between the generator feet and the baseframe. While some angular or horizontal misalignment can be removed by repositioning one or both machines; it **is** usually not possible to remove all the misalignment. Therefore, quality flexible couplings should be used to accommodate some residual misalignment. Nevertheless, every effort should be made to minimise it.

5.3.2 Belt drives

For belt drives the alignment is simpler, since only angular misalignment needs to be rectified; i.e, the two shafts should be parallel. The alignment is checked by stretching a thin string also the edges of the turbine and generator pulleys as shown in Fig 5.5.

The machines are moved in the appropriate directions until both the pulleys are in line.

5.4 Installation Procedure for Penstock

Penstock installation is usually carried out from the powerhouse to the forebay. After the turbine has been installed, the adaptor nozzle/manifold is assembled. Then the valve (if fitted) is attached. The valve, since it is heavy, will need to be supported. Subsequently, the first piece of penstock (usually a bend) is attached to the valve while firmly supporting them both.

The first anchor block is normally built just outside the powerhouse wall enclosing the first piece (the bend). Sections of penstock pipe are then connected one after the other up to the forebay (Fig. 5.6).

There is usually some discrepancy between the initial measurements and the actual length of the penstock; depending on how accurately the initial measurements were made.

Adjustments in the penstock length are made by, casting the bends or penstock pipes in the concrete of the anchor blocks as the penstock is being laid. If the bends or pipe sections to be embedded are cast in before the penstock pipe is laid; then it becomes difficult to make any adjustments (Refer to Chapter 4).

The penstock lengths are joined together at the flanges until the location of the second anchor block is reached. The section or bend to be embedded is then attached to the penstock while providing temporary supports. In this way, the whole penstock may be joined to reach the location of the entry into forebay, while being propped up by temporary supports. Then the support piers and anchor blocks should be completed (Chapt 4).

The forebay may be constructed after the penstock has been laid and the supports completed. This will make it possible to shift its position in order to accommodate any small differences in penstock length or alignment.

Steel penstock lengths are joined together by bolting the flanges on the lengths. A flat rubber gasket, at least 5 mm thick, or an 0-ring gasket is used to make the joint leakproof. In some rare cases penstock lengths may also be welded together if adequate equipment and qualified

welders are available at the site.

5.4.1 HDPE Penstocks

HDPE penstocks are joined together by butt welding the pipe ends. A hot plate is Used to melt the ends and join them together. The following is a step by step procedure for joining HDPE penstock lengths.

- The ends of the pipes are cut at right angles with a hacksaw and smoothed and levelled using a flat file. When the two ends are placed face to face the gap at any point should not be greater than one millimeter. If the gap is larger the ends must be smoothed until the gaps are reduced.
- The hot plate is heated to about 220 C. To determine if the correct temperature has been achieved a white thermo-chrom crayon is used. When the hot plate is marked with the crayon the mark should turn brown in about 5 seconds. If it takes longer, the plate is not hot enough. If it is too hot it will turn brown more quickly.
- The hot plate is then slipped into a Teflon envelope (the Teflon envelop prevents the HDPE from sticking to the plate). The plate is held between the pipe ends which are firmly pressed against it (Fig. 5.7). When the pipe is properly heated there will be a lip of molten plastic around the perimeter of the pipe ends. This lip should be of the same size all around the pipe.
- The pipe ends are removed from the heating plate and then joined together. While joining the contact must be even and the alignment perpendicular. Once the melted ends touch each other they must not be separated and realigned. The pipe ends are pressed firmly but not excessively (Fig. 5.8). It should then, be laid on level ground without causing any stress to the joints for about 15 minutes. If necessary some supporting packings should be laid .0
- 10.underneath the pipe at appropriate locations to maintain alignment and reduce stresses.
- The joint is tested by flexing it. It is also examined visually to ensure that there are no cracks or discontinuities. A proper joint is as strong as the rest of the pipe and cannot be cracked or broken apart. After joining a convenient length of pipe it is lowered into the trench and carefully joined with the pipe already in the trench.

5.4.2 Butted Penstocks

For buried penstocks it is not necessary to build support piers. Additional anchor blocks after the first block are usually not needed since the weight of the backfill is sufficient to restrain the penstock.

The penstock route is finalised and marked out using pegs driven into the ground and the penstock trench dug. The penstock trench must be even, without any protruding stones. **The** bottom should be filled with a layer of sand or fine soil around 100 mm deep. The penstock.,- is then laid along the trench. It is then tested. Then the trench is backfilled as shown in Fig 5.9.

HDPE pipes should also be buried since ultraviolet rays from surflight speed up its deterioration and thus decrease its useful life.

5.4.3 Fixing Penstock in Support Piers and Anchor Blocks

Construct' the support pier masonry until it reaches the level of the penstock. The base plate and anchor bolts should be cast into concrete or plastered into the top of the support pier. At least 1/3 of the pipe diameter should submerge in the support pier. To prevent damage to the pipe a bitumen sheet is placed between the penstock pipe and the metallic base plate fixed to the support pier.

Anchor blocks are normally made of concrete unlike the support piers which are normally built of stone masonry. The concrete should be poured in the form after the bend or other part of penstock has been properly positioned. The centre of the bend should be at the centre of the anchor block. Check that the correct bend is used and that the alignment is correct. The bend should have steel rods of 12 mm diameter welded to it in order to improve bonding to the concrete.

5.4.4 Installing Expansion Joints

An expansion joint is designed to take up the expansion of the penstock caused by variations in temperature. A typical expansion joint is shown in Fig. 5.11. Expansion joints are usually placed just below anchor blocks. Normally, one expansion joint is provided between two anchor blocks.

While installing an expansion joint, its temperature at the time must be taken into consideration so that a minimum gap is maintained when the pipe expands fully due to highest possible temperature rise and a maximum gap is not exceeded when the pipe contracts fully (Fig. 5.12). Note that the temperature of the penstock may be higher or lower than the ambient temperature, e.g. when the sun is shining directly on the penstock. Therefore, the gap (G) at the time of allation of expansion joint should correspond to the penstock temperature and its extent of expansion.

For example' if the expansion joint is installed at a time when the ambient temperature is the highest expected then it must be assembled in the fully expanded position. This will allow the pipe to contract when the weather gets colder.

For temperatures in between, the position of the pipe should be set in proportion to its deviation from the minimum or maximum temperatures. For example, if the surface temperature is halfway between the maximum and minimum temperatures then the joint should also be set in mid position. The following example explains the procedure further.

Example

Consider a site where the maximum temperature reaches 35 degrees and the minimum is minus 10 degrees Celsius. At installation time the pipe surface temperature is 15 degrees. The maximum expansion that the joint can accommodate is 50 mm. A minimum gap of 10 mm must be maintained under all conditions. Length of the pipe between two anchor blocks is 40 in.

Since the pipe temperature at present is 15 degrees the gap (G) set between the two pipe ends must be such that it maintains allowable G_{max} and G_{min} at lowest and highest temperatures (Fig.5.12). This value of G is determined as shown below.

$$G_{min} = 10 \text{ mm}$$

$$G_{max} = 10 + (35 - (-10)) \times C \times L$$

$$= 10 + 45 \times 12 \times 10^{-6} \times 40 \times 1000$$

= 10 + 21600 x 10^{-3}

= 10 + 21.6 = 31.6 mm where C is coefficient of expansion for mild steel

= 19.6 mm where Ta is ambient temperature of penstock.

Therefore, the gap between the pipe ends should be about 20 mm when the expansion joint -is being installed.

5.4.4.1 Positioning the Pipe in the Expansion Joint

The procedures for setting the expansion joints while installing it are different for a bolted type design and a welded type design.

Bolted type design

Since the distance between the flange of expansion joint and the pipe end is small; the gap is accessible and can be measured easily (Fig. 5.13). After the correct gap has been set by moving the pipes axially, the packing is placed and the stay ring tightened. The next length of penstock pipe is then bolted on to the expansion joint.

Welded type design

In a welded design the setting is more difficult because the gap is not accessible and it cannot be measured directly. As shown in Fig. 5.14 the gap "G" is the difference between the ends of lengths "A" and "B". The pipe is marked at the required length before fitting the stay ring. The expansion joint flange is then positioned over the i-nark and the stay ring tightened.

5.4.4.2 Installing the Packing

Ensure that the place where the packing will be placed is clean and greased or oiled. Squeeze one end of the packing rope into the gap between the inner and outer sleeves. Mark this point so that the number of turns of packing can be counted. The packing should be pushed firmly with a suitably sized piece of wood until it reaches the retaining ring. Continue placing the first round of packing firmly against the retaining ring. Repeat until about five turns have been completed and then cut it. Place the stay ring against the packing and tighten the bolts.

5.5 Controls and Instrumentation

If an Electronic Load Controller (ELC) is fitted the controls and instrumentations are an integral part of the ELC panel. All the meters should be adjusted to zero. All connections should be checked to ensure that they are tight and correctly done. The ballast load should be 20 % more than the maximum output of the generator and its resistance should be checked to ensure that it is functioning properly and that there are no short circuits.

CHAPTER 6

Installation of Transmission Lines

6.1 Steps before Installing Transmission Lines

It is usually necessary to resurvey the transmission route and plan for difficult features and obstructions, eg., landslide zone, gulley crossings, trees, ground clearance, cultivated land, etc. The following should be the main consideration while finalising the routes.

- Choose short & straight route.
- Calculate the required number of poles, for the given length and use pegs for marking the location of pole pit.
- If the wooden poles are proposed in design then select hard wood straight poles.
- The depth of pole length should be about one meter underground and bitumen paint should be applied to the buried portion to prevent rotting.
- The poles should have sizes indicated in Table 6.1 below.

Table 6.1 Sizes of Wooden Poles

Wooden Pole	**Single Phase 220V**	**Three Phase**	**11 kV**
Height of pole	6 m	7 m	8 m
Diameter of pole	125 mm	150 nun	175 mm
Ground clearance	4.5 m	5 m	6.3 m
Spacing of poles			
- For transmission	30 - 35 m	30 - 35 m	50 m
- For distribution	25 m	25 m	

6.2 Installation Procedure

Clear the path of transmission route.

- Dig holes in the ground and fix accessories (D-iron clamp, insulator, etc.) on selected wooden pole. The distance between the insulators is shown in Fig. 6. 1.

- Insert the pole base in the pit; ensuring that after erection the pole should be in line with other poles and vertical; check verticality with plum bob.
- Fill up the pit with earth & stones and compact well.
- Install stay wires on the poles at every bend, first and last pole and on the pole having a jumper (Fig. 6.3)
- Start to unroll wire and lift the end up to the pole carefully; the wire should not be over lapped during pulling (Fig. 6.4)

Generally pulling of wire can be started from the powerhouse; but if it is in a valley and the route is up hill (vertical slope); then pulling may be started from up hill to the powerhouse.

- Lines are generally pulled using portable and manual wire puller machines having a capacity of 2 tons.
- While pulling wires, make them tight enough so that they do not sag heavily or swing and touch another wire. The space between the wires should be uniform. Normally, that should be about 0.5 m per 50 m pole spacing.
- At the same time, sag of wire should be observed visually from some distance (about 50 meters); the extent of sag should be the same between all poles (Fig 6.5). The sag in the cable can be measured by level instrument but it is not possible in all cases.
- Excessive tension on the conductor should be avoided which may cause it to break.
- During installation of transmission lines, the ends of two wires may be connected using the following procedure (see also Fig. 6.6).

    - Open all strains of both ends of the conductors.
    - Bring two ends together, overlapping by at least 300 mm and twist each strain with another from the opposing conductor.
    - Wrap the remaining length of strands around the joint and pass the last position underneath another strand to give the joint a smooth, tight and unbreakable finish.

- During installation of transmission lines, safety belts should be used and necessary information regarding the safety aspects should be provided to the installers.
- After completing erection of transmission lines all routes should be checked, for ground clearance, road clearance, compaction of pole pits, stay wires, etc. Anticlimbing devices and 'Danger' boards should be installed on each pole.

6.3 Installation of Distribution and Service Lines

Distribution lines bring power from the transmission line to service wires supplying the consumers. The installation procedure for distribution lines is similar as for transmission lines. If these lines are to pass through a village, appropriate ground clearance, and distance from the houses should be provided and stay wires installed wherever necessary.

The service line brings electrical power from distribution line to the premises of individual consumers. It can be pulled by hand from pole to each house. Normally flat twin sheathed solid aluminium conductors are used, so excessive tension in the wire should be avoided. The wire should be fixed to the pole and connected to the distribution line by wrapping around it three four times. It may also be tied to the pole to avoid excessive stress at the joint.

6.4 Earthing

Earthing is the process of providing path to excessive electricity and voltage caused by short circuit or lightning to earth and preventing damage to equipment and personnel. It may be classified into the following two systems.

System earthing means connecting the neutral points of generators and transformers to the mass of earth. Equipment earthing mean s connecting the outer casing or supporting structure of all live electrical equipment to the general mass of earth.

Earth connections should be provided at the following points.

- Neutral of the all power systems such as generators, transformers, etc.
- Earth terminals of each lightning arrestor.
- The frame of generator, motor, ELC, ballast, transformer, control/instrument panel, etc.

- All metal casings or coverings containing or protecting any electric supply or apparatus
- The armouring of underground cable.
- The metallic poles and towers of overhead lines.

The system and equipment earthing should be made separated by minimum distance of ten meters.

A good earthing should have very low resistance; it should thus be made in an area, where the earth is normally moist; for example, near a canal. Salt and coal are used to further reduce earth resistance.

6.4.1 Earth electrodes

A plate or pipe of copper or GI driven into the ground and connected to an electrical system or equipment is called the earth electrode. 'The number and type of earth electrodes required per installation depend upon the factors such as: type of soil, the type and capacity of the installation or equipment, the value of the required earth resistance, etc. Roughly, following sizes of earth electrodes are recommended for MHP installations.

Table 6.2 Recommended Sizes of Earth Electrodes

Conductor Type (To be buried vertically)	Size (mm)
Copper plate	600 long x 600 wide x 3.15 thick
GI plate	900 long x 900 wide x 3.15 thick
GI pipe	38 dia. X 2500 long

It is recommended to use copper wire for copper electrodes and GI wire for GI electrodes having the 8 SWG size (4.06 mm diameter).

Pipe Electrodes

Pipe electrodes should not be smaller than 38-mm internal diameter if made of galvanised iron or steel and 10 mm. internal diameter if made of cast iron. A general arrangement is shown in Fig. 6.7.

The rod and pipe -electrodes should not be less than 2.50 m in length and driven in the ground fully. Where rock is encountered at a depth of less than 2.50 m, the electrodes may be buried inclined to the vertical having same length and inclination should not be more than 30 degrees with the vertical.

Pipes or rods should be one piece. If it is necessary to reduce the depth of burial of an electrode, this must be done without increasing the resistance. This is achieved by using a number of rods or pipes and connecting them together in parallel. The distance between two electrodes in such cases should preferably be not less than twice the length of the electrode.

The earth wire should now be joined at the top of the pipe by drilling a hole in the pipe and the earth wire should be tightened there with a brass nut and bolt. Before doing so, the copper earth wire should be scraped in order to make good contact between the wire and the pipe.

Plate Electrodes

Plate electrodes may be made of galvanised iron or steel having the minimum sizes as shown in Table 6.2. Plate electrodes should be buried such that the top edge is at a depth of not less than 1.50 m. below the surface of the ground.

When resistance of one plate electrode is higher than the required value, two or more plates should be used in parallel, the two plates being separated from each other by not less than eight meters.

The plates should preferably be set vertically. Plate electrodes should be used only when the current carrying capacity is the main consideration, as for example in the power house.

The earth wire should now be joined at the top of the plate by drilling a hole there and the earth wire should be tightened there with a brass nut and bolt. Before doing so, the copper earth wire should be properly scraped (Fig. 6.8).

6.5 Lightning Arrestors

During storms, high voltage of lightning can come in contact with transmission and distribution lines, which would transmit across the coils of generator and its body, causing a short circuit and damage. Therefore, earthing needs to be provided for this high voltage to discharge before - it gets to generator, via a lightning arrestor, which is connected between phase and earth. In case of three-phase transmission, separate arrestor is needed for each phase and earth as shown in Fig 6.9. For low-tension transmission 0.5 kV lightning arrestor will do the job but higher voltage rating is required for high-tension transmission.

The lightning arrestor should be installed as close to generator as possible, usually at the first pole outside the powerhouse. If the transmission line is more than a kilometer long, one lightning arrestor should be installed for every kilometer.

Installation Procedure

- ♦ Check whether the lightening arrestor is as per the specification.
- ♦ Mount a frame on the pole and fix lightening arrestor on it (Fig. 6.9). If more than one lightning arrestors are to be used, the distance between two arrestors should be at least 100 mm.

CHAPTER 7

Commissioning and Testing

Commissioning and testing of a MHP provides a system for checking that all the components of the MHP are functioning properly as per the design and/or specified by the supplier. The commissioning and testing procedure also provides a record of the operational status of the plant at startup which is a useful reference for the future. More practically, some problems may be encountered when the plant is operated for the first time. These problems, whether in the civil works or in the electromechanical equipment, must be removed completely, before the plant is put into normal operation.

7.1 Commissioning Procedure

The commissioning procedure should begin ONLY after all the installation work has been completed and checked. The commissioning report must have a list of all the items to be checked or tested. Alongside the items, their condition and whether this condition is satisfactory or whether it needs to be rectified, must be mentioned. Likewise, with the test results, the data obtained, calculation of results (eg., efficiency) must be noted along with whether or riot this meets the specifications.

7.1.1 Cleaning the Penstork

During penstock installation some debris would inevitably have been dropped into the penstock while it was being assembled. This debris must be removed before running the turbine otherwise the turbine will be damaged.

The penstock valve should be closed and the penstock partly filled with water in order to flush the debris to the bottom from where it can easily be removed. The debris -will collect behind the valve.

The water should then be drained by opening the valve or turbine vane just enough to allow the water to drain very slowly. After the water has drained out the debris can be removed in the following ways.

- ♦ If a gate valve is installed; by removing the top half which houses the spindle and gate.
- ♦ By removing the valve (in case of butterfly valve) and/or turbine adaptor.
- ♦ By removing the turbine cover.

7.1.2 Checks Before Starting

Before starting the plant the whole system from the weir and intake to the end of the transmission line must be inspected to ensure that there is no damage or possibility of breakup, especially in the canal. The following must be checked and/or carried out to ensure as follows.

Intake

- ♦ Intake and trashrack are clean.
- ♦ The intake gate operates properly.

Canal

- ♦ The canal is cleared of stones and dirt.
- ♦ There are no cracks or drainage to the canal. Repair cracks or damage if any.

Desilting

- ♦ The flushing valve opens and closes properly.
- ♦ Desilting basin is cleared of all debris.

Gates/stoplogs

- ♦ They operate properly.

Penstock Supports/anchors

- ♦ All nuts on the penstock straps are tightened properly.
- ♦ There is no damage to supports/anchor blocks and the base of the anchor blocks/supports have not been eroded. Repair as required.
- ♦ The drainage arrangements around the anchor blocks/ supports are not blocked or damaged. Repair as required.

Penstock

- All bolts are tightened properly.
- The penstock has not sagged at any point. Reconstruct the affected support piers if required.
- The paint work is intact. Repair as necessary.

Turbine

- Turbine is well mounted and in good condition.
- Corrosion protection and painting are ok.
- The ball bearings are well lubricated.
- The shaft is turning smoothly, there is no noise or vibration.
- Turbine-alternator alignment is ok.
- All the nuts & bolts are properly tightened.

Power transmission

- Coupling is aligned properly, no loose bolts
- Belt is aligned and tightened to correct tension

Alternator

- Alternator is well mounted and in good condition.
- Corrosion protection and painting is ok.
- The ball bearings are well lubricated.
- The shaft is turning smoothly, there is no noise or vibration.
- Turbine-alternator alignment is ok.
- No loose or untightened bolts.
- The ventilation system is not blocked.
- The stator windings to terminal are properly connected.
- All cabling is ok. and fixed well
- Name plate has correct information.
- Insulation resistance is ok.
- Continuity of each grounding circuit throughout the system is ok.

Control Panels

- Panels are properly fixed, doors and locks function properly.
- Painting is ok.
- Earthing is done properly, screws and terminals are tight.

- All cabling, connections, terminals and wiring are ok. and there are no loose connections.
- General cabling layout is ok and there is no damage.
- Labels are well fixed, have correct expression and are readable.
- Wiring diagrams are available.

Transmission/distribution

- Resistance of all earthing systems is within limits (usually less than 50) There is no excessive sag of any section.
- The ground clearance of all transmission lines is satisfactory. The lightning protection system is in place.
- The connections to the transformer are properly tightened.
- The transmission line is clear of trees and branches. Cut off any branches or trees that are too close (within 2 meters of the transmission line).
- All service wires are properly connected.
- All poles are undamaged, vertical and fixed properly. All inflators are undamaged.
- All connections to the insulators are properly made.

  All joints and splices in the transmission are properly made.

After all the checks have been completed, and are considered to be satisfactory, the waterways should be filled slowly with water to test all overflow systems and for slippage or leakage. All gates, stoplogs, flushing valves must be operated in this situation to ensure that they function in their normal operating condition. Check to see whether the penstock leaks.

This test should be carried out for a period of at least 24 hours while the canal remains full and some flow is spilling from the forebay. During this time the system must be monitored to check for any leakages of water from the car-al and the forebay. It must also be checked to see that no damage has been caused by the overflowing water.

7.2 Commissioning and Performance Tests

After all the above tests have been carried out the system is ready for commissioning.

Open the main valve or turbine valve SLOWLY to start rotating the turbine. The turbine is allowed to run at a low speed, with the generator connected, while ensuring that there are no unusual sounds, vibrations or behaviour.

If any unusal sound or odd behaviour is noticed then shut down immediately. The problem(s) should be investigated, identified and rectified before the tests are resumed (eg., misalignment, loose nuts/bolts, leakages, etc.).

Increase the turbine speed gradually until normal operating speed is attained. Allow the turbine to operate at this speed, with the generator excitation ON and with no load or a very small load, for about two hours. During this time, constantly monitor the equipment particularly for excessive temperature rises in the bearings and alternator windings.

Increase the load on the machines in steps of 20 per cent until maximum output is reached. At every load step the system must be allowed to reach a steady state (ie. theme are no fluctuations and flow as well as output is constant) and normal running condition before readings are taken.

While the machines are running, continue monitoring for unusual sounds, vibrations and odd behaviour.

7.2.1 Performance Test

After- operating the machines at different loads as described above, a performance test should be carried out by taking the readings of the machines and the outputs at different loads. Following are recommended to be measured and recorded.

Flow (if possible), pressure at the penstock outlet, turbine speed, bearing temperature, alternator temperature at different points, alternator voltage and current on all phases, exciter voltage and current and voltage drop across transmission line lengths on each phase.

The different readings should be taken at steps of 20% increase of the rated power output of the plant. In cases where an ELC is installed the power output may be increased by increasing the water flow. The ELC automatically switches on the ballast to maintain the correct speed. The tests can be continued using the ballast load but it is advisable to use an external load as it will provide visible evidence to the customer that the required output has been produced. For example in a 10 kW plant, 10 one kW heaters could be used; and for plants of 1-2 kW, 10-20 IOOW bulbs could be used.

A sample format of the test results is given in Annex. 5. *1*.

7.3 Rectifying Faults

During the commissioning -tests it is possible that, for various reasons, some problems are encountered in the functioning of the plant, or, some faults are detected. The severity of the problem must be decided and action taken as one of the following.

7.3.1 Serious Problems

Stop further commissioning work until the problem is fully rectified. Such problems are broadly of two types.

Safety related. Any conditions which, if not rectified and the equipment is operated, could lead to injury, loss of life, or serious damage to the infrastructure and equipment of the plant.

Examples:

- Inadequately built spillway which could cause erosion to anchor blocks/supports or to land.
- Transmission wires that can be touched by a person while standing on the ground.
- Any situation that causes electrical cables to overheat.

Operational These are cases which prevent the full output of the plant from being produced and have an adverse effect on the plant life in the long term, if it is continued to be operated.

Examples:

- Blocked or restricted canal which prevents the required flow

- Rapid and high rise in temperature of bearings or generator windings
- Excessive vibration
- Resonance speed that is close to the operating speed

7.3.2 Ordinary Problems

These are the problems that can be rectified straight away or later and will not hinder the commissioning work which can continue.

Examples:

- Minor leakages of water from the canal or a pipe joint.
- Minor misalignment which can be adjusted.
- Repainting surfaces where the paint has been damaged.

After any rectification work of a component, it must be tested before proceeding with the commissioning.

7.4 Endurance Test

After the performance tests have been completed the equipment should be run continuously for a period of at least 24 hours at full load to find out if the machines are able to give Continuous and trouble-free service. During this test the machinery should be continuously monitored for the following.

- ♦ Excessive vibration and noise.
- ♦ Overheating of mechanical and electrical components.
- ♦ Loss of output.
- ♦ Deviations in frequency, voltage, current.

If any of the above Problems occur then the cause of the problem must be found and rectified before further tests are done or before the commissioning and handover is done.

After completing the endurance test successfully, the plant is almost ready to be handed over to the owner-manager(s). However, it would be advisable that the owner-manager and operators continue operation of the plant for an additional 2-3 days under supervision of the installers. The plant should be started, stopped, load(s) applied/removed and flow varied, while continuously monitoring the output, instruments and overall behaviour (noise, temperature, vibration, leakage). This would lead to more confidence about the performance of the equipment and the plant operators would also have received some on-the-job training.

CHAPTER 8

Training Managers & Operators

It is necessary that the manager and operators for an upcoming plant be selected/appointed by the community/entrepreneur before the process of installation begins; so that these two or three persons participate in the installation process fully. This would increase their knowledge about the names, shapes, characteristics and functions of various parts of the electromechanical equipment in particular. They should be taught through actual practice instructions and explanations, the assembly and disassembly of various components (eg., bearing housing to check/replace a bearint4). They should also be informed/trained as to what would happen if a unit was not handled or operated properly; or what are the signs of a inflammation. The testing and commissioning phase is especially very important since the installers would be starting and operating the plant repeatedly looking for the faults or problems and removing them. Tile manager and operator must be fully involved and instructed to carry out some operations themselves (eg., starting/stopping, disassembling a component, carrying out an alignment check). Infact, some such operations may be repeated for the sole purpose of training these workers during the testing and commissioning phase since it is probably the best opportunity. Therefore, this training should be given due priority even if it may mean prolonging the process of testing and commissioning. Adequate training of the managers and operators should also be one of the clauses in the handing over certificate to be signed by the owner/community leader taking over the possession of the plant.

The following main features should be covered through this training

- Starting and stopping procedures including what to do if something goes wrong.
- Applying and removing the load (all aspects of operation).
- Identification and names of various components, their functions, operational characteristics, etc.
- Familiarity with most sections of operations and maintenance manual.
- Maintenance of all parts.
- Basic fault diagnosis and repairs.

- Cleanliness & safety.
- Basic book-keeping.

The operator is almost like a bus driver. Even a minor carelessness on his part may result in a serious breakdown and/or bodily harm. Therefore, the importance and conduct of this training should be taken seriously by the all concerned.

CHAPTER 9

Handing Over the Plant

The final step in the installation process is the handing over of the plant to the owners or the manager & community representatives. The installers must demonstrate to the recipients that the installation as been completed satisfactorily in accordance with the specifications provided; that the plant was producing the rated power and working satisfactorily in all respects land that it was likely to perform satisfactorily in all respects in future also. In addition, both installer and the recipient must sign and keep copies of some formal documents with regard to the satisfactory performance, handing over and the guarantees for future.

9.1 Completion Certificate

The completion certificate is usually needed by the installer to get his funds released from some other funding agency such as a bank; whereas the guarantee(s) from the manufacturers and the installers are needed more by the owner-recipient; so that he can oet services and parts to be replaced if something goes wrong during the guarantee period. These two types of documents must be written in clear and precise language to avoid any ambiguity. An indicative proforma shown in Annex. 9.1 may be used for the final certification. The manufacturer/installer must also provide all drawings, catalogues, figures, sketches, maps, a copy of feasibility study and a well-prepared and useful operation and maintenance manual to the owners.

9.2 Guarantees

Two or more guarantees may have to be provided by the manufactures, installers and suppliers of equipment, depending upon where the equipment has been acquired and by who.

The manufacturers), for example, would have to provide guarantees for a prescribed period (eg., one year), that the equipment would be repaired free of charge including replacement of parts if the machine or a part/unit fails within this period; except if the failure is caused by improper or careless use ' of the equipment by the operators. Usually, the guarantee is also provided for the -arts/components obtained from the market or from other manufacturers such as penstock pipes, bearings, bearing housing, couplings, belts, etc.

Similar guarantees should also be provided about the civil works (if constructed by a contractor/installer) and about the transmission and distribution lines.

A sample guarantee document is shown below which may be modified, rewritten or Unproved to accommodate all the relevant components or units. This guarantee is meant for the turbine, generator and coupling system; but other items can also be added.

Guarantee

The following equipment supplied/manufactured by ………………. is hereby guaranteed by the undersigned for a period of 12 months; if it breaks down or fails to perform satisfactorily to produce the rated output. The supplier/manufacturer hereby undertakes to repair such parts and replace the faulty parts, so that its performance gives the rated outputs. This guarantee, however, would be void if the failure of a component was caused by improper handling/operation, carelessness or an accident.

(1) …………… (type) turbine …………… kW capacity, …………… mm dia. rotor, …………… bearings manufactured by …………… (Country). Shaft diameter …………… mm, bearing housing …………… (type, make, country).

(2) Generator …………… (type), …………… phase …………… (rpm) with brushes/brushless, with/without AVR …………… (manufacturer name and country), capacity …………… kVA, ……………

(3) 2 Pulleys …………… mm dia & …………… mm dia; …………… mm shaft dia. and …………… mm dia., …………… (material); having …………… grooves …………… (type) key.

(4) …………… V belts …………… (manufacturer & country), nominal length ……………; x-section area …………… mm^2, …………… (material)

………………………………………
(Signature of guarantor)
Name: ………………………………
Designation : ……………………….
Organisation : ………………………
Address : ……………………………
……………………………

Date: ……………

STAMP

Annex 2.1

List of Tools and Other Materials for Installation of MHP Scheme

Particulars	Required		Checked	Tick when packed	Remarks
	Yes	No			
Mechanical					
Spanner sets (Ring and Open)					
Slide wrench					
Screw driver sets (Philips and plain)					
Hammer					
Pipe wrench					
File set (Round & Flat)					
Steel ruler					
Measuring tape (30 m)					
Level (Spirit & String)					
Hand drill machine					
Small bench vice					
Vice grip					
Allen key set					
Punches for making holes					
Grease gun					
Baring puller					
Wire Brush					
Hack saw					
Emery papers (different grades)					
Paint brush					
Differential chain					
Dreep pin					
Square					
Portable welding machine					

Electrical Common pliers Nose pliers Wire cutter Line tester Safety belt for climbing the pole Gas solder Crimping tool Wire puller Multi-meter Frequency meter Vibration meter Insulation tester					
Civil Tri squares Crow bar Strings Mason's trowel Showel Hammer Spirit level Chisel Pick Boring rods Abney level Theodolite Plum bob Dynamite					

Other Materials Cement (Needed quantity) Sealing materials Doors, windows Corrugated iron sheets Lintels Fuses (different sizes) Ballast heaters (if not available with ELC)					

Annex 5.1

Record Sheet for Performance Tests for MHP Turbine & Generator

Turbine type: Controller type: Rated output					Micro hydro Project Efficiency/Output test results						Date: Test done by: Page ________ of ______		
S. No.	Load (kW)	Voltage, V			Current, I			Turbine opening %	Flow l/s	Turbine Speed (RPM)	Net head (m)	Power output (kW) (V_rx I_r+ V_y x I_y + V_b x I_b	Overall Efficiency
		R	Y	B	R	Y	B						
1													
2													
3													
4													
5													
6													
7													
Remarks													

Annex 9.1

A Proposed Proforma for Handing Over and Taking over a MMHP Plant (Completion Certificate)

To be filled by the authorised representtive of the Installer.

A. General Information

Plant Name: ……………………….. Rated Capacity (kW): …………………………….

Stream Name: ……………………….. VDC: ……………………….. Dist: ……………………

Plant Location (describe) ……………………..……………………..………………………

……………………..……………………..……………………..………………………...

Owner name: ……………………….. Lead Person : ……………………..……………
(Recipient)

B. Completion of Civil Works

Weir constructed Yes/No. Type : ……………………….. Length (m): ………………………..

Distance between weir and intake mouth (m): ………………………..

Intake type : ……………………….. Size : ……………………….. (m)

Canal type : ……………………….. X – Section : ……………… Length (m) …………………

Are length sections of different types ? Yes/No. Description and length ………………………..

……………………..……………………..……………………..………………………...

Design flow (L/s) ………………………..

Control Gate type & Size : ……………………..……………………..…………………….

Desilting basins (No.): ……………………….. Size : ……………………..………………....

Construction types: ……………………….. Location: ……………………..………………...

Flushing Systems : Yes/No. No: ………………….. Construction type: ………………………..

Spillways: No. ……………………….. Construction type: ……………………..……………

Gate provided? Yes/No. Gate type and Size: ……………………..……………………...

Forebay size (L x W x H, m) ……………………..……………………..…………………..
Trash rack type and size ……………………..……………………..……………………….
Flush gate type and size ……………………..……………………..………………………..
Spillway type and size ……………………..……………………..…………………………
Disilting basin attached? Yes/No Type & Size ……………………..………………………...
Penstock gate provided? Yes/No. ……………………….. Type & Size ………………………..
Penstock material …………….. Type ……………….. Diameter (m) ………………………….
Length …………… Flanged pieces (No.) …………… Thickness ……….. Vent pipe? Yes/No.
Expansion Joints (No.) ………………..……………….. Type ………………..………………..
Bends (No) ………………..……………….. Type & Description ………………..…………….
Gross Head (m) ………………..……………….. Net Head (m) ………………..
Valve Provided? Yes/No.   Type ………………..………………..
Manufacturers (Name & Address) ………………..………………..………………..…………...
Powerhouse size (L x W x H) ……………….. Construction type ………………..……………
Roof type ………………..   Doors No. ……………….. Windows No. ………………..……
Tail race type ………………..……………….. Length ………………..………………..………
Civil works completed satisfactorily? Yes/No
Any leakage, earth movement from or around any of the civil works? Yes/No
Describe if Yes ………………..………………..………………..………………..……………..
Other Problems during commissioning of civil works (describe): ………………..…………….
………………..………………..………………..………………..………………..……………..
To what extent they were overcome? ………………..………………..………………..………..
………………..………………..………………..………………..………………..……………...

Test Results for Civil Construction

Flow measured in Canal? Yes/No. Flow (1/s) ………………..………………..………………...
Pressure gauge installed in Penstock ? Yes/No. Pressure at full flow (Kg/cm^2) …………………
Weir performing satisfactorily? Yes/No. If no, what needs to be done ………………..………...
………………..………………..………………..………………..………………..……………...
Settling basins performing satisfactorily? Yes/No. If no, what needs to be done ………………..

………………..………………..………………..………………..………………..……………...

All flushing systems performing satisfactorily ? Yes/No.

If no, what should be done ………………..………………..………………..…………………...

………………..………………..………………..………………..………………..……………...

Forebay & its accessories performing satisfactority? Yes/No.

If no, describe problem and solution ………………..………………..………………..…………

………………..………………..………………..………………..………………..……………...

Is penstock and its accessories performing satisfactorily? Yes/No.

If no, describe problem and solution ………………..………………..…………………………..

………………..………………..………………..………………..………………..……………...

C. Installation of Electro-mechanical Equipment

Turbine type ………… Rotor dia. (m) ……………… Rated capacity (kW) ……………………

Rated speed (rpm) …………… Runaway speed (rpm) …………………………………………….

Bearing type …………………… Size …………………… Manufacturer ……………………...

Test Results (Turbine)

Is turbine properly installed? Yes/No. If no, describe problem and remedy ……………...

…………………………………………………………………………………………………….

Was rated speed achieved? Yes/No. If no, suggest remedy ……………………………………...

Was rated power achieved? Yes/No. If no, describe problems and remedies ……………………

…………………………………………………………………………………………………….

Any other problem? Yes/No. Describe & suggest remedies ……………………………………..

…………………………………………………………………………………………………….

Generator

Type ………… Single/three phase. Rated kVA …………, Rated speed (rpm) …………………

Rated voltage (v) ……………… AVR? Yes/No. Type ……………………………………………

Manufacturer & Country …………………………………………………………………………

Generator properly installed? Yes/No.   If no, describe problem and remedy ……………..

……………………………………………………………………………………………….

ELC Provided? Yes/No.   Type …………   Manufacturer and Country ……………………

Coupling/Pulley sizes ……………………   Speed ratio …………………………………………

Belt types & sizes …………………………………………………………………………...

Power Transmission type (if different) ………………………………………………………..

Control Panel Instruments and No. provided (Details) ………………………………………..

……………………………………………………………………………………………….

Main switch type ……………………   Fuses type & No. …………………………

Over-voltage cutout …………………   Over-current cutout ………………………

Earthing system (describe) ……………………………………………………………………

All instruments and indicatorrs working properly? Yes/No

If no, describe problem & remedy ……………………………………………………………..

Test results (Generator)

Was rated electrical power achieved? Yes/No. If no, describe problem & solution ……………..

……………………………………………………………………………………………….

ELC tested and operated? Yes/NO. MCB/MCCB operated & tested? Yes/No.

Whole circuit tested within powerhouse? Yes/No. explain problem and remedy ……………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….

Any misalignment? Yes/No. If Yes, describe …………………………………………………

Any vibration? Yes/No. If Yes, describe …………………………………………………...

Any high temperature ? Yes/No. If Yes, describe ……………………………………………….

Any loose belts? Yes/No. If yes, describe …………………………………………………….

Endurance test done? Yes/No. Duration (hrs.) ………………………………………………..

If no, describe problem and remedy …………………………………………………………..

………………………………………………………………………………………………

Any problem during earthing continuity checks for generator, ELC, control panel? Yes/No. Describe problem (if any) and remedy ……………………………………………………..

………………………………………………………………………………………………

Is frequency meter installed Yes/No. If Yes, frequency range (Hz) …………………………….
Describe problem with frequency (if any) and remedy …………………………………………

D. Transmission Line Installation

Main transmission line length (m) ……… Wiring system single/three phase, three/four wires poles No. ……………… Type …………………… Size (L x W x H) …………………
Wire size ……………………………… Manufactures …………………………………….
Lightening arrestors, No. ………………………… Type ……………………………………….
Branch Transmission/Distribution lines, No. ……………………………………………………

	(i)	(ii)	(ii)
Lengths of each branch	…………………	…………………	…………………
Wire sizes	…………………	…………………	…………………
Single/three phase	…………………	…………………	…………………

Lightening arrestors; No. ………….. Poles, No ……………. Insulators, No……………

Test Results

Have all wires been inspected/tested for proper installation including jointing, continuity and resistance, sagging, etc? Yes/No. Describe problem (if any) and remedy ……………………….
…………………………………………………………………………………………………….
Have any other problems been noticed with wires, poles, nearby trees, buildings, etc? Yes/No. Describe problem and remedy (if any) ………………………………………………………..
……………………………………………………………………………………………………

E. Training

Training conducted for prospective operators and managers during Installation and Commissioning? Yes/No. If no, describe problem and remedy/If yes, give details ……………..
…………………………………………………………………………………………………….
…………………………………………………………………………………………………….
Additional training during the first supervised operational phase conducted? Yes/No. If no, describe problem and remedy/If yes, give details ……………………………………………..
…………………………………………………………………………………………………….
Describe the overall assessment of training absorbed by the personal to gain satisfactory expertise? ……………………………………………………………………………………

Level of expertise gained (Tick)

Person	Name	Satisfactory	Acceptable	Low	Negligible
Manager	………………………	……	…….	…...	……
Operator 1	………………………	……	…….	…...	……

Operator 2 ……………………… …… ……. …... ……

Operator 3 ……………………… …… ……. …... ……

Describe reasons for low or negligible gains and suggest remedy ………………………………
……

F. Overall Certificate of Satisfactory Completion of all Aspects of Installation Process

Certificate that all the aspects of the Installation process have been completed satisfactorily in accordance with the agreed specifications. All the defects and problems encountered during the commissioning phase have been removed and no problem is anticipated in future. This certificate applies to the following completed components.

Completed Components	**Signature by Installer**	**Signature by Recipient**
Civil works		
Electro-mechanical Equipment		
Transmission Lines		
Commissioning & Testing		
Training		

Certified further that all the relevant documents including; operations and maintenance manual, drawings, specifications (eg., for bearings), maps/sketches and feasibility/survey report; have been provided to the owner/manager/authorised recipient.

……………………………..

Signed by another prominent village leader Date: …………………..
Name, Position & Address …………………..…………………..…………………..…………..
…………………………..…………………………..…………………………..………...

……………………………..
*1(Signed by Authorised Representative of Installers) Date: ……………………………..
Name, Position and Address …………………………..…………………………..……….
…………………………..…………………………..…………………………..………..

*1 Note. If different aspects have been completed by different in installers (eg., civil works, transmission lines) then they should all sign at such spaces introduced in a modified proforma.

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