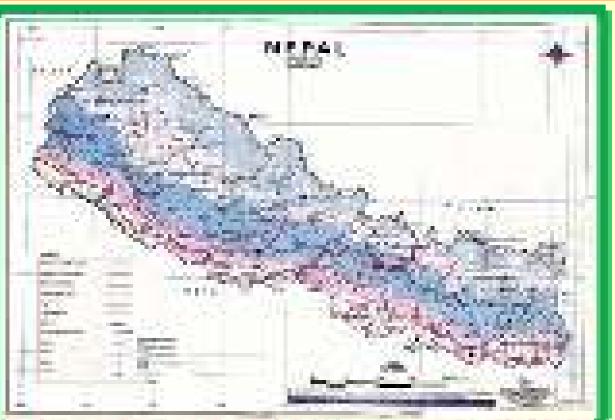



Government of Nepal
Ministry of Energy
DEPARTMENT OF ELECTRICITY DEVELOPMENT
Kathmandu

Guidelines for Operation and Maintenance of Hydropower Plants, Substations and Transmission Lines

January 2017

Foreword

Hydropower, the invaluable gift of nature to the country and the major source of renewable energy, can play vital role in Nepalese economy by providing cost efficient & environment friendly power supply to improve energy services and by contributing to GDP growth through its export. It could be considered as the major economic backbone of the country.

In the course of examining the numerous project reports related to prefeasibility study, feasibility study, completion reports, progress reports and other reports submitted, DoED has felt the need to maintain a uniform standard and streamline the quality of the reports in a manner consistent with international standards and norms, and compatible with the country's existing environment. Accordingly, since its establishment, DoED has been involved in preparation of standards, guidelines and manuals in various aspects of hydropower and its environment study.

To provide support, uniform and consistent approach for regulatory authority and owner(s) of the hydropower plant(s), substation(s) and transmission line(s), the department has prepared the present "***Guidelines for Operation and Maintenance of Hydropower Plants, Substations and Transmission Lines*** "; and this is one of a series of documents published by the DoED, Ministry of Energy, Government of Nepal, to establish procedural guidelines for various facets of hydropower development in Nepal. The department had signed the agreement on 9th October 2014 with the Joint Venture (JV) of GEOCE consultants (P) Ltd., Hydro-Engineering Services (P) Ltd. and Nepalconsult (P) Ltd. to prepare this guideline.

Standard engineering practices incorporating considerations and requirements arising from various conditions in Nepal has been used to develop this guideline. During the process a mechanism of Technical Advisory Group (TAG) consisting of ten experts were made to support the department in reviewing reports of different phases and provide suggestions to make the report of professional standard. Full day consultative meeting of concerned stakeholders was organized to discuss inception report in order to finalize the scope of work and pave ground for conceptualizing the outcome of the assignment. Similarly, field works including interactions between the study team and operation and maintenance staffs of few selected hydropower plants, transmission lines and substations were carried out to study and understand the O & M problems. Also, a 3- days residential workshop was held during the draft report stage for suggestions, inputs and experiences of the stakeholders and experts from the related field.

The objective of the guideline is to provide guidance to private and public sector for safe and smooth Operation and Maintenance of the hydropower plants, substations and transmission lines focusing on the owners and O & M crews to clear understanding of various dimensions. This guideline is different from manuals provided by the manufacturers and suppliers of the related equipment because in addition to safety and smoothness it also suggests appropriate scheduling of maintenance and hence lowering O & M cost.

The guideline aims to provide procedural guidance to agencies responsible for operation and maintenance of hydropower plant(s), substation(s) and transmission line(s) in Nepal and will be applied to all government, public and private sector agencies involved in the planning, design, construction, operation and maintenance and intends to serve as tools for the DoED to monitor and evaluate O & M of projects.

There are still rooms for improvement even though all pertinent suggestions received at consultative meeting, TAG meetings and residential workshop during draft report finalization stage has been incorporated in this document. As the power system in Nepal is still at development stage, while the technological advancement in respect of automation is occurring at a much faster rate, updating & improvement of the guidelines will have to be done in future as appropriate. Any suggested changes in the guidelines necessary to be incorporated during future revisions is greatly welcome and can be provided to DoED.

The Department acknowledges with deep gratitude the invaluable suggestions, comments and endeavor of many individuals, stakeholders from governmental and non-governmental institutions, TAG members, and participants of the consultative meeting and residential workshop. We also extend our thanks to the Joint Venture Consultants for undertaking the preparation of the Guidelines.

Nabin Raj Singh
Director General
Department of Electricity Development
January, 2017

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ABBREVIATION

A.C.	Alternative Current
AA	All Aluminum
ABCB	Air Break Circuit Breaker
ACE	Area Control Error
ACSR	Aluminum Conductor Steel Reinforced
AE/JE	Assistant Engineer / Junior Engineer
AGC	Automatic Generation Control
AVR	Automatic Voltage Regulator
BDV	Breakdown Voltage
BDV	Break Down Voltage
CBM	Condition Based Maintenance
CGLS	Central Grease Lubrication System
CO_2	Carbon Dioxide
CT	Current Transformer
CU	Copper
D.C.	Direct Current
D.G.	Diesel Generator
DGA	Dissolve Gas Analyzer
DLA	Dielectric Loss Analysis
DoED	Department of Electricity Development
DP	Degree of Polymerization
DT	Draft Tube
EIA	Environmental Impact Assessment
EMM	Emergency Management Manager
EPI	Engine Performance Indicator
FSL	Full Supply Level
G.B	Guide Bearing
GLOF	Glacial Lake Outburst Flood
GoN	Government of Nepal
GOS	Gang Operated Switch
GV	Governor
HP	High Pressure
HRC	High Rupturing Capacity
I^2R	Power Loss
I^2R	Power Loss
IIT	Indian Institute of Technology
INPS	Integrated Nepal Power System
IOC	Indian Oil Corporation
JV	Joint Venture
KDPP	Kulekhani Disaster Prevention Project
L.T	Low Tension
LAS	Lighting Arrestors
LGB	Lower Guide Bearing
MIV	Main Inlet Valve
MW	Mega Watt
NEA	Nepal Electricity authority
NPS	Nepal Power System
O&M	Operation and Maintenance
O/L	Over load
OLTC	On-Load Tap Changer

OPU	Oil Pressure Unit
OTI	Oil Temperature Indicator
PCB	Polychlorinated Biphenyls
PID	Proportional Integral Derivative
PM	Preventive Maintenance
PT	Power Transformer
RCC	Reinforced Cement Concrete
RCM	Reliability Centered Maintenance
RM	Reactive (Run to Failure) Maintenance
RoW	Right of Way
RTD	Remote Terminal Device
SCADA	Supervisory Control and Data Acquisition
SF_6	Sulfur Hexafluoride
SWL	Standard Reservoir Water Level
T&P	Tools & Parts
T.B	Thrust Bearing
T-G	Turbine-Generator
TSD	Temperature Sensitive device
TTR	Transformer Test Ratio
U.S.	United State
UGB	Upper Guide Bearing
UPS	Uninterrupted Power Supply
WTI	Winding Temperature Indicator

1.0 IMPORTANCE OF PROPER OPERATION AND MAINTENANCE

Every equipment and structure has its own life to serve the purpose for which it is meant. A well maintained equipment not only serves its purpose efficiently, economically and reliably but also exceeds its expected life time.

The lack of proper operation and adequate maintenance results into, not only higher failure rates and increase in the downtime of individual generating units, but also effects on efficient performance of the whole power system causing:

- a low degree of equipment service reliability;
- loss of service of electric power to consumers, and
- power energy losses to the utility(ies) in an economically unacceptable manner.

In the operation of the storage reservoir, the level is kept such that during rainy season, the chances of overflow is minimum. Similarly, in run-of-the-river type diversion plants, it is essential to keep the gates during flood conditions open to avoid flooding, while in the low water period, it is essential to check that there is no leakage from the gates or stoplogs, because the value of water during this period is quite high. Similarly, timely identification of sources of power/energy losses in the operation of power plants, sub-stations and transmission lines is equally important in order to immediately take the remedial measures. Reducing the malfunctioning of any of the components of the generation, transformation and transmission systems to a minimum should be the main aim of the inspection, testing, maintenance, repair, overhauling, etc.

Similarly, the managing inventory of spare parts also plays equally an important role in reducing the downtime of the equipment of the system.

Spare parts could be categorized as follows:

i) Consumable spare parts,
ii) Routine service spare parts,
iii) Major overhaul spare parts, and
iv) Breakdown spare parts

Such categorization may help ease the management of spare parts. Timely planning of management of spare parts is vital for reducing the downtime of equipment and related accessories.

A proper O & M program requires cooperation, dedication, attentiveness and participation at all levels and cannot succeed without everyone being involved while understanding the basic principles and supporting the cause.

2.0 MANUALS, INSTRUCTIONS AND GUIDELINES FOR OPERATION AND MAINTENANCE AND TYPES OF MAINTENANCE

2.1 Manuals, Instruction and Guidelines

Operation and maintenance manuals, instructions and guidelines are all the same. Basically, they are the directives for users, i.e., operators/ maintenance personnel of the structures, equipment, instruments, accessories, etc. However, while the manuals/ instructions are prepared specifically for specific equipment by manufacturers/ suppliers, the guidelines being prepared by the regulatory authority or on its behalf for general reference purpose and for standardization purpose of the operation and maintenance activities, in no way, can be substitute for manuals or instructions for operation and maintenance provided by the concerned manufactures. It should also to be noted that the hydropower station equipment are custom built, which cannot be fully assembled or tested at manufacturer's shop. Hence, they need to be tested after erection at the powerhouse; and records of actual performance of the equipment including their operation characteristics need to be established. It is to be kept in mind that this guideline is not a new invention, but drawn mostly from existing norms, guidelines and engineering practices taking also into account the prevalent O & M practices in Nepal. Due to absence of appropriate provisions in Nepal Standard for O & M of hydropower plants, sub-stations and transmission line, this guideline will refer to Indian Standard wherever it is relevant keeping in mind that Nepal Integrated Power System will be connected with Indian System in the coming years.

Any guidelines including the present one are to be taken as a dynamic process and should be updated periodically as new O & M procedures and technologies are developed and employed. The present guidelines has been formulated in an easily understandable manner to help the operation and maintenance crews based on collection and compilation of related information about O & M management and technologies, which have been formulated by the developed utilities in many years. The source of information is vast; hence, the process of making the guidelines should not stop here but continue in future as well.

2.2 Types of Maintenance

The Alternate Hydro Energy Centre, Indian Institute of Technology (IIT) Roorkee gives five types of maintenance, while the Bureau of Reclamation, U.S. Department of Interior gives four types. Two types (Preventive Maintenance and Reliability-Centred Maintenance), are mentioned in both the documents, while the Predictive Maintenance stated in IIT document is similar to Condition-Based Maintenance given in the document of Bureau of Reclamation. The fourth mentioned in the Bureau of Reclamation is Combination of Condition-Based and Preventive Maintenance, while the fourth and fifth given in the IIT document are Reactive (Run to Failure) Maintenance and Proactive Maintenance. In order to make full coverage of the types of maintenance, the descriptions given for each type of maintenance are depicted here from the IIT document. They are as follows:

a. <u>Preventive Maintenance:</u> Preventive Maintenance is planned/routine or scheduled maintenance. The intent of preventive maintenance is to "prevent" problems or failures before they take place by following routine and comprehensive maintenance procedures. It is designed to improve equipment life and avoid any unplanned maintenance activities. Preventive maintenance covers inspection, replacement, repair of any equipment or component based on time and set parameters. It includes painting, lubrication, cleaning, adjusting and minor component replacement to extend the life of equipment and facility. Its main purpose is to minimize breakdown and excessive deterioration and to achieve fewer, shorter, and more predictable outages.

b. Reliability-Centered Maintenance: This sort of maintenance is defined as “a process used to determine the maintenance requirements of any physical asset in its operating context”. It is ongoing process which determines the mix of reactive, preventive and proactive maintenance practices to provide reliability at the minimum cost. It recognizes that not all equipments in facility are of equal importance for generation as well as plant safety. It recognizes that design and operation of each equipment differs; and, therefore, possibility of failure differs from equipment to equipment. In this program diagnostic tools and measurement are used to assess when a component is near failure and should be replaced. In this program basic thrust is to eliminate more costly unscheduled maintenance and to minimize preventive maintenance. In this type of maintenance, unimportant maintenance activities are left to reactive maintenance approach. The goal, thus, of this program is to provide the appropriate amount of maintenance at the right time to prevent forced outages while at the same time eliminating unnecessary maintenance.

c. Predictive Maintenance: This sort of maintenance ensures ability to judge when a part of equipment is going to fail and replace the same before it does. Usually, it requires some form of testing and analysis which helps predict an eminent failure. Predictive maintenance can be used in conjunction with preventive maintenance practices. In hydropower stations, there are many monitoring systems, which can be used to predict problems and possible failures. These include vibration monitoring, oil analysis, temperature, system loading, IR values of generation, efficiency in power generator output, and leakages of oil and water. All of these data can be captured, tracked and analyzed through computer system. The results of analysis of data can predict the future.

d. Proactive Maintenance: Most recent innovation in maintenance is called proactive. It utilizes a technique called “root cause failure analysis”. In this type of maintenance primary cause of failure is diagnosed and corrected.

e. Reactive (Run to Failure) Maintenance: This is sometimes called crisis maintenance or hysterical maintenance. This has been dominant form of maintenance for long time and its costs are relatively high because of the unplanned downtime, damaged machinery and overtime expenditure. Run to failure should be a very small part in a modern maintenance program. Planned maintenance is preferred over this type so as to reduce downtime of machine and avoid uncalled for outages.

There are advantages and drawbacks of each type of maintenance. For example, the following table provides advantages, drawbacks and features of some of the types of maintenance.

S. No.	Type of Maintenance	Advantages, Drawbacks and Features
1	Preventive Maintenance (PM)	Advantages: • It is predictable making budgeting, planning, and resource leveling possible. • When properly practiced, it generally prevents major problems, thus, reducing forced outages, "reactive maintenance" and maintenance costs in general. • It assures managers that equipment is being maintained. • It is easily understood and justified. Drawbacks • It is time consuming and resource intensive. • It does not consider actual equipment condition when scheduling or performing the maintenance. • It can cause problems in equipment in addition to solving them, e.g., damaging seals, stripping threads
2	Reliability Centered Maintenance (RCM)	Features • It may be labour intensive and time consuming to set up initially. • It may require additional monitoring of quantities like temperature and vibration, to be effective. This may mean new monitoring equipment with its own preventive maintenance or more human monitoring with multiple inspections. • It may result in a "run-to-failure" or deferred maintenance philosophy for some equipment which may cause concern for some staff and managers. • It may require initial and later revisions to maintenance schedule in a "trial-and-error" fashion depending on the success of the initial maintenance schedule and equipment condition. • It should result in a more manageable maintenance workload focused on the most important equipment.
3	Condition Based Maintenance (CBM)	Features • Monitoring equipment parameters such as temperatures, pressures, vibrations, leakage current, dissolved gas analysis, etc. • Testing on a periodic basis and/or when problems are suspected such as Doble testing (power factor test for early detection of bushing contamination and deterioration), vibration testing, and infrared scanning. • Monitoring carefully operator-gathered data. • Securing results in knowledgeable maintenance decisions which would reduce overall costs by focusing only on equipment that really needs attention. Drawbacks • It being Very difficult and expensive to monitor some quantities. • It requires knowledgeable and consistent analysis to be effective. • Condition monitoring equipment and systems themselves require maintenance. Note: Because of these drawbacks, it is nearly impossible to have an entirely CBM program.

3.0 PREVENTIVE/ROUTINE/SCHEDULED MAINTENANCE IS THE ESSENTIAL OF ALL

Despite the advantages and drawbacks of each type of maintenance as indicated above in Section - 2.2, the preventive maintenance (PM) has been proven generally reliable in the past and is still the core of the most maintenance programs. In the Bureau of Reclamation, PM has been traditionally the standard maintenance program. The maintenance recommendations in the present document too are based on a PM philosophy and should be considered as "baseline" practices to be used when managing a maintenance program. However, care should be taken in applying PM recommendations as wholesale implementation of PM recommendations without considering equipment critically or equipment condition may result in a workload that is too large to achieve. This could result in important equipment not receiving needed maintenance, which defeats the purpose of PM management. In order to mitigate this problem, maintenance managers may choose to apply a consciously chosen, effectively implemented, and properly documented Reliability centered Maintenance (RCM) Program. Whether utilizing a PM, RCM, or condition based maintenance (CBM) program or a combination of these, scheduled/routine or preventive maintenance should be the primary focus of the in-house maintenance staff. This will reduce reactive (emergency or corrective) maintenance. Scheduled maintenance should have a higher priority than special ones and should be the number one priority. Therefore, this guidelines document has been focused for the preventive maintenance program.

4.0 GUIDELINES FOR OPERATION AND MAINTENANCE

4.1 Basics of Guidelines for O & M

4.1.1 General

Ease of operation and minimum requirement of regular servicing / maintenance are to be considered even in the design phase of the project taking into account practical constraints and difficulties prevalent at the hydropower development site(s). In the present era of advancement of technology, automation, computerization, enhanced human capabilities, etc., many things have become possible. A number of hydropower plants could be found under operation in the developed countries even unattended. However, the need of routine inspection, servicing, performance testing, undertaking of timely corrective measures such as repairs, overhauls, replacement of parts, etc. cannot completely be avoided. The levels of maintenance requirement differ from component to component depending upon their functions and conditions under which they are operated. Planned or routine/preventive maintenance helps reduce not only losses in revenue, but also saves from disastrous happening due to failure to structure(s), and breakdown of equipment at the time when their uses are most needed, because the inspection and performance tests during the routine maintenance make possible to detect or predict deficiencies in the equipment/structure(s) involved in the hydropower generation and transmission for timely planning of rectification, repairs and/or replacement.

As such the operator(s) and maintenance staff must fully be conversant with the physical features and functions of all the components of hydropower plants, transmission lines and sub-stations such as civil structural facilities, electro-mechanical equipment and the associated auxiliaries, control and safety devices installed at the headworks, water conveyance system, powerhouse complex, switchyard, transmission lines and sub-stations. All features may not be included in every plant and will depend on type of plant, water source, turbine and generator installed and power evacuation arrangement. Hence, the starting point for the guidelines will be the establishment of a comprehensive list of structural features and equipment of the facilities to be operated and maintained and the knowledge base on their functions.

4.1.2 Consideration of O & M Philosophy during Design Phase

The project planning and feasibility document during design phase should consider the O & M philosophy to properly evaluate the workability of various project alternatives. For example, the analysis of dam failures, particularly of embankment type has shown that the greatest risk to such dam safety is overtopping caused by river floods. The risk during construction appears to increase with design dam height. The lower height (less than 20 m in average) operating dams with smaller reservoirs are much safer, because they are designed with relatively robust gated structures. The reasons identified for dam failure during construction period were adoption of lower design diversion discharge (the 50 or 100 year flood) for high dams and designing of the gated dams with a smaller freeboard between full supply level (FSL) and the dam crest in case of operating embankment dams. In the context of Nepal, the design of structures should consider the potential GLOF (Glacial Lake Outburst Flood) events.

The risk of failure particularly during construction period is quite high. In a two year construction period, the risk to downstream populations may be greater than what is expected during operation of the dam for whole life span. It is, therefore, suggested the risk may be substantially reduced by designing high dams for the 1000-year flood instead of using the 50 or 100-year flood. In the case of design of the large Karnali (Chisapani) dam in Nepal a margin of as much as 30 m of flood surcharge has been provided to safeguard the dam from overtopping (reference-Karnali Chisapani Multipurpose Project Feasibility study Report, December 1989). Design requirements for the equipment should reflect the O & M philosophy and consider items as lubrication schedule and level of personnel experience. Necessary support facility must be consistent with on-site personnel time. The O & M concepts and staffing should be determined early in the planning phase of the project. The O & M concepts must be discussed with the project owner and established before formulizing the detail design. The facilities, equipment and components selected for use at the project should require a minimum of regular servicing. The plant operators and maintenance personnel should be familiar with the regular servicing required to operate the plant reliably. The operator staffing considerations should include reliability, response time, skill levels, physical conditions, and adverse weather conditions.

Major consideration with respect to transmission line and substation from O&M perspective should also not be missed out during design phase.

An accurate and detailed record of O & M duties performed and observations made are necessary for the safe and reliable operation. The plant operation log book/log sheets provide a means of recording plant conditions and changes that affect these conditions, for future reference. The telemetry system records some of the plant conditions; however, the records kept by the operator and maintenance personnel are also necessary. From these records potential problems can often be anticipated and prevented. Shutdowns can be scheduled by observing the trends in the operation of the plant. This will also help determine which spare parts and consumable materials should be kept on hand at the plant.

A document entitled “Operating and Maintenance Goals and Objectives” should be developed during the design phase of the project. It will significantly help the design team, plant owner and constructor in understanding the operational concept of the project.

In any circumstances, equipment specific user’s manuals, procedures for O & M including as-built drawing must be obtained from the manufacturers/suppliers to facilitate O & M activities.

4.1.3 Some Important Aspects worth Consideration in Operation and Maintenance of Hydropower Plants

Operation and maintenance of hydropower stations must aim at reducing failure rate by ensuring smooth operational levels of the power utility. This can be done by adopting timely preventive maintenance schedule regarding all vital areas of the power project.

4.1.3.1 Operation

Good practices in Operation of Hydropower stations shall be such that the downtime of individual generating Unit & Plant should be minimum. The operational reliability of the generating units of the hydropower stations shall be such that whenever the grid demands, it should be available for generation. Some of aspects, which can be taken into consideration, in Operation of hydropower stations, are given below:

- Each failure/tripping occurrence must be questioned with basic minimum three questions: (a) why this occurred? (b) How this occurred? (c) What is to be done to avoid its reoccurrence? This will definitely reduce failure rate to the greater extent.
- Since it is important to adopt timely preventive maintenance schedules covering all vital areas and plants, the detailed Daily, Weekly, Monthly, Quarterly, Annually and Capital Maintenance Sheets should be maintained properly.

- During replacement of any part or equipment after its full utilization or breakdown, it should be ensured that the replaced part or equipment should be of improved version & of latest technology having longer durability to meet all desired requirement so as to increase plant efficiency and reliability.
- Operating conditions should continuously be monitored and recorded. Records are very important to diagnose the cause of fault/ failure/ replacement & to determine residual life. Early action can be taken before any type of failure.
- Even though original equipment manufacturers recommend max./min. permissible parameters for their equipment, the records/ experience/past history play important role to set limiting values of parameters of these equipments, as characteristics of identical equipment vary from unit to unit and required to monitor its set values.
- On the basis of past history/records & recommendations of manufacturers maintenance schedules can be framed. Breakdowns/forced outages can be minimized by proper follow-up of the maintenance schedules based on recommendations of manufacturers. Life of the equipment, thus, can be enhanced.
- Starting/stopping of the units shall be planned to be minimum to increase the life.
- Procurement of the equipment spare parts should be planned as per the rate of the consumption, based on minimum requirement to optimize the inventory.
- Optimum utilization of the manpower & material to be planned.
- It would be beneficial to arrange training for O & M staff to refresh their knowledge to give advanced technical information to improve work quality & quantity. The training of O & M staff should be mandatory for transfer of O & M knowledge from original equipment manufacturers.
- Interaction amongst working staffs at various power stations in the country needs to be organized to improve performance of plant and equipment in totality so as to implement good Operation & Maintenance Practices.
- Provision of “On Line Condition Monitoring System” on generator, turbine and main transformers could be considered for installation on all existing power stations.
- Afforestation in catchment area will help reduce silt flow and conserve water, for which the catchment area treatment studies for the stations in operation should be carried out and as per recommendations of the studies, the power station should carry out afforestation work in the catchment area.

4.1.3.2 Maintenance

Some of the practices to be adopted at hydropower station for maintenance are broadly given below.

- **Water Intake, Water Conduit System and Associated Equipment:**

  Water storage (Reservoir) & water conductor system comprising of intake, headrace tunnel, surge shaft, emergency valves & pressure shafts, penstock, main inlet valves are very vital organs of a hydropower plant. Due to negative and positive water hammer during sudden changes in water flow, it is essential to attend to these plants & equipment very carefully. It is very important to regularly test operation of conduit isolation system/equipment, i.e. intake gates, butterfly valves, excess flow device, surge equipment, etc.

  Periodic physical inspection of water conductor system from inside as well as from outside to know its condition, silt deposition, rusting/erosion of conduit system is very much essential to find out various changes due to aging factor, stresses development due to water hammer, etc. The records of such physical inspection should be maintained by noting all the details, i.e. normal as well as abnormal. These records can be compared with the installation data. Any abnormality is to be further investigated by carrying out hydraulic testing, measurement of thickness by Ultrasonic testing & tests for measuring and computing stresses at strategic locations such as intake point, bends, besides observing sudden changes in elevations & sizes of pressure shafts, penstock, etc. Leakage, if any, should be scrupulously noted and records maintained. It should be ensured whether inside/ outside (wherever possible) painting is carried out to protect the conduit system. The valve seals, if deteriorated should be replaced by using new seals with latest materials for enhancing the life of this equipment. Purification and frequent testing of hydraulic system oil should be carried out as per recommendations of the manufacturers. For oil purification, on-line electrostatic liquid cleaners may give best results. Some of the additional points as mentioned below also need to be considered:

- Cavitations & erosion at top portion due to rushing of air during fill up,
- The inspection schedule for the durability of anticorrosive paints used,
- Replacement schedule for various vulnerable parts such as bends, open conduits, etc.,
- Due to humidity, open conduit deteriorates from outside. As such inspection & cleaning to be carried out from time to time at regular intervals,
- Anticorrosive-painting schedules followed,
- Timely operation & maintenance of the cranes & hoists,
- Healthiness of control & protection for isolating gates/valves & for cranes/hoists,
- Maintenance of trash-rack/intake gate filter, and
- Maintenance of communication systems, availability of power supply, equipment for emergency operations, approach roads, etc.

- **Turbine & its Auxiliaries:**

Regular inspection of runners of turbines should be carried out, and record to that effect should be invariably maintained. Many a times it is not possible for Francis Turbine being always immersed in water and needs isolation on either side. For this, it is done as recommended by manufacturer without any compromise. Due to cavitations, there may be huge damages to turbine wheel causing adverse effect on performance and consequently on efficiency. Sometimes, it would be necessary to undertake in-situ repairs of turbine buckets to recoup/ fill up erosions/ white pitting by using various cold compounds viz. Belzona compound, Loctite, SS Metalset, Throtex compound, etc. This may give satisfactory results. Low heat input welding can also be tried at some of the locations to some extent.

An effective system for monitoring of silt content (quantity and size in ppm) may be installed & commissioned by each power station, and silt content, particularly during rainy season, may be monitored continuously on the basis of which action to mitigate the damaging effect to under water parts may be initiated reducing the downtime of units/station.

Best efficiency microprocessor based digital PID speed governors provide fast response. Periodical maintenance of speed governors along with all associated mechanical, electrical, electronic components should be carried out. The control circuit should be neatly dressed with identification marks. The electronic components and cards should be carefully maintained at appropriate temperature level to achieve desired performance. Periodical calibration and testing of transducers, meters etc. needs to be done. Desired purity level of hydraulic oil is to be maintained to give trouble free operations. History of each important part should be maintained. Following maintenance works for turbine and governor also need to be taken up:

Turbine

- Periodic ultrasonic,
- Polishing of the various under water parts of the turbines once in a year to minimize the white pitting,
- Inspection & testing of the runners from experts to decide residual life so as to initiate action for procurement of runners for replacement,
- Inspection of labyrinth seals in case of reaction turbines,
- Painting of runner housing with anticorrosive/tar based paints,
- Applying anti-erosion coating to the runner, and
- Checking of brake jet operation in power stations having Pelton turbines once in three months.

Governor

- Purification of hydraulic oils by centrifugal as well as electrostatic liquid cleaner,
- Periodic maintenance of the servo valves and motors after carrying out inspection of the pistons & housings of the servo valves and motors for their worn-out parts. Replacement of the leaking seals, and
- Survey of the component failure & procurement of the same and maintain minimum inventory.

- **Generator & its Auxiliaries:**

Stator & rotor winding, bearings & excitation system are the main parts of a generator. As regards stator and rotor windings, regular recording of IR Values of these winding should be maintained at regular intervals. Tanδ (delta) and DLA (Dielectric Loss Analysis) tests of stator winding indicate the status/ condition of stator winding insulation. Likewise impedance test (voltage drop test across each pole) indicates condition of the rotor winding. Proper cooling system is to be maintained to limit rise in stator winding temperatures and consequently increase the life of stator winding. Inspection of the stator winding is also required to be carried out to verify its firmness in stator core slots and healthiness of overhang portion with firm end winding caps & end spacers, slots wedges checked for healthiness. Windings are re-varnished to enhance their life. Looseness of stator core or inter lamination, core insulation are direct factors affecting winding heating due to eddy current loss. Thus, recommended maintenance as per schedule should be carried out, its records maintained and corrective actions be taken if necessary.

Other precision and very critical components of generator are its guide and thrust bearings. The thrust bearing is main bearing holding complete thrust of rotating mass of turbine and generator unit. The generator and turbine guide bearings act as guides for controlling the vibrations of the unit. If T-G shaft alignment with accurate shaft level is achieved then the pad clearances are adjusted precisely and the rotating machine will operate smoothly without rise in bearing temperature and increase life of bearing. Following works also need to be taken up:

- Periodic checking of the foundations, tightening the bolts, filling the foundation with epoxy.
- Checking the vibrations periodically; & history of the recorded readings gives guidelines for realignment, looseness if any, unbalanced electrical components, increase in bearing gaps, coupling misalignment, uneven stator-rotor air gap etc.,
- Periodic cleaning or replacement of the generator air coolers and bearing oil coolers to improve performance of the generator,
- Primary and secondary testing of the protection system for its healthiness and correct operation,
- Inspection of the CTs, PTs and bus bars for overheating, temperature rise etc., and
- Inspection of circuits for protection & control of the fire fighting system along with evacuation system. Checking weight loss of the CO_2 cylinders and replenish as per recommendations of equipment manufacturer.

- **Transformers & Switchyard:**
  - Continuous monitoring of oil & winding temperature,
  - Periodic oil filtration,
  - Oil testing for various tests and Dissolved Gas Analysis,
  - Checking of Tanδ (delta) & insulation resistance etc. as per schedule,
  - Cleaning and replacement of oil cooler,
  - Testing protection system for healthiness,
  - Mock Maintenance and inspection for firefighting system, CO_2 & Mulsifyre,
  - Tests for operation time of the breaker,
  - Operation & testing of isolator opening & closing,
  - Checking of control circuit & healthiness of operating system of the breaker,
  - Periodic cleaning of transformer bushing & insulator strings,
  - Switchyards are to be kept neat & tidy. Minimum area surrounding the yard to be free from growth of scrubs and bushes to avoid any bush fire damaging the equipment.

- **Emergency Diesel Generator Set:**
  - Regular maintenance of the emergency DG set. Checking control & protection system, and
  - Running of DG set at regular intervals.

- **Other Powerhouse Equipment:**
  - Periodic maintenance of unit auxiliary, station auxiliary & station service transformer,
  - Checking healthiness of station batteries & battery chargers. The two chargers should be rotated once in a week,
  - Regular inspection of cable ducts to ensure proper ventilation / heat dissipation, and
  - Checking the healthiness of pressure relief valve, if provided.

4.2 Major Facilities and Equipment Covered by the Guidelines

The general list of facilities and equipment involved in the operation and maintenance of hydropower plants, transmission lines and substations are as follows:

4.2.1 Hydropower Plant

(i) Civil Structural Facilities

- Dam/Diversion Weir/ barrage and storage reservoirs, water operations including downstream release requirements and consideration of prior water rights,
- Intake and Approach Channel/tunnel, Gravel trap,
- Desilting arrangements,
- Water conveyance system including forebay/surge tank and penstock, and
- Powerhouse complex including tailrace and switchyard.

(ii) Hydro-mechanical Works

- Trashracks, stoplogs, penstocks,
- Gates and valves of different types including main shutdown valve, and
- Lifting devices (cranes/hoists).

(iii) Power/energy Generating Equipment

- Mechanical
  - Turbines and its auxiliaries,
  - Governors and associated OPU (Oil Pressure Unit) and guide apparatus, and
  - Main Inlet Valve (MIV), draft tubes and draft tube gates.
- Electrical
  - Generators and auxiliaries,
  - D.G. Set and A.C. auxiliary supply,
  - D.C. supply, batteries and battery charger,
  - Start up and synchronous panel, control panel, and
  - Station auxiliaries such as station compressor, drainage and dewatering system and cooling water system.

(iv) Powerhouse Auxiliaries

- Cooling system,
- Ventilation system,
- Lubrication system,
- Drainage and dewatering system,
- OHT crane, HVAC,
- Air compressor system,
- Lighting system, emergency supply system,
- Station earthing, lightening protection,

- Communication & SCADA system,
- Fire detection, fire-fighting and hydrant system, and
- Safety tagging and safety interlocks.

4.2.2 Switchyard

- Switchyard structure,
- Busbar system,
- Transformers,
- Switchyard equipment such as circuit breakers, isolation switches, C.T., P.T., C.V.T. safety devices / alarms, and
- Outgoing lines.

4.2.3 Transmission Lines

- Right of way,
- Length, voltage and point of connection/ inter-connection,
- Overhead lines,
- Poles/ towers, pole anchors,
- Insulators, cross-arms, jumpers.

4.2.4 Sub-stations

- Transformers,
- Circuit Breakers (different types),
- Reactors,
- Capacitors,
- Voltage Transformers
- Current Transformers
- Reclosers,
- Disconnect Switch,
- Surge arrestors,
- Wave traps,
- Medium Voltage switchgear, and
- Storage Batteries and Battery Chargers.

4.3 Guidelines for Operation of Hydropower Plants

The prime mover of hydropower plants is the energy contained in the water. Therefore, during operation of hydropower plants, besides operating properly the equipment and accessories installed in the hydropower stations, the water operation has also an important role to play. The aim of best operation practice should, thus, be such that both water and equipment of hydropower plants along with the related accessories are operated at the maximum efficiency to the extent possible. The following are the operation guidelines for each of these components to achieve that goal.

4.3.1 Water Operation and Operation of Associated Civil Structure Facilities

Water Operation in a hydropower plant depends on types of hydropower plants. Generally, the three types of hydropower plants in relation to water operation are in existence which are: (i) high dam storage type plants having reservoir capacities for seasonal, annual or even multi yearly regulation, (ii) pondage type run-of-the-river plant having the reservoir capacities sufficient only for diurnal (fluctuations that occur during each day) regulation, and (iii) Purely run-of-the-river type plants working on transit flow available in the river from time to time.

For the type (i) plants, the water operation is done in such a way that during rainy season the overflow chances are minimum, while at the same time the water level of the reservoir is raised quickly to the extent possible so that the head availability is maximized for a longer duration. Run-off forecasting, particularly during rainy season, will be important aspect for attaining this goal. Generally for reservoir operation, standard reservoir water levels (SWL) at the end of every month are established during design phase (A curve connecting these SWL is called as "Rule Curve"). This rule curve has to be followed in the operation of reservoir.

The type (ii) hydropower plants, due to their constrained situation of reservoir capacities, are capable only for diurnal regulation. In such plants in the off-peak periods (generally at mid-nights and mid-days), the flows not required for full generation, are to be stored in the daily pondage reservoirs and used for higher generation periods during peak hours (generally evening and morning hours). Their role will be quite important during peak hours of the dry season when the value of hydro-energy will be the highest.

In the (iii) type of hydropower plants, the operation is to be done in such a way that they generate in full capacity during wet season, while at the time when the water availability is low (i.e., during dry season), the generating equipment needs to be assigned for scheduled maintenance, and that way energy production from such plants could be maximized over a year.

The consideration of downstream water release requirement as per the prevailing laws and regulations particularly during low water period is a must along with abiding the prior water use entitlements (if any) during water operation.

By operation of associated civil structure facilities, it is to be understood that it is the operation of gates, lifting mechanisms, etc. fitted in the structures for regulation and control of water flows. For example, spillway gates fitted at the dam/barrages/weirs are aimed at raising the water level to a design level during low flow periods for channeling the available water to the conveyance system leading to powerhouse, while during flood period to allow the spills of surplus water to the river course. The gate is operated (opened) after reaching the maximum design water level of the reservoir. The gate needs to be operated following the flood routing principle established during design phase. Failing to achieve these objectives, particularly, if the spillway and undersluice gates could not be opened at the time of flood, disaster could happen due to flooding, at the same time creating problems due to sediment accumulation at the intake zone. Similarly, desanding basin forms an important part of hydropower plant as it is the silt tank that determines the wear and tear on the turbines. It is, therefore, wise to keep the silt tank in good condition particularly during rainy season, when the silt flows are highly concentrated. The collected silt should be removed as and when necessary; if not, it will collect up to a limit and any excess will pass into the turbine. The upstream and downstream gates of the desanding basin need to be operated in accordance with the types of desanding basin designed for flushing the deposited sediment in order to prevent turbine wear. The forebay is an essential part, particularly for non-pressure water conductor system. It serves the purpose of connecting penstocks and acts as tank. It takes care of small vibration in generation. The operation of forebay is important during picking up load and at the time of tripping of machines. Actual overflow through by-pass is always recorded to calculate water wasted during overflow, especially during lean season when the value of water is the highest. Similarly, observing the tailwater level, particularly for the hydropower plants equipped with reactive turbines is necessary to see that the tailwater is at a level that provides sufficient net positive suction head to avoid cavitations.

4.3.2 Operation of Hydropower Plant Facilities/Equipment

The operation of hydropower plants comprises: (i) operation of hydro-mechanical works such as gates, stop logs, valves, etc. to regulate the discharge through turbines, (ii) operation of generating equipment such as turbines and generators, and (iii) synchronization into a Grid (Power supply system). A number of checks are to be done particularly before starting the machine. The general checklists for this purpose are as follows:

- For mechanical works:
  a) At intake, check:
    - bypass gates,
    - position of intake gate,
    - power supply to gates.

  b) At power plant, check:
    - AC power for pump operation,
    - HP compressed air,
    - locking pin position,
    - level and pressure in OPU (Oil Pressure Unit),
    - spiral drain valve is closed,
    - D.T. drain valve is closed,
    - position of strainer valves ensure water flowing in cooling pipes,
    - gland seal valve open,
    - air seal valve closed,
    - top cover drain system okay,
    - levels in pressure accumulator and oil sump of OPU system, turbine gear bearing, lower guide bearing (LGB), upper guide bearing (UGB) and thrust bearing,
    - penstock pressure and pressures at spiral casing after opening of MIV (Main Inlet Valve), OPU, stator cooling water, thrust bearing, UGB, LGB, sealing water pressure and air pressure for brakes,
    - working systems: top cover drain, oil leakage unit, oil cooling unit, oil pressure unit, brakes, position of CO_2 batteries, guide vane lock (on or off), jacking de-jacking of m/c, flow relays, emergency slide valve reset and working of ventilation system.
- For electrical Works:
  a) General checklist:

- DC system,
- Grid power,
- DG set power,
- Event logger, and
- Disturbance logger.

b) Check list for generator:
- brake system,
- cooling water for bearings,
- generator fire fighting, if applicable,
- AVR condition, DC supply for field flashing,
- oil levels in bearing, IR values, jack position, and
- HP lubrication system, earth link for bus duct.

c) Check list for transformers:
- cooling water system, fire fighting system,
- transformer cooling oil pump position, Buccholz relay,
- oil level in conservator, color of silica gel, and
- IR of winding and core, BDV (Breakdown Voltage) of transformer oil.

d) Check list for switchyard:
- compressed air in case ABCBs are used,
- SF_6 gas pressure in case SF_6 breakers are used,
- earthing switch position,
- Isolator position-close, Breaker position-off, and
- Line isolator position.

Note: Check lists given above are for starting of the machine after long shutdown. If the starting of the machine is to be done after a short shutdown, certain checklists such as position of stop log gates, AVR condition, IR values, Jack position, earth link for bus duct, IR of winding and core, BDV of oil are not required. This applies for Black Start as well, but black start is done without relying on external transmission network (i.e., using Diesel Generator or other power source). This aspect is dealt in the NEA Grid Code.

The following are the activities to be carried out for operation of the hydropower plants after the general check-up as mentioned above:

- For intake gate opening, check intake gate power supply and hoisting system, give raising command and check gate position in raised condition.
- For Inlet Valve Opening, put oil pumps on ‘auto’ mode, open bye-pass valve manually or give opening command to by-pass auto valve, check water pressure on spiral side, and then give opening command to inlet valve on equalized pressure.
- For turbine operation, put oil pumps on ‘auto’ mode to maintain required pressure in pressure accumulator, check availability of Nitrogen cylinder and check also pressure of the same for systems using compresses nitrogen, check air pressure for maintaining proper oil level in pressure accumulator (if provided), open cooling water for bearings, open shaft seal water, put brake on ‘auto’ mode, unlock guide vane lock, fix GV (Governor) opening limit, and put machine on ‘auto’ mode.

- For generator operation, select AVR Auto/Manual mode as required, keep fire-fighting system operative (where provided), switch on DC supply for excitation flashing, at 30% of generator voltage DC supply from battery cuts off, at 90% speed switch on generator excitation (if not on auto), start machine on ‘Auto’ or ‘Manual’ mode as required.
- For synchronization, check grid voltage and frequency, check generator voltage and frequency, reduce or increase generator voltage & frequency to match with line voltage & frequency, put synchroscope in ‘ON’ position. Needle will start moving and lamps will start glowing. Needle on 12^{o} clock position and lamps on dark position indicate that voltages and frequencies of grid and generator respectively are matching, at equal grid & generator voltage and frequency, close generator breaker, now generator is synchronized with grid, and then take minimum prescribed load immediately.
- For checks after synchronizing and taking load, unit control board supply is changed to Unit Auxiliary Transformers, Change excitation from “manual” to ‘Auto mode, transformer “Motor for cooling water supply” started, all parameters in control room are matching and correct, and general check up for machine and other unit auxiliaries at all floors.

Following are the checks to be carried out at the “Time of Shift Change Over (Machine Running on Load)”:

General: Check lighting, ventilation and air conditioning, check water levels in Forebay & Tailrace channel, check availability of discharge, check communication systems, check instructions and status of various equipment and work permit/shut downs/ breakdowns, check general cleanliness of the area, equipment and control panel etc., check all indication lamps are glowing, check with test push button that all fault indication lamps are ok, physical check of all sub-distribution boards installed in the Power Station, check all inlet exhaust fans are working, check all batteries are physically in good condition and check battery chargers are in normal working conditions. Check operation of all the installed instrumentations whether they are functioning correctly or not.

Turbine and Generator: Check temperature of thrust bearing, upper guide bearing and lower guide bearing, check in normal working condition of cooling water flow and pressure of all bearings at inlet & outlet, sealing water flow and pressure top cover drainage system, stator cooling water flow & pressure and grease pump; check oil level in housings of all bearings, check if there is vibration or abnormal sound in OPU pumps and check grease in the container of centralized grease lubrication system; check working of OPU pump 1 & 2, OLU pump, drainage pump & dewatering pumps, governor compressor, general – purpose compressor, and cooling water strainers; check running & vibration of machine and ensure nothing is abnormal, check water, oil and air flow indicators, and check the physical appearance of various system such as manholes, valves, indicators, etc.

Generator, AVR & Excitation System: Watch running & vibration of machine and ensure nothing is abnormal, check for any sparking from the brush of slip ring, check temperatures of winding and core (ensure that these are within limit), check that all instruments and indicators mounted on unit control board, governor panel and AVR & excitation panel are in ok condition, check for any abnormality, sound chattering in busduct, and neutral cubical.

Control Room: Check that all parameters indicated on various panels are matching, all indicating lamps are glowing (also check annunciations are ok), check movement of all pointers & reset them, check all instruments mounted on panels are in working order, check all relays are reset, check rear of all panels and mounting on this side for OK condition, check emergency lighting system is ok, check position of circuit breakers for outgoing lines, and check grid voltage & frequency.

L.T. Room: Check all indication lamps are glowing, have general look on instruments and relays mounted on board, check various switches are in correct position, and check whether supply to various distribution boards are ok.

DC Distribution Board, Battery Charger & Battery Sets: Check DC voltage is correct, check batteries are in healthy condition, check DC supply is healthy by making momentarily float off (this would ensure that batteries are connected with load), check both batteries are in float, check all the switches on board are in correct position, check that both chargers are functioning correctly, and check all cells of battery functioning correctly, and check all cells of battery bank are healthy (their specific gravity and cell voltage are correct. It should be done in morning shift only).

Main Transformer: See that oil level in conservator is OK and there is no leakage from anywhere, check that oil pressure and water pressure are normal, check that oil temperature and winding temperature are normal, check silica gel colour is normal, see that oil and water flow indicators are normal, carry out checks of compressor and power for healthy condition of Multi-type System (wherever applicable).

Switchyard: Have general look at switchyard including bus bars, jumpers etc. Ensure that there is no sparking anywhere and everything is in order, check compressed air system in case of ABCB is ok (if provided), check SF_6 gas pressure in case of SF_6 breakers and check position of all breakers, isolators & line isolator and cast a look on all CTs, PTs, LAS, surge counters, wave traps and coupling capacitors, reactors and capacitors and ensure that everything is in order.

Following are the routine maintenance to be carried out during each shift:

- Cleaning of all panels, instruments, and equipment installed in power station.
- Oiling and greasing of all equipment as per the manufacturer's instructions.
- Topping up of oil in bearing, OPU sump.
- Replacement of lamps, fuses etc.
- Cleaning of trashracks.
- Inspection of forebay, bye-pass gates, intake gates.
- Draft tube gates and appurtenant works, and
- Any other works as assigned.

Note that inspection and observation carried out during each shift shall be logged daily in control room log book.

4.4 Guidelines for Operation of Transmission Lines and Substations

4.4.1 General

The objective of the transmission and substation system is to deliver electric power reliably and economically from generators to loads. Power systems are large, highly complex, ever-changing structures that must respond continuously in real time. Electricity must be produced and delivered instantaneously when it is demanded by a load. Power outages are not acceptable, so the system must also tolerate sudden disruptions caused by equipment failure or weather conditions. In addition, the system must perform as economically as far as possible. In the hydro-based system as in Nepal, the primary objective is proper use of water resources. Another distinctive feature of the electricity system is its inherent dynamic effects, which must be considered at all times. And it is a balanced system of demand and supply at all times. The transmission and sub-station system must be designed in a way that any unbalanced situation do not become destructive and cause some or all of the systems to crash. Herein lies the basic principle of transmission system operation.

The power system in Nepal is still a regulated system and developing gradually. In the developed countries electric power system has evolved from a historic structure of regulated, vertically integrated, regionally franchised utilities to the present-day market in which competition and entry new participants is encouraged. The system operation procedures are very much dependent on the power system constitution (mixture of generating sources) and configuration (AC transmission only or DC transmission included). In the Nepalese context, the DC transmission may be of long distant future consideration only.

The current development of Integrated Nepal Power system (INPS) suggests that the structure of interconnected generating plants and loads will not be drastically altered in near future. But at the same time it will be necessary to consider upcoming interconnection with the systems of neighboring countries, particularly with the Indian system in coming days.

The control of the system requires real-time coordination between production and consumption. Most of the fundamental requirements for system operation cannot change although the rules for operating the system might (and most likely will) be altered as the system develops.

Power system operation relies on the concept of independent but coordinated functioning of multiple "control areas." A control area is a (usually contiguous) portion of the system (lines, transformers, generators, loads, and other equipment) under the supervision and control of a single operator (or group of operators at a single location or under a single administrative structure). Control center operators maintain the system's integrity-prevent outages and insure reliable operation by following reliability rules that every control area enforces. The rules are intended to balance supply and demand without creating overloads, congestion, or other similar problems. Operations are based not only on maintaining a balance between supply (generation) and demand (load) but also on controlling the frequency of the system in a distributed manner. Sufficient reserves are to be provided throughout the system so that it can tolerate the loss of any one component at any time (the "N-1 criterion"). These requirements will remain the same although the system may change as a result of restructuring of the system.

Generally, the two following models are considered during operation of transmission line system:

- The "reliability-driven model," in which markets are permitted to operate but reliability concerns limit which transactions can take place, and when necessary, previously approved transactions are curtailed in the name of reliability, and

- The "market-driven model," in which the objective is to create a market that values reliability sufficiently and is nimble and precise enough that reliability problems are solved by market responses to price signals, which reflect system limits and thereby embody reliability rules in the prices paid to generators or paid by consumers at various times and locations.

The evolution of power system elsewhere implies that the power market structure is changing in such a way that it reaches all the way to an increased use of market situations for meeting operational needs which yields higher output of electricity and more appropriate utilization of the transmission grid. As the system develops the condition will evolve that will permit the

creation of a power system that supports and encourages competition without compromising reliability or operability.
Such a market should include sufficient incentives of grid operators to maximize their throughput not only in real time but also through greater use of existing assets, e.g., by optimizing maintenance schedules, increasing live maintenance, maintaining appropriate inventories of spare parts and components, and using dynamic line rating to maximize grid utilization. In the long term, this market structures should also encourage appropriate transmission grid expansion. In a generation deficit system like Nepal Power System transmission, grid expansion also is lagging behind along with generation capacity addition.
The primary (first) objective of power system operation is to maintain system integrity. This means that uncontrolled cascading outages must be prevented. Maintenance of system integrity is referred to as "security." Closely related to the notion of security is the notion of "reliability." Although the terms are used interchangeably, reliability is generally understood to include the concept of adequacy of supply, which means that methods for procuring reliability can be devised. At bottom, however, both terms refer to the avoidance of unintended blackouts.

The transmission system operators are expected to maintain system integrity and continue to operate properly without a major disruption even when a component fails. For example, if an overhead line fails because of a lightning strike, the resulting fault requires that the line be taken out of service immediately to prevent a further expansion of the problem or damage to other system components. The protective relaying system is designed to accomplish this automatically and more or less instantaneously. The overall power system should, however, continue to operate even with this line out of service and in spite of the transient disruption caused by the fault. Likewise, even if the largest generating unit were to suddenly go out of service for any reason, the system should be able to recover and continue normal operation. Normal operation means that

- the frequency of the system stays within acceptable bounds,
- all voltages at all locations are within required ranges,
- no component is overloaded beyond the rated value, and,
- no load is involuntarily disconnected.

A second objective of power system operation is to minimize operating costs. Thus, a system operator generally has two roles: to assure reliability and, in effect, run a real-time market. When conditions were tight, security would take priority. Otherwise, economy of operation dictated the operator's objectives.

4.4.2 Tools for Managing Operation

In order to accomplish the two (sometimes-conflicting) objectives of security and economy, in the developed system, system operators employ a number of tools to manage the system in real time. These tools range from Supervisory Control And Data Acquisition (SCADA) systems that monitor and display the status of the system in real time to more sophisticated tools such as State Estimator programs. A State Estimator program gathers all available telemetry data (real-time measurements) on the system and gives a complete, real-time picture of system status. An accurate, error-free picture of what is going on in the system is an important precondition for running the system reliably. In case of the INPS, Nepal Electricity Authority (NEA) has installed a simple SCADA system so far and State Estimator Programs are yet to be employed and, therefore, is of future concern only.

Operators also have means at their disposal for direct control of the transmission grid. These include control of switching operations (inserting or removing lines and/or transformers), shunt injections (usually reactors and capacitors inserted at buses, mainly as a means to regulate the voltage profile), and control of regulating transformers and other series and shunt adjustable devices. Operators can also adjust system area set points to help regulate system frequency, control flows on exports/imports to/from other systems, and maintain within specified bounds, the difference between the total power exported by a control area and the intended exports from the area, plus a component that represents the required contribution by that area to the control of system frequency. This difference is called Area Control Error (ACE). Control of interruptible load is also often within the purview of an operator. In emergencies, many operators also have control of feeders and ordinary system load.

4.4.3 Control Areas

Control areas are central to system operation and interconnection and have well-defined boundaries. Flows of power across control area boundaries are always metered and monitored. Although it may be possible to operate a large interconnected system functioning as one control area, the practical difficulties of doing so have been insurmountable to date. Even if the entire grid were to be integrated and operated as a single whole, it is likely that the notion of control areas would survive in some form as a practical means to attain distributed, decentralized, and redundant control. The concept of Control area is still new to NPS and has not been introduced yet. It will be more relevant as inter connections with Indian system are in place when specific responsibilities are to be assigned to the respective system.

In the developed system generally every location in a power system is assigned to a control area for practical operational reasons. Every control area in the system is made responsible for balancing its generation with its load because the amount of electricity generated must equal the amount of electricity consumed, plus losses. Whenever there is insufficient generation, the entire system slows down (i.e., the frequency drops). The opposite occurs when there is excess generation. It is most practical to balance generation and load on an area-by-area basis because the interconnected system consists of multiple components. However, it is necessary to precisely measure how much power is being exported or imported by an area to know whether the area is balancing its generation and load. Gathering this information requires that every line or transformer connecting an area to any other area be accurately metered and monitored in real time, and all measurements be aggregated at a central location so that an accurate ACE can be monitored.

The individual actions of correction in the different control area to adjust the ACE for each area inevitably accumulate errors because the control actions of generators are in reality different from what was intended or instructed, these are uninstructed deviations. From these deviations arises the notion of energy imbalance. Consistent errors in one direction or the other by a number of participants (along with random changes in demand) also give rise to frequency drift, which must be corrected with frequency regulation. Uninstructed deviations have been handled by having systems "payback" the energy at a later corresponding period (peak or off peak). In case of Nepal Power System, such situation has yet to come.

It may be desirable to have more numerous, smaller control areas to avoid communication problems, handling of large amounts of data, and complexity that might make the system difficult for operators to understand.

It is a question of future operational guidelines to establish the number of control areas for system operation needs because more the control areas, the greater need for coordination among them and a considerable increase in the number of monitored tie lines that must be precisely accounted for at all times. Fewer, larger control areas, however, might make the system more vulnerable to the effects of failure of one control center. One key point is clear: all control areas need to follow uniform (or at least compatible) practices for both reliability and business activities. In case of NPS two distinct control areas: Nepalese and Indian are a practical possibility.

In any circumstances, adherence of Electricity Regulation, 2050, is a must. For example, in case of high voltage transmission line between 33 kV to 400 kV the fluctuation should not be more than ±10%, similarly in the frequency level, it should not be more than ±2.5%.

4.4.4 Security

In a power system, system security is achieved by making system operation tolerant of the outage of any component (some multiple outages are also considered). That is, the outage of any single system component (or predefined set of components) should not cause a cascading outage of equipment that leads to a total or partial blackout. The system should be secure even when an outage is the result of a "shock" such as a short circuit or fault on a component prior to the component's outage. A system that is resistant to the outage of any one component is said to be N-1 secure. In a planning time frame, N-I security means that the intact system must be able to tolerate the outage of a component. In a planning timeframe, some allowance is often made for limitations that the system will encounter in real time. One way in which this is sometimes done is by considering the simultaneous failure of any one line and any one generator when doing planning time frame studies. In an operation time frame, however, N-1 security means that the current system must be able to tolerate the "next worst" contingency. Because an actual operating system may have already sustained the outage of one or two components, this is tantamount to operating the system in an N-2 or N-3 condition from the planning point of view. Previous contingencies are "sunk events" from the perspective of system operations. This means that, once a contingency occurs, meeting the N-1 criterion means considering the altered system, not the original system, as the new base case to which the criterion must be applied.

It is almost universally accepted that N-1 security is fundamental to system operation and that achieving this level of security is in roughly the same category as making sure that generation meets load: it must be done, regardless of cost.

To maintain N-1 (or better) security and achieve a secure operating point that is resistant to cascading failures requires some preconditions:

- The system must have sufficient spinning reserves. Spinning reserves are generators that can instantaneously increase their output when a decrease in frequency signals that load is exceeding generation. If there are sufficient spinning reserves, system frequency will, after the loss of the largest generator, automatically settle to a new, acceptable value as a result because a sufficient number of other on-line generators will immediately pick up the deficiency. Generators already at their limit plus other generators that do not have Automatic Generation Control (AGC) cannot be counted on to provide spinning reserves. (The outage of a component may be caused by a fault, which may pose additional problems of a dynamic nature.) At present in Nepal Power System due to lack of generation capacity NEA resort to load shedding. But with addition of new generation capacity which are on the pipeline it is expected that there will be spinning reserves in the system at least during wet season.

The operators need to be exposed to developed system so that they can rely on experience, training, and prior offline studies that specify parameters (often in the form of diagrams or monograms) that indicate whether the current condition of a system is acceptable from a security point of view. Currently, more and more operators also rely on sophisticated power-flow and contingency analysis software that can assess system conditions in real or near-real time. Nomograms continue to serve a useful purpose to account for real-time incorporation of stability limits. If system conditions are determined not to be acceptable, the operator should have at his disposal the tools mentioned above to help address the problem. With the development of the system, it is expected that such tools will be available to Nepal Integrated Power System Operators.

4.4.5 Balancing Generation and Load

A system operator is in charge of frequency regulation in addition to system security. Electric power customers expect that power will be a sinusoidal AC voltage waveform of 50 Hertz. Many system and end user components rely on this frequency. However, without some control of frequency (frequency regulation), the frequency would quickly drift outside acceptable bounds as a result of even slight imbalances between generation and load. Responsibility for frequency regulation is almost universally organized based on control areas. As mentioned above, every formally defined control area must match its generation to its load.

In any power system the system variations is random in nature and require the balancing of production and demand over designated intervals rather than at precisely, all times (which would be virtually impossible). If a control area has "under generated" over a short period, it is expected to "over generate" to compensate for the shortage. This is accomplished by adjusting the control set point to increase the output of generators within the control area in other words, and to adjust their generator outputs if necessary, in order to balance power.

4.4.6 Operating the System Economically

In addition to maintaining security and regulating frequency, a system operator has to maintain the system economy. In Nepalese context this meant that the operator has to find out a generator dispatch pattern that is not only secure but is as economic to operate as possible under the security criterion in effect (for example, the N-1 criterion). As Nepal Power System is predominantly hydro based with the addition of unreliable thermal generation the economic system operation is to maintain minimum system losses with the available transmission lines.

4.4.7 Application of the N-1 Criterion

The N-l criterion for system operation is deterministic. It requires that the system be able to tolerate the outage of any one component without disruption and does not concern itself with the probability of an outage. Even if an outage or contingency is highly unlikely, the criterion is still generally applied because system failure when a component is lost is unacceptable. The cost of meeting this criterion is not questioned; the criterion is generally considered as fundamental as the need to balance generation and load. The consequences of a failure to balance generation and load are immediate and measurable: system frequency drifts. However, consequences of failure to meet the N-l criterion may not be directly observable unless a critical component goes out of service. The absence of actual contingencies to reveal the failure to meet this criterion can create the false impression that a system is operating adequately when in reality it is operating at great risk.

4.5 Guidelines for Maintenance of Hydropower Plants

The Section 3.0 above has explained that the preventive or scheduled maintenance is a number one priority than the other approaches. It is again, the generally preferred one and hence, this section describes, among others, the following periodic inspection checks that are recommended for this type of maintenance. The components covered by the inspection checks are (i) civil structures, (ii) hydro-turbines and auxiliaries, (iii) generator components, (iv) power transformers, and (v) hydro-mechanical equipment and hoisting arrangement.

This section also deals with the capital maintenance or overhauling that requires dismantling and reassembling of hydro-generating unit(s) along with the typical maintenance encountered in the hydro-turbines.

4.5.1 Maintenance of Civil Structures

4.5.1.1 Dam/Weir and Headwork Structures

There are no legislations, guidelines, national practice codes on Dam Safety in Nepal, which should strictly be followed. The first dam (19 m high Phewa Dam located near the city of Pokhara) of Nepal failed in 1975 due to piping in its foundation. It was reconstructed and completed in 1983. This newly constructed dam consists of concrete spillway portion and concrete abutment besides the earth-fill portion. The spillway with 4 gates has a total discharging capacity of 1,000 m^3/s, the power and irrigation intake capacity has 8 m^3/s. For power generation at full load of 1000 kW requires 2 m^3/s of water and irrigation facilities for 320 ha of land are provided. As the dam is located at the outlet of Phewa Lake, erosion of ogee portion of the spillway due to silt flow is minimum in this dam as against the eroding experiences found on the ogees of the weirs of the run-of-river projects operating in Nepal.

Some longitudinal cracks occurred on the dam crest of 114 m high dam on Kulekhani river when for the first time the storage reservoir level reached its Normal Water Level (NWL) in November 1983 are the next event faced by the storage dam component of the civil structures of hydropower plants existed in Nepal. As soon as this event occurred, a team of experts was invited for inspection. The observations of the inspection were as follows:

- A noticeable longitudinal crack was seen in the centre of the crest parallel to the dam axis nearly along the whole dam crest. Opening of this crack was variable. It had maximum width of about 15 cm in the middle and was narrowing towards both the abutments;
- In addition to continuous crack in the centre of the crest longitudinal cracks were also seen on both the upstream and downstream shoulders of the dam crest. However, opening of the cracks on the upstream shoulder was greater (maximum about 15 cm) than that of the cracks on the downstream shoulder (maximum about 5 cm); and
- Leakage water gauge was showing that the leakage quantity was decreasing from 55.79 l/sec at reservoir level 1530.074 m (on Nov. 9, 1983) to 48.9 l/s at reservoir level 1529.076 (on Dec. 29, 1983), and the leakage water was completely clear.

The inspection team based on these observations concluded the following:

i) The longitudinal cracks must have been resulted from differential settlement of different material zones of the dam body; and

ii) Clear leakage water is the indication of the absence of transverse cracks in the core, thus, the cracks were considered to be not dangerous. However the team suggested the following:

   a) To seek services of an international consultant with relevant experience in this field for receiving suggestions to take appropriate measures, and

   b) Some improvement in the monitoring system.

Later on, an international expert (Mr. I. L. Pinkerton), who had provided his services an independent expert at several stages of construction of this dam was invited. During his visit to the site, a trench of about 3 m depth was opened on the dam crest to examine the crack.

It was found that at this depth the crack was bifurcating and was slightly dipping towards upstream. However, the opening width of the crack was decreasing quickly with increment in the depth. According to suggestion made by Mr. Pinkerton the cracks in the core were filled with betonite and since then the dam has no problem in this regard.

Nearly same time, noticeable cracks and signs of movement were seen on the hill slope behind the intake gate control shaft. A possible landslide at this place could block the intake and endanger the safety of the dam as well. Japanese specialist from Nippon Koei also visited the site. The following remedial works were carried out according to the suggestions made by Mr. Pinkerton and the Japanese experts:

- Extensive surface drainage were provided;
- Opening of the cracks were filled with clayey soil;
- Removal of the upper sliding mass was carried out; and
- Sliding mass located just behind the intake gate shaft was provided with suitable anchoring into the bedrock.

After treatment of this landslide, monitoring was carried out several years, which indicated that the above mentioned measures were appropriate.

A sloping intake as well had to be constructed under KDPP (Kulekhani Disaster Prevention Project) at the side of the Kulekhani-I Dam due to the reason that there was possibility of encroachment of the existing intake by increased sedimentation caused after the rainstorm of 1993 July. The sloping intake constructed was virtually an inclined shaft structure with full opening which shall be closed by concrete stop logs one by one from the bottom depending on the actual sediment surface elevation around the intake. The Mandu head pond and intake structure of Kulekhani-II HPP that was also completely destroyed by the debris flow containing numerous boulders occurred during the same flood event.

For Kulekhani-II operating in tandem with Kulekhani-I, besides covering the destroyed headpond of Mandu intake with concrete structure, monitoring of the size of riverbed of Khani Khola was initiated in order to take up the counter measures in a timely manner against (i) closure of the tailrace outlet due to rising of the river bed, and (ii) inundation of the Kulekhani-II power station and switchyard by flood from the water level rise due to rising of the river bed.

For existing dam as described above the maintenance/remedial measures are taken case by case based on events occurred rather than scheduled type maintenance, while for the weirs/ headworks of the run-of-river type hydropower plants, the scheduled maintenance works relevant particularly for the Nepalese context being performed consist of the following:

- Epoxy and magma quartz coating application in ogee surface;
- Underwater repair/concrete works at radial gates;
- Protection of sliding down of rip-raps on the river banks during rainy season by way of construction of gabion walls;
- Repair works such as high strength concreting on the downstream of under-sluices/replacement of plum concreting of downstream apron with RCC apron and construction of cut off wall at the end;
- Removal of sediment/boulders from intake zones and from downstream of under-sluices;
- Gabion protection works for flood control;
- Strengthening of foundation of desanding channel outlets;
- Painting works, if necessary.

4.5.1.2 Conveyance System

Generally the maintenance/ cleaning and repair works to be performed relevant for the water conveyance system are as follows:

- Open Canals: Rarely the power canals are unlined, because they suffer from erosion of the banks, from subsidence of cuttings in sidelong ground, and from obstruction by floating debris and siltation. Such canals are only suitable for very small interceptions. Maintenance of such canal consists largely of keeping the channel clear of debris, patching the banks, and encouraging the growth of vegetation on the exposed slope cuttings. By the judicious use of fences in vulnerable areas, the effect of drifting and debris may be minimized. In general, the maintenance of open power canals should include inspection of blockages. Any stones, silts or vegetation should be removed from the canal. It is important to repair any damage as soon as it appears. If leaks are not attended to, they get worse and sometimes wash away the ground that holds the canal. Drainage to carry rainwater away from canal should always be inspected and cleaned or repaired as necessary. Any repair and/or maintenance of the canal should not go beyond the original design of the canal itself.
- Aqueducts: Aqueducts could, both, be open and closed. The open aqueducts, lined or unlined, will have the same problem as it is in the open canals. The comparatively high maintenance cost of open aqueducts has led in recent years to adoption of piped aqueducts. Erosion and floating debris problems scarcely arise on piped aqueducts, but for inspection purposes fairly frequent manholes must be introduced together with catch pits to intercept rolling stones and sand which seem to find their ways into any and every form of aqueduct. The catch pits require clearing out by the maintenance squad at least once a year, and the pipes should be swept through at the same time. The manholes, in conditions of severe frost introduce a problem of their own - there is often a little water in a piped aqueduct, this water will probably freeze, and with the thaw long strips of quite thick ice will start to float down the aqueduct, these often become wedged at a manhole, resulting in a blockage and overflow with consequent erosion around the manhole, which may endanger the foundation. The design of manholes, as is the provision of light baffles to guide floating ice, is receiving special attention for locations of such climatic conditions. The piped aqueducts may have been laid in trenches or above ground on stools. In case the pipe is laid above ground on stools, care must be taken to ensure that local hill water does not undermine the stools, and in case, where the pipes appear partly above ground, there must again be adequate drainage to prevent any ponding against the pipe. These points should be checked periodically by the maintenance squad. The maintenance squad should also attend the patching of concrete in pipes, pipe supports and manholes in addition to the internal and external paint works, if any.
- Desanding Basin, Forebay and Daily Pondage: If the desanding basin forms an important part of hydropower scheme as it is the silt tank and device for excluder of silt that determines the wear on the turbines, the forebay/daily pondage have also their own roles to play. There is evidence of siltation even in the daily pondage reservoirs, e.g. the removal in quantum ranging from 10,000 to 12,000 m^3 of silt per year from the daily pondage reservoir of Chilime hydropower plant has been reported. For the desanding basin other than adoption of proper silt flushing through operation of the upstream and downstream gates by following the operation manual, it requires very little maintenance. The occasional repair of concrete gates and flushing passage and other civil structures may be carried out in the suitable time. Flushing valves/gates may need attention, as there are

moving parts, which need to be lubricated about once a week. The trashrack contained in the forebay will need maintenance of clearing as it is here that all the water borne vegetation and floating debris is prevented from entering the penstock. During rainy period it may be necessary to clean even twice a day. For the trashrack cleaning special device might have to be installed.

- Tunnels: A tunnel should receive comparatively frequent inspection especially during its early life say at the end of the first year's use and again after two more years. As a result of these inspections it should be possible to forecast the period that may reasonably allowed to lapse until the next inspection may well be five years in the case of a normal-sized tunnel under moderate pressure, while the large sized tunnels really subjected to high pressures, should be inspected more frequently. The draining, inspection and refilling of the tunnel is normally organized by the station or area superintendent, but much of the detailed work and organization will fall to the maintenance squad. The maintenance foreman must be fully acquainted with the procedure and with details of the time that should be taken over emptying and filling.

  When emptying/dewatering a tunnel, it must be borne in mind that natural ground water and water that has seeped out of the tunnel into the rock will tend to return to the tunnel; hence if pressure in the tunnel is allowed to fall too rapidly, external pressures may cause serious damage to tunnel linings, particularly to the comparatively flat inverts of horseshoe or D-shaped tunnels.

  A tunnel can usually be filled a little more quickly than it is emptied, but reasonable time should be given for stresses to distribute themselves and for temperatures to settle down and, on a long length of tunnel on an easy gradient, the rates of filling must be slow enough to ensure that there is no violent surging, resulting in the trapping of air and roof slapping. It is quite easy to do serious damage to the tunnel roof by filling too quickly.

  At the tunnel intake there must be an adequate air shaft downstream of the main gate. This shaft usually vents into the gatehouse which should have ample louvers and, during tunnel filling, all the doors and windows of the gatehouse should be properly opened, or they may easily be damaged by bursts of trapped air escaping from the tunnel.

  If there is a steel pipeline at the downstream end of the tunnel, the early stages of filling should be carried out with the utmost care so that the pipeline is stressed gradually and is not subjected to violent temperature .changes. A by-pass valve at the tunnel intake, for use in filling the pipeline, is a useful adjunct, as it is very difficult to ensure that a large main gate is cracked open by the very small amount that is usually necessary.

  The maintenance gang will play an important part in the tunnel inspection and should be equipped with powerful electric or paraffin pressure lamps giving a diffuse light and not a beam. A complete and accurate record should be made of all apparent damage to the tunnel lining; even small faults may increase very quickly and become serious, and any points where water is seeping or running into the tunnel should be noted. Clear chainage markers in the tunnel are of great assistance in locating defects, for comparison after each inspection.

  If on inspection it is found that some remedial work is necessary, it is usual, unless the work is very obviously of a vital nature, to refill the tunnel and continue generation of power until all the necessary stores, tools, etc., have been got together, and until the area generation program has been adjusted to allow for a prolonged shut-down of the tunnel concerned. It is unwise to start on the repair with incomplete stores and equipment in the hope that the balance will be forthcoming. The planned approach leads to better and more economical work, and affords the opportunity of adding minor repairs to the major program, including the cleaning out of sumps, repainting of the main gate, etc.

Minor faults in concrete linings usually appear at the vertical joints of shutters, at the joints between side walls and inverts, and in any “cold joints “that may have occurred during placing of the lining. The usual minor faults that occur in a tunnel lining can well be dealt with by the maintenance gang and largely consist of patching concrete. Patching by means of mortar is virtually useless; defective concrete should be cut away to an ample depth and replaced by concrete placed against shutters. Large patches should be reinforced with steel rods drilled and grouted into the sound surrounding concrete or rock. Any deterioration of the concrete lining that is obviously a purely surface deterioration may be patched with gunite (a mixture of cement, sand and water) provided the area is not great. It is advisable to protect all patchwork whether concrete or gunite with an ample coating of bituminous paint.

Excessive leakage into the tunnel may well indicate a point of leakage from the tunnel when it is full; such places should be dealt with by pressure grouting, on completion of which the grout holes should be carefully plugged with a fine concrete, not with a pure mortar.

While the tunnel is empty, the opportunity should be taken of inspecting the main gate; if a bulkhead or emergency gate is provided upstream of it, this should be lowered and sealed, so that the upstream face of the main gate and its guides may be inspected and attended to as necessary.

Most mountain waters produce an organic growth of one type or another on the concrete lining of tunnels; this fine slimy weed-like substance will in the course of time become sufficiently thick to have a material effect on the hydraulic characteristics of the tunnel, and its roots will affect the concrete lining. These algae must therefore be cleared away periodically. If the tunnel can be held out for a considerable time, perhaps during some major repair, and can be sufficiently ventilated, these organic growths will dry out, when they may be hosed off the tunnel walls quite readily. The humid conditions which exist in most tunnels and the cost of laying out mains often preclude the use of this method, though it is the best, and resort must then be made to brushing with stiff brooms.

Bituminous paint is thought to have a deterrent effect on the rate of growth of algae in tunnels and on underwater concrete structures generally, but there is insufficient evidence to prove this point. It may be that the application of bituminous paint destroys the roots of old growth and so prolongs the period before new growth becomes excessive.

Immediately before refilling the tunnel, a methodical inspection must be made to ensure that no tools have been left behind. It is remarkable how easily a wheel barrow, shovel, or length of scaffold tube hides itself away in a dark tunnel. Great care must be taken to ensure that all men are out of the tunnel, and a strict system of working passes should be employed if any large number of men is to enter the tunnel on the day it is to be refilled. Any manholes or other entrances to the tunnel should be closed methodically as the inspection party proceeds up the tunnel.

When re-sealing manholes, new sealing rings should be employed, and in the bolted type the correct size of spanner should be used for the nuts without the addition of long pipes, crow-bars, etc., and the nuts should be drawn up in proper sequence in the manner of tightening down a motor-car cylinder head.

- Steel-lined Tunnels: The use of steel linings in tunnels has become quite common in recent years, especially with the increase in the number of underground power stations that have been built. This type of construction has led to the adoption of drop-shafts and high-pressure tunnels in place of exposed pressure pipelines leading to conventional stations. In these steel-lined tunnels the strength of the surrounding rock is taken into account in determining the necessary weight of steel, so that considerable savings in the steel could be achieved.

  Steel linings are comparatively thin and are susceptible to collapse by buckling if subject to high external pressures; special care is necessary when de-watering such tunnels.

  At inspection time, the steel lining should be looked at with a view to discovering any signs of bulging; any sign of water entering the lining should be treated at once by drilling through it, grouting under pressure, and finally making good the lining by welding. During the grouting process, the steel lining must be carefully watched to ensure that it is not buckled by the grout. Steel lining should be tested with a tap hammer periodically to ensure that no voids have been developed between it and its concrete backing; any large areas of void should be grouted.

  It is extremely difficult to prepare steel lining for painting once the tunnel has been in use, as the humid atmosphere will tend to keep it damp so that the paint will not adhere properly; the invert section is the most difficult to deal with. Sprayed metal coatings of zinc or aluminum, or a combination of the two, applied at the time of construction, afford the best-known protection and, in view of the extreme difficulty of ever re-painting linings, it is advisable to give them the best possible protection in the first instance, in view of the extreme difficulty of ever re-painting linings.

- Pipelines/Penstocks:

  Pressure pipelines laid above ground may be painted internally during the right weather, when sun on the pipeline will help to dry it sufficiently for the paint to be applied. The sprayed metal coatings mentioned above afford excellent protection, and their use is well worth serious consideration in the construction stage.

  Pipelines laid on stools tend to show a first deterioration of the internal painting close to the stool, and in advanced stages the outline of the stool can be traced quite closely on the inside of the pipe by the series of fine hair cracks that have appeared in the paint work. This phenomenon is thought to be due to minute electric currents. These areas need attention more often than the rest of the pipeline, and being in the invert they are the most difficult to treat effectively.

  A variety of modem paints is suitable for internal use on pipelines, but red lead followed by three coats of fairly thin bituminous paint, well worked with the brush, appears to give as good results as any, and is certainly better brushed on than sprayed. Brushing of the paint has the advantage for adhesion of the paint, however, it is tedious and takes a long time to complete especially for large structures like penstocks. Thus, paint application can be done either through brushing or by airless spraying, both of which has their own advantages and disadvantages. The O & M operator should choose the most suitable method for their application.

Steel pipelines are usually steeply inclined and are extremely slippery when first de-watered due to organic growth, so that the maintenance men require ample staging and life-lines before they can embark on any inspection or maintenance work.

Pipelines require more attention externally than internally. Expansion joints, air valves, and sliding pedestal bearings should be inspected regularly, and the latter should be kept clear of grit and paint during any repainting or touching up of the pipeline.

Small rusty areas should be thoroughly cleaned, and periodically the whole pipeline should be repainted. If a bituminous paint was used in the first case, a large number of coats can usually be applied before there is any necessity for complete cleaning down and repainting.

In the case of pipelines on steep hillsides, the hillside should receive inspection at the same time as the pipe to ensure that no large boulders are being undermined and are becoming a potential danger, in which case they may be broken into harmless sizes or underpinned with concrete pads.

For amenity reasons, pipelines are sometimes painted green or brown, to blend with their surroundings, but such attempts at camouflage are seldom wholly successful. Small trees may be encouraged to grow adjacent to the pipeline but should not be allowed to grow too large or too near.

It is to be noted here that in the 6.2 MW Puwa Khola Hydropower Plant there is not only a threat to the penstock alignment especially during rainy season, but also the water leakage due to crack development at the head tank/forebay due to fragile geology in the vicinity. In such case, the penstock alignment must be always under close watch along with all possible measure with crack filling, repair works with high strength concrete in the head tank/forebay, improving the penstock support blocks, constructing saddle supports, etc. such problems, however, require a thorough geological investigation.

4.5.1.3 Powerhouse Structures

The major items to be attended and necessary repair works undertaken during maintenance of powerhouse structures are leakages, river and slide protection works in the vicinity and regular painting of powerhouse building.

4.5.1.4 Tailrace

The tailrace is usually lined with concrete for a short distance, to a point where the greatest turbulence has subsided. Up to this point, maintenance is usually very light, but thereafter, in the original river bed, some minor trouble may be expected.

The tailrace lining usually consists of a base slab and concrete retaining walls. The tops of the retaining walls should be sloped to avoid any standing puddles, which may result in crazing. Adequate weep holes are necessary and should be extended a few inches from the face of the wall to avoid unsightly staining.

Screens may be provided in the tailrace to prevent fish or any other animals swimming into the machines, in which case efficient tackle is necessary for lifting the screens for periodic cleaning. Though the tailrace screens are covered by the intake screens, it is surprising how much trash reaches them. It is every bit as important to keep tailrace screens clean as it is to maintain free passage through the intake screens.

Owing to fluctuating load on the turbines, conditions downstream are not as they were in nature. The greater floods may have been abolished or much reduced by the reservoir (if the plant is with the reservoir), but the equivalent of a minor flood occurs each time load is taken up quickly by the power station; so that these minor floods are frequent and have an unnaturally rapid rise and fall, which may easily lead to scouring of the river bed and banks to an objectionable degree and for surprisingly long distance downstream of the station.

4.5.1.5 Specific Inspection of Civil Structures

The specific maintenance check of civil structures and of surrounding protection works / areas for crackers, settlements, instabilities, etc. needs to be carried out after monsoon, earthquake and/or GLOF (Glacial Lake Outburst Floods) in order to take timely the remedial measures. Similarly, monitoring of discharge at all the streams and adits before and after water filling is to be done.

4.5.2 Maintenance of Hydro-turbine & Auxiliaries

4.5.2.1 Routine Inspection and Maintenance

The following daily, weekly, monthly, annual and five yearly inspection checks are to be done for the routine maintenance of hydro-turbines & auxiliaries.

Daily Maintenance Checks:

S. No.	Items/Components/parts to be checked	Checked for
1.	Foundation gallery parts and expansion joints	Any leakage in draft tube manholes, spiral casing manhole, expansion joint, cooling water tapping.
2.	Vacuum Breaking Valve/ Air Admission Valve (if provided)	The working of vacuum bearing valve and see that there is no abnormality in the springs, seals, etc.
3.	Water Seal	i. The position of leakage of the seals and see that there is no excessive splashing and water level do not rise in top cover. ii. Note the water pressure of water sealing.
4.	Turbine guide bearing	i. Oil levels (stand still machine/running machine). ii. Note the temperature of bearing and check that the temperature of oil and guide bearing pads are within limit. iii. Note the maximum and minimum temperature and compare with readings of the previous day. iv. Any oil leakage from the bearing housing and check that oil is flowing above the bearing pads. v. Check cooling water system and oil coolers.
5.	Guide apparatus	i. Any leakage from GV (Governor) servomotor and its piping ii. Guide vane link breakage.
6.	Oil Leakage Unit	i. Any leakage from pipe line joints. ii. Satisfactory running on "Auto"
7.	Tap cover drain system	i. Main supply "ON". ii. Vibration/ noise in the pump motor iii. Any leakage from the water piping

		iv. Working and water pressure of the ejector.
8.	Centralized Grease Lubrication System	i. Any leakage from grease pipes, unions and nipples. ii. Grease container is filled with grease.
9.	Oil pressure System	i. If there is any abnormal sound in the running of the motor and pump unit of OPU. ii. The oil level in pressure accumulator and oil sump. iii. Any oil leakage from oil piping and its valves. iv. Oil level recorders as also oil film in the tailrace. v. Overheating of motor. vi. Note the timing of OPU pumps running and compare with previous day running hour. Any increase in leakage in the system can be watched.

Weekly Maintenance Checks:

S. No.	Items/Components/parts to be checked	Checked for:
1.	Greasing of Guide vanes and servomotor with centralized grease lubrication system and manually.	i. Grease in the grease container. ii. Any leakage. iii. Working of end pressure relay and solenoid valves, if defective, should be reported.
2.	Throttle filters	Cleaning of throttle filters (if provided) in the governor mechanical cabinet.
3.	Governor Compressor air filters	Cleaning of governor compressor air filters and checking of oil levels.
4.	Oil of OPU of the running machine	Checking physically oil of OPU of the running machine after taking sample through sampling cock, do the crackle test for detecting presence of water. Take remedial measures.
5.	All the bearings	Oil level of all the bearings.
6.	Coupling flanges and oil header servo tube.	Check working of shaft at coupling flange and at oil header servo tube.
7.	Cooling system	Any leakage.

Monthly Maintenance Checks:

During monthly maintenance checks, all the checks covered in weekly maintenance checks as indicated above are carried out, but while carrying out these checks more attention is paid and short shutdowns (if required) for rectification are taken.

Annual Inspection and Maintenance:

After successful running of plant for about one year, few weeks are required to be allocated to inspect rotating parts, control equipment and measuring instruments, etc. and analyze cause of change in the performance characteristics (if any). Modify/repair/replace, whenever required, the worn out parts in order to prevent forced outage of machine at later date.

Following inspection and checks should be carried out during maintenance:

S. No.	Items/Components/parts to be inspected and checked	Checked/ inspected for and remedial measures taken
1.	Water Path Parts	i. Condition of water path system. The damage due to cavitations and wear to be rectified. ii. Painting of spiral casing, penstock, draft tube. iii. Condition of stay vanes, guide vanes and under water parts for wear, tear, etc.
2.	Runner	i. Condition of the surface of the runner hubs, cone, blades and buckets. The damages due to cavitations and wear to be

		rectfited by welding and grinding. It is to be ensured that hydraulic profile of the blades is not disturbed. ii. The runner blade seals to be checked by pressurizing the system, change seals (if necessary).
3.	Guide Apparatus	i. The pressure of rubber sealing cords and the tightness of the rubber sealing between the adjacent guide vanes in fully closed position of guide apparatus (wherever provided). ii. Guide vane bedding in fully closed position. iii. Change grease in the regulating ring. iv. Replace damaged shear pins. v. Check cup sealing of guide vane journals and replace (if necessary). vi. Check the bushes of guide vanes and change the worn out bushes of guide vane journals (if possible). vii. Water jets, needles, deflectors and their servo-mechanism (if the turbine is Pelton). viii. Inspect the servomotor and change the seal (if these are worn out).
4.	Guide Bearing	i. The condition of rubbing surfaces of guide bearing. Clean the surface and polish it with the help of chalk powder. ii. Adjust the clearances by moving the segments with the help of adjusting bolts. iii. Thorough cleaning of housing is necessary. iv. Check all the RTDs and TSDs, replace damaged ones.
5.	Shaft Gland Seal and Air Seal	i. The condition of rubbing surface of sealing rings. In case found damaged, change the same. ii. Pipe lines and piping joints for leakage. If found any, attend the same.
6.	Emergency Slide Valve	i. The functioning of emergency slide valve and the condition of inner surface. ii. Swift return of the valve in its original position after emergency operation should also be checked.
7.	Centralized Grease Lubrication System	Satisfactory working of CGLS system and attend wherever fault is located.
8.	OPU	i. Leakage and attend leakage (if any) from any valve or flanged joints, etc. ii. Provide proper lubrication to the bearings of pump motor. iii. Filter and repair, if required. iv. Clean oil sump, refill with centrifugal oil. v. Setting of the pressure relays for proper sequence of operation of pumps.
9.	Oil Leakage Unit	i. The satisfactory working on auto as well as manual. ii. Clean the tank. iii. The pipeline joints and valve for leakage, attend wherever necessary.
10.	Oil Cooling Unit	i. All the oil and water pipe lines for leakage and attend if necessary. ii. The satisfactory working of all cooling unit.
11.	Governor Mechanical Cabinet (if applicable)	i. Filter the throttle; replace the same if found damaged. ii. Attend leakage of oil through pipe line joints and valves. iii. Auto rod setting. Set the same, if found disturbed. iv. Alignment of feedback wire rope pulleys.

Five Yearly Maintenance:

After every five years it is necessary to inspect / check the machine more critically for abnormalities like fatigue defects for excessive wear and tear of some parts or any change in original parameters/clearances, etc. This exercise becomes very essential in cases where performance level has been observed to have gone down in five years of operation.

4.5.2.2 Capital Maintenance

Capital maintenance or overhauling of hydro-turbine set is usually done after about 10 years of operation or as and when necessary. During this maintenance, the whole unit is to be stripped off and all the defective/worn out parts/ components repaired/ replaced with new ones. Then the unit is re-commissioned as per originally established commission practice of the power plant. After capital maintenance, the units are subjected to all the periodic maintenance outlined in above sections before it reaches the next cycle of capital maintenance. Following checks are to be exercised during capital maintenance of hydro-turbine set.

S. No.	Items	Checks to be exercised
1.	Turbine Bearing	i. Dismantling, inspection, cleaning, measurement of clearances, polishing of guide pads, centering of shaft, reassembly, setting of clearances, filling of oil sump with filtered oil. ii. Checking of the temperature sensing device. Replace with new ones, if necessary.
2.	Gland Seals and Isolating Air Inflated Seals	Dismantling, inspection, cleaning and reassembly. Replacing of worn out rubber flaps or carbon segments, if necessary.
3.	Guide Vane Servomotor	Dismantling for inspection and cleaning. Reassembling and replacing the seals with new ones, if necessary.
4.	Guide Vanes Bush Housing	Dismantling, cleaning and inspection for wear and tear, replacing with new ones, if found necessary. Replace seals as well, if necessary.
5.	Guide Vanes	i. Guide vanes are reconditioned and proper bedding in closed position is ensured. ii. Repair of guide vane journals to remove ovality. iii. Alignment of complete guide vane with all journals.
6.	Governor	i. Cleaning and checking OPU pumps. Replace bushes, bearings, etc., if found worn out. Attend also the pump motors. ii. Clean OPU sump and pressure accumulator and refill with filtered oil. iii. Attend oil pipeline flanges and valves for leakage. iv. Check setting of pressure switches installed for Auto operation for OPU pumps. v. Attend Governor mechanical cabinet (if provided) for leakages, loose links. Clean main and pilot slide valves. Set Auto rod as per designs. Alpha Beta setting may also be checked in case of Kaplan turbine. vi. Check electrical circuit. Tightening of all the connections should also be done.
7.	Under Water Parts	i. Inspect condition of spiral casing, runner chamber, draft tube cone, compensating ring and draft tube, and rectify defects by welding and grinding. ii. Penstock filling line valve, spiral drain valve, draft tube drain valve should also be checked and repaired. iii. Cleaning and painting of penstock, spiral casing and draft tube liner.
8.	Runner	i. Dewatering of draft tube. ii. Fabrication of platform in the draft tube for inspection of runner chamber/static labyrinths. iii. Inspect blades/ buckets of the runner and make up profile by welding and grinding, if found damaged due to erosion and cavitations. After weld repair, heat treatment and dynamic balancing is must before installation. iv. In case the runner is found to be irreparable, arrange to replace the same with new one.

9.	Turbine Auxiliaries	i. Drainage pump motor set for top cover drain. • Inspect top cover drain system, overhaul the ejector and drainage pump. • Check pipelines and valves. Replace gasket and other parts, if necessary. ii. Oil cooling unit • Overhaul cooling pumps. • Attend all the valves and pipe line for leakage. iii. Centralized Grease Lubrication System. • Overhaul greasing pump. • Check whole greasing lines. Replace worn out valves and gasket, etc. • Check all the nylon pipes connected with the guide vane bushes. Replace damaged pipes. • Check that all the guide vanes are receiving grease properly. iv. Clean Water System • Clean water pipes are dismantled, cleaned, reassembled with new gaskets. • All the valves are attended for any leakage. v. Oil leakage unit. • Check the oil leakage unit and overhaul the pumps. • Clean tank and check that float is properly working. • Check all the pipe lines and valves for leakage.

4.5.2.3 Typical Problems in the Maintenance of Hydro-turbines

The typical problems in the maintenance of hydro-turbines encountered are damages in runner chambers and runners due to erosion, cavitations & cracking, failure of turbine bearings and leakage of water through guide vane seals and turbine gland seals etc. They are discussed in the following paragraphs.

<u>Erosion</u>

The damages in runners, chambers, guide vanes and other underwater parts have assumed serious proportions especially in the Nepalese context due to predominance of run-of-river hydropower plants in the Nepal Power System. The rivers of Nepal carry enormous silt loads particularly during summer monsoon so much, so that the power stations had to be closed down to prevent serious damage to the turbine parts and the water conveyance system. Even with greater attention being paid to desilting arrangements, heavy damages have been observed on the runner, labyrinth seals, guide vanes, inlet valves, shaft seals and draft tube cone. The wear due to silt occurs so fast that the unit has to be taken out for reconditioning every few years. The remedy appears to lie in effective desilting arrangements and manufacturing of turbine parts with harder and erosion resistant materials like stainless steel of proper grade. In the Chilime hydropower plant (22.1 MW), even in the peaking pondage reservoir in the water conveyance system enroute to powerhouse, sediments used to be trapped. The annually removed sediment from the pondage reservoir amounted in the range from 10,000 to 12,000 m^3 per year.

<u>Cavitations& Cracking</u>

The phenomenon of cavitations occurs due to the vaporization of flowing fluid in a zone of excessive low pressure. Normally the discharge side surface of buckets or blades, areas on the crown on the throat ring and the tip of blades and the upper portion of draft tube liver are affected by the action of cavitations. The problem of cracking of runner and pelton buckets can be due to (i) faulty design and fabrication, (ii) poor metallurgy, and (iii) metal fatigue. In order to minimize cavitations following steps are appropriate:

- Annually inspect the runner and other turbine parts and take remedial measures.
- Operate the machine as per the instruction given by the manufacturers. Mind that the unit should not be run below certain specified load to avoid cavitation prone zones.
- Cavitations can be effectively controlled at the design stage itself by way of ensuring proper submergence, use of cavitation resistant material and adoption of optimized runner profile based on model test.
- Vibrations, excessive noise and cavitations are also experienced as a result of draft tube pulsation and surges at no load or part gate opening. For minimizing the pulsation of the draft tube, the following measures are to be taken:
  - Air admission through air admission/vacuum breaking valve installed at top cover.
  - Provision of fins of flow splitter in draft tube to break the vortex flow.
  - Provision of a by-pass arrangement for releasing the pressure built-up below the top cover.

<u>Failure of Turbine Guide Bearing</u>

A number of cases of turbine guide bearing failures have come to notice depending upon types of guide bearing designs (plain water cooled bearing, bath type bearing and grease lubrication bearings). In the case of plain water cooled bearing, either ferrobestos or rubber lined pads are used against a welded shaft sleeve. The ferrobestos lined bearings have given considerable trouble at one of the power plants in India and these had to be replaced by rubber lined pads. Complaints of excessive oil splashing have been recorded about the rotating bath type bearing, while the grease lubrication bearings have a tendency to clog when in contact with the water and it is very essential to use grease with the right type of properties.

<u>Shaft Gland Seals</u>

Two types of shaft gland seals (i) carbon or ferrobestos segment (ii) Rubber flap are generally in use. The maintenance of rubber flap type gland seal is simpler and easier over the carbon or ferrobestos segment. Only the precaution to be taken during assembly of rubber gland is to see that the jointing of the rubber seal is done in the proper way. It is, however, to be noted that the quality of rubber used plays a very important role for satisfactory performance of the rubber gland. The shaft sleeve should also be checked, it should be circular and smooth and properly secured on the shaft. In case of carbon or ferrobestos segment type of shaft gland seals, the seal segments are housed in stuffing box, which being always in touch with the shaft is subjected to excessive wear and tear. The overhauling of the staffing box becomes necessary when it is observed that consumption of cooling water has considerably increased or excessive water in top cover appears to be coming. Normally the maintenance of this type of seals is required to be done annually. In the event of breakage or damage to a carbon segment, it is advisable to replace the whole set of carbon segments. In very rare case only, the damaged segment is replaced. Whenever reassembly of the gland seal with existing gland ring or new ring is done it is important to ensure:

- All carbon/ferrobestos segments are carefully examined for any chipping or damage.
- All stainless steel facings are flat and square with the gland sleeve and there are no steps at the facing joints.
- Stainless steel facing and sleeve are completely free from grease.
- Ensure proper bedding of segments with shaft sleeve.
- All segment to segment and segment to stainless steel mating surfaces are perfect.

- All garter springs are assembled to obtain even tension all around.
- Alignment of segments in the lower assembly is carefully checked with a hard wooden peg or similar device before fitting retaining pins.

Guide Vane Servomotor

In the guide vane servomotor, main source of trouble is rubber cup seals, which need to be replaced after a few years. Normally rubber seals are replaced during capital maintenance. It is important that all the parts are match marked before dismantling so that reassembly is correctly done.

Governor

Governors are of four types (i) mechanical (ii) governor employing magnetic amplifier (iii) governor employing electro-hydraulic amplifier, and (iv) digital governor. The digital type of the governor is maintenance free and fast response modern day governor, while the other three types of governor may require maintenance because of the following reasons:

- Chocking of oil parts and throttles.
- Wearing out of throttles due to which oil leakage becomes more and readjustment of governor becomes essential. In this case, governor should be opened and all the throttles, etc. should be cleaned. Filters also should be cleaned, and after cleaning and reassembly, governor parameters and characteristics should be readjusted so that there is no hunting of the governor.

Governing Oil System

The normal problem, which had been faced in different hydropower stations, is entry of water in the governing oil system particularly from top cover through oil leakage pumps which caters leakage of servomotor oil. Its sump being located well below the level of servomotors in the top cover may not be properly sealed, thus providing access to the top cover water which may ultimately delivered to the OPU sump. To eliminate this problem the oil leakage unit delivery should be isolated from the OPU sump and connected to a separate tank.

The oil sump should be properly cleaned and filled with filtered oil. The oil samples should be got tested for verification of the desired properties. Regular centrifuging of oil with the help of De-Laval type oil purifying machine would go a long way in enhancing the life of the oil. In certain case, oil retained its properties even up to 15 to 20 years of continuous use. During annual overhauling, the OPU sump and pressure accumulator should be completely emptied and cleaned. The strainers should be inspected and repaired, if necessary. The OPU pumps require maintenance when they develop excessive noise or vibration. This may be due to some worn out bearing, screw/impeller and body of the pump, which would be replaced. Some time oil level in sump is found decreased which may be due to system leakage in the system. This requires to be attended.

4.5.3 Maintenance of Generator & Auxiliaries

4.5.3.1 Routine Inspection and Maintenance

The following are the hourly, daily, weekly, monthly, quarterly, half-yearly and yearly maintenance checks to be conducted on the generator components.

Hourly Maintenance Checks

Hourly maintenance check is done to keep the temperature record on log sheet for core and winding, hot and cold air of the stator. Similarly, the temperature of Thrust Bearing pad and oil as well as the same of Guide Bearings are measured by RTD & TSD and recorded on log sheets. The checking of the temperature of cold & hot water of oil pipeline / external oil cooling system is also done on hourly basis to keep record on log.

Daily Maintenance Checks

The daily maintenance checks are normally done for the following:

S. No.	Assembly / Item	Check for	Remarks / Remedial Measures
1.	Stator / Core	i. Abnormal noise around stator through periodic listening ii. Temperatures through temperature scanners	i. Checking for core looseness especially at the frame joints. If abnormal add additional paramax paper in core joints. ii. Check cooling system.
2.	Stator winding/ stator coils	Winding temperature through temperature scanners	Check cooled air & cooling system.
3.	Guide & Thrust Bearing / Bearing Pads	Bearing temperature by R.T.Ds	Abnormal vibrations, Balancing of rotor, choked oil coolers, contaminated oil, bearing clearances.
4.	Bearing Oil/ Oil Level	Gauge level is checked visually	i. High –due to water leakage. ii. Low – leakage of oil from Housing.
5.	Air coolers / cooler tubes	Water leakage is checked visually	Plug the leaking tubes
6.	Slip ring and brushes / Brushes	Check visually sparking mix of Dust / oil	Cleaning
7.	Brake and Jack / Air Pr.	Check by pressure gauge	Check for leakage pipe line, joints.
8.	D.C. exciter / commutator brush gear	Check visually commutation	
9.	Brushless excitation system / AC exciter and rotating Diodes	Check by periodic listening: Abnormal noise around stator	Checking for core looseness

Weekly Maintenance Checks

The weekly maintenance checks are done for the following:

S. No.	Assembly / Item	Check for	Remarks / Remedial Measures
1.	D.C. Exciter: i. Cooling ring ii. Brushes iii. Commutator	Visually check for accumulation of dirt and pitting. Sparking, chattering, wear and clearance	Smoothen collector surface clean, compare IR value Brushes are not sticking in their boxes. Adjust Brush. Rough or high spot on commutator/ smooth surface
2.	Brake / Lining	Air leakage, excessive wear visually	Attend leakage / check air pressure, clean track, change lining.
3.	Brake / Track	Clean liners & oil sludge / Moisture trap visually	Clean Drain Trap and clean Brake Track

Monthly Maintenance Checks

The monthly maintenance checks are done for the following:

S. No.	Assembly / Item	Check for	Remarks / Remedial measures
1.	Slip ring & Brush Rocker	Clean the brush rocker, brushes, slip rings and surrounding areas	Special care be taken to clear carbon dust from "V" shaped insulation pieces fitted between slip rings.
2.	Slip ring and Brush Rocker	Check distance of brush holder from slip ring and keep it as specified in the drawing	
3.	General	i. Blow with compressed air the internal surface of the generator. ii. External inspection of current carrying leads; PMG (Permanent Magnet Generator), Bus Bars, Terminal Blocks, Panels, etc. iii. Check the condition of lighting inside the barrel	To be cleaned, if necessary
4.	Oil Pipe Line	i. Check the operation of the electrical contact pressure gauge. ii. Check conditions of gland packing of the pump and see that air is not being sucked into the system. iii. Check the operation of D.C. pump motor set (if provided)	
5.	Stator Core/Back of stator core	Check visually	Adjust core packing of jack screws, insert paramax paper.
6.	Field winding / Field Coil top	Check visually or through filter gauge	Clean through compressed air.
7.	DC exciter/ commutator, Brush gear, Air filter	Check visually	Replace brushes, clean commutator and risers. Clean with detergent solution. Dry the same.

Quarterly Maintenance Checks

The quarterly maintenance checks are done for the following:

S. No.	Assembly / Item	Check for	Remarks / Remedial Measures
1.	Slip ring/ Brush rocker	i. spring tension ii. Check pitting and grooving slip ring. iii. Check carbon brushes for absence of pitting and severe wear and tear.	i. Use a precision spring balance for adjusting spring tension. The carbon brushes can be used till it is not possible to measure / adjust spring tension. ii. In case of excessive grooving rectify by grinding. iii. In case the damage is excessive, replace complete set.
2.	Guide Bearings	Analysis of oil from oil bath	Record to be kept
3.	General	Check connections of current carrying leads & cables. Tighten the bolts, if required after removing the insulation.	

Half-Yearly Maintenance Checks

The half-yearly maintenance checks are done for the following:

S. No.	Assembly / Item	Check for	Remarks / Remedial measures
1.	Stator	i. Visual inspection of the overhang parts of the stator winding. ii. Checking of the fixing of winding, condition-winding joints with bush bars, etc. iii. Clean the winding with dry & clean compressed air.	Cleaning to be done such that the dust does not collect inside machine.
2.	Slip ring and Brush Rocker	i. Check IR value of rotor through slip rings before & after cleaning slip rings. ii. Check all fasteners of slip rings, brush rocker & current carrying lead	Keep a record.
3.	Thrust Bearing	Analysis of oil from oil bath	Record to be kept.

Yearly Maintenance Checks

The yearly / annual maintenance checks are done for the following:

S. No.	Assembly / Item	Check for	Remarks / Remedial measures
1.	Stator	i. Check overhang parts of stator winding, bush bars, inner periphery of stator core (if possible), parts of stator winding in slots (specially at sector joint) binding & spacers between the winding bars/ bandage rings. ii. Check looseness or overhang bush bars slot wedges, etc. iii. Check the fixing of stator active iron (core) with the frame body in all possible places, Tighten the studs of pressing plates, if necessary. iv. Check pins & fixing of stator with foundations. v. Check D.C. resistance, IR and PI Value vi. Check functioning of RTDs of stator. vii. Blow the windings, active iron and bandage rings etc. with dry & clean compressed air. viii. After cleaning apply Red-gel coat on the overhang. ix. Joint bolt tightness and dowel pins of the frame.	iv. Record is to be maintained. v. Record is to be maintained. viii. Retighten (if necessary by hammering. ix. Any local looseness between punching can be filled up with

		x. Tightness of the core xi. Core duct xii. Stator winding	paramax paper glued with epoxy varnish and core bolts retightened. After repairs spray the top & bottom packs with loctite -290. Check visually for contaminations and clean with dry compressed air. Check visually cleanliness and general condition. Then clean the end windings.
2.	Rotor	i. Check rotor winding and insulation condition of current carrying leads. ii. Check the condition of inter-polar connection. iii. Check the condition of damper winding. iv. Check the locking of pole wedges. v. Check locking of rim wedges vi. Check the gaps of spider arms, brake tract. vii. Check tightening & proper locking of all fasteners. viii. Clean rotor from dust by blowing compressed air free from moisture. ix. Measure DC resistance and IR value of rotor winding. x. Check the pole coils for inter turn fault. xi. Rotor assembly (tightening of fasteners) – tighten all the approachable fasteners on rotor assembly including tightening pole and rim keys & local all of them. xii. Check the rotor gap. xiii. Check vibration.	• Carry out additional wedging if required. • In case, the wedges are loose, contact manufacturer before attempting any rectification. • Keep a record.
3.	Slip Ring & Brush Racker	i. Interchange polarity of slip rings. ii. Carry out thorough cleaning of slip ring area. Stop oil leakage in this area. iii. In case the original insulating enamel is peeling off remove the balance enamel and apply fresh enamel iv. Check visually general conditions and cleanliness.	• While cleaning avoid using insulating paint removers. • If the slip ring is running out, correct it. Any grooves etc. to be removed by oilstone, grinding or turning to prevent excessive sparking. All the insulated parts are to be cleaned by dry compressed air.

4.	Thrust Bearing	i. Measure insulation resistance of T.B. disc. ii. Check calibration of the TSD's & RTD's of thrust bearing. iii. Check the working surface of thrust bearing pads, scrapping, if required, should be carried out with respect to T.B. disc after applying lard (animal fat) on the pads and giving rotation to the unit. Load sharing on T.B. pads and the verticality of the unit is to be checked thereafter . iv. Check visually the condition of weld seam of oil bath & oil pipe lines for leakage. v. Check the condition of insulation of RTD leads.	
5.	Guide Bearing	i. Measure insulation resistance of G.B. pads. ii. Check calibration of TSD's & RTDs of GB. iii. Measure and record guide bearing clearances. iv. Check bearing insulation and vapor seal insulation by measuring IR value. v. Check each pad for (a) absence of scratch marks (b) heavy damage on bebbit surface of pads vi. Check the friction surface of the bearing journal. vii. Wash pads & journal with aviation petrol and then carry out assembly of the guide bearing. viii. Check the condition of welding seems of oil bath & leakage from them and oil pipe lines. ix. Clean all inner surfaces of oil bath, wash them with kerosene and dry with clean cloth. x. Check operation of the level relay and its calibrations. xi. Check welding of pad support block with oil bath. xii. Check looseness of pad and pad support bolts.	• If the pad clearance has to be reset the shaft must be centered first. • Replace insulation, if needed. • Full set is replaced from spares • Carry out its polishing, if necessary. • Oil bath is to be finally flushed with fresh turbine oil to be discarded after use.
6.	Air/Oil coolers	i. Visual and pressure test in the cooler tubes. ii. Check water boxes for clogging by opening them. iii. Check the gasket between oil cooler and oil bath & between air cooler and stator frame.	• Clean inside & outside of tubes. Check for any tube leakage by pressurizing to a pressure slightly more than maximum expected working pressure. • In case of clogging, clean with wire/nylon brush. Remove all dirt, etc. & finally clean with fresh water & dry. • Gasket to be replaced, if necessary.

7.	Upper and Lower Brackets	i. External inspection ii. Check fixing of the generator cover plate. iii. Check all fasteners of upper and lower air baffles. iv. Check the value of air gap between air baffles and rotor. v. Clean the brackets of dir& dust. vi. Check fastening between upper bracket & stator and foundation plates. vii. Check foundation bolts tightening for stator and lower bracket. viii. Check all fasteners for locking / tightness.	• Tightening of the lock nuts in the radial jacks, if required. • These gaps are to be compared with original values and maintained as such. • Cleaning can be done more often if possible.
8.	Overhauling of Brake system.	i. Check thickness of brake pad. ii. Check if excessive brake dust is generated and find its cause. iii. Check function of the breaking system on manual and auto and the operation of limit switches of brakes. Check leakage through pipelines during braking. iv. Check the condition of brake track and its holding with the rotor. v. Open brake-cum-jack assembly. Clean the inner surface of dust with kerosene and reassemble. vi. Brake limit switch.	• Record is to be maintained. • Clean the affected areas. • Record is to be maintained. In case of any problem brake panel & brakes are to be checked & rectified. • Replace the gasket, if required. • Proper operation and cleaning.
9.	General	i. Check the vibrations at TGB (Thrust Guide Bearing), UGB & LGB (Lower Guide Bearing) at predetermined points. ii. Check the calibration of all electrical measuring instruments. iii. Check the sensitivity and stability of generator electrical protection scheme.	
10.	Oil pipe line	i. Completely clean the oil tank & T.B. oil bath. ii. Clean the oil pipe line after disconnecting it. iii. Check the operation of the valves of the pie line. iv. Check all sample for acidity, viscosity, moisture content foreign material & sludge-formation. v. Clean holes for oil entry into the T.B. housing	• Separate oil sample for each bearing should be sent for chemical analysis & record to be kept.
11.	HP Lubrication system	Inspect bearing & grease. Check the condition of the hoses as well.	Replace the hoses, if necessary.
12.	PMG/ Air Gap Winding	General condition & cleanliness.	Check air gap, clean the stator & field windings. Check the open circuit voltage and if less than specified, re-magnetize.
13.	Shaft run out & centering & rotor level		Readjust, if necessary

14.	Water flow relays, flow indicators & flow meters	Visual inspection	Clean water passages, if necessary, remove silt, check movement of flap and electrical contacts.
15.	Electrical connections	Electrical joints by way of tightness	Tighten all electrical joints.
16.	Generator Auxiliaries	Check for proper operation	
17.	Cooling water valves	Check for proper operation	Clean and replace glands where needed.
18.	Over-speed devices	Check for proper operation	

Note: The need to focus particular attention to a specific area of the generator or the need to perform specific investigative tests is often determined by past operational experience, the accumulated maintenance history of the unit, unusual operating conditions, or unusual changes in the unit's performance. Unusual operating conditions may include excitation disturbances, unusual or abnormal vibration or noise, voltage or power surges, overloads, loss of cooling water, or unexplained excursions in generator temperatures.

4.5.3.2 Capital Maintenance

For capital maintenance of hydro-generator, the generator is first dismantled. The procedure for dismantling is as follows:

- Record insulation resistance value of stator, rotor and exciter;
- Decouple generator shaft and turbine shaft after recording guide bearing clearances, air gaps between stator and rotor, air gaps of main, pilot exciter & PMG etc. if mounted on shaft;
- Dismantle other components one by one in proper sequence till rotor is free to be lifted.
- Rotor should be taken out very carefully and kept in rotor assembly pit duly bolted with base place. Rotor rim needs to be supported by blocks and jacks all around the circumference;
- All stator air coolers are to be dismantled and kept for testing and repair;
- Breaking and jacking units are to be dismantled;
- All cares are to be taken during dismantling to ensure safety of all components, fasteners, pins and temperature sensors, etc.
- Prior arrangement of proper T & P, special T & P, slings, D-shackles etc. is also necessary.

After dismantling, the maintenance of generator components is carried out one-by-one as follows:

S. No.	Generator Components	Maintenance Activities
1.	Stator Frame	All the joints, tightness of bolts and location pins, etc. are checked. They are retightened, if necessary.
2.	Stator Core winding.	• Tightness of core especially at the top and bottom packets is checked; • Any local looseness between punching can be filled up with paramax paper glued with epoxy varnish & core bolt retightened. • After repair spray top and bottom three packets with locite - 290; • Clean core duct with dry compressed air; • Clean the ends of winding; • Measure IR value of winding after thorough cleaning. After assembly dry out if IR is low;

		• Carry out Electronic Core Imperfection test also to ensure healthiness of core; • After rectifying all defects and thorough cleaning of the inner bore and overhang portion is done and winding is to be spray painted. Paint used should be specified insulating paint.
3.	Rotor	• The rotor is to be thoroughly cleaned with dry compressed air; • Check general condition of coil and pole, clean with dry compressed air; • Check the coil joints for any cracks due to overheating, etc.; • Check field coils and rotor leads for inter twin fault. Measure impedance of coils by applying 60 to 100 VAC, 50 c/s. if the impendence of some coil is very low (<4%), they must be checked for possible inter turn faults; • Shaft is to be checked specially at G. B. (Guide Bearing) journals for any marks, roughness etc. Remedial measures are to be taken if marks, roughness is found. • Check top and bottom rotor fans. If found damage replace the same; • Check tightness of all the joints of rotor spider and extension arms; • Check tightness of rotor rims, pole key, rim keys, etc; • Check rotor gap. • Check vibration. • After rectification of all defects and thorough cleaning, spray paint the rotor pole with insulating red-gel paint; • Keep the rotor covered with appropriate cloth to prevent deposit of dust and fire safety; • All safety precautions for external damage, fire, etc. are to be taken during maintenance period.
4.	Brush gears and slip rings	• Check if there are grooves, roughness high points use oil stone for rectification; • Check brush gear connections, clean all the insulated parts with dry compressed air.
5.	Guide &Thrust bearings	i. <u>Guide Bearings</u> • Check condition of housing; • Check condition of pads. If required bedding is to be done; • In case babbitt material found damaged or thinned, rebabbitt pads with proper grade of white metal; • Check insulation of pads. If found damaged, replace the same; • Check IR value; • Check all RTDs & TSDs and calibration of temperature indicators. ii. <u>Thrust Bearing</u> • Check condition of pads. If found some damage to babbitt material, get rebabbitting done; • Get bending of pads done to ensure removal of high points and having desired contact area; • Check bearing insulation by measuring IR value. Replace insulation if found damaged; • Check insulation of vapor seal also and replace, if found damaged; • Check housing, pivot points of thrust bearing; • Check all the pressure gauges and level indicator; • Check all RTDs (Remote Temperature Device) & TSDs (Temperature Sensitive Device) and calibration of temperature indicators.

6.	Air and Oil Coolers	• Clean inside and outside of coolers; • Check for any tube leakage by pressurizing to a pressure slightly more than maximum expected working pressure; • Change full set of tubes or change only leaking tubes, if more than 10% tubes are leaking; • After repair paint the body of cooler.
7.	H.P. Lube System	• Inspect bearing and grease; • Check the condition of hoses. Replace if necessary; • Check for any leakage and take remedial measures; • Check pressure gauges.
8.	Flow relays, visual flow indicators and flow meter	• Inspect, clean water passages and remove silt; • Replace all defective meters.
9.	Braking and jacking system	• Check brake units and clean inside and outside of the unit; • Change seals; • Carry out hydraulic test; • Clean the filters, bowl of lubricator; • Check brake track, tighten dog clamps; • Check working of brake limit switches; • Replace brake lining, if necessary.
10.	General checks	• Check condition of current carrying leads; • Check all water & oil valves for their proper working; • Check general operational healthiness of all auxiliaries; • Check proper working of over –speed device.

4.5.4 Routine Maintenance of Power Transformers

The maintenance of power transformers is also an ongoing process as the maintenance of other major generating equipment and their components. The preventive or routine maintenance is being carried out rather than acting when a fault occurs. The inspection procedure and action required (if unsatisfactory condition indicated) are given below in a tabular form. The time schedule of periodic maintenance has also been given in the table.

S. No.	Item to be inspected	Inspection Procedure	Action required, if unsatisfactory condition indicated
A. Hourly			
1.	Ambient temperature	Take air or water temperature respectively near transformer or at the inlet depending on air or water cooled transformers.	Record the temperature
2.	Winding temperature	Check for abnormalities in relation to ambient temperature and load	If the temperature indicated is more than envisaged as per loading condition, check: • That radiator valves or cooler circuit valves are all open; • Fans operate at set value of temperatures; • Fans/oil pumps are in circuit; • Calibration of OTI (Oil Temperature Indicator) and WTI (Winding Temperature Indicator).
3.	Oil temperature indicator reading		- Do -
4.	Load (Amperes)	Check against rated figures	Reduce load (if it exceeds the specified limits)

5.	Voltage		Correct tap position in line with voltage.
6.	Transformer/ shunt reactor humming and general vibration	Check for any abnormality in sound	Tighten any looseness in external parts. If abnormal sound persists, complete checking will have to be done.
B. Daily			
1.	Oil level in transformer/shunt reactor	Check oil level from oil gauge glass	• Top up, if found low; • Examine transformer shunt reactor for leaks; • Tighten gasket joints at the leak points.
2.	Oil level in diverter switch	Check oil level from the gauge glass	• Check sealing gasket between diverter switch and transformer/reactor tank, if oil leakage is found; • Top up oil.
3.	Oil level in bushings	Check oil level from the oil gauge of the bushing in which oil remains separate from the tank oil.	• If low, top up oil; • Examine bushing for any oil leakage.
4.	Pipe work and accessories for leakage	Check for oil leaks	• If leakages are observed, tighten evenly the gasket joints. Replace "O" ring or washer suitably. • Replace gasket, if needed.
5.	Relief vent diaphragm	Check for any crack	• If cracked/ broken, replace; • If broken, ensure from other protections provided that there is no fault inside the transformer.
6.	Fans/oil pump running	Check that fans/oil pumps are running as required	• Check connections; • Correct them if found defective.
7.	Oil & cooling water flow	Check oil and water flow indicators	• Check opening of valves, if restricted flow observed.
C. Weekly			
1.	Leakage of water into cooler	Check by opening the end covers of cooler.	• Plug the tube leaking
2.	Operation sequence of oil pump and the cooler	Change over from one cooler to the other	
3.	Operation of anti condensation heater in marshalling box and OLTC motor drive panel.	Check anti condensation heaters are working	• Set them right if not working
D. Monthly			
1.	Dehydrating breather	• Check color of silica gel • Check oil level in the oil cup and contamination of oil visually • Check that air passes are free	• If more than half of silica gel has turned pink, change by spare charge. The old charge may be reactivated for use again. • Add oil, if required to maintain oil level. Replace oil, if contaminated. • Ensure free air passes
2.	Maximum pointer of OTI and WTI	Record the maximum oil and winding temperature readings	Check whether the readings are within permissible limits. Reset maximum

		reached during the month.	pointer of OTI and WTI
3.	Operation of fans	In mixed cooling in ONAN/ONAF, if the temperature of oil has been less than the fan control setting temperatures, operate the fans manually to check their running.	Ensure smooth running of fans
E. Quarterly			
1.	Bushing	Visual inspection for cracks and dirt deposits	Clean dirt deposits. If cracks are observed, cracked bushing should be rectified/replaced.
2.	Cooler fan bearing and control pumps	Check contacts and manual control	Lubricate bearings. Replace worn out contacts. Clean fans and adjust controls.
3.	External earth connections	Check all external connection for discoloration or hot joints	If loose, tighten them.
4.	OLTC	• Examine contacts, check step by step mechanism operation, end position limit switches and brakes • Check that wiring is intact and all terminals are tight.	• Replace all the worn out and burnt contacts. Set limit switches in position. Clean/replace brake shoe lining, lubricate all bearing and coupling points suitably. • Tighten terminals, if found loose.
5.	Marshalling box	Check wiring and that terminals are tight	Tighten them, if found loose.
6.	Oil in Transformer and diverter switch	Check for dielectric strength and moisture content	Take suitable action to restore quality of oil.
7.	Insulation resistance	Measure IR value between windings and to earth	Compare with previous values. The comparison should be done with these values where transformer/reactor is connected externally to the line and bus ducts. If the values are low, measure IR values after isolating it.
8.	Oil bag sealing arrangement where provided	Check pressure of oil outside the oil bag in the conservator	If oil is present, check leakage in the oil bag by applying air pressure
F. Half Yearly			
1.	Alarm, trip and protection circuits	Check operation of alarm/trip contacts of each protection by actual initiation and also check display and annunciation on the panel.	In case of faulty operation, check contacts and wiring circuits.
2.	Oil in bushings	Check BDV and moisture content of oil.	Replace with fresh oil
3.	Vibration level of tank walls for shunt reactors.	Measure vibration level	Compare with previous values.
G. Yearly			
1.	Oil in transformer / shunt reactor	• Complete testing of oil. • DGA (dissolved gas analysis) of oil.	Filter to restore the quality or replace, if the values have reached discarding limit.
2.	Oil and winding temperature indicators	• Calibrate and also check difference between WTI and OTI by feeding current to the WTI pocket heating element. • Check oil in the pockets.	• Adjust if found reading incorrectly. • Replenish, if required

3.	Magnetic oil level gauge and prismatic level indicator	• Check oil level in conservator by dipstick method. • Clean the oil gauge glass	• If oil level indication is not correct, check the float. • Replace glass, if cracked.
4.	Buchhloz relay	Mechanical inspection: • Close valve between Buchhloz and conservator and lower oil level. • Check the movement of floats for rise and fall. • Check tightness of mercury switches. • Check the operation of alarm and trip contacts by air injection. • Clean cable entry terminal box.	• Buchhloz contacts should operate when oil level comes below Buchhloz relay level. • Make the movement smooth • Tighten clamps, if loose. • Check contacts, if abnormality found. • To be sealed to avoid ingress of moisture
5.	Fan motors	Check IR value of motor winding, noise and vibration of fans	Dry out, if found low. Check balancing of fans.
6.	Tanks and accessories	• Check painting and surface finish • Mechanical inspection of all accessories	• Touch up/repaint, if required • Replace any component found damaged.
7.	Gasket joints	Check the tightness of bolts.	• Tighten the bolts evenly to avoid uneven pressure.
8.	Earth resistance	Check earthing resistance	• Take suitable action, if earth resistance is high.
9.	OLTC	• Diverter switch servicing • Check the contact of diverter switch for burning or pitting marks	• Draw out diverter clean & tighten contacts. • Recondition/ replace, if required.
10.	Bushing top connectors and arcing horns	• Check contact joints. • Clean arcing horns and check gap	• Retighten. • Adjust arcing horn gap
11.	Air bag sealing arrangement where provided.	• Check healthiness of air bag	• Clean, if required
12.	Cable boxes, if provided	• Check for sealing arrangements for filling holes. Examine compound for cracks.	• Replace gasket, if leaking. Replace compound, if necessary.
13.	Lighting arrestors	• Examine for cracks and dirt deposits. • Measure IR value of each stack • Measurement of leakage current	• Clean or replace • In case IR value is poor, replace.
14.	Off circuit tap switch	• Move from minimum to maximum tap position & return to minimum position. • Check resistance measurement at each tap.	• Compare resistance values with previous results. If resistance is high, tap switch contact to be attended to.

15.	Condenser bushing	• Measure power factor/capacitance measurement	• Dry out bushing if values are abnormal and replace oil, if required.
16.	Electrical tests	Carry out: • Resistance measurement at all taps for transformers with off circuit tap switch and at maximum, minimum and normal taps for transformers with OLTC, • Magnetizing current at 415 volts. • IR values after isolating the transformer. • Turn ratio	• Compare with previous values. In case of abnormality, investigate causes.
17.	Oil coolers	Clean oil coolers. Check for leaky tubes.	Flush cooler tubes, repair leaky tubes. If more than 10% tubes are leaking, replace the total tube nest.

H. 7-10 Yearly

As there is continuous deterioration of oil and insulation in a transformer, it is preferable that the core and windings and the inside surfaces of tank be thoroughly cleaned for any deposits. This can be done while the transformer is in position. Close all valves connecting the cooler circuit/radiators to be the tank. Drain oil from the tank while letting the dry air to go inside. Clean core and winding by hosing down clean dry oil through the inspection cover. Remove dirty oil from the tank and wipe off this oil from the tank bottom. Let there be a continuous entry of dry air into the tank while the cleaning activity is on so that there is a minimum contact of the transformer core and windings with the atmospheric air. Similarly, drain oil from cooling circuit and radiators and fill dry clean oil.

Where transformer windings are to be taken out due to any reason such as to repair a damage, thorough washing due to sludge formation or for thorough inspection to locate a fault as a result of DGA or some other tests, after carrying out the necessary works for which the transformer was opened, do the following also:

- Tighten all coil clamping screws to remove looseness from the windings, if any;
- Tighten all nuts and bolts whether metallic or made if insulating material on mechanical and electrical joints;
- Tighten core yoke bolts, core-clamping screws, etc.

I. 20 Yearly			
1.	Life assessment tests	DP and Furan content measurement	Under the normal operating condition transformer has a useful life of about 25-30 years. This may vary considerably depending upon the overloads it has carried and the temperature at which it has worked during its span of operation. Therefore, for any future planning it may be worthwhile to know well in advance the remnant life of the transformer in service. This can be done by assessing extent of degradation of cellulosic paper through furan content in transformer oil or/and degree of polymerization (DP) of paper. It is proposed to carry out this study after a period of 20 years of service. After knowing the remnant life of a transformer, the action can be planned in conjunction with life assessment studies on generating unit.

Besides, the partial and complete services as follows are recommended for transformers.

Equipment Name	Type of Maintenance / Service and Activities	Time Interval
Transformer	(a) <u>Partial Service</u> • Perform diagnostic tests as per manufactures instructions. They include: – oil tests (dissolved gas analysis, dielectric test, color test, acidity test and interfacial tension test), – test for gas in the nitrogen blanket (if applicable). • External inspection & maintenance – Inspection of the transformer includes the concrete pad, bolts, grounds, bushing, oil leakage, paint condition, and all connections, – Maintenance includes checking all temperature and pressure switches to ensure operation at the proper values, checking gauge calibrations, lubricating, cleaning, adjusting aligning and checking control circuits, testing operating fans and oil pumps (if applicable) and making any needed repairs, recording all required gauge, meter and counter readings and performing the tap-changer maintenance if so supplied. • Check the nitrogen pressure (if applicable) and add nitrogen as required. Also check the oil conservator system (if applicable). • For placing the transformer back in service, test all alarms and switches, clean and/or repaint/ touch up transformer, cleanup work area, remove personnel protective grounds, do a walk around inspection, release clearance on transformer, return to normal status and place transformer back in service.	1 year
	(b) <u>complete Service</u> For complete service, in addition to the activities enumerated above in (a), the following additional activities will have to be carried out: • For diagnostic test, perform turns ratio test and power factor test. • Drain and process oil if the oil test indicates a problem. For phase shifting and tap-changing transformers, drain the tap changer and inspect the contacts, spring mechanisms, operating cabinet, etc. as per manufacturer's instruction. • Internal maintenance – accessing the tank includes removing the cover, ventilating, testing the oxygen level, and visually inspecting the interior, – check for loose bolts including blocking, and insulation condition. Also, check to ensure all leads are secured and properly placed, – check for any signs of arcing or abnormal discoloration of the insulation that would indicate overheating, – verify that all tools have been removed from the tank, – replace cover and seal, – vacuum the transformer, if so designed, to specifications – refill with oil to proper level. For placing back in service follow the same procedure as during partial service.	5 years

4.5.5 Routine Maintenance of Hydro-Mechanical Equipment

The major hydro-mechanical equipment to be covered by routine maintenance are Intake Gates, Main Inlet valves (butterfly and/or spherical) and Draft Tube gates. The following are the periodic inspection and checks for the preventive maintenance of hydro-mechanical equipment.

4.5.5.1 Intake Gates

The maintenance of intake gates include (i) cleaning up, (ii) adjustment, (iii) lubrication with recommended lubricants & methods, (iv) replacement of defective parts, (v) repair of damaged parts, (vi) recoating of damaged coat on ropes, (vii) recording details of all works carried out with date & time, and (viii) painting of gates and hoisting arrangement. Following inspection and checks are recommended for routine maintenance of intake gates:

(a) Daily inspection should be carried out by gate operator to ensure:
- Proper oiling and greasing whenever required;
- Tightening of loosened parts of tightening contacts in electrical system;
- Checking of ropes and hoisting arrangements;
- Checking general condition of gates and gate grooves wheels, etc.

(b) Periodic inspection (half-yearly or annual)
- Dismantle and check all components for any damage;
- Rectify damages or replace worn out irreparable components;
- All safety precautions, e.g., taking proper shut down, installing safety tags, red flags, etc., must be taken, when any work is being done on gates;
- Before taking up work on gates, stop log gates (duly inspected and repaired) must be lowered in the groove meant for the same and plug all leakage through them.

(c) Lubrication of gate parts
- Servogem EPI (IOC) or equivalent of other brand.
  - Rope drum shaft for all hoisting units (once a month)
  - Plumber blocks for all hoisting units fitted with bush bearing (once in two months).
  - Coupling for transmission shaft (once in two months)
  - Plumber blocks for manual operation (once in three months).
- Servogem -3 (IOC) or equivalent of other brand.
  - Spherical roller bearings for gate wheels (once in two months).
- Compound –D (CAMAX Bharat Petroleum) or equivalent of other brand.
  - Lifting ropes (once in six months)
- Servocoat 120 T (IOC) or equivalent of other brand.
  - Gears and pinions for all hoisting units (once in two months –Meshing faces only)
  - Gears and pinions for manual operation (once in 3 months).
  - Gears and pinions for all travel mechanism (once in two months).
  - Gears and pinions for position indicators (once in two months).
- Servosystem (320 IOC) or equivalent of other brand.
  - WOM reducer for all hoisting units (once in two months).

Note: All brand name products such as lubricating oil etc., which have been mentioned in the text on this page and elsewhere in the document are the products used in the NPS power plants and cited for illustration only. However, it is up to the plant owners to utilize other products best suited to them.

4.5.5.2 Main Inlet Valves (MIV)

The turbine may have either a butterfly or spherical valve. This valve is used each time the unit is shut down. Valve seats, seals, operating links, bearings, bushings, power source and hydraulic links are the main primary concern for maintenance. The valve function should be verified periodically through test or normal frequent operation.

Butterfly Valves: Butterfly valves generally consist of a disc or lattice mounted on a shaft that rotates in cylindrical body. Usually, the disc and lattice profile is contoured in the flow direction to provide a smoothen hydraulic flow and balance forces on the valve. The disc is oriented parallel to the flow to minimize any restriction when opened and at right angle to the flow to provide full closer. Valve seals are on the circumference or in contact portion of the valve body. These seals can be replaced or adjusted without removing the disc from the valve. Valves have flanged connection and spool pieces to facilitate dismantling. Sometime welded connections are preferred to save cost. The maintenance procedures and frequencies for these valves are as follows:

- Check operating system daily and ensure it is working smoothly;
- Check for any leakage through joints daily;
- Replace main seals in annual maintenance, if damaged;
- Other seals may be replaced as and when heavy leakage is observed;
- Overhaul operating system annually;
- Replace gaskets in flanged connection during annual overhaul.

Spherical Valves: Spherical valves have a body shaped like hollow sphere with flanges or other connection for mounting in a piping system. The rotor (shaped like ball) has a cylindrical hole through its centre at right angles to support shafts located on each side of valve. In open position with rotor opening parallel to the flow direction, the valve offers and unrestricted flow with minimum disturbance to the flow path. To close the valve, the valve rotor is turned to 90^o from the axis of rotor opening. Spherical valve has tendency to close for positions less than 50% opening which facilitates under emergency closing. Movable seals reduce valve leakage when the valve is closed. Mostly the valves have both upstream and downstream seal. The upstream seal is maintenance seal or emergency seal, the downstream seal is working seal. When valve is closed under full pressure, the upstream maintenance seal allows replacement or maintenance of the working seal without dewatering the penstock. The upstream maintenance seals have positive mechanical locking to prevent accidental opening. The maintenance procedures and frequencies for these valves are as follows:

- Daily checks of operating system and remedial measures are must;
- Annual inspection and overhauling of mechanical seal after dewatering penstock is must;
- Annual inspection and overhauling of operating seal is also essential;
- Annual overhauling of operating mechanism to ensure smooth working throughout the year is also done;
- Annual overhauling of the valve rotor and other parts are also taken up as required.

The following checks and attending are also essential during annual maintenance:

- Checking and attending leakage from valve and dismantling joint;
- Check and attending oil leakage from servomotor;
- Checking and attending the setting of Limit Switches & Operation of the same;
- Check and attending the leakage of distributing valve;

- Check the correct working of the pressure gauges. Lubricate the parts, if necessary;
- Checking and attending for leakage in the piping;
- Checking all the MIV system connection & union for tightness;
- Checking all the MIV servo linkage during operation, look for backlash;
- Cleaning of valve body, seal and solenoid valve;
- Checking the actuating solenoids for operation of valve. Cleaning the contacts and rollers;
- Checking the operation of by-pass valve;
- Checking for cracks, pitting and cavitations, etc. of MIV and Servomotor;
- Inspection of rubber seals;
- Checking trunions & bushes, bolts & nuts, etc;
- Checking gland packing and lubrication;
- Checking foundation bolts and nuts of valves and servomotor. Cleaning the bolt, nuts etc.
- Checking servomotor piston and its collars & its gland packing;
- Checking hole of the servomotor cylinder;
- Checking the pins and bushes of servomotor & its air valve;
- Checking the operation & closing times of the MIV.

4.5.5.3 Draft Tube Gates

One, two or three bulk head gates are needed to close off the draft tube. These are usually cable suspended gravity gates and designed for balanced pressure closure. These are usually dropped to close or lifted to open through hoisting arrangement having rope drums. The main problem with sealing is due to collection of debris at bottom seal area. For withdrawal of gate, equalizing pressure across the gates is done with by-pass line valve located within gates. When machines are running, these gates and hoist remain available for maintenance. These should always remain in perfect condition for use during emergencies for power station. During annual maintenance of unit, these gates are required to be lowered so that dewatering of draft tube is possible. As such, maintenance and overhaul of these gates are taken up before starting annual maintenance of machine. Lubrication of operating mechanism, its electrical system and coating all ropes meant for lifting are of main concern for maintenance.

4.5.6 General Problems in Electrical Circuit and Checks

Problems could be in electrical circuit as well. Hence, the maintenance checks to avoid general problems in electrical circuits should not be undermined. The following maintenance checks / actions with respect to electrical circuits need to be carried out:

S. No.	Problems	Actions to be Taken
1.	No supply at control panel in spite of turning on main switch	Check fuses.
2.	Incoming supply healthy but voltmeter is not showing	check fuses of voltmeter circuit.
3.	Motor is running even after pressing stop button	– Immediately put-off main switch; – Check contact of motor control contactor & push button contacts, replace them if damaged; – Reset O/L relay before starting again.
4.	O/L relay tripped	– Check control fuse; – If fuse ok, check control transformer

5.	Gate is creeping down & restoration has failed indicating lamp is glowing but alarm is not ringing.	Check position of toggle switch (it should be in reset position)
6.	Indication lamps are not glowing	Check by pressing lamp test push button. Replace bulb, if found fused

4.6 Guidelines for Maintenance of Switchyards, Transmission Lines and Sub-stations

4.6.1 General

The lack of proper maintenance in the electrical system comprising of switchyards, transmission lines, substations and related equipment results into primarily a high power losses and consequently a low degree of equipment service reliability and loss of service to the consumers that are not economically acceptable to an electric utility. Therefore, the maintenance of switchyards, transmission lines and substations and related equipment are addressed primarily for minimizing the high power (I^2R) losses, for which identification as well as locating the sources of such losses are necessary.

The power losses are mainly in the transformers, in the poor connections between the bus and line conductors, disconnect switches, circuit breakers, recloses and fuse cutouts, non-use of appropriate bi-metal connectors and the continued use of non-essential equipment. Some of such deficiencies may be indicated by visual inspection of the experienced eye, but many high resistance connections creating high power losses could only be detected by the use of a special device called the Thermo-vision Scanner. This device is used to determine the location of “hot spots” or connections that are operating at abnormally high temperatures. As per the Standard for Operation and Maintenance of Transmission Line (Reference: Gazette of India, June 26, 2010), the thermo-vision scanning for hot spots on all overhead lines and sub-station equipment at voltage level of 220 kV and above need to be carried out at least once a year and necessary remedial measures are taken where hot spots are detected.

4.6.2 Inspection and Patrolling

The switchyard and sub-stations are routinely checked/ inspected, while patrolling are carried out for overhead transmission line and associated right of ways.

The following are the recommended equipments for sub-station / switchyard inspection:

- Transformers;
- SF_6 Gas Circuit Breaker;
- Oil Circuit Breaker;
- Air Circuit Breaker;
- Vacuum Circuit Breaker;
- Air-Core Reactor;
- Oil-filled Reactor;
- Capacitor;
- Voltage Regulator;
- Oil-filled Recloser;
- Disconnect Switch;
- Storage Batteries; and
- Battery Charger.

The other items recommended for sub-station inspection are as follows:

- Fences and Yard (warning signs on fences, security such as locks, alarms, fence, etc., yard lighting, weed abatement, soil erosion and contamination, oil containment and/or secondary containment, cable trenches, surface water monitoring systems, general housekeeping such as rags, debris, etc. and loose asbestos).
- All outside equipment (oil leaks, counter readings, oil levels in bushings, tanks, and tap changer compartments, gas pressures, operation of fans, heaters, and compressors, deterioration, rust or other damage to bush work and support structures, solid ground connections, paint conditions, PCB labels, and designation levels, condition of operating platforms).
- Storage containers (all barrels or containers whether approved, properly documented and labeled, secondary containment, flammable materials cabinets).
- Buildings (overall structure such as roof, floors, doors, gutters, downspouts, exterior walls, foundations cable entries, paint, etc., heaters/air conditions with temperature settings, timers and filters, water heaters and cookers, sink, showers, toilets, drains, eye wash, and water supply, indoor lighting, emergency lights and lighting covers, fire protection along with service date on fire extinguishers and general housekeeping such as rags, debris, etc., loose asbestos, ventilation of dust generation areas.
- Battery backup system (UPS system, motor-generator base, windings, commutator, rings brushes, shaft and bearings, charger transformer or reactor, dial switch or rheostat).
- Annunciator board (abnormal indications).
- Switchboard and control equipment (relay targets set).

Besides the above, the following are also recommended:

- A thermo-graphic survey be conducted on an annual basis and problems that are identified by the survey should be scheduled for repair.
- Ground mat resistance testing should be performed.

The patrolling (aerial or climbing / ground / task specific) of overhead transmission lines and along the right of way are done for the following purposes:

- Aerial (Helicopter) patrolling or pole climbing patrols is carried out to conduct, close-up inspection of power line component;
- Ground patrols are undertaken to assess the condition of pole and of right-of-way (RoW), trees concerns, access trails and to identify apparent line deficiencies;
- Task specific patrols are carried out to locate hot spots, to determine condition of cross arm and to locate the insulation problems.

The sub-station inspections are, generally, done two to four times per year, while the patrolling are done annually or on 6 monthly basis. Based on the report of patrolling required maintenance of tower foundation, insulator replacement of line, strengthening of earthing of towers and clearing of bushes and trees shall be done.

4.6.3 Maintenance Schedule for Switchyard and Substation Equipment

4.6.3.1 Main Equipment

Following table gives details of the maintenance schedule for Switchyard/ Substation equipment. It is also to be noted that the safety and clearance are first steps required before conducting any maintenance activity on the sub-station / switchyard equipment.

Equipment Name	Type of Maintenance / Service and Activities	Time Interval
SF_6 Gas Circuit Breaker	(a) Partial Service • Perform pre-maintenance diagnostic tests as per the instructions/ procedures of test equipment manufacturers and breaker manufacturers. They include: – contact resistance test, – power factor insulation test, – motion analyzer (time travel) test, – trip test, – moisture test on the gas. • External inspection and cabinet maintenance: – inspection of the breaker includes the concrete pad, bolts, grounds, bushing, paint condition, and all connections, – maintenance includes checking all temperature and pressure switches to ensure operation at the proper values, checking gauge calibrations, lubricating, cleaning, adjusting, aligning, and checking control circuits, compressors and pumps, verifying the correct operation of heaters, making any needed repairs and recording all required gauge, meter and counter readings. • For placing the breaker in service, test operate the breaker and record the number of operations (the test should include all alarms including control centre, alarms, switches and manufacturer's recommendations, clean and/or repaint/touch up breaker, cleanup work area, remove personnel protective grounds, do a walk around inspection, release clearance on breaker and return to normal switching and then place breaker back in service.	1 year
	(b) Complete Service For complete service in addition to the activities mentioned above in (a) the following additional activities are to be performed: • For breakers equipped with pneumatic operators, drain and inspect the air tanks. Remove SF_6 gas from the breaker using a gas processing unit, pull a vacuum on the breaker to ensure all of the gas has been removed and then release the vacuum on the breaker with dry air or nitrogen to avoid pulling moisture into the tanks. • Perform internal maintenance: – accessing the tank includes opening the tank, vacuuming any residue (if present), ventilating, and using the inside of the tank with approved solvent, – inspect all parts for wear and damage including the fiberglass components and seals, – install factory-recommended overhaul and sealer kits. Replace all	6 years

Equipment Name	Type of Maintenance / Service and Activities	Time Interval
	desiccant materials, if applicable, – perform repairs or adjustment, if any needed, – seal the breaker tank and pull a vacuum as per manufacturer's specifications. If the vacuum holds for the specified amount of time, this indicates that no leaks are present, – refill the tank to the proper pressure. • Perform post maintenance diagnostic tests on breaker as per the manufacturers' instructions. The tests include contact resistance test, motion analyzer (time travel) test, if necessary, power factor test, trip test and moisture test on the gas. • Test operate the breaker and record the number of operations. The tests should include all alarms, switches and manufacturer's recommendations. For placing the breaker back in service, perform the same activities as during partial service.	
Oil Circuit Breaker	(a) Partial Service Except the following for diagnostic test, conduct all the same procedures for as in (a) of SF_6 Gas Circuit Breaker: – Instead of power factor insulation test and moisture test on gas, perform oil dielectric test.	1 year for greater than 66 kV
	(b) Complete Service For complete service, beside the activities mentioned above in (a), conduct the following: • Filter the oil to remove both carbon and water. • For internal maintenance, accessing the tank includes removing the door, ventilating, visually inspecting the interior and wiping down the tank and interior parts. The maintenance of internal parts such as contacts, interrupter assemblies, internal CT's, resistors, capacitors and lift rods includes checking, measuring, adjusting, aligning, and making repairs as needed. Lubricate all parts and components that are required to be lubricated. Replace any seals and gaskets if necessary. Replace all desiccant materials, if applicable. • Reseal the tank. • Refill the tank to the proper oil level and inspect for leaks. • For post maintenance diagnostic test instead of moisture test in case of SF_6 gas circuit breaker, conduct oil dielectric test for oil circuit breaker. • For other aspects including placing the breaker in service follow the same procedure as in SF_6 Gas Circuit Breaker.	6 years for 66 kV and 1 year for voltage under 66 kV
Air Circuit Breaker	(a) Partial Service Except the following, conduct similar test, inspection and maintenance as in (a) of SF_6 Gas Circuit Breaker. – For diagnostic test conduct dielectric test instead of power factor insulation test and trip test.	1 year

Equipment Name	Type of Maintenance / Service and Activities	Time Interval
	(b) <u>Complete Service</u> In addition to the above, perform the internal inspection as follows: • Check the contacts for excessive wear and replace if necessary. • Check the interrupters and insulating parts for burns or cracks that may indicate thermal aging. Repair or replace as needed. • Check the blast valves. Rebuild if necessary. • Replace all desiccant materials, if applicable. • For breakers equipped with pneumatic operators, drain and inspect the air tanks. • For placing the Breaker in service test operate the breaker and record the number of operations, and then follow the same procedure as for the above.	6 years
Vacuum Circuit Breaker	(a) <u>Partial Service</u> For diagnostic test, conduct only contact resistance and motion analyzer (time travel) tests, if necessary as per the instructions of the manufacturer. The remainder activities to be carried out are as for other breakers mentioned above.	1 year
	(b) <u>Complete Service</u> The general maintenance procedures to be followed during a complete service in addition to the above indicated activities are the following internal maintenance: • Measure the contact wear. • Perform a power factor test. • Replace oil desiccant materials, if applicable. The other activities to be carried out are as per the complete service for air circuit breaker.	6 years
Air-Core Reactor	<u>Complete Service</u> • Perform inspection and maintenance as per the instructions of the manufacturer. • Check and tighten bolts. • Check the ground on and the condition of the guard fence where applicable. Repair as necessary. • Check connections and condition of winding. Varnish if needed. • For placing Air-core Reactor in service, clean up work area, remove personal protective grounds, do a walk around inspection, release clearance on reactor and then place reactor back in service.	6 years
Oil-Filled Reactor	<u>Complete Service</u> • Conduct visual inspection. During this inspection check and clean bushings, and check the gauges. • Conduct diagnostic tests as per the instructions of the manufacturer. The tests include: – oil tests (dissolved gas analysis, dielectric test, color test, acidity test, moisture test, and interfacial tension test),	6 years

Equipment Name	Type of Maintenance / Service and Activities	Time Interval
	– power factor test. • Test operate the fans and pumps. • For placing the reactor back in service, perform the same activities as for Air-Core Reactor as above.	
Capacitor	Complete Service • Perform inspection as follows: – visually inspect the electrical connection and fuses, – make sure that all insulators, bus supports, fuses and capacitor bushing are clean, – visually inspect bushing and cans for damage. • Perform any necessary diagnostic tests on transformer banks associated with the capacitors, if applicable. • For placing capacitor back in service perform the usual activities as for the reactors as given above.	1 year
Voltage Regulator	(a) Partial Service • Perform the following diagnostic tests as per the manufacturer's instruction: – dielectric test – total combustible gas test. • Inspect visually the bushing and clean the bushing connections. Check all gauges. • Test operate the fans and pumps. • For placing Voltage Regulator back in service perform all activities as per partial service for SF_6 Gas Circuit Breaker as given above.	1 year
	(b) Complete Service In addition to conduct of the activities given above in (a), perform the internal inspection as follows: – drain and filter tap-changer oil, – inspect the contacts and other internal parts, – perform any needed maintenance, – refill the tap changer to the proper level. Then, place the Voltage Regulator back in service performing the activities as stated for partial service above.	6 years
Oil-Filled Recloser	(a) Partial Service • Perform the external inspection as follows: – check all cables, bolts, grounds, bushing, and connections, – check for any leakage from gaskets or openings, – check the paint condition, – clean up any oil spots. • Filter the oil to remove carbon and water, if necessary.	1 year

Equipment Name	Type of Maintenance / Service and Activities	Time Interval
	• For placing the Recloser back in service, besides carrying out normal general activities mentioned above, return to normal switching.	
	(b) <u>Complete Service</u> For complete service/maintenance, besides the activities given above in (a), • Perform pre-maintenance diagnostic tests on recloser as per the instructions of the manufacturer. It includes contact resistance test, trip coil current test and trip test. • Besides external inspection conduct cabinet maintenance. It includes checking gauge calibrations, lubricating, cleaning, adjusting, aligning and checking control circuits and making any needed repairs. • Conduct internal maintenance as follows: – drop the tank for internal access, – conduct the maintenance of the internal parts such as contacts, interrupter assemblies, resistors and capacitors. It includes checking, measuring, adjusting aligning and making repairs as needed. Lubricate all parts and components that are required to be lubricated. Replace any seals and gaskets if necessary, – reset the tank, – refill the tank to the proper oil level and inspect for leaks. • Conduct post maintenance diagnostic tests on recloser as per the instructions of the manufacturer. It includes contact resistance test, trip coil current test, oil dielectric test and trip test. • Test operate the recloser and record the number of operations. The test as usual for other equipment should include all alarms, switches and manufacturer's recommendations. • For placing the recloser in service perform the normal activities as listed above for bringing back the equipment in service.	5 years
Disconnect Switch	<u>Inspection and Maintenance</u> • Check for loose bolts and nuts, tighten if needed. • Examine the contact surfaces for wear or pitting. – clean the contacts, use steel wool to polish. Wipe clean and apply grease to the surface, – if severe damage has occurred, replace damaged parts. • Examine the switch blade contact alignment and realign if necessary. Test operate as a unit (three phase operation). • Check all galvanized surfaces for chips. If chipping has occurred, use "Galvan-Ox" or equivalent as a touch-up. • Grease any parts equipped with grease fittings.	6 years
Station Batteries	<u>Recommended Maintenance Procedures</u> • Check visually the general appearance and cleanliness of battery storage system, check the ambient temperature and condition of the ventilating equipment, record the float voltage measured at the battery terminals, record pilot cell data, check for evidence for corrosion at terminals or connectors, check for cell cracks and loose connections, and check for evidence of voltage leaks to ground.	Monthly

Equipment Name	Type of Maintenance / Service and Activities	Time Interval
	• Perform the monthly maintenance procedures recommended by the manufacturer, check 10% of intercell connection resistances chosen at random, record the voltage of each cell for lead-acid batteries corrected for temperature, and record the electrolyte temperature of one out of each six cells chosen at random.	Quarterly
	• Perform the recommended quarterly maintenance procedures, tighten all bolt connections to the specified torque requirements, record all cell to cell and cell-to-terminal connection resistance, perform an integrity test and, if convenient, thermo-graphically scan the battery connection during the test to check for "hot spots", and check the Integrity of the battery rack.	Annually
	• Besides performing annual maintenance, perform a capacity test.	Every 5 years
	• If the battery has experienced abnormal conditions such as a severe discharge or the age of the battery, nearing its useful life the maintenance interval should be adjusted accordingly. The maintenance procedures should include as much of or all of the monthly, quarterly and annual procedures including the performing a capacity test if necessary.	Special maintenanc e as and when necessary
Battery Charger	<u>General Maintenance Procedure</u> • Record the charger output current and voltage. Check the following items: – ripple, – current-limiter circuit, – over-voltage, – under-voltage, etc.	Monthly
	• Verify the accuracy of the charger panel voltmeter test, alarms and automatic shutdown functions, as per the manufacturer's instructions, and clean the battery charger	Annually
Lighting Surge Arresters	• Perform usual inspection to detect cracking settling or shifting of base supports. Check that surge monitor is properly connected and is in working order and shows a leakage current.	Monthly
	• Check jumper and clamps for tightness, clean porcelain insulators and arrestor unit shells, repair chipped spots on porcelain with lacquer such as red glyptic, check and tighten grading rings on high voltage arresters, check external gaps and smooth off arc burned spots and read just spacing, see that whether sheds and hooks of oxide film arresters are securely fastened in place (repaint if necessary), check the tighten line and ground connections, check ground lead for corrosion or damage below ground line, check ground resistance, see that all leads are as short and direct as possible. Check the general working of lighting arresters. [<u>Note:</u> Healthiness of earth connections to be checked as it plays a vital role on operation of the arrester. Normally it is not recommended that if one stack fails it is replaced with healthy stack. It is always a good practice to change the entire arrester as the stressed stacks will start failing along with the new stack.]	Annually

Regarding maintenance of Gas Insulated Switchgear (GIS), the following should be followed:

Before taking up the maintenance of GIS recommended safety rules from the manufacturer are required to be adhered to:

- Employ the authorized personal
- Define and discuss in advance the maintenance to be performed and the relative hazards. Proper formatted record sheets to be prepared.
- Use parts only supplied by Original Equipment Manufacturers (OEM).
- It is necessary to identify the equipment which is required to be maintained.
- Ensure that it is in de-energized/degassed condition.
- It is essential to make sure that the equipment is earthed on all sides of the work-zone.
- The work-zone should be barricaded and operator should have necessary protective clothing and recommended safety devices.
- It is required to be ensured that necessary maintenance equipment such as slings, platforms, scaffoldings and electrical equipments/tools are in proper shape.

Generally GIS requires no or very little maintenance. For maintenance of the GIS, regular inspections, routine scheduled maintenance and overhaul maintenance are specified by the manufactures. The maintenance to be carried out and their periodicity is indicated in the. Manufacturer's manuals and they are to be followed for special tests, if any, for that particular make of GIS substation. Following monitoring measurements/tests are recommended for GIS maintenance.

As SF_6 gas is used in all chambers of GIS. The monitoring of pressure and quality is of the importance. As per IEC 62271-203/2003 the leakage rate from any single compartment of GIS to atmosphere and between compartments shall not exceed 0.5% per year for the service life of the equipment. The pressure inside a GIS may vary from the rated filling pressure level due to different service conditions. Pressure increase due to temperature and leakage between compartments may impose additional mechanical stresses. Pressure decrease due to leakage may reduce the insulation properties. Further the quality and dew point of SF_6 gas should also be monitored as the property of SF_6 is related to it insulation quality.

(a) Partial Discharge Measurement

Electrical Ultra High Frequency (UHF) or Acoustic PD (Partial Discharge) measurement techniques are being employed. Electrical UHF technique gives higher sensitivity and PD detection necessitates the installation of sensors inside the gas compartment during manufacture. Acoustic methods employ sensors which are fixed outside the enclosure. For both the methods the sensitivity depends on the distance between the defect and the sensor.

(b) UHF Partial Discharge Measurement

The partial discharge signals in the range 1000 MHz to 2 GHz can be detected in the time domain or frequency domain by means of installing sensors usually installed inside the chambers. Due to the complexity of the resonance pattern, the magnitude of the detected PD signal depends strongly on the location.

(c) Acoustic Partial Discharge Measurement

Acoustic signals are emitted from defects in a GIS mainly by the floating particles emitting a mechanical wave in the enclosure when they impinge on it. Discharges from the fixed defects create a pressure wave in the gas, which is then transferred to the enclosure. The resulting signal will depend on the source and the propagating path. As the enclosures are normally made of aluminum or steel, the damping of the signals is quite small.

Acoustic signals can be picked up by means of externally mounted sensors. The location of the defect can be found by searching for the acoustic signal with highest amplitude or time travel measurements with tow sensors. Bouncing particles producing discharges in the 5% range can be detected with a high signal to noise ratio. Sensitivity decreases with distance because the acoustic signals are absorbed and attenuated as they propagate in the GIS. Acoustic measurement is immune to electromagnetic noise in the substation. The acoustic sensitivity to bounding particles is much higher than the sensitivity of any other method. PD measurement in a GIS installation is recommended once in 5 years.

In GIS substation some of the equipment like Bushings, Surge Arresters, Transformers shall be provided outside the GIS area. Condition monitoring of these equipment is to be carried out as followed for AIS substation equipment.

4.6.3.2 Protection Equipment and Control System

Protective relays provide critical protection functions for all types of plant equipment associated with power generation and power delivery. The protective devices must operate during abnormal plant operating conditions and, in most instances, are the last line of defense to protect equipment from a catastrophic failure. It is critical, then, that these protective devices function properly to adequately protect the associated piece of equipment and that adjustments and calibrations are routinely conducted to eliminate the possibility of the protective device disoperation. Therefore, it is imperative to conduct periodic maintenance testing to validate that the operational parameters of the functional protective device are properly set and coordinated.

Protective relays currently in use in power systems include electromechanical, solid-state, and microprocessor-based packages. The protection relays contained within this section also shall include the lockout relay to ensure that the proper operational and functional testing of the device and associated control circuits is performed on a regular maintenance interval as prescribed in the associated table. Calibration and maintenance recommendations differ from type to type because of the different design and operating features of the protective device.

Calibration and Maintenance

This process usually includes removing the relay from service to a test environment. Injecting current and/or voltage into the relay and observing the response according to the manufacturer's test procedure verifies the recommended settings. Calibration of electromechanical relays is recommended frequently since operating mechanisms can wear and get out of adjustment. Calibration of solid-state and microprocessor-based relays is recommended less frequently since there are fewer ways for them to get out of calibration.

Relay Functional Test

This process verifies that the protective outputs of the relay (e.g., contact closures) actually operate as intended. This can be accomplished as part of the calibration procedure in most cases, but relay functional testing should be verified according to the prescribed maintenance schedule associated with the particular type of relay being tested.

Protection Circuit Functional Testing

Protective relays operate into protection circuits to accomplish the desired protective action. Similar to control circuits, protection circuit integrity may be compromised by construction, modifications, deterioration, or inadvertent damage. A compromised protection circuit may not provide the system and plant protection desired. Periodic functional testing is recommended to ensure the integrity of protection circuits.

This process verifies that the entire protective "trip path" from protective relay through circuit breakers (or other protective equipment) is intact and functional. This requires actually operating the entire circuit to verify correct operation of all components.

Maintenance Schedule for Electromechanical Relays

Maintenance or Test	Recommended Interval
Calibration maintenance	2 years
Relay functional test	2 years

Maintenance Schedule for Solid-State Relays

Maintenance or Test	Recommended Interval
Check for relay power supply indicating light	Weekly
Calibration maintenance	2 years
Relay functional test	2 years

Maintenance Schedule for Microprocessor Relays

Maintenance or Test	Recommended Interval
Check for relay trouble light	Weekly
Relay functional test	6 years
Monitored	
Relay functional test	4 years
Unmonitored	

Maintenance Schedule for Protection Circuits

Maintenance or Test	Recommended Interval
Protection circuit functional tests	2 Years

4.6.3.3 SCADA Systems

Supervisory Control and Data Acquisition (SCADA) systems are computer-based, real-time control systems. Theses SCADA systems are used to monitor and control water and power operations at a variety of power facilities. These systems operate continuously and, in many ways, are self-diagnosing; but some maintenance and testing of these devices are necessary to ensure system integrity and identify potential failures. As well, circuits that are infrequently used may require periodic functional testing to ensure they will be operational when the need arises.

Maintenance Schedule for SCADA Systems

Maintenance or Test	Recommended Interval
Lamp integrity tests	Monthly
Enclosure physical inspections	Monthly
Circuit functional tests (all inputs and outputs)	2 years

SCADA power supplies and uninterruptible power supply (UPS) systems	3 years
Communications testing	6 years

4.6.4 Incorrect Connectors/Faulty Equipment and Redundant Equipment

Every connector in an electric circuit is a potential source of resistance. Hence, the connectors must be appropriate ones and the number of connectors should be kept to a minimum. The purpose is to limit the contact resistance of connectors in circuits so as to keep the I^2R looses as small as possible. Good contact with low contact resistance in the connection needs to be achieved by observing, if

- any specific torque values are specified, these should be followed explicitly;
- crimped connectors are used, the correct crimping tool and correct dies must be used;
- wedge connection are used, the correct gun and correct cartridges must be used; and
- any erosion inhibiting grease is specified, the correct application and quantity should be adhered.

It is to be noted that when dissimilar metals are connected, bimetallic connectors should be used (usually equipment connection pads are copper and jumper wires are aluminum). Similarly, during replacement of the connectors, such connector need to be selected that matches (a) the equipment terminal configurations that are to be connected, (b) the sizes of both conductor and terminals to the connector, (c) the bolt pattern, and (d) the materials being connected. It is important to use the bolts supplied for the connector, using galvanized steel bolts with copper will badly corrode the galvanized bolt, thereby greatly increasing the contact resistance with time. Field modification will render the connector invalid for adequacy of current carrying and designed temperature rises, and, therefore, the manufacturer's connectors should not be modified, cut or misapplied as these have been designed and tested for the service and application specified.

The causes of "hot spots" could, among other things such as poor contact, the incorrect connectors, corroded connections etc., be the equipment undersized for load growth, damaged/deteriorated or field modified, they need to be replaced by appropriate equipment. It is not recommended to improvise on manufactured equipment due to shortage or unavailability of fittings. Have complete replacement equipment on hand before the outage for change out. Using incomplete equipment defeats the purpose of the replacement which caused the problem.

There could have been non-essential equipment left in the circuit for a number of reasons. They generate hot spots at each corroded or high resistance connection. These redundant equipments in the circuit, if not actually contributing to the system operation, must be removed from the circuit and replaced with an appropriate jumper for service continuity.

4.6.5 Procedures for Maintenance of Transmission Lines and Inspection and Tests for Individual Equipment in the Sub-stations

This section describes the procedural aspects of maintenance of overhead transmission lines and inspection and tests for important individual equipment in the sub-station.

4.6.5.1 Maintenance of Overhead Transmission Lines

Conductor Repair/Replacement: An insulated boom and bucket allows conductor and equipment repair to be done "hot", meaning the power line is still in service. Where the equipment cannot be used, the line must be taken out of service (de-energized) before the conductors can be repaired.

Pole Replacement: The old pole is typically pulled out intact using a hydraulic boom. If the old pole cannot be extracted without a major amount of land disturbance, then the pole is cut off approximately 1 m below ground line and cover with soil. New pole(s) are installed by auguring a new hole approximately 9 feet deep.

Conductor Joining: Conductor joining could be done either by Implosive Method or by Hydraulic Ram Method. Under the Implosive Method, two power line conductor ends can be joined together by inserting each end into a metal sleeve. Explosive is wrapped around the sleeve and detonated. The explosive force compresses the sleeve tight against the conductor, and thus joining them together. Under "Hydraulic Ram Method", a hydraulic force is used to compress the joining sleeve. This method is quieter than implosive method but does have the potential for hydraulic oil leaks.

Insulator Washing: Insulators can become coated with dust and other particulates, especially adjacent to highways. This compromises the insulators electrical insulating capability and can become a safety hazard. Hence, Insulators are washed, as required, using a high pressure spray with organic abrasive substance such as cornhusks.

Vegetation Management on the RoW: Trees and incompatible vegetation species have the potential to contact or conflict with power lines. Trees contacting a power line pose a major safety concern to people and wildlife, they can also start wildfires and disrupt power service. Hence, vegetation management on the RoW occupies important place.

The vegetation management methods include manual brushing (slashing), trimming, bush moving and herbicide applications. The selection of method is specific to the desired vegetation management objective and is influenced by site characteristics such as terrain, RoW access, vegetation species & density, public use, water body buffers.

4.6.5.2 Inspection and Test for Individual Equipment in the Sub-station

Transformer impedance Test: Impendence test locates problems within transformer windings.

The following is the procedure for impendence test:

a. Set the no-load tap changer to the nameplate voltage before proceeding with the test.
b. Short-circuit the secondary terminals together and connect the voltmeters and ammeters to the high-side bushings.
c. Connect the variable power supply and slowly increase the voltage to 120 volts. Watch for the over current range of the ammeter, change the scale if necessary.
d. Record the voltage, current, and the combination of high-side bushings (e.g. H1-H2, H2-H3 and H1-H3.
e. Disconnect the variable power supply and move the power leads to the next high-side (or low-side) bushing combination. Repeat steps c, d and e until all combinations have been recorded.

f. Calculate the percentage impendence.

The result of impedance tests performed in the field should be within 5% of manufacturer's data. Values beyond this range should be investigated by further tests.

Switchgear Inspection and Test: The switchgear inspection and testing are performed to ensure that the equipment and connections are all in working order.

The following are the steps for visual and mechanical inspection:

- Inspect for physical, electrical and mechanical condition;
- Compare equipment nameplate information with latest one-line diagram and report discrepancies if any;
- Check for proper anchorage, required area clearances, physical damage and proper alignment;
- Inspect all doors, panels and sections for paint, dents, scratches, fit and missing hardware;
- Verify if the fuse and/or circuit breaker sizes and types correspond to the drawings;
- Inspect all bus connections for high resistance by using a low resistance ohmmeter. Check the tightness of bolted bus joints.
- Test all electrical and mechanical interlock system for proper operation and sequencing;
- Closure attempt shall be made on locked open devices. Opening attempt shall be on locked closed devices;
- Key exchange shall be made with devices operated in off-normal positions;
- Clean entire switchgear using manufacturer's approved methods and materials;
- Inspect insulators for evidence of physical damage or contaminated surfaces;
- Verify appropriate contact lubrication on moving current carrying parts and on moving and sliding surfaces;
- Exercise all active components;
- Inspect all mechanical indicating devices for proper operation.

The insulation-resistance test for the switchgear shall be performed in accordance with the prescribed test voltage. Values of insulation resistance less than the corresponding recommended minimum values should be investigated. Over potential tests should not proceed until insulation-resistance levels are raised above minimum values. Test results are evaluated on a pass/fail basis by slowly raising the test voltage to the required value.

4.6.6 Procedures for Detection of "Hot Spots", Replacement of Incorrect Connectors and Faulty Equipment, Removal of Redundant Equipment and Replacement with Jumper, Formation of "Drip Loops" in vertical Jumpers and Changing Transformer No-Load Taps Manually

4.6.6.1 Procedures for Detection of Hot Spots

For the detection of "Hot Spots" thermo-vision camera is used. It is capable of detecting the heat generated by individual substation components operating at temperatures above their equipment design ratings. The I^2R losses produce the heat that is observed by the camera as a hot spot. Transmission and distribution lines including substations can be tested with this equipment to locate hot spots on conductors and equipment caused by loose connections and hardware and other defects. This equipment can be operated from a helicopter, a van or by an operator carrying it. For its use refer the manufacturer's instruction/ manual and follow the procedure given below to identify the hot spots:

- Calibrate the equipment.
- Select the temperature range from 20°C to 100°C.
- Check the substation load logs to determine the Peak Load Period, because scanning has to be done during peak load period.
- Commence scanning (pointing the camera lens towards the item being scanned does scanning from the high side of the transformer and follow the electrical path all the way through to each 11 kV outgoing feeder line.
- Hot spots show up as light blue, yellow, orange, red or white on a dark blue background. The temperature of the hot spot increases as the colour goes from light blue to red to white being the hottest.
- When a hot spot is located, zero in on the hottest area, and set the record and its temperature in memory.
- Hot spots should be checked from different camera angle. Relying on scanning from one location may give erroneous results due to shadow effects of other equipment. Thoroughly check the electrical system circuitry from different angles.
- Downloaded data and images with all temperature readouts into a computer.
- Analyze the cause of the hot spots, perform additional resistance measurement checks, visual checks and/or follow up tasks to determine the plan for repairing or replacing the equipment or item causing the abnormally high temperature.

Besides the thermo-vision camera, other available techniques for hotspot maintenance such as infrared thermometer based on laser technology can be used.

4.6.6.2 Replacement of Incorrect Connectors

Every connector in a circuit is a potential source of resistance and, therefore, it should be noted that (i) the number of connectors and the resistance of connectors should be kept to a minimum (ii) corrosion of connectors should be avoided to prevent high contact resistance over time. The purpose is to limit the contact resistance of connectors in circuits so as to keep the I^2R losses as small as possible. The following is the procedure for replacement of incorrect connectors:

- Identify which of the hot spots detected by thermo-vision scan is the result of the wrong connector type.
- When replacing connectors, select one connector that will match:
    a. the equipment terminal configurations that are to be connected. Examples of configurations include 2-hole pad to 2/0 cable, or, 4-hole pad to 2/0 cable, or stud to 4/0 cable, or, 2-hole pad to 336 MCM cable at a right angle take off, etc.
    b. the sizes of both conductor and terminals to the connector.
    c. the bolt pattern on the pads, i.e., either 2-hole pattern, or 4-hole pattern, to the connector.
    d. the materials being connected, i.e., Aluminum to Aluminum requires an Aluminum connector. Al-cu requires a bimetallic connector.

- Use the bolts supplied for the connector. Using galvanized steel bolts with copper will badly corrode the galvanized bolt, therefore greatly increasing the contact resistance with time. When in doubt, use stainless steel bolts.
- Good contact with low contact resistance in the connection must be maintained. This can be achieved by observing, if
  - any specific torque values are specified, these should be followed explicitly,
  - crimped connectors are used, the correct crimping tool and correct dies must be used,
  - wedge connectors are used, the correct gun and correct cartridges must be used,
  - any corrosion inhibiting grease is specified, the correct applications and quantity should be adhered to.
- Do not modify, cut or misapply the manufacturer's connectors as these have been designed and tested for the service and application specified. Field modifications will render the connector invalid for adequacy of current carrying and designated temperature sizes.
- Follow strictly the manufacturer's recommendations.

4.6.6.3 Replacement of Faulty Equipment

Among the corrective actions to reduce high I^2R losses identified as hot spots, the replacement of faulty equipment is one important area. The procedure for replacement of faulty equipment is as follows:

- When the thermo-vision scan of the substation indicates that the specific equipment is the source of hot spot, the causes of the hot spot must be determined first. The cause could be one or more of the following:
  a. high current flow above thermal limits overloading circuits,
  b. poor contact connectors,
  c. incorrect connectors,
  d. corroded connectors,
  e. poor contact resistance with the equipment,
  f. undersized equipment for the growth of load with time,
  g. field modified equipment due to unavailability of replacement parts,
  h. deterioration of current carrying parts with time due to oxidation, corrosion, pitting, etc.
- Once the cause(s) of hot spots had been identified, take the corrective action as follows:
  - for (a) replace the equipment with adequately rated current circuits,
  - for (b), (c) and (d), replace the equipment connectors in accordance with standard industry practices stated elsewhere in the relevant manual(s),
  - for (e) clean the contact causing high resistance,. For oil circuit breakers, air switches and reclosers, follow the manufacturer's O & M manual/ instruction,
  - for (f), change out the equipment and size adequately for the high current requirements,

- for (h), remove the field modified equipment and replace with adequately rated standard manufactured equipment,
- for (h), damaged or deteriorated equipment needs to be replaced with new equipment. Field modifications, often times results in hot spots.

4.6.6.4 Removal of Redundant Equipment and Replacement with Jumper

For a number of reasons non-essential equipment may have been left in the circuit. They can already be removed from the service in order to eliminate the I^2R losses. However, the removed equipment must be replaced with a jumper for service continuity. For this purpose, the following tasks need to be performed:

- Determine the ampacity of the jumper to be used.
- Select jumper material and cross section by checking the ampacity tables for current rating in free air for either CV, AA or ACSR jumpers of the various cross-sectional areas.
- Measure length of jumper required from terminal to terminal of the connecting equipment leaving enough stack for the "drip loops", if connections required a vertical jumper connection.
- Select the connectors required at either end of the jumper to connect to the equipment at either end. The selection of the connectors will depend on the material of the jumper and material of the connecting equipment terminations, and also on the configuration of the terminating connections.
- Apply and install connectors properly and in accordance with the connector requirements, if
  - when making bolted connections, use the correct bolts (material and size) and apply required torque,
  - compression type, use proper crimping tool and dies,
  - wedge type, use proper gun and cartridge for type, size and metal of connectors.
- After installation, measure the true resistance of the jumper i.e., jumper including connectors at each end. This resistance should be less than 0.05 ohms.
- The circuit continuity across the equipment removed and replaced with a jumper is, thus, restored with a low loss, in line, through connection.

4.6.6.5 Formation of "Drip Loops" in Vertical Jumpers

Jumpers, when in a vertical configuration and connected to equipment, provide a path for water to trickle down and flow into the connector joints. Forming a "Drip Loops" at the bottom of the jumper eliminates this action. It also deters corrosion and electrolytic action and, thus, reduces the I^2R losses, which occur as a result of the development of high contact resistance. When vertical jumpers are changed, measurements for the new jumpers should include an easy "S" drip loop before connecting the terminal bushings of the equipment to bottom of the jumper. The "S" type "drip loop" is required on all vertical jumpers that terminate on outdoor circuit breakers, reclosers, automatic voltage regulator, etc. When replacing the jumpers in the substation, the following steps are to be taken.

- Select the material and cross section of the new jumper for the required current carrying capacity.
- Remove all sources of energy from the equipment to be worked on.

- Apply safety grounds, ground clusters and ground chains to safely isolate the equipment.
- Remove old jumper.
- Measure length of old jumper but add an extra length of 2 feet to form the “drip loop”.
- Prepare connection between jumper and the equipment and select the correct connector.
- Make the connection of the vertical jumper to the equipment at the bottom and form a “drip loop” with the slack in the jumper so that rainwater will run down the jumper and run off the jumper at the lowest point preventing it from flowing into the equipment connector at the end of the jumper.
- Complete the top connection of the jumper.
- Check for continuity and proper connections.
- Remove safety grounds.
- Energize the sub-station.

4.6.6.6 Changing Transformer No-load Taps Manually

The characteristics of transformers that directly affect losses are the impendence and secondary side voltage. These determine the output voltage at no load, and the voltage drop attributable to the transformer when carrying load. Higher transformer impendence could give rise to higher losses. By using full winding, the maximum losses occur for the same load current. Following is the procedure for changing transformer no-load taps manually.

- Remove transformer from all energized sources including primary and secondary sources.
- Remove tap position locking bolt.
- Move tap changer to desired position.
- Secure locking bolt.
- Test transformer for proper ratio, and measure windings resistance using Megger.

If transformer test ratio (TTR) and Megger tests are successful, then energize transformer.

5.0 REQUIREMENTS FOR EFFECTIVE OPERATION AND MAINTENANCE

The following are the basic requirements to ensure effective operation and maintenance:

- Manpower planning and arrangement.
- Training program for operation & maintenance.
- Planning and arrangement of spare parts, consumables, tools and testing equipment.
- Logging and reporting.
- Equipment labeling.

5.1 Manpower Planning and Arrangement

In order to ensure all structures and equipment are operated and maintained in a safe and efficient manner, planning and management of manpower needs to be done well in advance preferably during the pre-commissioning of the plant. The manpower required will be based on following factors:

- Type of plant.
- Number of shifts.
- Location of the plant.

RoR type of plant demands more manpower than for dam type because of the spread of hydraulic structures. Similarly, if the numbers of shifts are more there will be more need of manpower. For remotely located plant there may be a need of additional staff for the support services such as transport, maintenance of residences, drinking water supply, etc. However, the manpower can be kept minimum by employing a multidisciplinary force such as an engineer with experience in civil and electro-mechanical work or technician with driving experience and by employing local labor during requirement of additional work. The guiding factor is safety of equipment and manpower. Similarly, the contractual work such as civil maintenance, welding and fabrication, etc. may be awarded on annual basis to keep work force low.

In selecting manpower e.g. for a position of plant in-charge or plant manager a person having basic degree in electrical with experience in civil and mechanical works is most suitable while for testing engineer, he/she should be familiar with all equipment testing to take decision in case of any fault on electrical equipment such as generator, transformer and switchgear. For the technician, a technician level certificate holder with hands on experience in electro-mechanical work such as diesel generating (DG) plant, electrical installation, hydraulic equipment, electrical panel, PLC panels, cable work, etc.

Keeping n view that the private hydropower plants will be handed over to the GoN after a designated period of Operation and Maintenance of the plant, the GoN staff to be deployed for O & M need to be trained at least for a duration of one year before the end of License Period.

5.2 Training Program for Operation & Maintenance

Each employee must receive training to meet the responsibilities of their position. New or transferred employee is required to familiarize themselves with facility reference documents, facility system, policies and procedures. The plant manager selects which facility–specific or other training programs personnel must attend to be qualified to operate or use the facility.

The plant manager may authorize training exemptions based on assessment of the individual's experience (Note that the exemptions must be documented). Annual training (continuing type) to ensure the staff is proficient in the knowledge and skills needed to perform their duties. Training must be provided sooner if there is a change in job assignments, change to systems or processes, or a change in procedures. The remedial type of training must be provided when there is a reason to suspect deficiencies or inadequacies in the employee's knowledge or skills.

The method of training could be:

- On-the-job: The primary mode of training for the facility is through on-the-job training. Training must be carefully supervised and controlled to avoid mistakes.
- Instructor-led: Classroom or in the field.
- Computer–based: Online or other.
- Required Reading: Assignments require signatures by the employee to indicate that they have read and understood the document.

The contents of training should, in general, be safety, theory (electrical, mechanical and operation principles), and knowing and understanding of operation limits.

The knowledge and skills should be evaluated and the assessment methods must be documented. The training program needs to be reviewed annually and recommendations are to be made for any changes or improvements.

5.3 Planning and Arrangement of Spare Parts, Consumables, Tools and Testing Equipment

For effective maintenance, it is necessary to list out all required ordinary and special tools, spare parts, consumables and testing equipment along with assessment of the quantity and arrange the same in a timely manner in advance so that time is not lost in re-commissioning the plant after the shutdown. Ordinary tools and parts include different type and sizes of screw drivers, pliers, spanners, hammers, etc., while the special type of devices and parts is required during assembly or dismantling of machines. For example, rotor lifting device and endless slings, pole turning device, shaft lifting device, rotating device and slings for alignment, shaft extension pieces and so on. These are not required for day to day maintenance; as such these should be properly stored and secured. Necessary maintenance, if required, must be carried out on these devices in time. Slings should be stored duly coated with preservatives as recommended by the manufacturers. A typical format for Spare Parts List is given in Annex -1.

5.4 Logging and Reporting

5.4.1 Logging

A station log needs to be maintained at each facility in the Control Room. The station log contains chronological record of all operating and maintenance activities and events which provides a reference for future use. Operation and maintenance personnel use these information to evaluate present and past plant status. The station log may be paper, electronic or a combination of both. The station log documents are following:

- Staff on duty
- Operations of waterway equipment including gates, valves and changes to spillway gate positions.
- Communications involving plant operations, switching, Hot Line Orders, clearances, special conditions, alarms and relay operations. All communications with Transmission Operators shall also be logged.
- Water elevations and releases and operational changes affecting water elevations and releases.
- Status of auxiliary equipment.
- Testing of equipment or gate controls.
- Act of vandalism or other security incidents.
- Requests and occurrence to change from normal operation during an emergency or unusual conditions.
- Communication network checks and emergency exercises conducted.
- The disabling and re-enabling of facility alarms.
- Unit start and stop times.
- Any equipment failures and malfunctions.
- Line outages.
- Breaker opening and closing.
- Callouts.
- Any change in unit status (available, unavailable, etc.)
- Status of all major equipment.
- Listing of personnel (visitors) arrival and departure.

The plant manager must review and initial the operating Log Book.

Shift turnover is critical part of the facility's operation and provides oncoming operation staff with an accurate picture of the overall status of the facility. Hence, the incoming operation staff must review logs, turnover checklist (if used), SCADA displays, alarm displays, disabled alarms, protective devices, and computer pages, and they must receive verbal briefing from the on-duty operator prior to assuming responsibility for the operation of the facility. A visual inspection of control boards including a test of the annunciator windows will be completed to verify indication/annunciation light is operational. During a shift turnover, at a minimum, the information on major equipment status, alarm status, work in progress, hazardous energy control procedures, any abnormal plant conditions, water release, power schedules and work schedule should be exchanged. The operation staff, then, will sign into the log documenting that shift turnover has been completed.

5.4.2 Reporting

With the passing of time along with growth of demand in electricity and due to advancement in the technical development the interconnected power system are becoming more and more complex. This requires increased emphasis on the analysis of system performance to ensure achievement of the best reliability. One of the most important requisites for such analysis is the availability of clear, concise and the accurate reports on power system operation and maintenance (O & M) for review by management at various levels. Specific details regarding preparation, issuance, and distribution of the monthly O & M reports is described in the following paragraph.

A narrative report of power plant O & M activities shall be prepared and distributed monthly by the power plant O & M office on each project that includes operating power facilities. The report shall briefly describe all important non-routine events of a power plant O & M nature that occurred during the month, such as date, time, duration of major items of maintenance undertaken or accomplished new equipment or service installation or connections, changes in system arrangement or interconnections with adjacent utilities, major power interchanges between systems or water movements scheduled or accomplished, new facility(ies) added, important personnel activities, etc. The report shall be distributed to the concerned as specified by the system operating authority/ regulating authority as applicable. The format for the report has been given in Annex –2.

In addition to the above indicated monthly O & M report the following reporting are required for record keeping for future reference. The typical formats for the reports will be as given in Annex-3.

- Annual Outage Program,
- Annual Availability Declaration,
- Monthly Generation Outage Program,
- Weekly Generation Outage Program,
- Scheduled Outage, Request Form,
- Forced/Maintenance Outage Request Form,
- Monthly Availability Declaration on Hour to Hour Basis,
- Monthly Availability Declaration on Hour to Hour Basis,
- Weekly Availability Declaration,
- Daily Availability Declaration,
- Verbal Dispatch Instruction Confirmation,
- Daily Generation Report Form,
- Daily Generation Log Sheet,
- Fault Registration Form,
- Monthly Generation Performance Report Form,
- Monthly Generation Report Form,
- Monthly Outage and Reduced Output Report,
- Maintenance Outage Report Form,
- Loading Status and Scheduled Outages,
- Forced Outages of Transmission Lines and System Failures, and
- Transmission Line Shutdown Implementation Form.

In case any accident occurs, the accident hazard notice needs to be given as earliest as possible to the chief electricity inspector appointed by GoN.

5.5 Equipment Labeling

In order to help ensure that the facility and the support personnel can identify, instrumentation, controls and equipment, a well established and maintained program for labeling equipment is a must. A good labeling program that is understood and maintained by O & M personnel enhances the effectiveness of work activities. Such a program also helps to reduce errors by O & M personnel as errors can result from incorrect identification of equipment and controls. Equipment labeling is required also to comply with the safety regulations and for protecting from the health hazards.

At a minimum, the following items should be labeled:

- Emergency exits, fire alarms, fire protection, and fire extinguishers.
- Rescue and first aid equipment.
- SCADA displays.
- Circuit breakers, disconnects, and power panels.
- Annunciator panels
- Grounding switches
- Valves
- Piping systems.
- Major plant equipment
- Control switches
- Protective devices, including relays.
- Metering.

The labels are placed on, or as near as practical to, the controls or equipment being labeled. Labels are oriented so that they are easy to read. The operation manager should be responsible for ensuring that missing or damaged labels, once identified, are promptly replaced and that newly installed equipment or new modifications to existing equipment are properly labeled.

6. FIRE PROTECTION AND FIRE FIGHTING, CONSIDERATION OF SAFETY AND DISASTER MANAGEMENT

6.1 Fire Protection and Fire Fighting

6.1.1 General

Fires are broadly classified in the following categories, based on the kind of combustible involved:

Class –A: Ordinary materials like wood, paper textile and rubbish;

Class –B: Flammable liquids like oils and greases; and

Class –C: Live electrical equipment.

The types of extinguishers are (i) carbon Dioxide, (ii) Dry Chemical, (iii) Water and (iv) Vaporizing. Carbon Dioxide (CO_2), Dry chemical and vaporizing are suitable for all three categories of fires, while water is unsuitable for Class –B and Class –C types of fire.

The following are the Fire Risk Areas:

a) Transformers,
b) Battery rooms,
c) Cable galleries,
d) Control room,
e) Store room,
f) Fuel storage room, and
g) Generators.

The following are the fire hazards and their causes;

- Electrical short–circuit, earth fault, overheating in electrical circuits and electrical contact getting stack up,
- Smoking in "No Smoking" area,
- Hot surface or excessive heating due to friction or lack of cooling,
- Gas Cutting, welding, splatters,
- Bad housekeeping,
- Leakage of inflammable gas or liquid,
- Accumulation of static charges,
- Open storage of combustible materials or their storage near a heat source,
- Addition or modification to the plant and/or building,
- Inaccessibility or obstruction of fire protection equipment, and
- Poor standard or maintenance of fire protection system.

6.1.2 Precautions for Prevention of Fire

The precautions relating to common type of different class fires that are to be taken for prevention of fire are tabulated below:

S. No.	Precautions to be taken for:		
	Class –A Fire	Class –B Fire	Class –C Fire
1.	Glowing cigarette butts and matches shall not be thrown into waste buckets, oil regimes and other places of oil hazards	Cable trenches inside stations containing cables shall be filled with sand or pebbles or covered with non-flammable slabs.	Electrical equipment shall be installed, operated and maintained properly and in a manner as to eliminate arcs due to poor contacts in switches and fittings, worn insulation, crossed wires, opening of switches, carry larger current, etc.
2.	Smoking and use of pen flames shall be prohibited in oil filtration and storage room, storage battery rooms and places where combustible materials are kept.	Oil filled containers and equipment in receiving stations, sub-stations, buildings, storerooms, etc. shall be so located that fire and smoke from oil is not likely to do any damage.	Leakage on and/or overloading of circuits with consequent heating up of wiring must be guarded against.
3.	High standard of cleanliness shall be maintained. Waste material, rags, etc. shall be removed from the premises daily and suitably disposed of.	Concrete dikes, curbs or floor drains and loose rock filled pits shall be provided near oil storage rooms and oil filled equipment to prevent spread of spilled oil.	Motors shall be equipped with over-current and under-voltage protection to prevent excessive heating.
4.	Trees and rank vegetation shall not be permitted to grow in the neighborhood of receiving stations/ sub-stations, pole yards or other buildings. Roofs/buildings shall be kept clear of leaves, etc.	Empty oil drums, boxes or other combustible materials shall never be piled near storage oil tanks and oil filled equipment.	Insulation strength of the equipment and cables shall be checked periodically.
5.	Before starting welding and cutting operations, it shall be ensured that sparks arising from there do not lodge in woodwork or ignite other combustible materials in the area.	Petroleum containers shall be labeled and kept securely.	Temperature and loading condition of the equipment shall be recorded and studied.
6.	While installing heating devices, hot water pipes, suitable clearance from the combustible materials shall be maintained.	When a vehicle is refueled or petrol transformed from one container to another no smoking or flames shall be permitted in the vicinity.	Electrical lamps shall not be surrounded by or laid on combustible material. Inflammable gases or material shall not be stored near electrical equipment.
7.		Places where paints, varnishes, lacquers, thinners, etc. are stored or used shall be kept scrupulously clean and well ventilated.	Battery rooms shall have no loose connections and there shall be no sparking devices like bells, buzzers, fuses, etc. in the rooms. Smoking shall be prohibited and rubbish and other combustible shall not be permitted to accumulate in the battery room.
8.			Metal parts of oil tanks, electrical equipment and buildings shall be adequately bonded to prevent fire by lighting and static electricity. The earth resistance shall be checked periodically.
9.			Inflammable gases or material shall not be stored near electrical equipment.

6.1.3 Fire Inspections

The fire officer shall inspect the following:

a) Oil drains, gravel pits, etc. to ensure that these are kept clean at all times,
b) Fire escapes to ensure that all fire doors and shutters and their hardware (including fusible links, if any) are kept in good condition,
c) Premises, stores, etc. to ensure that the fire hazards due to bad housekeeping, improper storage of inflammable material are eliminated, and
d) The firefighting equipment / appliances to ensure its adequacy and effectiveness.

6.1.4 Fire Fighting Appliances/ Equipment

The fire fighting appliance/equipment or fire extinguishers are portable foam, CO_2 or water, sand and water buckets. These portable fire extinguishers are necessary to have, even if the premises are equipped with an automatic sprinkler installation, because these may enable an outbreak to be extinguished before\ the automatic sprinkler comes into operation.

Fixed installation is provided where the fire risk is sufficiently high to warrant the cost of installation. Such equipment will always be supplemented by hand-held portable gear and may, in many instances, come into operation automatically. These installations are:

- Hose Reels: Possible with automatic actions for use in offices and workshops.
- Hydrant system: For general use throughout the plant area.
- Sprinkler system.
- Mulsifyre System: Used for transformers.
- CO_2 installations: Used in closed areas such as generator housing, switchgear rooms, cable galleries and control rooms, etc.
- Mechanical foam: Used in fuel oil protection.
- Halogen agent system: Used in computer suites, control room, cable galleries and L.T. switchgear area.

All these equipment need regular checking and maintenance. Their operationalibility need to be verified by experts of accredited company.

6.1.5 Maintenance Procedure of Fire Extinguisher

The following are the maintenance procedure for fire extinguisher:

- Weigh the appliance and compare results with the previous reading,
- Empty the extinguisher and dismantle in accordance with the correct safety procedure and examine contents,
- Examine the inside of the extinguisher body and check for the absence or corrosion,
- Weigh the cartridge and check this against the weight marked on it. If there is more than 10% difference, replace the cartridge,
- Ensure that vent hole in the cap is clean,
- Examine the nozzle and discharge tube. Do not grease or oil the operating mechanism, which should be freely operable,
- Rebuild the fire extinguisher using new component where necessary,
- Refit the safety clip to prevent in advertent operation, and

- Record all dates and data of overhauling. This type of maintenance procedure will give maximum availability.

6.1.6 Fire Fighting Procedure

The following are the procedure for Fire Fighting:

a) As soon as a person discovers a fire he or she shall immediately turn the alarm and intimate the control room giving exact information as to the location, type and event of fire. He/she shall then proceed to extinguish or control the fire with proper extinguishing apparatus until help arrives. If he/she is not certain as to the action to be taken, he/she shall just wait.

b) In case of a fire involving electrical apparatus, the first essential is to render till circuit dead. Where it is not possible to switch off the current, the fire must be attacked in a way, which will not involve danger to the operator, i.e., by the use of non-conducting extinguishing materials, i.e., carbon dioxide, dry Chemical Powder, dry sand, ashes etc. Water should not be used on fires involving electrical equipment,

c) When extinguishing a fire known to have been started through an electrical fault, the current, in any event, shall be switched off to avoid ignition,

d) The operator in the control room after receiving the fire alarm shall inform immediately his immediate superior and the security officer, the nearest available fire fighting squad and the local fire brigade giving the exact information regarding the location, type and extent of fire, it will, however, be the endeavor of the station staff to control the fire,

e) The following principles shall be kept in view, in fighting fire:

   - To extinguish fire, it is necessary to eliminate one or more of the following three factors causing fire:
     - Heat is eliminated by cooling and water is good heat absorber.
     - Oxygen is eliminated by smothering and exclusion of air.
     - Fuel is eliminated by segregation, cooling or smothering.
   - The person in-charge shall size up, the situation, plan and direct the line of attack. Besides, automatic fire fighting systems could be employed.
   - Precautions shall be taken to prevent the spread of fire to adjoining buildings, plant and material not affected, by use of segregate on methods, water streams to break that waves, etc. Tarpaulins shall be thrown on unaffected plants and materials to prevent damage by water.
   - Ventilation shall be arranged to let smoke out and fire fighters in.
   - Extinguishers or hose line streams shall not be directed into the clouds of smoke. Base of the fire shall be located and attacked.
   - In the event of cloths catching fire, he/she shall cover his/her face with palms of the hands and roll himself /herself on the ground or he/she shall lie down and cover himself/herself with a blanket.

f) Fire fighters and rescue works should use suitable protective equipment or gas masks, wet cloths, etc. They should crawl on their hands and knees to keep their faces close to the floor and they should move along the wall.

g) The first aid personnel shall be arranged to be available at site of fires for rescue and first aid work.

h) All fires shall be reported on prescribed form (Refer Two pages from PTCLU’s Draft Code of Practice for Safety).

6.1.7 Functions of Fire Officer

The fire Officer shall maintain adequate firefighting equipment and fire alarm system at important situations. Framed plans showing the position of firefighting equipment, water supplies and hydrants, means of access and other useful information shall be displaced at suitable points. He shall also ensure that in all premises, where persons are required to work, adequate means of fire escape are available. The fire officer shall arrange periodic classes to ensure that all its regular employees are trained to be familiar with (i) common fire hazards, techniques of fire prevention & fire fighting, (ii) use of various types of fire safety equipment, (iii) location of exits and firefighting equipment, (iv) precautions against electric shock and inhalation of toxic gases, (v) operation to be carried out in case of fire involving electrical equipment or in the vicinity thereof, and (vi) observation of unusual suspicious conditions, e.g. overhauling of apparatus. He/she also conducts the fire inspections mentioned above in 6.1.3.

6.2 Safety Aspect of Operation and Maintenance

Three major causes of accidents are follows:

- Those which human has limited control like floods, landslides, earthquakes, fires, lighting and other acts of nature;
- Those due to improper or defective equipment and failure to provide adequate protective devices; and,
- The human elements or "Human Factor" is by far the greatest cause of serious accidents. Statistics show that more than 90% of industrial accidents are not due to defective equipment but due to failure on the part of workman and those in authority to observe safety rules and adopt safety devices for accident prevention.

The accident could be (i) electrical, and (ii) non-electrical. Accidents cause human suffering and loss of production to the organization. Safety measures are, therefore, essential. Success of safety measures depends on safety mindedness of the management supervisions and workers. Some of the methods to improve safety consciousness are:

- Prompt, investigations, pin pointing cause of accident and remedial measures,
- Use of personnel protective equipment such as helmet, goggles, gloves, safety belts, etc., and
- Arousing safety consciousness through the use of posters, films, journal, safety talk, safety competition, etc.

6.2.1 General Safety Precautions

All voltage level, even low, shall be considered dangerous even though the voltage may not be high to cause shock. All electrical circuits are to be treated live and no work should be carried out without proper shut down and ensuring that it is (i) de-energized, (ii) isolated from all sources and (iii) effectively connected with ground.

6.2.2 Fundamentals of Safety

Prevention of accidents requires whole–hearted cooperation of all members of organization. A capable, mentally alert employee will avoid accident.

Unsafe acts which may cause accidents are as follows:

- Operation of equipment without authority and warning,

- Operating without proper instructions,
- Making safety device inactive,
- Working nearby dangerous or live electrical equipment which could conveniently be de-energized, and
- Using defective tools & parts (T & P) or equipment or its improper use.

Unsafe conditions which may cause accidents are as follows:

- Ungrounded equipment,
- Defective materials or equipment,
- Improper illumination, and
- Non-standard design and construction.

Accidents are, therefore, results of unsafe acts and unsafe conditions or combination of both.

6.2.3 Safety Precautions and Practices in O & M

The O & M team shall be trained in safety requirements and practices at the project. The O & M team shall also have periodic safety meetings to discuss any safety related issue and mitigations measures in the project.

Following are the safety precautions and practices in the Operation and Maintenance of hydropower plants, transmission lines and sub-stations.

- No unsafe operation will ever be permitted. Feedback regarding unsafe operation/ condition should be taken into consideration with proper spirit and review should be made to avoid accidents.
- Interlocks should not be by-passed unless it is very essential. Written permission should be obtained from the superintendent/ in-charge of the station. Extra precaution should be taken by all the parties during such cases.
- Equipments are designed for certain operating conditions. It should be operated within prescribed operation limits. Over stressing of the equipment should be for minimum possible time with minimum percentage of overloading. This will avoid damage to the equipment.
- O & M staff should be familiar with the station layout and operation limits of different equipment such as breakers, transformers, isolators, CTs, PTs, etc. A person should be allowed to operate or take over the equipment only after he has acquired adequate knowledge of the equipment.
- Operation should be carried out as per operation instructions. This will help in carrying out operations safety and maintaining uniformity. In case of any modifications/change in the layout operating instruction should be reviewed.
- Booklets/ manufacturer's instructions for different equipment should be available and should be refereed to before taking out equipment for maintenance.
- It is the responsibility of the supervisor to interpret correctly and explain safety rules and regulations to all the persons concerned and to ensure that they thoroughly understood the same.
- Breach of safety rules should be suitably dealt with.
- Only authorized persons shall be allowed to carry out O & M.
- Supervisor shall guard against the use of defective safety appliances, tools and materials.

- In case of any emergency, in which quick action is needed, in order to safeguard personnel and/or property, only authorized persons will take necessary action. Under no circumstances attempt shall be made to carry out operations, which are not safe.
- All persons must use the standard protective equipment intended for the job.
- All protective equipment should be periodically tested.
- Metal ladders should not be used in switchyard.
- Adequate number of first aid and firefighting equipment shall be maintained.
- First aid and artificial respiration chart shall be exhibited. Every person shall be familiar with the same.
- Every person shall be familiar and should know how to operate firefighting equipment so that fire can be extinguished promptly minimizing damage.
- In the event of the fire on electrical installation, the affected part shall be immediately switched off and isolated from all the sources.
- Use HRC fuses only with proper capacity.
- While opening isolator confirm that it is not carrying load current. Similarly isolator should not be closed on load.
- Under-rated circuit breakers should not be used to clear the faults.
- No breaker should be operated beyond stipulated operating duty.
- While working on the breaker, its operating mechanism should be de-energized such as discharging spring, releasing air pressure, etc.
- Transformer should be discharged and grounded from all sides (windings). Neutral grounding of the transformer should not be treated as grounding.
- Current transformer secondary should never be left open circuited.
- After cutting out capacitor bank, it should be allowed to discharge through discharge PT for about 10 minutes. The bank should be grounded with hot stick before commencing the work.
- ASKAREL compound used in capacitor bank as dielectric is very toxic and harmful, hence, should be handled with great care.
- Apparatus, framework and other non-current carrying metal parts associated with power system are to be effectively grounded.
- Lighting arresters shall be grounded independently.
- Isolating switches provided for generators and synchronous condensers and other rotating machines should never be opened when connected to any voltage source even when the machine is carrying no load.
- The areas should be cordoned off indicating location of work on the particular equipment.
- Use of safety tags must be insured while allowing shut down or maintenance on some part/ equipment.

6.2.4 Check-list for Electrical Safety

6.2.4.1 General Instructions

- Workmen should not wear loose dress and the dresses shall not have metal buttons.
- Workmen shall be properly trained.
- All lines shall be treated as live till proper line clears are received.
- Lines/equipment shall be earthed before proceeding with the work.

- Adequate clearance between lines on which work is being done and other line wires shall be ensured or line clears are taken on those line also.
- Display of all precautionary boards such as Danger Boards shall be ensured by both persons issuing/ receiving line clear.
- Shoes with metal nails etc. shall not be used and one those with rubber bottom shall be used.
- Items made of metal like chains of wrist watch, key bunches, rings, bracelets shall not be used while on work.
- Tools should not be thrown at each other while on work and use a proper tool for each job.
- Rubber gloves/ gauntlets can be used when (i) line voltage is 5 kV or below (ii) earthing, (iii) opening of isolators, and (iv) working on street light fittings. Please note, while earthing, other personnel shall be 12 to 15 feet away.
- Avoid haste and joking while working.
- Loose connections can cause fire.
- Ensure all three blades of isolator are open before working.
- Do not work while feeling exhausted.
- Mind your personnel safety and do not depend on others.
- Keep safe distance from rotating equipment. Do not attempt to handle them while in motion.
- Use of safety belts while works on poles/ platforms above 3 meters height will be carried out.
- Every tool or appliance such as flings, pulleys, chain block, etc. shall be in good condition, non-working tools/ appliances shall be permanently discarded. Also the damaged pipes, spanners, hammers shall be discarded.
- Use always insulated pliers and screwdrivers (only on LT). When more than one LT circuit is laid from a transformer, ensure that street light circuits are also separate. Better take LC on both CT circuits.
- "Double feeding point-Danger" board shall be displayed when supply from two sources is available.
- When loads on one transformer are transferred on to another, it should be noted in the log book and intimation given to duty staff.

6.2.4.2 Do's and Don'ts

<u>First of all, study the manual carefully. Note that ignorance of rules and regulations will result in accidents to himself and his co-workers. No operation or activity is so urgent that it has to be performed in an unsafe manner.</u>

Following are the items of Do's and Don'ts.

Do's

- Obey safety instructions given by the person in-charge.
- Insulate yourself from earth by standing on rubber mat while attempting to get the person who is in contact with live line or apparatus.
- Remove the casualty from the cause, render first aid and send for doctor or take the casualty to the nearest hospital.
- Break the circuit by opening the power switch and release the victim.

- Use correct size and quality of fuse wire while renewing the blown out fuse.
- Turn your face away whenever an arc or flash occurs.
- Ensure controlling switches are opened and locked or fuse holders are withdrawn before working on lines.
- Disconnect the supply immediately in case of fire on or near electrical apparatus.
- Keep away inflammables from electrical apparatus.
- Report all accident whether minor or major, fatal or non-fatal, departmental or non-departmental immediately to the person in charge.

Don'ts

- Do not replace a blown fuse until you are satisfied with the cause and you have rectified the irregularity.
- Do not disconnect a plug by pulling a flexible cable when the switch is on.
- Do not use wire with poor insulation.
- Do not close any switch/GOS/Breaker unless you are familiar with the circuit, which it controls and know the reason for its being kept open.
- Do not work on energized circuit without taking extra precautions such as use of rubber gloves and gauntlets.
- Do not touch or tamper with any electrical equipment or conductor unless you have made sure that it is dead and earthed.
- Do not work on the line circuit without the specific orders of the AE/JE and make certain that all safety precautions have been taken.
- Do not disconnect earthling connections or render ineffective the safety gadgets installed on mains and apparatus.
- Do not open or close switch or fuse slowly or hesitatingly.
- Do not touch an electrical circuit when your hands are wet, or bleeding, cut or in abrasion.
- Do not use fire extinguisher on electrical equipment unless it is clearly marked for that purpose.
- Do not throw water on line electrical equipment in case of fire.
- Do not attempt to disengage a person in contact with a line apparatus, which you cannot switch off immediately.
- Do not touch the body of electrical shock victim, rather than push him with a piece of dry wood.
- Do not discontinue artificial respiration until recovery or death is confirmed by the Doctor.
- Do not allow visitors and unauthorized persons to touch or handle electrical apparatus or come within the danger zone of HV apparatus.
- Do not test circuit with bare fingers.

6.3 Disaster management

6.3.1 General

Disaster management is aimed at ensuring safety of people, protection of environment, protection of installations and restoration of generation and supply. Power station staff should remain always alert for such emergent eventualities. Power station in-charge should arrange drills, training for the staff at regular interval especially before rainy season.

6.3.2 Possible Disaster

The following disaster in Hydropower Plants, Transmission Lines and Sub-stations could be foreseen:

- Disaster due to natural calamities such as floods (including GLOFs), earthquake, landslides and wind storms which may affect outdoor installations,
- Areas prone to disaster on account of fire are cable galleries, switchyard and switchgears, transformer, oil containers, generators/ motors and records, etc;
- Over-speeding of turbines,
- Failure of underground structures due to inadequate support or geological reasons,
- Following occurrence may cause flooding on power stations:
  - i. Failure of top cover studs,
  - ii. Failure of draft tube inspections window or nearby liner plates,
  - iii. Entry of water from downstream side windows of power stations during floods (GLOFs),
  - iv. Failure of diversion dam gates opening during floods and entry of water from upstream side in Dam toe power stations,
  - v. Failure of drainage dewatering system, gate seal failure and inadvertent opening of gates during maintenance.

6.3.3 Constitution of a Task Force

A task force consisting of O & M personnel of different disciplines needs to be constituted who will identify the following:

- Source of disaster & steps to contain the same.
- Isolate remaining plant and keep them in safe condition.
- Organize safe shut down of power plant.
- Organize all support services like fire fighting system, etc.
- Attend to all emergency maintenance jobs on top priority.
- Apprise authorities on all safety related issues.
- Record accident details.
- Arrange for evacuation of man, material from affected area(s).
- Arrange ambulance and emergency first aid.

6.3.4 Development of Disaster Management Plan

The disaster management plan for generating stations, transmission lines and sub-stations shall take care of the following:

- Information to management on urgent basis.
- Emergency power supply system shall be made operational.
- Back start procedure must be prepared and needs to be reviewed from time to time.
- In case of fire, the unit/station needs to be emergency tripped through the emergency push button, if felt necessary depending upon location on fire.
- Ensure immediate shut down of affected or likely to be affected portion of the power station so that rest of the plant remains healthy.
- Fire tenders need to be summoned immediately.

- The fire extinguishing system needs to be automatically cut in; and in case of failure of auto system, the system should be manually started.
- The earmarked hospital needs to be informed of such emergency.
- Emergency evacuation of site personnel in extreme emergencies.

6.3.5 Development of Action Plan

A disaster action plan and an organization for effective control and management of disaster shall be prepared by power station in-charge along with responsibilities apart from training of personnel for handling of such situations. This shall consist of following factors:

- Responsibility of employees about first information.
- Responsibility of Emergency Management Manager (EMM to be nominated by the plant in-charge) for declaration of emergency.
- Responsibilities of various teams constituted to deal with specific emergency requirement.
- Responsibility of EMM for "All Clear" signal after disaster has been cleared off.

6.3.6 Essential Help Staff

In plants immediately affected or likely to be affected efforts will be made to shut down and make other units safe. The plant supervisor and operators will carry out this work without exposing them to any risk. The following staff will also help them:

- Attendants,
- First aiders, (if available, otherwise all operation staff should have proper training for first aid),
- Persons responsible for emergency lighting,
- Persons responsible for transport,
- Persons working as runners, in case communication fails,
- Persons manning plant entrance, liaison with police, fire tenders, call for emergency vehicles, ambulance.

It is the responsibility of EMM to identify such staff and form task force to carry out above activities. In case separate staff for carrying out such activities is not available, existing staff should be trained for these eventualities.

7. REFERENCES

The following study materials likely to be relevant for the proposed assignments were collected from the secondary sources through literature surveys and internet search:

- Operation and Maintenance of Hydropower Stations Planning and Management – An Indian Perspective.
- Transmission Facilities Operation and Maintenance Projects covered by the Model Class Screening Report, Altalink Model Class Screening, Highland Environment Management.
- Standard for Operation and Maintenance of Transmission Line, The Gazette of India, June 26, 2010.
- Manuals for Transmission Lines and Substation Construction and Maintenance Activities, prepared for Dairy land Power Cooperative by HDR Engineering Inc. Fels, 2007.
- Maintenance and Inspection Schedules for Transformers, Allied Sub-stations equipment and lines, Haryana State Electricity Board, September 16, 1999.
- Standards/ Manuals / Guidelines for Small Hydropower Development Prepared by Alternate Hydro Energy Center, Indian Institute of Technology for Ministry of New and Renewable Energy, Govt. of India.
- Civil Engineering Guidelines for planning and Designing of Hydroelectric Development, American Society of Engineers, 1989.
- Design Guidelines for Water Conveyance System of Hydropower Projects, DoED, Govt. of Nepal, August, 2006.
- Nepal: Kali Gandaki “A” Hydroelectric Project, An Independent Performance Evaluation by ADB, December, 2012.
- Best Practice in Operation and Maintenance of Hydropower Stations.
- Standard Maintenance Guidelines-Substations & Power System Maintenance Manual, Western Area Power Administration, Department of Energy, United States of America.
- Sub-station Preventive Maintenance Manuals prepared by International Resources Group for Haryana State Electricity Board, August 1998.
- Year Books of Nepal Electricity Authority.
- Publication of Nepal Electricity Authority-Generation, Operation and Maintenance Business.
- Vidyut half yearly bulletins of Nepal Electricity Authority.
- Annual Reports of Chilime Hydropower Company.
- Manual and Guidelines for comprehensive Flood Loss Prevention and Management, Economic and Social Commission for Asia and the Pacific, UNDP, Jan. 1991.
- Draft Code of Practice for Safety, Power Transmission Cooperation of Uttaranchal Limited.
- Draft O & M Manual, Power Transmission Cooperation of Uttranchal Limited.
- General Guidelines for 765/400/220/132 kV Sub-station & Switchyard of Thermal/Hydropower Projects, Central Electricity Authority, June 2012.
- Articles Pertinent for the proposed assignment:

- मर्स्याङ्गदी जल-विद्युत केन्द्र संचालनः एक परिचय in VIDYUT, 1 Bhadra, 2049.
- २०४९/०५० को पटाक्षेपमा देवीघाट जल-विद्युत केन्द्र in VIDYUT, Bhadra, 2050.
- Dams that have failed by flooding: an analysis of 70 failures in International Water Power & Dam Construction, Sept./Oct. 1993.
- Turbines: Abrasive matters at Nathpa Jhakri in International Water Power & Dam Construction, February, 1995.
- Optimum use of run-of-river hydropower schemes in The International Journal on Hydropower & Dams, Volume Six, Issue Six, 1999.

• Proceeding of the Symposium on Electricity Generation in Nepal, the Operational and Maintenance Aspects, April 27-29, 1993.

• Marsyangdi Hydroelectric Project: Training for Operation and Maintenance Personnel-Quarterly Report (Period January, 1994 to March 1994) by Lahmeyer International in Association with Snowy Mountain Engineering Corporation.

Annex-1:

A Typical Format for Spare Parts List

ANNEX-1: A TYPICAL FORMAT FOR SPARE PARTS LIST

Spare Part No.	Description of Spare Part	Equipment & Its No.	Quantity	Location

Annex -2:

Format for Monthly Report of Power Plant Operation and Maintenance

ANNEX – 2: FORMAT FOR MONTHLY REPORT OF POWER PLANT OPERATION AND MAINTENANCE

Name of Power Plant: …………………………………… Installed Capacity:…………… Reporting Month:………………

Gross Generation: ………………………… (kWh) Plant Use: ………………….. (kWh) Net Generation: ………………….. (kWh)

Water for generation: ……………………….. m^3 Downstream Release: ……………. m^3

Maximum hourly Generation: ………………….. (kWh)

Plant Factor: ………………… (%)

Water Use factor: …………………. (%)

Elevations (m) at

Forebay/Reservoir	Tailrace

Unit Service Record

Operation Information					Maintenance Information					
Unit No.	Gross Generation	Time Operated (hrs)	Availability (hr)	Availability factor (%)	Outage for Maintenance			Actual Maintenance Time		Description of Forced Outage
					Day	Time (hr: min)	Duration	Individual outage (hr: min)	Total for month	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										

Annex -3:

Typical Formats for Reporting

ANNUAL OUTAGE PROGRAM

NAME OF GENERATING PLANT:

NAME OF THE GENERATING COMPANY:

FOR: F/Y …………………… B/S …………………. AD.

Month (Nepali)	Srawan	Bhadra	Aswin	Kartik	Marg	Poush	Magh	Falgun	Chaitra	Baisakh	Jestha	Ashad
Month (English)												
Week												
No. of days												
Outage in Hrs.												
Generating Unit												
No.1												
No.2												
No.3												
Power Transformer												
No.1												
No.2												
Unit Circuit Breaker												
No.1												
No.2												
No.3												
Line Circuit Breaker												
No.1												
No.2												
Other Equipment												
No.1												
No.2												

Note: If the month starts on a day other than Sunday, the days before the first Sunday of the month shall be included in first week of the month.

If the month ends on a day other than Saturday and number of weeks in the month happen to be more than four, the days after the last Saturday shall be included in fourth week of the month.

Notes if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Comments if any:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

ANNUAL AVAILABILITY DECLARATION

NAME OF GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: F/Y ……………………. B/S …………………. AD.

S.No.	Month (Nepali)	Srawan	Bhadra	Aswin	Kartik	Marg	Poush	Magh	Falgun	Chaitra	Baisakh	Jestha	Asadh
	Month (English)												
1	**Power Availability:**												
	Average Discharge Available CMPS												
	Average MW Avaialbe in Month												
	Max. MW Available in Peak Hr.												
	Min. MW available in Peak Hr.												
2	**Energy Availability:**												
	Av. MWh/day available in the Month												
	Peaking facility MWh/day												
	Total declared MWh in the Month												
	Design MWh for the Month												

Notes if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Comments if any:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

MONTHLY GENERATION OUTAGE PROGRAM

NAME OF GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: F/Y ……………………. B/S …………………. AD.

Month:

Week No. as per Month Week No. as per Nepali Calendar	Residual* Previous Week	W1	W2	W3	W4	Partial** Last Week
Nepali Date (From----to)						
English date (From----to)						
Generator Unit No.1, Outage Hrs.						
Outage MW.						
Generator Unit No.2, Outage Hrs.						
Outage MW.						
Generator Unit No.3, Outage Hrs.						
Outage MW.						
Transformer No.1, Outage Hrs.						
Outage MW.						
Transformer No.2, Outage Hrs.						
Outage MW.						
Line Ckt. Breaker No.1, Outage Hrs.						
Outage MW.						
Other Equipment Outage Hrs.						
Outage MW.						

* If month starts on a day other than Sunday then the days before the first Sunday of the month are termed as Residual previous week.
** If the month ends on a day other than Saturday then the days after the last Saturday of the month are termed as partial last week.

Notes if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Comments if any:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

WEEKLY GENERATION OUTAGE PROGRAM

NAME OF GENERATING PLANT:

NAME OF THE GENERATING COMPANY:

FOR: YEAR ……………………. MONTH …………………. WEEK.

Day	Sunday			Monday			Tuesday			Wednesday			Thursday			Friday			Saturday		
Date (Nepali)																					
Date (English)																					
Outage Time	From To	Hrs.	MW Deferred	From To	Hrs.	MW Deferred	From To	Hrs.	MW Deferred	From To	Hrs.	MW Deferred	From To	Hrs.	MW Deferred	From To	Hrs.	MW Deferred	From To	Hrs.	MW Deferred
Unit No.1																					
Unit No.2																					
Unit No.3																					
Transformer-1																					
Transformer-2																					
Line CB-1																					
Line CB-2																					
Other Equip.																					

Notes if any:

Comments if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

FORCED/ MAINTENANCE OUTAGE REQUEST FORM

NAME OF GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: ……………….YEAR ……………………. MONTH …………………. DATE.

Start Date	Start Time	Location and Description of the Works	Finish Date	Finish Time	Duration of Shutdown

Reason for Outage:

Note: Request form should be submitted at least 48 hours prior to proposed time for maintenance outage.

Submitted by:
Name:
Designation:
Date of submission:
Signature:
Company Seal:

Approved by:
Name:
Designation:
Date of submission:
Signature:
Official Seal:

SCHEDULED OUTAGE REQUEST FORM

NAME OF GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: ……………..YEAR ……………………. MONTH …………………. DATE.

Location	Description Works	Start date and Time	Finish Date and Time	Duration of Shutdown Requested

Note: Request form should be submitted at least seven Business Days prior to planned scheduled outage.

Submitted by:
Name:
Designation:
Date of Submission:
Signature:
Seal:

Acknowledged by:
Name:
Designation:
Date of Submission:
Signature:
Seal:

MONTHLY AVAILABILITY DECLARATION ON WEEKLY BASIS

NAME OF GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: ……………………..YEAR ……………………. MONTH.

S.No.	Week* as per month	Residual*** Previous Week	W1	W2	W3	W4	Partial Last Week ****
Week No. As per Nepali Calendar							
Nepali Date (From-to)							
English date (From-to)							
1	**Power Availablility**						
	Average Discharge Available in CMPS						
	Average MW Available in the Week						
	Max. MW Available during Peak Hours**						
	Min. MW available during Peak Hours						
2	**Energy Availability**						
	Av. MWh/day available in the Week						
	Peaking MWh available/day						
	Total declared MWh in the Week						
	Design Capacity averaged over Week						

* Week means 00:00 hrs on Sunday to 24:00 hrs on Saturday
** Peak hour means the duration between 18:00 hrs to 21:00 hrs
*** If the month starts on a day other than Sunday then the days before the first Sunday of the month are termed as Residual previous week.
**** If the month ends on a day other than Saturday then the days after the last Saturday of the month are termed as partial last week.

Comments if any:

Notes if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Notes if any:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

MONTHLY AVAILABILITY DECLARATION ON HOUR TO HOUR BASIS

NAME OF GENERATING PLANT:

NAME OF THE GENERATING COMPANY:

FOR: ……………………..YEAR ……………………. MONTH.

Date Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	MW																															
0.00																																
1.00																																
2.00																																
3.00																																
4.00																																
5.00																																
6.00																																
7.00																																
8.00																																
9.00																																
10.00																																
11.00																																
12.00																																
13.00																																
14.00																																
15.00																																
16.00																																
17.00																																
18.00																																
19.00																																
20.00																																
21.00																																
22.00																																
23.00																																
24.00																																
Total																																

Notes if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Comments if any:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

WEEKLY AVAILABILITY DECLARATIONS

NAME OF GENERATING PLANT:

NAME OF THE GENERATING COMPANY:

FOR: ……………..YEAR …………………. MONTH………….….. WEEK.

Day	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Date (Nepali)							
Date (English)							
Hour	MW	MW	MW	MW	MW	MW	MW
0.00							
1.00							
2.00							
3.00							
4.00							
5.00							
6.00							
7.00							
8.00							
9.00							
10.00							
11.00							
12.00							
13.00							
14.00							
15.00							
16.00							
17.00							
18.00							
19.00							
20.00							
21.00							
22.00							
23.00							
24.00							
Total							

Notes if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Comments if any:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

DAILY AVAILABILITY DECLARATION

NAME OF GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: ……………..YEAR ……………. MONTH …………….. DATE (NEPALI).
..…………..YEAR... …………. MONTH. …………….. DATE (ENGLISH).

Unit Hour	Unit 1 MW	Unit 2 MW	Unit 3 MW	Unit 4 MW	Unit 5 MW	Unit 6 MW	Total MW	Remarks for Shutdown
0.00								
1.00								
2.00								
3.00								
4.00								
5.00								
6.00								
7.00								
8.00								
9.00								
10.00								
11.00								
12.00								
13.00								
14.00								
15.00								
16.00								
17.00								
18.00								
19.00								
20.00								
21.00								
22.00								
23.00								
24.00								
Total								

Notes if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Comments if any:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

VERBAL DISPATCH INSTRUCTION CONFIRMATION

FROM: LDC, NEA
TO:
NAME OF THE GENERATING PLANT:
NAME OF THE GENERATING COMPANY:

We hereby confirm our verbal dispatch instruction as per following details,
issued to you by telephone at …………. (insert time) hrs. on …………… (insert date).

Time (Hrs.)		Verbal Instruction	Verbal Instruction given by
From	To		

Operation Engineer

DAILY GENERATION REPORT FORM

NAME OF THE GENERATING PLAN:
NAME OF THE GENERATING COMPANY:
FOR : ………….. YEAR ……………… MONTH ……………. DATE.

Energy Meter Reading Previous:
Energy Meter Reading Present:
Multiplying Factor:
Total Generation of the Day: MWh
Cumulative Energy for the Month: MWh

Time Hours	Unit No.1 MW	Unit No.2 MW	Unit No.3 MW	Total MW	Reactive MVAR	Calculated MVA	PF	Remarks
13.00								
14.00								
15.00								
16.00								
17.00								
18.00								
19.00								
20.00								
21.00								
22.00								
23.00								
24.00								
1.00								
2.00								
3.00								
4.00								
5.00								
6.00								
7.00								
8.00								
9.00								
10.00								
11.00								
12.00								
Average								

Regards,

____
Operation Engineer

DAILY GENERATION LOG SHEET

NAME OF THE GENERATING PLAN:
NAME OF THE GENERATING COMPANY:
FOR : ………….. YEAR ……………… MONTH ……………. DATE.

Time Hours	Freq.	Unit # 1			Unit # 2			Unit # any additional no.			Total Generation		Trans. Line Voltage kV	Step-up Transformer (AMP)
		Generation (MW)	Reactive Power		Generation (MW)	Reactive Power		Generation (MW)	Reactive Power		Active (MW)	Reactive (MVAR)		
			P.F.	(MVAR)		P.F.	(MVAR)		P.F.	(MVAR)				
1.00														
2.00														
3.00														
4.00														
5.00														
6.00														
7.00														
8.00														
9.00														
10.00														
11.00														
12.00														
13.00														
14.00														
15.00														
16.00														
17.00														
18.00														
19.00														
20.00														
21.00														
22.00														
23.00														
24.00														
Total														

Note: (a) + MVAR means export and (b) - MVAR means import

Submitted by:
Signature:
Name:
Designation:
Seal:

FAULT REGISTRATION FORM

NAME OF GENERATING PLANT:
NAME OF THE GENRATING COMPANY:
FOR: ……………….. YEAR ………………… MONTH.

Power Plant:	Date of Fault: Nepali ………………. English: …………………	Time:
Affected Parts of the Power Plant:		
Description of the Fault:		
Cause:		
Tripped Breaker:		
Alarms & Indications on Protection Relay:		
Outage Time:		
Loss of Generation:		

(…………………………...…………….)
Operation Engineer

MONTHLY GENERATOR PERFORMANCE REPORT FORM

NAME OF THE GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: …………………… YEAR ……………….. MONTH.

S.No.	Particulars	Unit No.1	Unit No. 2	Unit No.3			Transformer No.1	Transformer No. 2		
1	Present Reading at …………. Hrs On …………									
2	Previous Reading at ………. Hrs On …………									
3	Difference									
4	Multiplying Factor									
5	Energy (MWh)									
6	Cumulative From beginning of the Year									
7	Total Energy Supplied to Interconnection Point									
8	Total Hours in Month									
9	Actual Running Hours in Month									
10	Percentage Running Hours									
11	Average Power Production (MW)									
12	Maximum Demand									
13	Plant Load Factor									
14	Number of Trippings on Plant Side									
15	Type of Tripping									
16	Number of Trippings on System or Transmission Line Side									
17	Types of Tripping on System									

Notes if any:

Comments if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

MONTHLY GENERATION REPORT FORM

NAME OF THE GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: …………………… YEAR ……………….. MONTH.

Date	Total Generation MWh	Delivery to Interconnection Point (MWh)	Local Distribution (MWh)	Deemed Generating of NEA outage and reduced outputs (MWh)	Deemed Generation of Plant Outages and Reduced Outputs (MWh)	Remarks
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						

Notes if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Comments if any:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

MONTHLY OUTAGE AND REDUCED OUTPUT REPORT

NAME OF THE GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: …………………… YEAR ……………….. MONTH.

Date	NEA outages and reduced outputs						Description of event	Plant Outage and Reduced Outputs		
	From Hrs.	To Hrs	Prorated hours	Load before event (MW)	Load during event (MW)	Deemed gen. Loss (MWh)		Load before event (MW)	Load during event (MW)	Deemed gen. Loss (MWh)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										

Notes if any:

Submitted by:
Signature:
Name:
Designation:
Seal:

Comments if any:

Acknowledged by:
Signature:
Name:
Designation:
Seal:

MAINTENANCE OUTAGE REPORT FORM

NAME OF THE GENERATING PLANT:
NAME OF THE GENERATING COMPANY:
FOR: …………………… YEAR ……………….. MONTH………………. DATE.

Type of Outage (maintenance or forced):
Actual start date and time of outage:
Actual finish date and time of outage:
Length of outage:
MW output before outage:
MW output during outage:

Description of work:

Submitted by:
Signature:
Name:
Designation:
Seal:

LOADING STATUS AND SCHEDULED OUTAGES

NAME OF SUBSTATION:
NAME OF AREA GRID OFFICE:
FOR: …………………… YEAR ……………….. MONTH

S. No.	Substation	Voltage level and feeders name	Maximum Load								Frequency of		Duration of		Total Planned Outages		Remarks
			First week		Second week		Third week		Fourth week		Shut down (a)	Load Shedding (A)	Shut down (b)	Load Shedding (B)	Frequency (a+A)	Duration (b+B)	
			Amp	Date and time	Amp	Date and time	Amp	Date and time	Amp	Date and time							

FORCED OUTAGES OF TRANSMISSION LINES AND SYSTEM FAILURES

NAME OF SUBSTATION:
NAME OF AREA GRID OFFICE:
FOR: …………………… YEAR ……………….. MONTH

S. No.	Substation	Voltage level and feeders name	Trippings								Total Forced outages		System Failure		Remarks
			Terminal related				Line related				Frequency (a+b)	Time (A+B)	Frequency	Time	
			Relays operated		Outage		Relays operated		Outage						
			Main protection	E/F+O/C	Frequency (a)	Duration (A)	Main protection	E/F+O/C	Frequency (b)	Duration (B)					

TRANSMISSION LINE SHUTDOWN IMPLEMENTATION FORM

NAME OF GENERATING PLANT/OR GRID OFFICE:
NAME OF THE GENERATING COMPANY:
FOR: …………………… YEAR ……………….. MONTH…………….. DATE

A. Shutdown Request (Shutdown may be for User, Grid Owner or both):

Shutdown Requested by:	
Date of Shutdown:	
Earliest start time:	Latest completion time:
Location of work:	
Description of work:	
Type of outage (scheduled or form):	
In-charge Supervisor	Safety Officer
Name of the person approving the shutdown and date of approval:	Signature:

B. Shutdown Placement

Step	Time	Description of Operation	(Insert User Name)		NEA	
			Lock No.	User SO	Lock No.	ISO
Disconnection at the end-1 …………………………………..						
1		…………………… shall open Circuit Breaker				
Disconnection at the end-2 …………………………………						
2		…………………… shall open Circuit Breaker				
3		……………………. Shall open isolator				
Disconnection at the end-1 ……………………….						
4		…………………. Shall open isolator				
Grounding						
5		User shall close ground switch at the end-1				
6		NEA Shall close ground switch at the end-2				

After step six the Implementation Safety Officer (ISO) shall inform User's Safety Officer (USO) that shutdown has been effective and he can authorize his personnel to work on the line. No personnel other than the personnel under the supervision of the supervisor in-charge are allowed to work on the line. The USO will hold the key for all isolators throughout the shutdown and is the only allowed to work on the line. The USO will hold the key for all isolators throughout the shutdown and is the only person that can release the shutdown.

C. Shutdown Release

Step	Time	Description of Operation	----------------------------		NEA	
			Lock No.	User SO	Lock No.	ISO
1		The User SO shall remove the grounding switch at end-1 and NEA personnel shall open the grounding switch at the end-2				
2		verify CB is open at end-2.				
3		ISO shall remove the lock isolator at the end-2 and NEA personnel shall close isolator at end-2.				
4		Verify CB is open at end-1.				
5		The User SO shall remove the lock on isolator at end-1 and operator shall close isolator at the end-1.				
6		User SO shall report the LDC that shutdown is complete and system is ready for operation.				

system is in normal operating after completion of shut down and reconnection.

User Job Incharge   NEA Job Incharge.