

## CHAPTER - 5

### BEST PRACTICES IN CONSTRUCTION MONITORING OF HYDRO ELECTRIC PROJECTS

***“Eternal vigilance is the price of liberty”- these words of wisdom are nowhere more relevant than in the case of hydro power projects and their construction monitoring. Constant construction monitoring ensures freedom from trouble and assurance of quality and maximum output. Monitoring involves setting up of objectives, assessment of critical items, planning and organisation, personnel management, contract management and adoption of an appropriate mechanism for reducing time and cost over-runs.”***

#### 5.1 MONITORING SYSTEM FOR HYDRO- ELECTRIC PROJECTS

Monitoring is a general term implying continuous tracking of progress in comparison to a predetermined plan, i. e. the schedule, and to avoid and remedy any straying from the schedule. Monitoring is essential for all kinds of projects or jobs where a certain task is to be completed within given time and/or cost by proceeding on a determined path. In a hydroelectric project, it is all the more important as the delay can cost heavily. Whenever a hydel project is visualized for execution, the most important aspect to be taken care is the time (duration) required for its completion. The viability of the scheme depends largely on the execution period since the cost and benefits vary considerably with period of completion and even good projects can be rendered unprofitable due to large time overruns and cost overruns.

Since big projects involve huge investments and massive engineering activities, stakes are large and it is essential that the progress of various activities be kept under a constant vigil at various levels in order to check any avoidable straying from the schedule of construction. At the time of

approval of a project for execution, the target of completion, cost of each activity and the overall completion date of the project are fixed. The monitoring of a project comprises:

- a. Defining and setting targets
- b. Reporting achievements against the targets.
- c. Deviations from the targets and reasons thereof.
- d. Corrective action to undo and to contain the damage and avoid further delay.
- e. Rigorous follow-up for enforcement of the decisions of the management for augmenting the progress, directly as well as indirectly.

The overall plan of project works and completion of all activities up to commissioning are spelt out in a project schedule. The overall aim of whole monitoring process is to adhere to this schedule and commission the project by the scheduled commissioning date. It is essential therefore that various components of the project are completed as per their respective schedules.

## **5.2 Objectives of Monitoring:**

The following are the main objectives of monitoring mechanism:

### **5.2.1 Completion Period:**

This covers determination of period of construction project as a whole and firm up the completion dates of each of the project components. The determination of completion period depends on the following factors :-

- i) Location of the project.
- ii) Number of major components.
- iii) The most critical item of each of the components.

#### **5.2.1.1 Location of the Project**

To assess the working months available.  
Proximity to important rail line & roads.  
Communication facilities.

### 5.2.1.2 Number of major components

Determine the actual number of major components as independent packages.

Time factor with matching financial back for these major components.

### 5.2.1.3 Critical items

The various critical items in each of the components of the project.

All other items of respective components to match the critical path as parallel activities to match the completion of critical items.

**5.2.2 Implementation Plan:** Implementation plan with organizational and financial implications. This is practiced with,

- i) Network Technique planning with detailed realistic programme.
- ii) Need based planning.
- iii) Term work planning and responsibilities.

**5.2.2.1 Network Planning:** This include development of Network; tabulation of objectives and requirements and Realistic & Accurate Estimation.

- Detailed programming of various important items of all components.
  - Determining the critical path (main item) for all components.
  - Develop network of various activities culminating them with the critical item.
  - Develop master network with all components indicating the main critical activity of each of these components.
- ❖ Tabulation of objectives and requirements
- The various requirements and inputs to be tabulated and enlisted with probable date of requirement.
  - The important objectives and targets termed as mile stones to be enlisted with dates for achievement indicating incentives and penalties.
  - The dates of requirement and dates of targets to match the component network and the master network.

- ❖ Realistic and Accurate Estimates
  - Updated geology
  - Firmed up design requirement and drawings in the chronological order as per the plan.
  - Accurate estimates of quantities.

Any deviation of any of the above factors will upset the smooth passage of networks.

**5.2.2.2 Need based planning:** The need based requirement towards planning are :-

- i) Equipment planning
  - ii) Material planning
  - iii) Planning and evaluation of working cycle.
- ❖ **Equipment Planning:** Determination of plant and equipment requirement which will depend on :
    - Topography of the area.
    - Accessibility to various spots of working area.
    - Speed of construction to be based on available time factor.
    - Construction specifications of the components.
    - Economy of construction.
    - After determining the plant and equipments further planning for optimum utilization of the plant and equipment.
    - A shift pattern is devised to work at all available time for continuous working system and optimum utilization of men and machinery.
  - ❖ **Material Planning:** Material inputs naturally available and those to be supplied.
    - Requirement of all types of materials to be enlisted.
    - Daily, monthly and yearly requirements be determined and productive and procurement planned accordingly.
    - For natural materials like sand and aggregates, difficulties envisaged and phased planning of extraction.
    - For procured materials, competitive market rates to be assessed before determining method of procurement.

- ❖ **Planning and evaluation of working cycle:** Evaluation of the working cycle time for the main critical item.
  - Evaluation of the working cycle time for all other activities considered as parallel activities.
  - The cycle time for men and machinery to be properly evaluated taking into consideration Job & Management Factors.
- ❖ **Job & Management Factors:** Availability of time and space depends on several factors inherent in the job resulting from management limitations. These are job and management factors.

Job factors pertains to the physical condition of the job apart from the type of material to be handled. These factors are broadly classified as:

- Site topography, magnitude of work, availability of working space.
- Climate conditions and the climate of the area.
- Geology of the area to determine the methodology of execution.
- Accessibility to and within the site.
- Specification of the work including sequence of construction and testing procedures.
- Management factors pertain to stability of organizational set up and efficiency of operations of workmen and staff.
- Selection of equipment.

Operational personnel – Skilled and supervising – honesty, diligence, aptitude and skill. Incentive plans and inputs by HRD sector.

Finalizing plant layout, supervisions of works, maintenance of equipments, works and communications.

**5.2.2.3 Team work planning & Responsibilities:** Determination of plant and equipment requirement depends on personnel familiar with functional areas such as “Combined analytical intuitive approach”/ “Total involvement of project team in planning stage itself”. In a nut shell, it is a total team work with commitment and responsibilities and understanding specially at the supervision level that yields the desired planned results.

### **5.3 Computerization:**

The various practices enlisted above can be computerized to yield better practices.

- i) A computer solution for preparing and achieving the various objectives can be developed.
- ii) The daily, weekly and monthly reports are computed and analyzed for lacunae and better results both at field level and Corporate offices.

### **5.4 Monitoring Mechanism:**

The best practice at field at the end of the day is assessing the work done during the last 24 hours, with various constraints and determining the work for the next 24 hours envisaging constraints and thus providing for optimum utilization of all men and machinery available.

Classify the project under one of the Job factors and one of the Management factors. This would yield a single value of Job & Management factor, which is used to compute the expected progress.

To keep a proper track of the progress, schedules are prepared for the complete project (Level-I schedule which is the Master Control Network) as well as for their individual components of works (Level-II schedules). Further detailing of activities is done if required which gives a Level-III schedule, generally in form of bar charts. The Level-I network therefore enables one to gauge the overall position of works vis-à-vis the plans, at any point of time.

### **5.5 The Schedules:**

The Project Management consists of four major parts- Planning, Organization, Execution and Control. Monitoring system carries out the control part, i.e. controlling the activities of project so that they proceed according to the plan and accomplish the required target in time.

Monitoring basically involves acting on feedback to avert any hindrance

affecting or likely to affect the activities. The yardstick for how the activities should proceed is the schedule, while the feedback is the progress report, i.e. the targeted and actual achievements up to any point of time. In other words, it is a comparison of what significant milestone has been actually achieved at a given point of time and when it was due. The primary tools of monitoring are therefore, the schedules and the milestones derived from it.

Hydroelectric projects, or for that matter any big project has large number of interlinked activities, some of which are more important than the rest. It is therefore, necessary to have a plan that gives a bird's eye view of how the whole project work will proceed and which activities are more important than others, requiring special attention. Such a schedule is termed "Master Control Network" or Level-I schedule, which is basically a schedule based on Critical Path Method (CPM), and shows only the major activities with their interdependence, start/end dates, allowable delays (floats) and criticalities. The critical path in a schedule is the longest chain of successive related activities without any float i.e. allowable delay and therefore decides the total completion period of the project. Obviously, there has to be at least one such path but there may be more than one also. Critical path, by definition, has no float and therefore any delay in critical activities results in the delay in completion of the project as a whole. The activities lying on the critical path therefore have to be paid special attention. Level-II schedule is more detailed, component-wise, while Level-III is of still lower level, generally in form of bar chart and indicates quantitative monthly or weekly targets. Level-I, II and III schedules essentially have to be in conformity.

The Project work is required to proceed as per these schedules and feedback on the progress given from site to the monitoring office is compared with these schedules to gauge the deviations and pace of progress.

The Master Control Network (Level-I Schedule) also shows the desired completion dates of some important activities. A list of such 'milestones' is prepared and actual achievement compared with it. For monitoring at

highest level, say minister's level, even Level-I schedule is a bit too detailed and cumbersome. In this situation, 'milestones' i.e. completion of an important activity, like excavation or concreting of tunnel, dam etc., is the best tool. A list of important milestones is derived from the Level-I schedule. Achievement of each milestone by its due date simply means that the work is progressing as planned. This saves the high level management from trivialities. The Ministry of Programme Implementation & Statistics monitors all major projects in the country, hydroelectric projects included, through list of milestones.

**5.5.1 Preparation of Schedules:** Schedules can be prepared either upwards or down wards. In upward scheduling first level-III schedule for each work is worked out, then Level-II as aggregate of Level-III schedules, and finally Level-I or Master Control Network is prepared by aggregating Level-II schedules. In preparing schedule downwards, first an empirical Level-I schedule is prepared taking into account the constraints in the project, like time, climate & weather etc. Level-II and Level-III schedules downwards are then prepared which are in conformity with Level-I. Finally, all the three schedules are refined later on according to the actual conditions.

In hydroelectric projects, normally downwards scheduling has to be done since without an idea of approximate time required for a project, contract process cannot proceed at all. This overall period and an imperial schedule are worked out at Detailed Project Report (DPR) stage after investigations. After final approval of the project, actual working schedules are prepared incorporating the required changes. These schedules and the milestones derived from them are used for monitoring the project.

## **5.6 Contract Management:**

Since most of the works are done through large contracts, the management of contracts is very vital for the progress. After award the contracts are operated by the site officials. Major components of the project involve large civil and electrical works and supplies and have to be executed in parts and mostly through contracts. Works are broken down into various contract packages according to the quantum of work,



type, location etc. These contract packages are awarded to suitable contractors selected through open tendering, and also from contractor prequalified and short-listed.

The contractor is supposed to execute the awarded work as per the specifications and schedule given to him. The schedules provided to all contract agencies are in conformity with the overall schedule of the project viz. the level-I schedule. Slippage of even one package from its programme may lead to disturbance in other works and delay in commissioning of the project, besides other legal problems that follow the delays. Due care is therefore taken to keep the pace of work as per the plan. Whenever there is any apprehension of delay or problem in execution of work, necessary assistance is provided to the project.

#### **5.7 Financial Control:**

Adequate financial control is exercised on the project works at the appropriate levels by suitable financing and accounting system. Normally Finance & Accounts (F&A) Wing exercises the financial control, i.e. the arrangement and control of funds in accordance with the approved cost estimate of the project. The project furnishes in advance the detailed budget proposals for each approaching year, which is approved and accordingly the funds are provided to the projects through monthly bank withdrawal limits at the local bank at site. In case the expenditure overshoots the prescribed limits, the cost has to be revised and necessary approval for the Revised Cost Estimate (RCE) is sought from the Government.

The project is required to be completed within the approved cost that was envisaged at the detailed estimate stage of the project. During the execution stage, attempts are made to maintain the expenditure incurred on each work within the provision kept for that work. All financial controls are enforced both at the project level and at the Corporate Office level to ensure this vital aspect by constant monitoring. However, sometimes due to unforeseen or unavoidable reasons, the cost overshoots the prescribed limit inspite of best efforts to contain it. In such circumstances the estimate has to be revised and a fresh approval needs to be obtained by following

due procedures for the same which includes severe scrutiny by the Govt. at various levels.

#### **5.8 Monitoring mechanism adopted for reducing time and cost over-runs:**

Steps are required to be taken with a purpose of making Project Management more effective in completing the projects as per the schedule and eliminating or at least minimizing the time and cost over run. Towards this end, following measures can also be taken:

- i) More aggressive and pro-active project monitoring at all levels; top priority being accorded to issues effecting the progress and stringent accountability at all levels.
- ii) Advanced Project Management Software like 'Primavera'/MS Project.
- iii) Interaction with staff as well as contractors increased through Project Review Meetings and other meetings for the purpose; claim and dispute settlements being done at top priority.
- iv) Improved communication.
- v) Inventory Management to be computerized through special software, in order to check blockade of money in non-productive inventory.
- vi) Fund flow to Projects improved: no work suffering because of paucity of fund.
- vii) Improved construction methodology and equipment being deployed at the sites. A team of geologists is stationed at every project to take care of the geological problems to minimize the time over-run and cost over-run.

#### **5.9 Hydro Projects classification and commonly used equipment during their construction:**

Hydro power projects can also be classified broadly into three categories from their operation point of view:

- i) **Run-of-river project:** As the name implies, the project is planned as run of the river. Water is diverted from the river, routed through the project & finally left back to the river at a lower level downstream. It

takes advantage of the drop in elevation that occurs over a distance in the river and doesn't involve water storage. Conceptually very simple, but it has one big problem, i.e., power generation fluctuates with the river flow and the firm power is considerably low, as it depends on the minimum mean discharge. Canal power projects are also run-of-river projects.

- ii) **Storage Project:** Storage projects provides storage or pondage, and thereby, evens out stream flow fluctuations and enhances the water head. Thus, it increases firm power & total power generation by regulating the flow. However, providing storage is complicated & costly as it involves construction of dam.
- iii) **Pump - Storage Project:** Pump - Storage projects store the surplus energy in the power grid system during the off-peak hours and utilize the same energy during the peak hours. These involve reversible turbines, which can generate power from water of upper reservoir during peak hours & pump back water from lower reservoir to the upper reservoir during off-peak hours. These are advantageous in power grid systems of mix type, which have thermal & nuclear power houses in addition to hydro power projects.

Selection of a particular type of Hydro power projects depends primarily on techno-economic considerations, which varies from case to case basis. This can be done only by undertaking a detailed study. The major common components of a Hydro Project and the equipment normally used in Hydro Stations component wise is as under:

- The Main Dam/ Barrage
  - The Water conductor system (Head race Tunnel)
  - Surge Shaft/ Pressure Shaft
  - The Power House
- a) **Dam/Barrage:** Location on rivers, where rock is available at larger depth, Cut off Wall Trenching equipment is being used. River bed excavation by Cut off Wall trenching equipment is very much economical in comparison to conventional methods of deep river

bed excavation since it avoids re-handling of huge quantity of materials and dewatering etc.

For excavation of Dam/ Barrage, Excavators of capacity between 0.9 Cum and 3.0 Cum may be used. The Transportation of muck carried out with conventional Rear Dumper/Tipper result in higher down time and retarded progress rate. The multi-axle Dumper with multi-drive system may prove better to enhance the progress rate. Now a days improved version of Dumpers are fitted with electronic engine monitoring system which constantly monitor vital functions. The system also meters fuel rate, engine torque and power levels to match job and equipment requirements for optimum efficiency. All time better grip & traction is available with least downtime. It has also been observed that conventional Batching & Mixing Plant of indigenous makes pose problems due to frequent break downs. These could be replaced with improved version, computerized batching and mixing plants with hydraulic drive motors, which control the batching & mixing operations with greater accuracy.

b) **The Water conductor system (Head Race Tunnel):** Depending upon geological predictions and length of the tunnel, use of drill jumbos & other conventional equipment may be replaced with Tunnel Boring Machine (TBM). Now improved design TBM are available in market, which can tackle any unforeseen condition of geology with probe drilling, roof shielding & other concurrent activities (shot-creting, rib erection, rock bolting, fore-poling, grouting, erection of pre-cast segments etc.) along with boring of tunnel. With the help of Probe drilling, rock strata/geology could be investigated in advance so that further advancement of TBM could be decided. Loose strata could be tackled with fore-poling equipment which would ensure stability in rock strata and smooth operation of TBM.

Excavation with Hydraulic Excavator or Front End Loader can be considered to be replaced with Side Dump Loaders, which ensure minimum mucking time. Transportation of muck could be carried out with Low Profile articulated Dumper which can move in both directions with

low cycle time in comparison with conventional rear dumpers, which require additional niches for turning.

For small tunnels, conventional excavation equipment could be replaced with tunneling excavator-loaders, continuous muckers & rail bound shuttle trains for quick removal of muck. In case of shear zones coming across the tunnel alignment, we may tackle loose fall of collapsing rock with the help of fore poling equipment. Holes are drilled in different directions with this equipment. After inserting perforated tubes, grouting is carried out with the help of jet grouting equipment at a pressure of 100 to 150 Kg/sq. Cms. By doing so, a consolidated solid mass is build up and then tunneling is done through this media. This operation needs minimum time as compared to any other conventional methods.

For continuous concreting hydraulic collapsible telescopic shutter/gantries are available which would definitely reduce the time required for concreting. Transit Mixer could be replaced with Agitator Mixers having better efficiency wherever compatible with work requirement. For ventilation, conventional steel duct system could be replaced by light weight flexible duct or semi-rigid duct with twin blower at a particular distance or jet fans.

c) **Surge Shaft/Pressure Shaft:** Raise borers are available now a days with improved guidance system to maintain the accuracy and location of shaft as desired. Inclined shaft also could be constructed with blind hole boring version of raise boring machines with an angle of 45 to 90 degrees from the horizontal axis of shaft.

d) **Power House:** The three categories of Power House are:

**Surface Power House:** All components of the hydro power projects are on the natural / excavated ground surface. This has the advantages of determinate design & ease in construction. However, this has the disadvantage of limitation of head available as per the topography.

**Underground Power House:** All major components of the hydro power projects are underground in tunnels & caverns. In favorable geological

settings, this is very advantageous as it overcomes the limitation of head available as per the topography and provide compact & economical layout. However, this has the disadvantages of geological uncertainties resulting into indeterminate design & construction problems leading to time & cost over runs.

**Semi-underground Power House:** Some components of the hydro power projects are underground, while others are on surface. Sometimes the advantages of both surface & underground power houses are clubbed together in a semi-underground power house, provided topography & geology so permits.

In underground Power House generally excavation of top dome and access tunnel are carried out with Hydraulic Excavator, Tunneling Excavator & Rear Dumpers. By deployment of Side Dump Loaders & L.P articulated Dumpers, excavation of access tunnel & dome could be expedited.

In conventional method, the excavation of Power House cavern is carried out with power winches & buckets. This could be replaced by drilling nos. of drop shafts with raise borer & enlarging thereafter. One shaft (pilot hole + reaming) requires around 15 days for a normal height powerhouse. As such four to five shafts could be completed in 2-3 months. Further benching down and pushing the muck through drop shaft to Adit down below for mucking, could complete the total excavation in next six months.

Rock columns may be considered for providing the EOT crane beam in underground power house as conventional methodology involving taking the columns up from power house bottom to bottom of crane beam takes time and delays construction and erection activities.

## CHAPTER - 6

### BEST PRACTICES IN OPERATION & MAINTENANCE OF HYDRO POWER STATIONS

*“Operation and Maintenance of hydro power 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. Engineers are well-advised here to follow the well-known dictum: “Prevention is better than cure”.”*

- 6.1 Best Practices in Operation & Maintenance of Hydro Power stations shall be such that by following such procedures, the downtime of individual generating Unit & Plant should be minimum. The operational reliability of the generating units of the hydro power stations shall be such that whenever the grid demands, it should be available for generation. Some of the aspects, which can be taken into consideration, in Operation & Maintenance of Hydro Power Stations, are given as under :
- i) Each failure/tripping occurrence must be questioned with basic minimum three questions **a) Why this occurred? b) How this occurred? And c) What is to be done to avoid its reoccurrence?** This will definitely reduce failure rate to the greater extent.
  - ii) 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.
  - iii) During replacement of any part or equipment after its full utilisation 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 requirements so as to

increase plant efficiency and reliability.

- iv) Operating conditions should continuously be monitored and recorded. Records are very important to diagnose the causes of fault / failure/ replacement & to determine residual life. Early action can be taken before any type of failure.
- v) Eventhough 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 equipment, as characteristics of identical equipment vary from unit to unit and required to monitor its set values.
- vi) On the basis of past history/records & recommendations of OEMs maintenance schedules can be framed. Breakdowns/forced outages can be minimized by proper follow-up of the maintenance schedules based on recommendations of OEMs.etc. Life of the equipment thus can be enhanced.
- vii) Starting/stopping of the units shall be planned to be minimum to increase the life.
- viii) Procurement of the equipment spares should be planned as per the rate of the consumption, based on minimum requirement to optimise the inventory.
- ix) Optimum utilisation of the men & material to be planned.
- x) It would be beneficial to arrange training to O&M staff to refresh their knowledge and to give advanced technical information to improve work quality & quantity.
- xi) Interaction amongst working staff at various power stations in the country needs to be organised to improve performance of plant and equipment in totality so as to implement good Operation & Maintenance Practices.
- xii) Provision of “On Line Condition Monitoring System” on generator,



turbine and main transformers could be considered for installation on all existing power stations.

xiii) Afforestation in catchment area

Catchment Area Treatment studies for the Stations in operation could be got carried out and as per recommendations of the studies, the Power Station should carry out afforestation work in the catchment area. This would help in reduction of silt content in the inflow water.

## **6.2 MAINTENANCE PRACTICE**

Some of the practices to be adopted at hydro power stations for maintenance of certain main plant are broadly given below.

### **6.2.1 Water Intake, Water Conduit System and Associated Equipment**

Water storage (Reservoir) & water conductor system comprising of intake, head race tunnel, surge shaft, emergency valves & pressure shafts, penstock, main inlet valves are very vital organ of a hydro power plant. .Due to negative and positive water hammer during sudden changes in water flow, it is essential to attend to these plant & 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 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 developed 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. Leakages, 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:

- Cavitation & 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.
- Maintenance of communication systems, availability of power supply, equipment for emergency operations, approach roads etc.

### **6.2.2 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 cavitation there may be huge damages to turbine wheel causing adverse effect on performance and consequently efficiency. Sometimes, it would be necessary to undertake in-situ repairs of turbine buckets to recoupe/fillup erosions/white pitting by using various cold compounds viz. Belzona compound, Loctite, SS Metalset, Throtex compound etc. This may give satisfactory



*New Turbine Runner of Unit No. 3 of Burla Power House of Hirakud Power System being replaced for RIM & U Works.*

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 may be monitored continuously on the basis of which action to mitigate the damaging effect to under water parts may be initiated reducing the down time of units / station.

Best efficiency microprocessor based digital PID speed governors provide fast response. Periodical maintenance of speed governors alongwith all associated mechanical, electrical, electronics component 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 also need to be taken up:

### **Turbine**

- Periodic NDT viz. Ultrasonic, etc.
- 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.
- 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.
- Survey of the component failure & procurement of the same and maintain minimum inventory.

### **6.2.3 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. Tan Delta and DLA tests of stator winding indicates 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





*Machine Hall of Bhabha Power House 3x40 MW*

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, slot wedges checked for healthiness. Windings are revarnished 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.

Another 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 bearings. Following works also need to be taken up:

- Periodic checking of the foundations, tightening the bolts. Filling the foundations 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 over heating, temperature rise etc.
- Inspection of circuits for protection & control circuits & mock trials of the fire fighting system alongwith evacuation system. Checking weight loss of the CO2 cylinders and replenish as per recommendations of OEM.

#### **6.2.4 Transformer & Switchyard**

- Continuous monitoring of oil & winding temperature.
- Periodic oil filtration.
- Oil testing for various tests and Dissolved Gas Analysis.
- Tandelta & insulation resistance etc. as per schedule.
- Cleaning and replacement of oil cooler
- Testing protection system for healthiness.
- Mock trials of Checking, maintenance and inspection for Fire fighting system, CO2 & mulsifire.
- 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 bushings & insulator strings.
- Switchyard 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.

#### **6.2.5 Emergency D. G. Set**

- Regular maintenance of the emergency set. Checking control & protection system.
- Running of DG set at regular intervals.

#### **6.2.6 Other P. H. Equipment**

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