RENOVATION, MODERNIZATION AND UPGRADEATION OF OLD HYDRO POWER STATION- A WAY FORWARD TO SUSTAINABLE DEVELOPMENT

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ABSTRACT

Renovation, Modernization and Upgradation of old power stations is extremely cost effective, environment friendly and meets sustainability requirements. Further it requires less time for implementation. Capacity addition through RM&U of old power stations is an attractive proposition in the present scenario, when most of the Power Utilities on account of their financial conditions are not in a position to invest in creation of new generating capacity. The economy in cost and time, essentially results from the fact that apart from the availability of the existing infrastructure, only selective replacement of critical components such as turbine runner, generator winding with class F insulation, excitation system, governor etc. can lead to increase in efficiency, peak power and energy availability apart from giving a new lease of life to the power plant/equipment. RMU of hydro power station not only increases the life of the Project but also helps in sustainable development in power sector especially in case of hydropower.

INTRODUCTION

Normally the life of hydro-electric power plant is 30 to 35 years after which it requires renovation. In a fast changing technological environment, it has become desirable after elapse of 15 years to go for modernization in view of the new system requirements thereby enhancing the machine availability/generation with minor modifications. While renovating the machine, care should be taken to replace old items/equipment by the new technological alternatives.

Modernization is a continuous process and can be a part of the renovation programme. The reliability of a power plant can certainly be improved by using modern equipment like static excitation system, microprocessor based controls, electronic governors, high speed static relays, data logger, vibration monitoring system, silt measurement devices etc.

Upgrading / Uprating of hydro plants calls for a systematic approach as there are a number of factors viz. hydraulic, mechanical, electrical parameters and further economics, which play a vital role in deciding the course of action. For techno-economic feasibility, it is desirable to consider the uprating along with Renovation & Modernization / Life extension. Recognizing the benefits of RMU of old hydro power plants, Government of India had constituted a National Committee in 1987 to identify the hydro power plants in the country needing RMU Works and thereby formulate a national strategy on RMU of hydro electric power plants. This became an integral part of the National Policy in the following years. Based on the recommendations of the National Committee and subsequent reviews, 55 nos. of hydro schemes with an aggregate capacity of 9,653 MW were identified for renovation,
modernization and uprating work at an estimated cost of Rs.1,493 Crore to accrue a benefit of 2,531MW/7,181MU.

Out of these 55 schemes, RM&U work on 29 hydro schemes with an aggregate installed capacity of 5,642.70 MW have been completed during 8th and 9th plan at an estimated cost of Rs. 605.26 Crore, which have accrued a benefit of 1,717.18 MW. In addition to that, 4 more schemes having an installed capacity of 591.4 MW under Phase-II have also been completed during 9th plan at an estimated cost of Rs. 119.95 Crore, which have accrued a benefit of 53.90 MW.

Experience so far gained, reveals that uprating is the most cost effective way of capacity addition in a much shorter time span. As uprating is possible by changing partly or wholly the electro-mechanical equipment within the existing civil work as hydro units are designed and manufactured with liberal safety margins to meet the guaranteed parameters and specifications. The safety margins are always available between designed parameter and operating parameters. So it is possible to enhance the output of the units by about 10% to 15% by careful study and evaluation and further by utilizing the safety margins without sacrificing the basic safety factors. The technological development, computer aided precise design technique and advancement in material science have made it possible to design the new equipment with uprated capacity without changing the existing civil structures.

REASONS FOR RENOVATION, MODERNIZATION AND UPGRADEATION

The ever-increasing demand–supply gap in the power sector and the sectoral imbalances (thermal – hydro mix) are the major concerns, which needs to be addressed, in the Indian power market. In spite of having enormous potential for hydro generation in India, the share of hydro sector has continually declined in the last three decades. Due to highly finance intensive and being more risky hydro sector has not attracted many private players to have their hands on it. There are many new projects, which have been allotted to different private developers and only a few have achieved their targets and rest of the developers are still in the hunt.

Central / State Government has come up with various policies in last 15 years to attract private participation and private finance for the development of hydro sector. But the results obtain till date are far from satisfaction. The results are further deterioration in the thermal – hydro mix. In order to cope up with the persisting situation of Indian power scenario, government has decided to go for Renovation, Modernization & Upgradation of old Hydro Power Plants due to its following benefits:

No / Minimum clearances required

For development of any new hydro-electric project following statutory clearances are required:

- Techno-economic clearance of the project
- Site Clearances by MOEF after feasibility studies
- Environmental Clearances based on EIA (Environmental Impact Assessment) and EMP (Environment Management Plan)
- Forest Clearances
• Land acquisition etc.
• R&R Issues

These clearances are the major risk to the development of the project as they take considerable time and effort. In case of RM&U of the old HEPs, these stages are already taken care of during its initial construction. Any clearances, as the case may be, required only if any land is to be used other than the project land, which may be meagre in quantum and can be accommodated as a parallel activity. Moreover, Rehabilitation & Resettlement issues are either nil or very less for the RM&U projects.

**Less Gestation Period**

Every hydro project is unique and different from other project unlike thermal, which are tailor made in nature. Each hydro project needs to start afresh since its inception. The geological conditions are different at different sites, which make it a very uncertain venue to invest. These uncertainties and enormous civil works could extend the gestation period of a new hydro project to over eight years, resulting in cost overruns and less return on investments.

RMU of old hydro power station is having very less gestation period in comparison to an equivalent new hydro project. Proper scheduling of the works can reduce the implementation period of any RMU project by 3-4 years and that too most of the machines of power station continue to generate during this period as the is taken up on machines one by one.

**Less Risks**

New Hydro Projects are high-risk investments with geographical terrain playing major role in their successful completion. There are various major risks associated with the development of any new hydro project such as clearance risks, geographical risk, construction risk, regulatory risk, resettlement & rehabilitation risk, social risk etc. These risks not only increase the gestation period of the project but also delay the return on the investments, causing hydro sector as less lucrative sector to work with. However, these risks are not at all associated with the RMU of old HEPs. The return on investments would be far earlier as compared to any new hydro project.

**Less investment as against equivalent new project**

Cost of development of any new hydro electric project may range from Rs. 10 to 12 Crore per MW, whereas, depending on the scope of RMU, the cost of development of RMU of old HEPs may range from Rs. 2 – 7 Crore per MW. Arrangement of finance for development of any project is a major hurdle for any management. Lesser the cost and lesser the risk easier would be the arrangement of finance and since the risk associated with the RMU projects are very less, financial institutions would readily make available the required finance. Any management has to arrange 30% as equity of total project cost; lesser the project cost lesser will be the requirement of the equity.

**Improper River Basin Development**

Most of the river basins of India have not been properly developed as far as hydro sector is concerned. One of the best example is Ganges River Basin. There are at least 10 hydro
projects, which have been identified since 1960s, but due to non-availability of basic infrastructure, the developments of the power plants were not proper. For example, Chilla HEP was commissioned in year 1980, but after commissioning of Tehri Stage – I in year 2007, which is in the upstream of Chilla, the availability of water is more and regular. Now after getting more and regulated water supply, Chilla HEP can be uprated to even 172.8 MW from its present installed capacity of 144 MW.

Thus development of hydro power plant in the upstream of any existing hydroelectric project would provide sufficient and regulated water for its Upgradation.

Technological Advancement

Technology is ever changing and hydro sector is not untouched of it. In this field, technology changes occur in ever 10-15 years. Obsolescence of the equipment only leads to unavailability of the spare parts. Continuous R&D in this sector is providing new products at regular intervals. For example, there is improvement in technology to Class F insulation (instead of Class B), High Velocity Oxy Flame (HVOF) coating on the runner and underwater parts.

Some of the auxiliaries such as excitation system, governor, control & instrumentation, which may be of old design and technologies can be modernized with latest microprocessor based SEE / AVR, Governors, Control & Instrumentation, SCADA, Online monitoring systems etc. This would not only help in increasing the availability of machines but also will be helpful in proactive maintenance of the equipment and spares can be availed from the market in minimum time.

Safety Margins and Overload Margins in the Old design

Most of the old hydroelectric power stations are very pessimistically designed. At times the safety margins of the civil structure is to the tune of 200% to 400%. Also overload margins of old hydro stations are on higher side, which can be usefully exploited to get about 10 -15 % additional capacities. These margins can be optimized by enhancing the parameters responsible for the generation of energy.

Life Extension of Existing Facilities

RMU of old hydro power stations will not only be beneficial in enhancing the capacity of the plant but also help in the life extension of the plant by another 25 -35 years depending on the degree of RMU.

Technical Reasons

- Some parts of machine like core stampings, rim, spider, poles, shafts, servo motors, valves, steel embedded parts, bearing etc have very long life as compared to parts like AVR, stator and rotor windings etc. Therefore, instead of complete replacement, refurbishment of those parts that have outlived their useful lives or frequent trouble is considered a cheaper option as its cost is restricted to the extent of refurbishment. Moreover, government is also willing and providing grants for this kind of refurbishment of old outlived components of the hydro plants. As an illustration, examples of Chibro,
Khodri and Chilla HEP, where under APDP scheme old Excitation system and Governors are being replaced by state of art Static Excitation Equipment and Digital Governors.

- In old machines, stator and rotor winding is of class B insulation having higher thickness than present day class F insulation. So if the insulation of old machine is replaced, the copper area in the existing slots can be increased by about 30%. This increases the capacity of stator and rotor. If the capacity of other parts viz turbine & shaft etc is adequate, then the unit can be upgraded by about 20 – 30 %. It also gives extension to the life of machine as it is the winding of the machine, which deteriorates first.

- On reservoir based power plants, gross available head and quantity of water during monsoons increases. While this is kept in view at the initial stages of designing of power stations, yet some enhanced output may become possible during high head period by replacing some components. Margins in turbine are always available as it is designed on weighted average head.

- Sometimes by replacing generator, runner and some other parts by better designed equipment and retaining under water parts; additional capacity can be achieved.

- All the above factors not only make the RMU of old HEP as a lucrative business but also help in life extension of the project along with mitigating the imbalance of the energy mix in India.

**STAGES OF RENOVATION, MODERNIZATION AND UPGRADATION**

Following are the stages involved in successful accomplishment of RMU of old hydro power station:

- Identification of hydro power stations
- RLA & LE study of the identified hydro power station
- Feasibility studies / DPR preparation for RMU
- Tendering / Bidding stage
- Implementation stage

Most of the utilities go for RMU of old power station which have completed their normal operative life or if the technology of the existing facilities has obsolete to such an extent that, it becomes very difficult to arrange the spares.

Identification of the RMU of hydro project is solely based on the aforesaid factors. Bidding and implementation phase of any RMU project is similar to development of any new project, with a difference that during implementation the old equipment are to be dismantled and removed from the site and installation of new equipment is to be done only in the existing structure.

**RLA & LE STUDIES**

RMU of an old power plant is a difficult, complex and challenging task. It involves retrofitting of a new uprated machine in the existing space / water passage. It involves complicated design assessment to retain original healthy parts and for discarding them. A systematic approach to check each and every part is necessary.
This systematic way of checking the conditions of health of every component of the old hydro power station is done by Residual Life Assessment and Life Extension (RLA & LE) studies. RLA studies are helpful in determining which component of the plant to retain and which one to discard and replace.

Following essential studies need to be carried out for assessing uprating feasibility of machines:

i. General Guidelines
ii. Assessment of existing condition of machine
iii. Studies on generator and its parts
iv. Studies on turbine and its parts

General Guidelines

i. While delay of RMU after machine has reached end of its life can cause irreparable loss, early renovation for the sake of modernization is a luxury. A proper techno-economic balance should be struck.

ii. Uprating of unit capacity is governed by capacity of both generator and turbine, which in turn is dictated by capacity of each of their components. The reliable life of machine is dictated by the life of worst component. Final decision is thus arrived at after checking each and every part. Coordination of RMU work of generator and turbine can reduce outage time.

iii. Major, equipment viz generator stator, rotor can undergo very little change in outer dimensions as these are to fit in existing barrel. Runner, head cover etc cannot undergo any change in outer dimensions as clearances between these & water path is already of the order of 1-2 mm.

iv. Higher output of generator will mean more losses and temperature rise for which, better heat dissipation shall have to be done by some major / minor modifications in ventilation system.

v. Higher output by turbine shall mean higher quantity of water and hence more guide vane opening. This shall increase run away speed of machine, axial thrust, speed and pressure rise on tripping.

vi. Earlier electromagnetic relays and controls and dial type instruments were used. With the advancement of technology, very fast acting, accurate, compact reliable microprocessor based control systems and relays are available. These can be considered at the time of Renovation and Upgradation.

Assessment of existing condition of machine

The first step towards refurbishment is to assess the existing condition of machine and its various components. For this, a very detailed study of temperature, vibrations and metallurgical needs of various components is to be done. The power plant maintenance engineers may not be competent to carry out such works. This work should be got done from manufacturers / experts as they know the latest techniques of stress analysis, which can be used to get actual operating stresses at different heads and output. However, sufficient knowledge of the tests to be performed and data to be collected should be known to plant engineers. The existing condition can be assessed from the following:
i. History of Machine

Following data should be collected:

- Age of machine & number of hours it has run.
- Number of starts & stops and from this and item above, to calculate residual break down voltage of the insulation.
- Number & history of faults and break downs of different components of machine.
- History of replacement or modifications of different components already carried out.
- Frequency of normal & capital maintenance.

ii. System parameters of Machine

Following is to be recorded and compared with original / design data and latest trend / specifications:

- Temperature of different components viz stator, rotor, bearing etc.
- Vibration and noise level at different locations.
- Load, guide vane opening, servo motor stroke, pressure pulsation.

iii. Diagnostic tests on machine

Generally replacement or RMU is carried out when the equipment has or is approaching end of its useful life. This assessment is very delicate and difficult task and requires complete knowledge of design and metallurgy of equipment and further various diagnostic tests have to be carried out. For this, experts from various disciplines pool their expertise, plan and carry out various tests to assess the actual condition of the equipment.

These studies will indicate the health and residual life of machine and would be the main deciding factor for replacement or refurbishment of different components of machines.

Studies on generator and its parts

Due to ever increasing technical advances, it is possible to get higher output from the same size of old generator after considering following:

i. Improved insulation system
ii. Improved material
iii. Redesign of ventilation and cooling system
iv. Advance design and manufacturing technology

The overall effect of uprating under different options is as follows:

a) Uprating without changing winding reduces short circuit ratio, energy constant and transient stability.

b) Uprating without modification of excitor and hence some ceiling voltage reduces the excitor response ratio.

c) Uprating with or without major changes increases short circuit torque.
Various components of hydro generator are discussed as under:

**Generator Stator**

**Existing Design Margins**

Check the following from manufacturer’s data and compare with existing parameters to find available margins:

- Any overload capacity of short / long duration provided in specifications
- Ambient temperature
- Cooling water temperature
- Stator winding, stator core and field winding temperatures
- Hot air temperature
- Cold air temperature
- Excitation current and capacity.

From above data, some fair conclusions about available margins can be drawn. A margin of about 10 % is generally available in old machines. It may increase due to less cooling water temperature of hydro power stations than the designed figure.

**Change of Class of insulation**

As mentioned earlier, by changing insulation from class B to class F, extra generator capacity of 25 -30 % can be obtained. Actual would depend upon ventilation system and other mechanical parts.

**Stator Core**

Generally stator core is not changed, as silicon used in punching is non-aging. However special considerations like repeated faults or saving of time during uprating might require complete disassembly, inspection, repair, partial or complete replacement.

**Ventilation System**

**Cooling Fans**

Fans are designed to produce sufficient quantity and pressure air to dissipate heat generated by stator or rotor due to copper and eddy current losses in stator and rotor, windage losses, fans losses etc. Air guides and air baffle guides divert air to all portions of stator and rotor in required quantities. Higher capacity of generator would cause higher losses requiring more dissipation of heat and hence better ventilation system. For calculations, load run tests of the generator at full load is carried out where besides recording temperatures; air speed at different positions is measured. With this, the accuracy of fan blades, air guides and air baffles etc are checked and inaccuracies can be set right.
Further, depending upon temperatures expected upon uprating, more dissipation of losses can be planned by carrying out changes / modifications of fan blades, air guides and air baffles. Additional air baffles and guides can be placed in airflow path to divert more air towards higher temperature areas with minimum airflow resistance. If it is not possible to modify internal system, external fans can be installed to cater to increased load.

**Generator Air Coolers**

Generator air coolers are designed to cool above air. For uprated conditions, increase in copper losses may need greater capacity of the coolers. So these may also be checked for any enhanced requirement along with above study. Many cooling tubes might already be plugged and or might have become thin. Maximum 10% plugging is permissible.

**Excitation System**

The excitation system of generating plants is an important factor for accurate voltage control, transfer of power, torque angle etc during normal and disturbed conditioned of plant operation. Usually excitation system is liberally designed with sufficient margins of offset errors of generator air gaps etc. For RM&U studies, all components viz pole, coils, excitor, field breaker, transformer, thyristors etc needs to be studied as per following brief conventional system:

**Pole Coils**

For increased output from stator winding, the requirement of rotor field winding i.e. current and or turns would have to be increased and this would need detailed study of field coils. If found of inadequate capacity, remedial measures to increase conductor size and or number of turns would have to be taken. If it is of class B insulation, it can be converted to class F.

**Excitor**

Like above, the capacity of excitors and other connected system would have to be checked. There can be following possibilities:

- The existing excitor may be sufficient to cater the marginal increase in the requirement.
- If the field coils of rotor are being replaced, then these can be so designed that excitor may not have to be replaced i.e. the current and turns can be designed to accommodate existing margins of the excitor.
- If existing excitor is having manual voltage control or if due to aging; AVR and other system is not functioning properly; then an improved state of art version of AVR can be considered. It would be worthwhile to replace the old system with the new digital static excitation system (as done in Chibro, Khodri and Chilla HEP of UJVNL).

**Mechanical Parts of Generator**

Upon uprating, torque-transmitting components like shaft, spider, rim, poles and connecting lugs require investigation regarding their suitability to withstand increased torque. Similarly load bearing components like thrust bearings, guide bearings, brackets, stator frame require investigation for increased loads.
Shaft and Coupling Bolts

The mechanical design of shaft and coupling bolts depends upon the torque to be transmitted, axial hydraulic thrust, normal speed, run away speed & critical speed. Both torsional and tensile stress act on the shaft.

Existing stresses and stresses upon uprating should be calculated and compared with the safe limit. Generally the diameter and hence the yield and tensile strength of the shaft are kept higher due to other considerations like accommodation of bearings, spider, seals etc. Thus, generally for up to 25 -30 % uprating, the shaft may not need replacement. It may be possible that the coupling bolts may require replacement.

Spider, Rim & Connecting Lugs

Upon uprating, torque to be transmitted by shaft increases. Further, if field coils are envisaged to be changed by higher weight coils, centrifugal force due to field coils increases. This necessitates the calculations of increased torque on spider, rim and connecting lugs.

Rotor Pole

Normally for uprating of upto 20%, poles may not need replacement as the punching there in have long life. However, when pole coils are changed with higher weight coils, then its end plate and keys should be checked. Similarly, inter polar space and pole to pole connecting lead be also checked.

Thrust bearing & Guide Bearing

The load on thrust bearing would directly increase with the weight of rotor poles and axial hydraulic thrust. Load on guide bearings would also increase due to greater hydraulic unbalanced forces. The increase may be marginal as compare to the existing loads yet the capacity would have to be verified. Small increase can be met by increasing the cooling water inflow. To dissipate more heat, external casing and separate oil coolers can be installed.

Stator frame

Generally during refurbishment and 10 -20 % uprating, stator frame does not require replacement as these are generally capable of handling small increased load. However there may be special circumstances necessitating its replacement.

Upper and Lower Brackets

Since the whole weight of the machine along with the axial thrusts have to be passed to the foundation through brackets, their suitability for enhanced load may have to be checked. Generally these would not need replacement for augmentation of capacity upto 20%.

Generator Foundation

Generally the generator is supported on two foundations. While rotating or resting on the thrust pads, the whole rotating and stationary weight is passed via thrust bearing, upper
bracket and stator frame to sole plates fixed on first foundation. When resting on jacks, the weight of stator frame and upper bracket rest on this foundation but weight of rotor, runner and shaft etc is passed via jack pads to lower bracket which rests on sole plates of second foundation. The loads acting on foundations are vertical loads. Along with this vertical load the foundations need to absorb the hydraulic thrust and load during the fault and earth quakes. Thus upon uprating, there is some increase in load foundations due to marginal increase of all items (except earth quake) which need study.

Studies on turbine and its parts

Following studies need essentially to be carried out for uprating of turbines:

Existing Design Margins

Turbines are designed on the weighted average of load it needs to cater. Therefore, turbine always have design margin to cater to higher load. Generally on reservoir based power plants, higher than rated head is available for 4-5 months in a year due to filling of reservoir during monsoon period. Depending on the availability of discharge and head one can even change not only the profile of the blade but also the kind of turbine. For example, as in the case of Chilla Project, it is possible to change the present Kaplan turbine with Francis with major changes in civil structure and with Propeller with minor changes in civil structure.

Hydraulic Studies

Discharge capacity of runner

The turbine output of turbine is determined by

\[ P = Q \times H \times g \times \eta \]

Where Q is discharge, H is net head, g is gravitational constant and \( \eta \) is efficiency of turbine. From the above equation it is clear that one way to increase the power output from turbine is to increase the discharge though it. This can be achieved by increasing the guide vane opening, but excessive opening leads to lesser output due to the decline in the efficiency of the turbine. Therefore, for better utilization of the discharge up gradation of the turbine is necessary if the existing turbine is not able to give the maximum output. The discharge capacity of turbine is governed by:

a. Radius of outer edge of runner blade from axis of rotation
b. Angular speed of rotation
c. Rated Head
d. Angle of flow at the runner inlet
e. Area of outer section of runner

Due to various embedded parts, it is not possible to increase a, c & e, until major change in civil structure is not considered for uprating. The only possibility is by changing the specific speed or carry out modifications on the stay vanes, blade profile, runner, labyrinth etc.
• Cavitations

Cavitation is major problem with any hydro turbine. Increase in discharge through turbine after some limit increases the turbine’s critical cavitation coefficient. Thus, either the available model test report of the turbine should be checked for the cavitation calculations. If not present then manufacturer should be asked to conduct the model test for uprated turbine.

• Runaway speed

All rotating components should be checked for the suitability at enhanced runaway speed. As increase in speed causes increase in the centrifugal forces.

• Pressure Pulsation

If same runner is used for increased output, then pressure pulsation must be checked, as it will be very dangerous for the health of the generating equipment as well as the civil structure. If new runner is used then the pressure pulsation should be checked at the time of model testing and same should be verified during actual run.

• Load Throw off test

This test is carried out to check the response and behaviour of the governor during the load throw. This test also helps in checking the pressure rise in the draft tube and penstock. It is also worth mentioning that this test is helpful in determining the surge level in canal-based schemes.

Mechanical Studies

Following components are required to be thoroughly checked:

• Runner

Mechanical design of runner depends upon maximum head with pressure rise, maximum runaway speed & axial hydraulic thrust. There would however be a marginal increase in stresses at higher output due to these factors, pressure rise and runaway speed etc. Yet this should be calculated and compared with the safe limits. Mechanical strength of the runner is generally high as compared to the normal operating stresses.

• Shaft & Coupling Bolts

These have already been covered in generator.

• Guide Bearing

The design of guide bearing depends upon journal diameter, height & speed of rotation. The radial load on bearing depends upon hydraulic unbalanced forces, which further depend upon head, guide vane height & runner diameter. Out of these, only hydraulic unbalanced forces increase with increase in load. This increase may be marginal but should be calculated.
• **Shaft Seal**
  
  Pressure on shaft seal depends on the tailrace level & leakages through labyrinth. When unit is uprated, generally both increase & the extent of increase, how so ever small it may be, should be calculated.

• **Pen Stock, Scroll Case, Stay Ring, Draft Tube Head Cover, Guide Vanes etc**
  
  The water passage is already designed for maximum head conditions and certain pressure rise upon full load tripping. In uprating conditions, the head may not vary but pressure rise, velocity increase, water hammer etc. would increase and these require detailed studies.

• **Governor and Servo Motor**
  
  For increased quantity of water, guide vanes will have to be opened more. This means higher power for servo motor. This extra power requirement will also be needed for enhanced output at higher head but same guide vane opening. Earlier governors and servo motors generally operated at a oil pressure of 20 Kg/cm². Now a days governor of operating pressure of 120 Kg/cm² is available in the power market. This increase in pressure has reduced the size of the governor and hence the space requirement along with better response time. Thus, during RM&U of old power stations, it is better to replace the existing governor by digital governor of higher operating oil pressure for better stability.

• **Station Auxiliaries**
  
  ✓ The **crane capacity** is dictated by the heaviest part, which is generator rotor. At enhanced generator output, the rotor weight may increase due to possible increased weight of pole coils.
  
  ✓ RMU is the opportunity to upgrade **controls**, relays, protection and instruments. The degree of automation depends upon the utility.
  
  ✓ If the power station is upgraded then additional requirement of water, air etc requires additional pumps, fans, compressors etc. Any addition of these leads to additional requirement of power and hence requires enhancement in the **Station Power Supply** either AC or DC and therefore associated facilities.
  
  ✓ Other auxiliaries like fire fighting system etc may also need Upgradation. Efforts should be done in providing the fire resistant cables, more fire detectors etc.

After completing these tests of Electrical, Mechanical & Civil and plant audit a comprehensive report is prepared, which will be used in the preparation of Feasibility Study / DPR.

**FEASIBILITY STUDIES / DPR**

After completing the RLA & LE studies and Plant Audit; the next phase is preparation of DPR. The scope is not restricted to the results of RLA & LE studies. Some cases are very complex, which even involve complete philosophical change in the approach. For example, in case of enhanced discharge availability at site it may be possible to have complete change of all equipment along with generating equipment. As is the case with Chilla HEP; where after commissioning of Tehri Stage I project, the availability of water at Chilla has enhanced by about 15 %, which if taken into consideration require more changes in the option. It is even
possible to have Francis or Propeller turbine in place of Kaplan and in that case every thing needs to be changed. Following are the contents of any DPR (Detailed Project Report):

**Introduction**

This portion of the DPR contains the details about the project under considerations and the objective of the project.

**Hydro technical Aspects**

This portion of the DPR contains the details about Natural flow of river, Flood flow analysis, any other change in the flow of river, capacity of water conducting system, level of head race & tail race, sedimentology.

**Appraisal of present condition of plant and associated hydraulic facilities**

This portion of DPR contains the details about conditions of the present equipment and remedial actions to be taken for improving the deteriorated components or replacement along with detail about change in the hydraulic facilities.

**Alternative solutions for upgrading**

This portion of DPR contains the details of the options, which are available for RM&U of the power station under consideration and what to do for the options suggested.

**Hydraulic Transient Analysis**

This portion of DPR contains the details of the basic criteria considered for any change in the parameters of water conductor system. Also details about the pressure rise and speed rise, which may occur after implementation of the proposed options should be mentioned.

**Hydraulic Improvements**

This portion of DPR contains about the details of how to improve the hydraulics of the project. For example, how to increase the velocity of water in the tunnel (if tunnel based) or how to cope up with the transient conditions, which may happen in the tunnel based or canal based hydro power stations.

**Energy Evaluation**

This portion of DPR contains the details of energy evaluation of the project. This is done by taking the discharge data of last 25 years (or more if available) and any enhanced discharge. After this we do the calculation for 90 % dependable year and 95% availability of machine. This will provide power potential from the data and after considering the overall efficiency of the generating equipment, it is possible to arrive at the power potential of the plant.
Construction Schedule

This portion of DPR contains the details of the construction schedule for implementation of proposed and approved option for the RM&U. It is either prepared on Primavera, MS Project or any suitable software.

Cost Estimates

This portion of DPR contains the details of the cost to be incurred on the project for its implementation along with other detailed calculations of Interest During Construction (IDC) or any other escalation if required.

Economic Analysis

This portion of DPR contains the details of the appraisal of the financial viability of the project. It shows all the calculations of NPV (Net Present Value), IRR (Internal Rate of Return), BC (Benefit – Cost) ratio etc. These calculations are carried out on the incremental benefit philosophy. This section also contains the sensitivity analysis for the project.

Socio-Environmental Aspects

This portion of DPR contains the details of the environmental assessment, its impact, management of dismantled equipment, socio-economic considerations.

Summary, Conclusions and Recommendations

This portion of DPR contains the details of the overall summary, conclusions and recommendations for the project.

Appendices

This portion of DPR contains the details of all the calculations and details, which may be used in the preparation of DPR.

EXPERIENCE OF UJVNL IN RMU

UJVNL has taken up RMU of following old projects in recent past:

Mohammadpur (3 X 3.1 MW)

Mohammadpur Hydro Power Plant was commissioned in 1952 with three hydro generating set of 3.1 MW each. The Project is situated on Upper Ganga Canal about 20 km from Roorkee. This project was under continuous operation since its commissioning and previous utilities (UPSEB / UPJVNL) had not invested much on this project to have continuous optimum generation. As such the generation capacity of the units at this Project had deteriorated upto 30% and the units were able to achieve maximum load of only about 2 MW. UJVNL took the initiative for RMU of this Project in year 2009-10 and after completing the tendering procedure; the implementation was started in year 2010-11. The tenders for this Project were invited on ‘Turnkey Basis’ and complete RMU work was awarded to a sole
Contractor responsible for supply, procurement and coordination of bought out items, erection, testing and commissioning of complete Project. Implementation period of 36 months was provided and machines were given one by one in order to have minimum generation loss except for the period where common works were to be carried out and complete shutdown of the Power Station was required.

Major scope of work for RMU was complete replacement of runner, guide vane, servomotor, stator core & windings, rotor windings, complete instrumentation, replacement of all items in switchyard including all power and station transformers, SCADA, provision of numeric relay protection for generators, line & bus, state of art TRCM to be fitted at existing site conditions, trash-rack panels, complete replacement of power & control cable, refurbishment of all hydromechanical gates, provision of motorized hoist for intake & bypass gates and civil works. On the basis of reverse engineering report pivot ring was additionally ordered during the course of execution.

The Project was completed in 37 months with total cost of INR 73 Crore. Per MW cost was high because of the machine’s larger size due to low head and high discharge. At the DPR stage it was envisaged that 65 MU generation shall be achieved after RMU against the prevailing average generation of 40 MU. UJVNL has achieved the desired output and deliverables from the project during the post RMU operations.

**Pathri (3 X 6.8 MW)**

Pathri Hydro Power Plant was commissioned in 1955 with three hydro generating set of 6.8 MW each. The Project is situated on Upper Ganga Canal about 10 km from Haridwar. This project was under continuous operation since its commissioning and previous utilities (UPSEB / UPJVNL) had not invested much on this project to have continuous optimum generation. As such the generation capacity of the units at this Project had deteriorated upto 30% and the units were able to achieve maximum load of only about 4.5 MW. UJVNL took the initiative for RMU of this Project in year 2009-10 and after completing the tendering procedure and the implementation started in year 2010-11. The tenders for this Project were invited on ‘Turnkey Basis’ and complete RMU work was awarded to only one Contractor responsible for supply, co-ordination between various bought out items, erection, testing and commissioning of complete Project. Implementation period of 36 months was provided and machines were given one by one in order to have minimum generation loss except for the period where common works were to be carried out and complete shutdown of the Power Station was required.

Major scope of work for RMU was complete replacement of runner, guide vane, servomotor, stator core & windings, rotor windings, complete instrumentation, replacement of all items in switchyard including all power and station transformer, SCADA, provision of numeric relay protection for generators, line & bus, complete replacement of power & control cable, refurbishment of all hydromechanical gates, provision of motorized hoist for intake & bypass gates. On the basis of reverse engineering report turbine shaft, top cover, rotor pole body along with punching, labyrinth was additionally ordered during the course of execution.

The Project was completed in 52 months with total cost of INR 112 Crore. Per MW cost was high because of the machine’s larger size due to low head and high discharge. At the DPR stage it was envisaged that 155 MU generation shall be achieved after RMU against the
prevailing average generation of 90 MU. The delay in the Pathri was due to non-usability of the items, which were to be retained as per actual scope of Contract. These items were finally replaced and due to long delivery period for these items the Project got delayed. UJVNL has achieved the desired output and deliverables from the project till date as envisaged.

CONCLUSION

Considering the present scenario of gap between demand and supply of power, RMU is a beneficial option to increase the energy availability from old hydropower projects. The enhancement in energy availability does not ask for damages to environment and ecology and benefits are carried over to the people without compromising on the future needs of the next generation. It is way forward for increasing generation by utilizing the same resource with reasonable investment and adequate return.

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