RENOVATION MODERNIZATION UPRATING & LIFE EXTENSION: OPTIMAL SOLUTION FOR SMALL HYDROPOWER DEVELOPMENT

Priyabrata Adhikary[1], Susmita Kundu[2]

[1]*Assistant Professor (Mechanical), S.V.I.S.T. (W.B.U.T.), Kolkata, India* ***priyabrata24@gmail.com***
[2]*Assistant Professor (Electrical), M.S.I.T. (W.B.U.T.), Kolkata, India* ***susmita_kundu7@rediffmail.com***

Abstract

Renovation, Modernization, Up-rating and Life Extension (RMU&LE) has been recognized world wide as a well proven cost effective technique for improving the performance, efficiency and reliability of old hydropower plants. Small hydropower projects (SHP) are emerging as a solution for sustainable, green, environment friendly and long term, cost-effective source of renewable energy in India for the future. Selecting the appropriate small hydropower project and its parameters such as project development, plant operation, plant maintenance etc. in which to invest is a critical task involving different factors and policies. In this paper an attempt is made to discuss RMU&LE methodology on development of cost effective small hydropower projects. To the best of the author's knowledge this novel approach for standard practice on small hydropower project development through RMU&LE is absent in renewable energy literatures due to its assessment complexity.,

Index Terms: *Small Hydropower, RMU & LE, Renewable Energy, MCDA*

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1. INTRODUCTION

Industries like oil refining, health care, power generation etc. have (24x7) type continuous schedules almost from the day they start [1, 2]. When a company needs to move from 5-day operations to 7-day operations, the strategy can result in significant human relations and operational problems if not handled properly. In India, the total installed power generating capacity was reported as 2, 02,979.03 MW (2012) out of which only 19.24% i.e. 39,060.40 MW is thru hydro power. The identified small hydropower project (SHP) potential sites are 14300 MW (approx) and installed are 2150 MW (approx.) [3, 4]. The cost of clean-green-friendly small hydroelectricity is relatively low i.e. Rs2.5/KWH (approx.), compared to others and thus making it a competitive source of renewable energy. Setting up a SHP is complex, time consuming process with large number of uncertainties [5, 6]. The common factors that affect decision making of a sustainable solution are technical, economic, environment and social [7, 8]. Small hydropower projects (i.e. up to 25MW in India) are much more advantageous than conventional medium or large hydropower projects. Small hydropower plant requires very less flow or head compared to conventional hydropower plants. Reservoir is also not required for small hydropower projects as they are mostly run-of-river type. Environmental and social impacts of small hydropower projects are also negligible compared to conventional medium or large hydropower projects [9, 10].

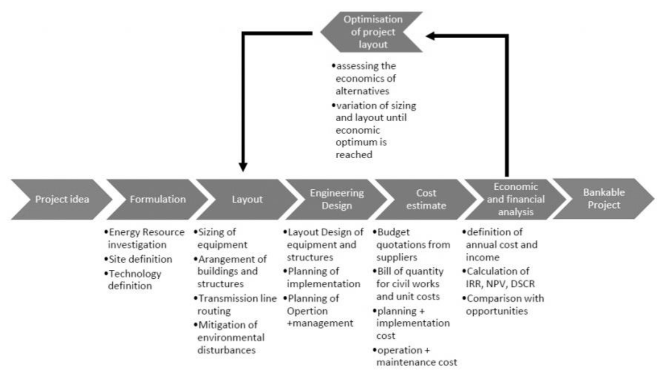

Fig-1: SHP Project Optimization Phases

The optimization of generation from the existing capacity is of utmost importance. The installation of new SHP involves much higher investment and longer gestation period. In view of the large quantum of finances required to install additional capacity, the optimisation of generation from the existing SHP through Renovation, Modernisation, Up-rating & Life Extension (RMU&LE) has been considered to be the best option at a much lower cost and in a shorter time. The useful life of the plant is also increased. The aim of the optimization is to obtain a maximum global efficiency of the small hydropower plant through the optimal power allocation among the available units. In the hydro power plant optimization, the load allocation between the available units is changed in a periodic way in accordance with the measurements variation, that could be efficiency, flow or head (if any) etc.

The problems associated with the new SHP approval includes: various statutory clearance issues (techno-economic approval from CEA or CWC, defence approval, environmental approval etc.); various risks (geological, Socio-political etc.); funding problems etc. Hence in the present scenario of resource constraint RMU&LE of SHP is considered as one of the best options, as this is cost effective and quicker. Renovation, Modernisation, Up-rating & Life Extension (RMU&LE) has been recognized world wide as a well proven optimal or cost effective technique for improving the performance, efficiency and reliability of old SHP. The performance, efficiency and reliability of electro-mechanical equipments in a SHP deteriorate over a period of time. The output, efficiency and reliability of units can be increased by replacing old or damaged components, by redesigning or improving mechanical, electrical or civil design to increase efficiency and reliability.

Recently in order to augment the hydropower generation and improve the availability of existing hydropower projects, MNRE (GOI) placed special emphasis on RMU&LE of various existing old SHP in the country namely: 20.4MW Pathri SHP (Hardwar), 9.3MW Mohammadpur SHP (Hardwar), 3MW Galogi SHP (Dehradun) etc.

Fig-2: 20.4 MW Pathri SHP (Hardwar, U.K., India)

Recognizing the benefits of the RMU&LE of hydroelectric power projects, Govt. of India constituted a National Committee in 1987 and a Standing Committee in 1998 there after and identified the projects to be taken up for implementation under RMU&LE. The National Perspective Plan document for RMU&LE of hydro-electric power projects in the country was also prepared in CEA during the year 2000, incorporating the status of various projects already identified for implementation or completion through VIIIth to XIth Plan. Hence we can understand that the main reasons for RMU&LE of SHP involves: less environmental issues, less techno-economic issues, less socio-political issues, less risks etc. over a new SHP project.

Small hydropower project schemes are classified as mentioned below:

Run-of-river scheme: They utilize the instantaneous river flow without a dam. A weir or a barrage is constructed across the river simply to raise the water level slightly and divert water into a conductor system for power generation. Such a scheme is adopted in the case of a perennial river.

Canal fall based scheme: These schemes are planned to generate power by utilizing the flow and fall in the canal. These schemes may be planned in the canal itself or in the by-pass channel. These are low head and high discharge schemes. These schemes are advantageous due to low gestation period, simple layout, no rehabilitation problems and no socio-environmental problems.

Dam-Toe scheme: Here the head is created by raising the water level behind the dam by storing natural flow and the powerhouse is placed at the toe of the dam or along the axis of the dam on either side. The water is carried to the powerhouse through a penstock.

Pumped storage scheme: It is a method of keeping water in reserve for peak period power demands by pumping water that has already flowed through the turbines back up a storage pool above the power plant at a time when customer demand or tariff for energy is low, such as during the middle of the night. The water is then allowed to flow back through the turbine-generators at times when demand is high and a heavy load is placed on the system. Because pumped storage reservoirs are relatively small, construction costs are generally low compared with conventional hydropower facilities.

There are two basic components in all four types of SHP schemes; i.e., civil works (Diversion and intake, De-silting tank, Power channel, Fore-bay, Penstock, Powerhouse building, Tail race channel etc.) and electro-mechanical equipment (Valves, Hydraulic Turbine, Generator etc.). Most of the components are same in different types of schemes; some components, however, are different. The development of new SHP typically takes 3 to 5 years to complete whereas RMU&LE of SHP takes only 1 to 3 years. This time is required to undertake studies and design work, to receive the necessary approvals and to construct the project. SHP can be operated by trained full time or even part-time operator. Trained personnel are required for plant maintenance. Once constructed, small hydro plants require little maintenance over their useful life, which can be well over 35 to 50 years [11, 12]. The standard life of most of equipment cannot be more than some tens of years. By proper routine and capital maintenance, it can be increased to 30-50 years. The complete replacement cost of new SHP is very high. Continuous design improvements are also taking place. After using the machine for 25 to 30 years, it may techno-economically be feasible to get higher output & efficiency by making some minor or major changes. RMU&LE is done before complete replacement of machine. Some parts of machine like core stampings, rim, spider, poles, shafts, servo motors, valves, steel embedded parts, bearings etc. have a very long life as compared to parts like AVR, stator & rotor winding etc. Therefore, instead of complete replacement, refurbishment of those parts that have out lived their lives or give frequent trouble is considered a cheaper option. However while deciding refurbishment & replacement of parts, the down time involved has to be considered. Sometimes, breakdown of a major component becomes immediate cause for starting refurbishment work.

2. RENOVATION OF SHP

Renovation (or Rehabilitation or Refurbishment) aims at extending the SHP life. Restoration work is done to recover the damages caused due to natural calamity. The first step towards refurbishment is to assess the existing condition of machine & its various components. For this, a very detailed study (temperature, vibrations & metallurgy etc.) needs to be done. The power plant engineers may not be competent enough to do it alone. This work should be got done from manufacturers or experts as they know the latest techniques of stress analysis which can be used to get actual operating stresses at different heads & output. However plant engineers should have sufficient knowledge of the tests to be performed & data to be collected. These electrical and mechanical studies will indicate the health and residual life of plant or machines. It would be the main deciding factor for replacement or refurbishment of different components of machines. More than 200 old hydropower stations exist in India. RMU&LE of SHP concerns only old stations (7–Year or older stations). MNRE (India) gives financial support for RMU&LE of SHP stations. Consequences of SHP aging are: lowering of plant performance, reduced generation, uneconomical operation, difficult maintenance. Renovation doesn't only mean replacement or repair of worn out and damaged parts. It also includes use of new materials, designs and technologies for improving efficiency and reliability of the power station and enhancing generation. Renovation is advantageous as it takes lesser time (1-3yrs) than new project development (3-5 Yrs). It doesn't require any statutory clearances or rehabilitation of people involved. But it extends plant life by only 20 –25 years. The governing factors of Renovation are: project cost, project life, shutdown time, efficiency and project feasibility. Hence renovation is considered as an opportunity to modernize or up-rate a plant.

3. MODERNIZATION OF SHP

Modernization aims at enhancing the plant performance. Cost-benefit analysis is essential for modernization. Benefits of modernisation are: increased plant output; improved efficiency; higher availability; higher reliability etc. Briefly it includes both replacements of manual systems with modern accessories and controls (Gates, Governors, and Relays etc.) as well as addition of new features (PLC or SCADA etc.) for smooth operation of the SHP.

4. UPRATING OF SHP

Up-rating aims at increasing the SHP capacity. Essential studies need to be carried out for assessing up-rating feasibility includes: assessment of existing condition of machine; study general guidelines; studies on electrical equipments & parts; studies on mechanical equipments & parts. An up-rating possibility has to be carefully studied to identify the possibility of increasing efficiency or capacity of turbines & generators. Again it has to be carefully studied to identify the possibility of utilizing increased discharge or head (if any). It may be achieved by up-rating of existing machines through technology up-gradation, unit addition or revising operating margins (10–30%). It may also be achieved by adding new technology or replacing old equipments or technology with advanced ones (use of Class F insulation in stator, use of faster relays or breakers, use of advanced runner blade material, use of PLC or SCADA etc.).

5. RLA & LE OF SHP

Systematic way of checking health of every component of the old SHP is done by Residual Life Assessment and Life Extension (RLA&LE) studies. This study helps in assessing the up-rating of the existing facilities of the plants. RLA&LE studies are helpful in determining which component of the plant to be retained and which one to be discarded or replaced.

6. RMU & LE STUDY OF SHP

Renovation, Modernisation, Up-rating and Life Extension (RMU&LE) study of a SHP is carried out in following 6 steps:

Study of drawings, data and records (Equipment drawings, Hydrological data, O& M records etc.);
Survey and inspection (Hot survey of equipments, Cold survey of civil structures, Inspect and identify problem areas etc.);
Testing (NDT, Electrical, Non-electrical, Hydraulic, Efficiency, Structural, Laboratory testing etc.);
Analysis (Decision making on repair or replacement of equipment or parts, Cost-Benefit analysis etc.);
Study of societal & environmental implications (various environmental, socio-political, economic impacts etc.);

Preparation of detailed project report (DPR) (Includes detailed study, analysis result, scope of RMU&LE work, cost-benefit analysis, EIA study reports etc.)

There are 200 (appox.) old small, medium or large hydropower projects in India. The complete replacement cost of new power plants is very high. Again continuous design improvements are also taking place. After using the machine for 10 to 15 years, it may techno-economically be feasible to get higher output & efficiency by making some major or minor changes.

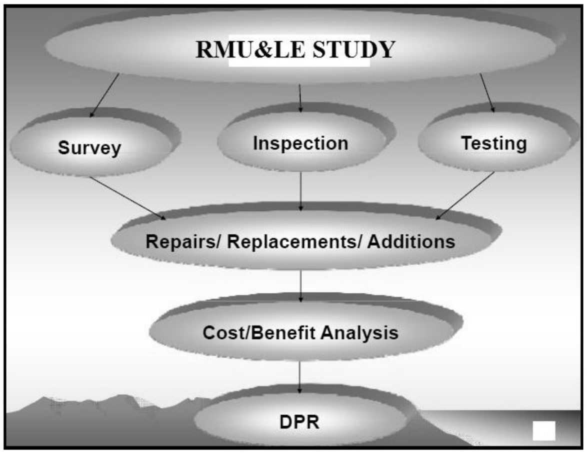

Fig-3: RMU & LE Study of SHP

Renovation, Modernisation, Up-rating and Life Extension (RMU&LE) is redesigning, retrofitting and upgrading 7-years or older SHP (up to 25MW) and some of their components with the aim of achieving enhanced safety, reliability, durability and efficiency. It is done before complete replacement of the plant and machines.

7. DECISION MAKING

Small hydropower projects (SHP) are complex, interdisciplinary integrated systems, because there are large numbers of civil, mechanical and electrical components with different characteristics. The success of a SHP is no longer dominated by only economic criteria. Several other criteria, such as environmental, social and technical aspects need to be taken into consideration. Therefore, SHP development can be analyzed as a typical multi-criteria decision analysis problem.
The present scenario of various fields of research in SHP segment can be summarized as:

Material Science (Effect of corrosion / erosion / water hammer)
Equipment standardisation (moving away from site specific design to standard equipments);
Variable speed low head turbine operation (power electronics application);
Electronic control and telemetry (permits unattended operation of small hydropower projects or AGC);
Submersible turbo-generators (Eliminate power house hence reduces initial cost);
Inflatable weirs (efficient use of flexible water-filled rubber weir crests);
Innovative turbines (various novel types of turbine – fish friendly turbine or pump-turbines);
Improved design of runner, trash-racks or other hydro turbine parts (self-cleaning or self flushing type);
RMU&LE of SHP
Decision Making (Efficient application of various MCDA or MCDM tools)

In the final analysis of any renewable energy research, it is the energy delivered versus the investment cost which has to be optimised for a feasible engineering solution. Inaccurate design, improper selection of project or any parameter will have high negative impact on the overall cost and efficiency. Thus it will result in producing less power at a higher cost-per-watt. In general, evaluating or decision making of small hydropower project or any of its parameter is a complex analysis. The use of multi-criteria decision analysis (MCDA) or multi-criteria decision making (MCDM) or multi-criteria analysis (MCA) techniques can provide a reliable methodology to rank alternatives in the presence of different objectives and limitations [1, 2]. These methods can be used as empirical validation and testing tools of various needs. In addition they can be also applied to group decision making scenario as well as for uncertainty analysis. A review of various published literatures on sustainable energy planning indicates greater applicability of MCDA methods in changed socio-economic scenario [3, 4]. The methods have been very widely used to take care of multiple, conflicting criteria to arrive at better solutions. Increasing popularity and applicability of these methods beyond 1990 indicate a paradigm shift in water resources or renewable energy planning, development and policy analysis. More research is still to be done to explore the applicability and potentiality of more MCDA methods to real-world planning and designing problems to reduce the gap between theory and practice. Many soft-wares (1000Minds, D-Sight etc.) have also been developed to facilitate such analysis or study [5, 6]. The preliminary step in MCDA method is to formulate the alternatives for sustainable energy decision making problem from a set of selected criteria (technical, economical, environmental, social etc.) and to normalize the original data of criteria. The purpose of normalization is to obtain dimensionless values of different criteria so that all of them can be compared. Secondly, criteria weights are determined to show the relative importance of criteria in MCDA method.

Then, the acceptable alternatives are ranked by MCDA method with criteria weights. Finally, the ranking of alternative is ordered. If rank orders, in different MCDA methods are just the same, the decision making process is ended [7, 8]. Otherwise, the ranking results are aggregated again and the best scheme is selected. Popular criterion selection methods are Delphi Method, Least Mean Square (LMS) Method etc. All criteria or factors have their internal impact reclassified to a common scale. Weight is assigned to the criteria to indicate its relative importance. Different weights influence directly the results or ranking [9, 10]. Consequently, it is necessary to obtain the rationality and veracity of criteria weights. Three factors are usually considered to obtain the weights: the variance degree of criteria, the independency of criteria and the subjective preference of the decision-makers. Popular weighting methods are Equal Weights Methods, Subjective Weighting Methods (Delphi Method, AHP etc.), Objective Weighting Methods (LMS Method, TOPSIS etc.) and Combined Weighting Methods. Then it is the turn to determine the preference orders of alternative after determining the criteria weights so that MCDA or MCDM Methods are employed to get the ranking order. For water resource or renewable energy projects MCDA or MCDM methods are divided into four categories: Distance Based Method (TOPSIS, VIKOR etc.), Outranking Method (ELECTRE, PROMETHEE etc.), Priority or Utility Based Method (Weighted Average Method, AHP etc.) and Mixed Category (EXPROM-2, STOPROM-2 etc.). Usually, the decision maker selects the best alternative based on the ranking orders after the calculation in a selected MCDA method. However, the creditability of a process is necessarily verified so that the results of the ranking orders are computed by a few other MCDA methods sometimes along with a final physical verification [11, 12]. The application of various MCDA methods of calculation may yield different results. Therefore, the ranking results are necessarily aggregated again and the best scheme from the alternatives is selected. The methods used to aggregate the preference orders are called as aggregation methods (Voting Method, Mathematical Aggregation Method etc.).

8. RMU & LE OF PATHRI SHP: A CASE STUDY

The Pathri SHP is located on the Upper Ganga Irrigation Canal that takes off from the Bhimgoda Barrage near Haridwar at a distance of 13 km downstream of Haridwar. The SHP was commissioned in the year 1955. The discharge in the canal is regulated by UP Irrigation Department depending upon the irrigation requirement in the command area of the irrigation canal. The estimated cost of RM&LE works were Rs 99.05 Crores (without IDC) or Rs 113.25 Crores (with IDC) [13, 14].

Fig-4: 20.4 MW Pathri SHP Visit (February 2014)

The scope of work (RM&LE) includes reverse engineering: replacement of runner, rehabilitation of generators, installation of intake hoisting arrangement, installation of DT gantry crane, 11 kV Circuit Breakers, control protection and instrumentation, governors, pumps and life extension of units based on RLA studies, replacement of switchyard equipment etc.

TECHNICAL SPECIFICATIONS OF PATHRI SHP	
Installed Capacity	3×6.8MW
Type of Power Station	Surface Run-of-River
Commissioning Year	1955
Water Conductor System	HRT
Water Outlet	TRC
Design Head	9.75 m
Design Discharge	253 m^3/s
Turbine Type	Kaplan
Turbine Output	84000 HP
Generator Type	Umbrella
Generator Output	8 MVA
Main Transformer	5 MVA 11/66 kV
Switchyard	66 kV
Design Energy	80 MU

Fig-5: Technical details of Pathri SHP

The RM&LE work was awarded to M/s Andritz Hydro in March 2010 with a completion schedule of 36 months as per UJVN Ltd report. MNRE granted Rs 12.50 Crores and loan amount from PNB was Rs 65.00 Crores. It has been noticed that the scope of the project got exceeded due to replacement of the items which were to be repaired (turbine shaft, top cover, rotor pole body etc.) as per scope. Due to these unforeseen change in scope the cost as well as time of the project has increased. Main reason which has been noticed for this issue is non-accessibility of items during RLA&LE studies. For Pathri SHP one month shutdown of unit was given for 'Reverse Engineering' initially. Thereafter prolonged shutdown of units was given after detailed engineering and receipt of the material at site. The RM&LE work completion is scheduled in FY: 2014-15 as per UTTARAKHAND - XIIth Plan Programme.

FINANCIAL DETAILS OF PATHRI SHP

• Average annual energy generation	89.91 MU
• Proposed annual energy generation after M&U	155.6 MU
• Expected gain in energy	65.69 MU
• Project Cost	Rs. 92.86 Crore
• Project Cost (Including IDC)	Rs.105.62 Crore
• Debt – Equity ratio	70:30
• IRR	16.92%
• NPV	70.68 Crore
• BCR	1.87
• Tariff (Rs/kWH)	
• First Year Tariff	Rs 1.4
• Tariff after repayment of loan	Rs 0.54
• Levelized Tariff	Rs 1.03

Fig-6: Financial details of Pathri SHP

After 'Reverse Engineering' the scope of the contract changed changing planned time schedule & cost. As a result there was an increased generation loss as against the planned loss.

9. DISCUSION

The optimization of generation from the existing SHP capacity is of utmost importance. The installation of new SHP involves much higher investment and longer gestation period. In view of the large quantum of finances required to install additional capacity, the optimisation of generation from the existing SHP generating capacity through Renovation, Modernisation, Up-rating and Life Extension (RMU&LE) has been considered to be the best option to achieve additional capacity and generation at a much lower cost and in a shorter time. The major reasons for RMU&LE of SHP are:

No or minimum clearances required
Lesser gestation period
Lesser risks involved
Lesser costs as against equivalent new project
Easy financing
Accommodate basin development in future
Technological advancement
Use of Safety Margins and Overload Margins in old SHP
Life extension of existing Facilities
Other Technical Reasons

There is a series of standards, guidelines and manuals on hydropower development or RMU&LE issued by international standards organizations like ISO, IEC, IEEE, ASME, USBR and the national statuary bodies of several countries, including India (CEA, REC, BIS and CBIP). But most of them were prepared keeping in view the large or medium hydropower projects. To make SHP cost effective and reliable, standard guidelines are required covering entire range of SHP (Pico, Micro, Mini and Small) activities. RMU&LE studies should be got conducted through reputed agencies like CWPRS, CPRI, BHEL etc.

10. CONCLUSION

The useful life of the plants is increased by RMU&LE yielding benefits in the shortest possible time at a reasonable cost as compared to new plants. The rural energy scenario in India is characterized by inadequate, poor and unreliable supply of energy services. The optimization of generation from the existing capacity is of utmost importance. Small hydropower projects can provide a solution for the energy problem in rural, remote and hilly areas where extension of grid system is comparatively uneconomical. Stakeholders generally consider the RMU&LE cost of SHP based on thumb-rules (Rs.1.5-2.5 Crore / MW), without considering the scope and size of the units but in reality it is nearly double (Rs.4-6 Crore / MW). The major issues and challenges that are associated with RMU&LE of SHP are:

RMU&LE of SHP is difficult for demand–supply gap;
Not much of expertise is available in the Indian market;
No standard benchmark for such projects;
Non-availability of initial documents of the SHP;
Issues related to copyright of the original manufacturer;
Employee reluctance to accept the change.

While these projects are developed by various state agencies responsible for renewable energy, the projects are normally maintained with local community participation. Such SHP faces the problem of poor plant load factor and making financial return difficult for the plant. But this provides opportunities for the overall socio-economic development of the rural area and hence gaining importance widely.

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BIOGRAPHIES

Priyabrata Adhikary is presently working as an Assistant Professor-Mechanical at S.V.I.S.T. (W.B.U.T.), Kolkata for last 2-years. Prior to teaching he is also having 8-years of H.V.A.C. & R industry experiences in India and abroad (GCC). He has done his B.E. (Mechanical) and M.E. both from Jadavpur University. He is author for several national and international publications.

Susmita Kundu is working as an Assistant Professor-Electrical at M.S.I.T. (W.B.U.T.), Kolkata for last 10-years. She has completed her B.Tech (EEE) from S.M.I.T. and M.Tech from Calcutta University. She is author for several national and international publications.