FINANCIAL ANALYSIS OF MODIFIED DRAFT TUBES IN HYDROPOWER PLANTS USING CFD

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Abstract: To check the optimal adaptation of the flow streamlines complete turbine water passages is to be analyzed using CFD tools. A poorly adapted profile allows local flow accelerations and boundary layer flow separations and further deteriorates the flow distribution and uniformity. The impact of flow deterioration on the hydraulic behavior of the components leads to additional secondary losses. The quality of the hydraulic investigation is important to correctly identify the potential of improvement in performance of each component. During the upgrading and rehabilitation of old power plant or new design of plant, flow analysis using CFD should be carried out prior to preparation of the bid specifications to accurately define the scope of work. In this study, different approaches for rehabilitation of hydro power projects along with different challenges in modification of existing draft tube at site were discussed.

Index Terms **- Hydro power, Draft tube, CFD simulation, Financial Analysis.**

I. INTRODUCTION

Rehabilitation of hydro power plant may be done to achieve one of three options i.e. (a) restoration to original/initial performance (b) enhancement of unit performance and (c) uprating of unit performance using updated technologies depending on availability of inflows Fig. 1. Focus of rehabilitation is to replace the major associated electrical and mechanical equipment i.e. the turbine and generator but major changes in civil works are generally excluded with the possible exception of draft tube modifications.in the first option of rehabilitation, in restoration of plant components during rehabilitation, the efficiency and output of the plant are brought back to the initial values as shown in Fig. 2. This type of rehabilitation can be carried out with minimum efforts to restore the original output of the station and is least costly. However, it is generally used for the extension of plant life only.

In contrast to the first option, performance of the plant can be enhanced with the use of modern/updated techniques such as CFD and model testing etc., however with increased costs and is justified by the additional gain in energy production over the life of the equipment. For plant with initial inflow/design conditions, the rehabilitation enhances the performance of the plant with modifications in flow passages of runner and draft tube. In the option three, the plants with increased inflow conditions, uprating of the plant is undertaken which involves redesigning of hydraulic turbine with new inflow conditions yielding greater output around 15% to 30% [3].

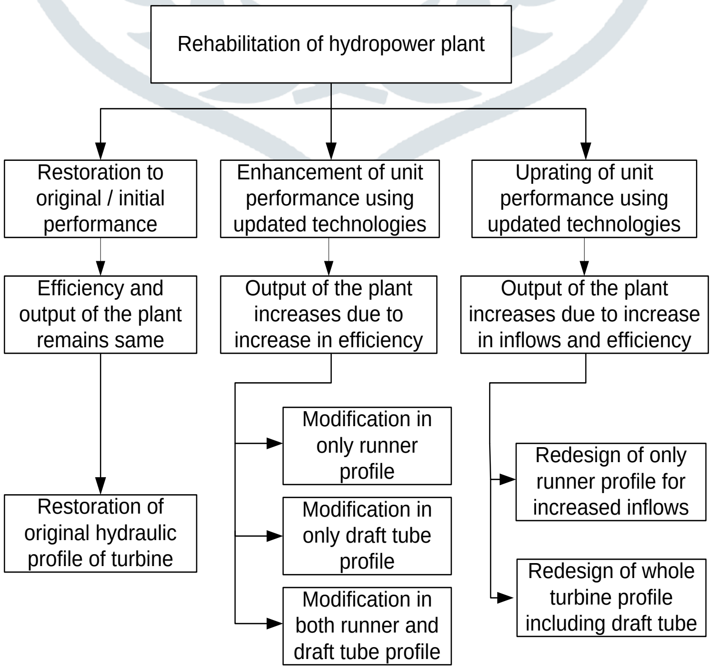

Fig. 1: Type of rehabilitation and respective changes in hydraulic profile

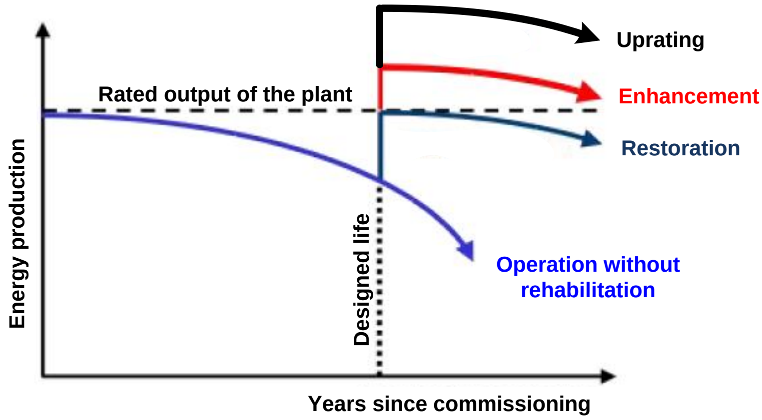

Fig. 2: Energy production over time with and without rehabilitation modified from [1]

Rehabilitation of hydro power plants involves various steps as shown in Fig. 3. The assessment of the performance improvements is a very important phase of the preparation work [4, 5, 7]. It includes the civil works, mechanical and electrical installations and also considers the scheduling, cost and risks analysis. After the assessment a new turbine is designed test to meet the fixed target using CFD and model test. It will give the better reliability of the prevision before to carry out the prototype modifications. The final assessment of improvement is carried out by prototype test. Every site of hydro power plant is unique in its design and operation, and also different in the technical requirement, therefore, it is necessary to carefully adapt the new design to the existing components. Except to solve the existing problems i.e. cavitation and erosion, the goal of the rehabilitation is to increase the output and efficiency through the replacement of modified runner and draft tube. In some specific cases other components such as stay vanes or spiral case are also modified.

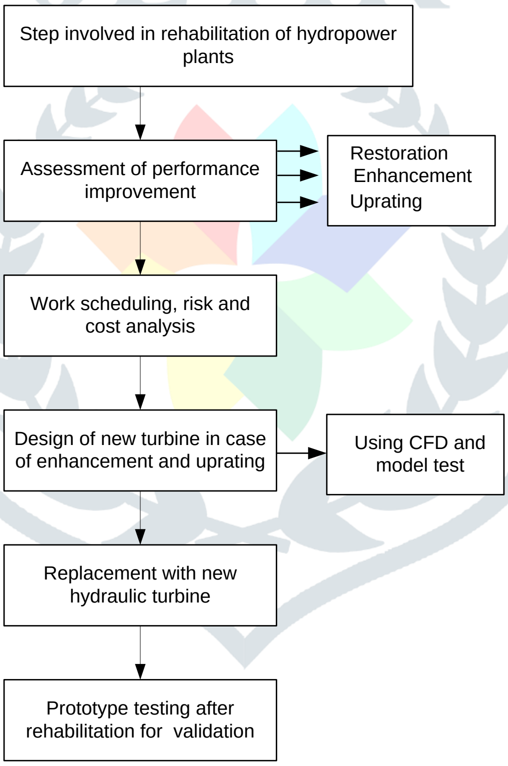

Fig. 3: Steps involved in rehabilitation of hydro power plant

Unit capacity improvement and enhancement of the efficiency level are the main guiding parameter for on-going market of refurbishment/rehabilitation. The risks at each phase of project from the bidding to the prototype testing have to be managed. Model testing is a tool guiding towards an optimized solution and validates the performance at the model scale. Feedback from field test at and prototype operating conditions is a key point to improve the knowledge in order to optimize the shape and size of turbine components i.e. runner and draft tube.

Very limited studies regarding replacement of existing draft tube with optimized draft tube coupled with modified runner are available for rehabilitation and renovation of hydro power projects for capacity enhancement. It was observed that replacement of runner by keeping the existing draft tube resulted sudden drop of 0.8% in efficiency near best efficiency point [1]. This drop in efficiency occurred due to flow separation at the pier nose area and a change in the ratio of discharge rate at the outlets of the draft tube. In such cases, tests were conducted to validate the performance of turbine runner by changing the existing draft tube with an optimized modern design of draft tube obtained from CFD simulation. Performance of existing and optimized draft tube with upgraded runner with different operating range is shown in Fig. 4.

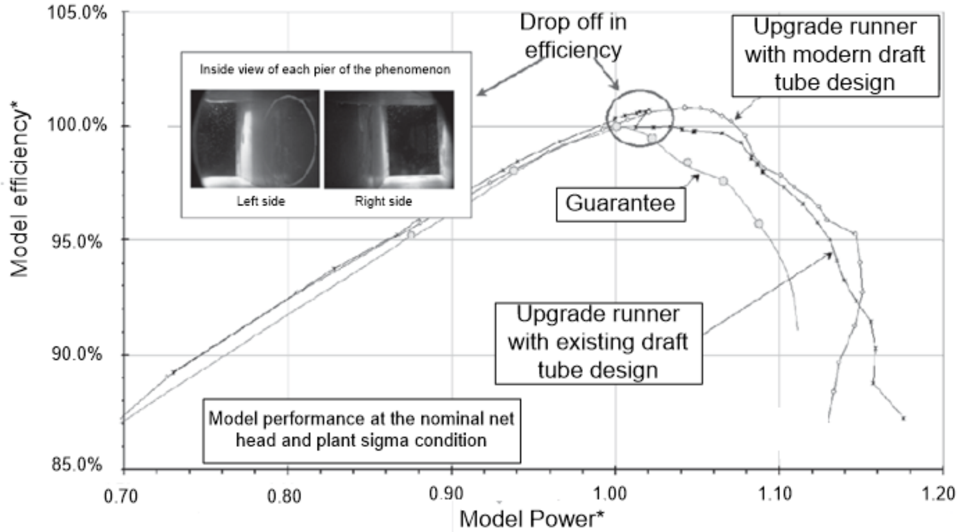

Fig. 4: Performance of upgrade runner with modern and existing draft tube in low head propeller turbine [1]

In literature, during rehabilitation and renovation of hydro power plant replacement of draft tube with existing runner were not reported. In this chapter, financial study is conducted for both optimized cases of draft tube modification.

II. CHALLEGES AND METHOD INVOLVED IN MODIFICATION OF DRAFT TUBE AT SITE

Planning the sequence of activities is very important during the draft tube modification in rehabilitation projects so that work involved in modification of draft tube could be completed within scheduled time. It should start as soon as the turbine is disassembled and the components taken away for refurbishment/repair. The delay in reassembly of the turbine could be avoided with timely modification of draft tube profile. The draft tube gate is operated during the rehabilitation in order to dewater the wetted parts. Self-compacting concrete may be selected for the work to ensure that there are no voids behind the formwork. However, because of the vertical distance the concrete had to be moved, and there are some risks of aggregate becoming more concentrated due to gravity. This problem is not new to pouring concrete and just needs to be managed to suit the specific application.

Health and safety are the biggest challenges faced during modification of existing draft tube at site. Generally, the manpower available at the plant is used to carry out civil works also during rehabilitation. The manpower doing civil work needs to be equipped with knowledge of the health, safety and work management requirements. The lack of knowledge may lead to risks that had to be managed while the draft tube work is under process. Before and after the draft tube modification, a 3D survey of the draft tube should be conducted to compare with original drawings. It can be concluded that systematic planning is required to ensure the implementation of works according to the budget and schedule. It should also ensure that the modified dimensions of draft tube are achieved as desired and work is completed safely.

III. METHODOLOGY

In this section, general method adopted for financial study of both cases of optimized draft tube are discussed. The various costs involved for implementation of two optimization cases are also presented in Fig. 5.

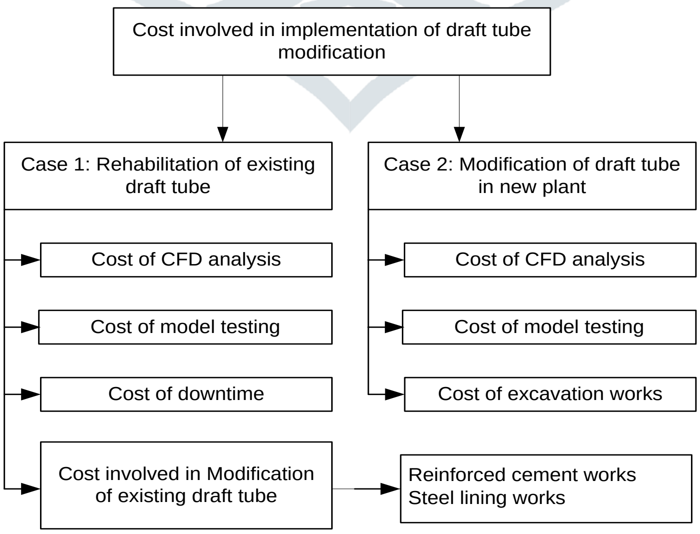

Fig. 5: Cost involved in implementation of draft tube modification

3.1 Cost of CFD Analysis for Optimization of Draft Tube

The modern computational facility and skilled manpower is required to optimize the draft tube geometry using CFD analysis.

3.2 Cost of Model Testing of Modified Draft Tube

Model testing should be conducted as per IEC 60193:1999 [2] to validate the performance of optimized draft tube obtained from CFD.

3.3 Downtime Loss

In the financial analysis, cost of generation due the downtime for carrying draft tube modifications should be considered. Forced shutdown can be avoided /reduced with proper planning of maintenance and calculation of time between overhaul of the components [6]. The loss of electricity generation during work involved in modifications of draft tube can be minimized with availability of adequate tools and manpower. The downtime for modification in draft tube may be avoided with proper planning of the modernization schedule taking one unit at a time while other units keep functioning. The loss of electricity generation due to downtime is calculated using eqn. 1 and eqn. 2.

$$E_{Stutdown} = (t_{Shutdown} - t_{rehab}) \times C_{Capacity} \times W_{Usable} \quad \text{for} \quad t_{Shutdown} \geq t_{rehab} \quad (1)$$

$$E_{Shutdown} = 0 \quad \text{for} \quad t_{Shutdown} < t_{rehab} \quad (2)$$

where,

$E_{Shutdown}$ = losses in generation of electricity due to shutdown, kWh

$t_{Shutdown}$ = shutdown duration, hour

t_{rehab} = rehabilitation duration, hour

$C_{Capacity}$ = per unit capacity of rated generation, kW, and

W_{Usable} = availability factor for water during the duration of shutdown

The availability factor for water varies from 0 to 1. The water availability factor has the minimum value 0 during lean season with assumption that the entire available water is utilized by other generating units causing no wastage of water. It is the best time for refurbishment/rehabilitation of hydro power plant which may also involve modifications in the draft tube without any electricity generation loss. The availability factor has the maximum value 1 during rainy season which may lead to the maximum electricity generation loss.

3.4 Cost involved in Modification of Existing Draft Tube

The costs of various repairs work during modification of existing draft tube are presented here. Generally, the repair cost depends on labour wages which includes rate of persons involved and total man hours. For a hydropower plant, the cost of the civil works is dependent on labour costs in the country which in developing countries is lower than developed countries due to local labour involved. But, poor infrastructure, remote sites and higher prices of construction materials may sometimes significantly increase the overall cost in developing countries and remote places.

3.4.1 Steel lining work

The draft tube of low and medium head reaction turbine is normally steel lined in draft tube cone portion. The elbow and horizontal portion are concreted. But in case of high discharge, elbow and diffuser parts are provided with steel lining. In case of rehabilitation, modification of draft tube shape is dependent on existing structure of draft tube. Modification in existing hydraulic profile of draft tube is carried out at site and steel lining works are used to obtain the optimised shape of draft tube. Gap between steel plates and surface of existing draft tube are to be filled with reinforced concrete. These steel linings are in many pieces of steel plates and are welded to avoid deformation of job and stress locking in welded pieces. After wielding process grinding, heat treatment and stress relieving work are carried out.

3.4.2 Reinforced concrete work

Gap between steel liner and surface of existing draft tube are to be filled with reinforced concrete. Proper setting time is provided to reinforced concrete work.

3.5 Excavation Cost

In new design of draft tube, height of draft tube may be more than existing height. It will lead to more excavation of power plant compared with existing power plant. Cost involved in excavation works may be calculated as volume of earth work required under the specific condition for new design of draft tube.

IV. CONCLUSIONS

Different approaches for rehabilitation of hydro power projects along with different challenges in modification of existing draft tube at site were discussed. Further, different types of cost involved in rehabilitation were also presented. For power plants undergoing rehabilitation woks, it is recommended for power plant manager to focus on optimizing the shape of existing draft tube in addition to the improved turbine runner profile. Moreover, power plants in which turbine runners are manufactured and supplied with considerations of modern techniques, substantial gain in power production can be achieved with optimization in draft tube profile only keeping the same runner profile.

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