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MODELLING THE INFLUENCES OF HYDRO POWER REFURBISHING PROJECTS

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Abstract: The paper shows the development of a knowledge based system to evaluate the technical condition of a hydro power plant including its components. This system analyses the condition of the components by evaluating selected influencing parameters and together with selected parameters about the whole power plant, it leads to statements about the existing refurbishing potential and the urgency of refurbishment measures including a priority list of technically advantageous component refurbishments. A subsequent economic evaluation analyses the influence of several economic influence parameters on the optimum refurbishing time. Finally results of case studies including sensibility analysis of the influence parameters will be shown. Copyright © 2002 IFAC

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1. GENEREAL PROBLEM

In a time of rising competition and limitation of budget means, lasting decisions concerning the further operation of technical systems are urgent. Even concerning the scope and point in time of refurbishing and replacement projects, solutions for optimisations are needed.
Regarding Hydro Power plants, the technical condition of the power plant components, the possibilities of implementing new parts as well as the economic advantages or disadvantages of such projects have to be analysed and taken into consideration. Due to the fact that it is not always easy to gather detailed data about an existing power plant with several years of operation, strategies and evaluations for the refurbishment and the further operation of Hydro Power plants have to be based on a simple and effective knowledge based system.
This system should analyse the condition of the components by evaluating selected influencing parameters and together with selected parameters about the whole power plant, it should lead to statements about the existing refurbishing potential and the urgency of refurbishment measures including a priority list of technically advantageous component refurbishments.
Based on this technical evaluation, an economic evaluation should be realized. The goal of this economical evaluation is, to assess the economic effect of refurbishing several components with a high technical refurbishing priority. By including and varying economic parameters it should be possible to evaluate the optimum refurbishing time and the influence on the optimum refurbishing time.

2. THE SOLUTION

The representation of the problem by analysing the knowledge about hydropower plants and their evaluation is the first step to develop an appropriate evaluation system. After analysing several

revitalisation projects on hydro power plants, a knowledge based system called REVEX© was developed, which consists basically of two parts.
The first part is the technical evaluation, which includes the evaluation of the component-condition and the upgrading possibilities for the hydro power plant. After the decision for possible changes on the power plant, an economic evaluation will take place to find out the optimum time for the reconstruction by optimising the global gross-profit.

2.1. The technical evaluation

An application of the system on different types of hydropower plants, in order to compare installations and their need for refurbishment is an important task. Therefore the developed method requires sufficient data to grasp the condition of the components and the plant itself, but data has to be general, that it can be adapted easily on different hydraulic installations.
A simple marking system, based on a point-evaluation of significant indicators was selected to give a conclusion of the current condition. As a result of investigations the 10 most important indicators have been selected (see Fig 1), which will be weighted individually by points from 0 (good) to 10 (critical), giving a conclusion about condition, the refurbishing potential and the further use of the hydro power plant and its components.
This statement is the basis to investigate the economic effects of refurbishing selected components in the economic evaluation.

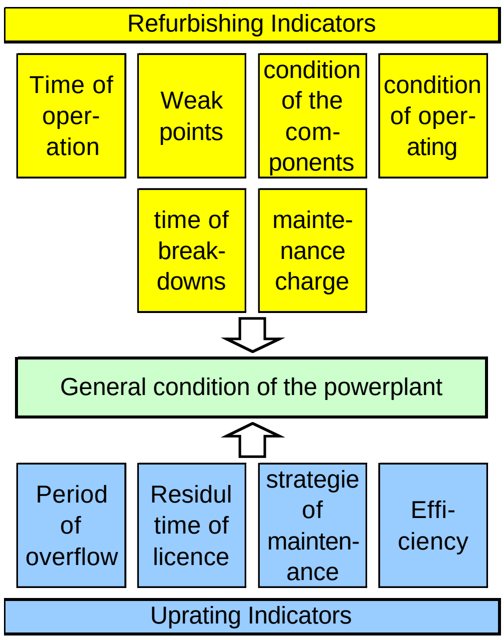


Fig 1 Refurbishing and Uprating indicators

These indicators will interact with all physical components of a hydro power plant. Because of the complex structure, it is necessary to abstract the whole hydro power plant and to investigate the main parts respectively the main components.
In this case it is advisable to be as precise as necessary but so general as possible. Fig. 2 gives a impression of a possible model and its implementation in REVEX©.
All parts will be investigated separately and then joint together for a final evaluation. The institute for waterpower and pumps has developed scoring mechanisms for all the parts at the sections listed in Fig.2.

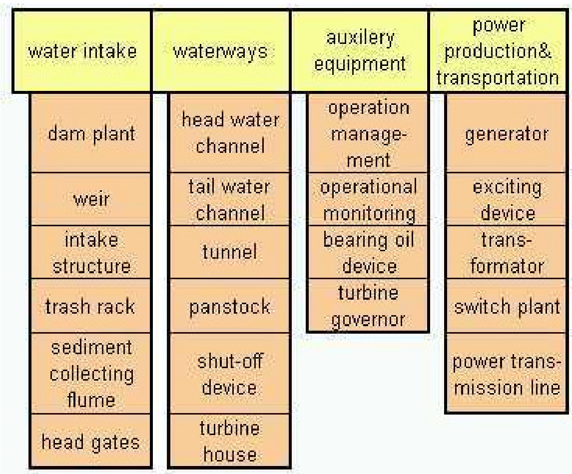


Fig. 2. Main components of a hydro power plant model

2.2. The technical evaluation of weirs

Especially for weirs, which are a main group of the water intake section, a more detailed technical evaluation has been developed by Doujak (2000).

The technical evaluation of weirs is divided in several parts and each part has a scoring mechanism included. Four main investigation groups cover the weir and gates section:

- the evaluation of resistance and life expectancy
- the evaluation of the surface protection
- the evaluation of the operating mechanism and
- the evaluation of the general conditions.

The structure of the whole scoring mechanism is shown in Fig.3.

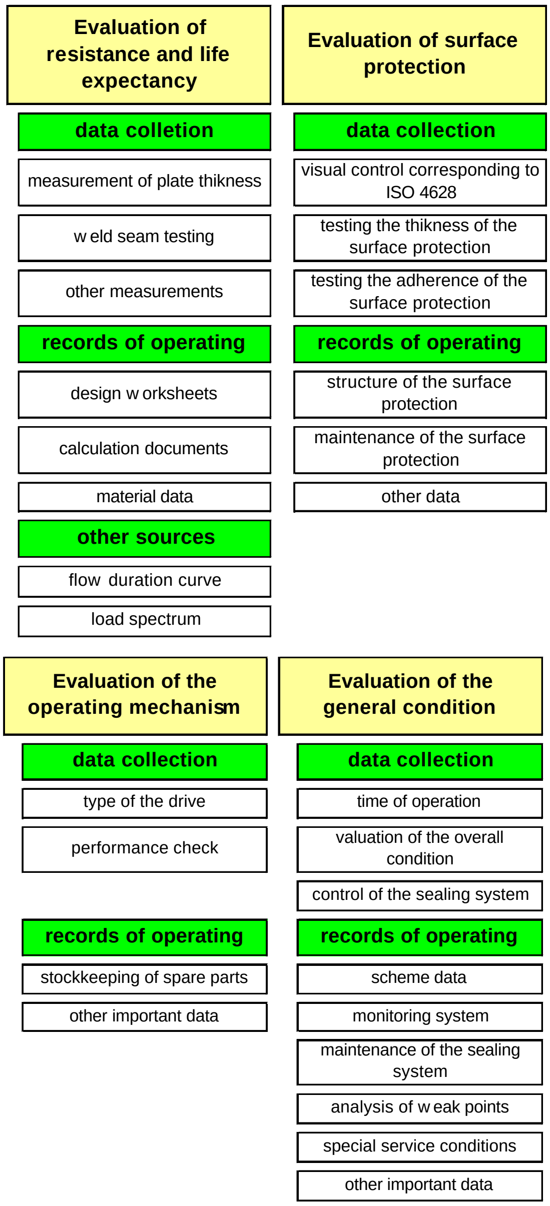


Fig. 3. Structure of a scoring mechanism for gates and weirs

Investigating gates and weirs in detail is always a manner of collecting the right data. Datas can be available at different places and stages. It is important to collect all possible information to get the best overview about the condition and of course the residual lifetime of the investigated gate or weir. The data acquisition for the scoring mechanism has been divided into three groups:

- group of the data collection in situ (this means data collection by measurements at the site for example)
- group of data out of the records of the operation
- group of other sources which can be provided by different companies or institutions.

As an example for rating the module "evaluation of the surface protection" will be discussed.

The rating is built from a data collection as well as from records of operation:

$$P_{Ob} = \frac{\sum G_{Ob,I-II} * P_{Ob,I-II}}{\sum G_{Ob,I-II}} \qquad (1)$$

$P_{Ob,I}$ = rating surface protection (in situ data collection) $0 \le P_{Ob,I} \le 5$
$G_{Ob,I}$ = weighting factor surface protection (in situ data collection) $1 \le G_{Ob,I} \le 1{,}5$
$P_{Ob,II}$ = rating surface protection (records of operation) $0 \le P_{Ob,II} \le 5{,}333$
$G_{Ob,II}$ = weighting factor surface protection (records of operation) $1 \le G_{Ob,II} \le 1{,}2$

The in situ data collection comprises all information that can be collected during an inspection of the gate:

$$P_{Ob,I} = \frac{P_{Ob,Op} + P_{Ob,Sch} + P_{Ob,Ha}}{3} \qquad (2)$$

$P_{Ob,Op}$ = valuation of visible surface irregularities $0 \le P_{Ob,Op} \le 5$
$P_{Ob,Sch}$ = testing the thickness of the surface protection $0 \le P_{Ob,Sch} \le 5$
$P_{Ob,Ha}$ = testing the adherence of the surface protection $0 \le P_{Ob,Ha} \le 5$

If a detailed visible inspection is not possible the scoring system includes auxiliary values for a rough estimation of single parameters. Otherwise the evaluation can become more detailed:

$$P_{Ob,Op} = \frac{P_{Ob,Op,Bl} + P_{Ob,Op,Ro} + P_{Ob,Op,Ri} + P_{Ob,Op,Ab}}{4} \qquad (3)$$

$P_{Ob,Op,Bl}$ = valuation of blisters $0 \le P_{Ob,Op,Bl} \le 5$
$P_{Ob,Op,Ro}$ = valuation of rust formation $0 \le P_{Ob,Op,Rol} \le 5$
$P_{Ob,Op,Ri}$ = valuation of cracks $0 \le P_{Ob,Op,Ri} \le 5$
$P_{Ob,Op,Ab}$ = valuation of flaking $0 \le P_{Ob,Op,Ab} \le 5$

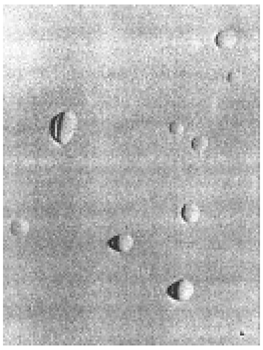
The valuation of blisters can be done according to the following rule:

$$P_{Ob,Op,Bl} = \frac{(Bl_M + Bl_G)}{2} * \frac{A}{100} \qquad (4)$$

Bl_M = number of blisters $0 \le Bl_M \le 5$
Bl_G = size of blisters $0 \le Bl_G \le 5$
A = infected area of the gate $0\ \% \le A \le 100\ \%$

In order to determine the factors Bl_M and Bl_G the pictures published in DIN ISO 4628-2 (1997) can be used. The appearance of the surface protection has to be compared to the classification done in this standard.

blisters:
number = 2, size = 3



blisters:
number = 2, size = 5

blisters: number = 4, size = 3

Fig. 4. Classification of blisters (extract of DIN ISO 4628-2, 1997)

As the whole task of rating all the influences on a gate or weir is very complex, we have given here only a short overview about one aspect of this scoring. The other points of the scoring system for the component "weirs and gates" have been published by Doujak (2000) and are included into the whole mechanism of a technical evaluation of a hydro power plant.

2.3. The economic evaluation

To record all the dynamic influences on costs and returns, it is important to analyse a longer period of time with a dynamic capital-value-method. The goal is to calculate the gross-profit over a defined time-period for different refurbishing times of components rated by the technical evaluation. The maximum gross-profit will characterise the optimum refurbishing time. By implementing the time, costs and affects of maintenance strategies, it is also possible to optimise the revision measures.

The most important influence parameters implemented in the evaluation system are:

- The expected cost-trends for maintenance and repair of the hydropower plant components
- Initial price for new components
- Annual power-generation
- Curves for the loss of global efficiency and possible increase of efficiency after refurbishments
- Sales-price of electricity and belonging trends
- Calculated interest rate and cost-index
- Overhead costs for the hydropower-plant
- Time of depreciation and the interest rate for new investments
- Non-productive-time and reduction of output during reconstruction
- Strategy of maintenance including the economic effects, costs and time-periods
- Probability of breakdown

The selected period for the calculation mainly consists of three different time-spans (See Fig. 5).

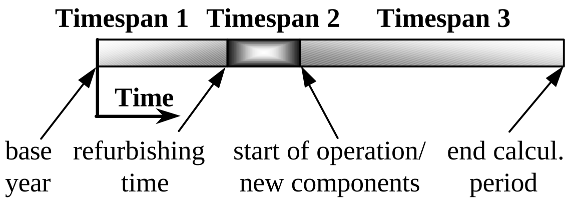


Fig. 5 Different time-spans of the calculation period

Time-span 1: original condition
Time-span 2: reconstruction
Time-span 3: new constellation after refurbishment

With subsequent sensibility analysis, it is possible to find out the influence of different input parameters on the expected gross profit in dependence on the refurbishing time.
As an example, the influence of the non-productive time during the refurbishment of an example refurbishing project is shown in Fig. 6. Interpreting this result shows an increase of the optimum refurbishing time (higher gross-profit) by expanding the non-productive time during refurbishment.

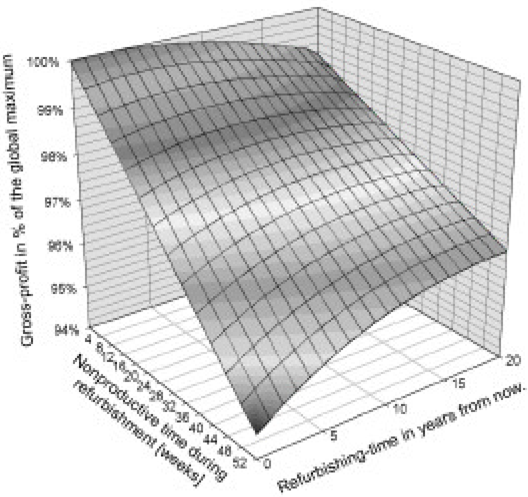


Fig. 6 Refurbishing and Uprating indicators

3. RESULTS

Based on real data, several refurbishing projects have been investigated with this system.

By benchmarking and comparing two power plants, it is possible to analyse its revitalisation situation in order to find advantages for the revitalisation of one of these projects.

As an example: Two investigated power plants have been in operation for 40 years (power plant 1) and for 18 years (power plant 2). After including the relevant input parameters and the evaluation with the system, a statement about the rehabilitation situation and the modernisation potential can be given. Fig. 7 shows the points which represents the global revitalisation situation and the modernisation potential of the two plants. Together with additional detailed point evaluations this will lead to the statement, that for power plant 1 a detailed refurbishing study is urgent and an uprating study with a good modernisation potential is advisable, but for power plant 2 there is no need for refurbishing at the moment.

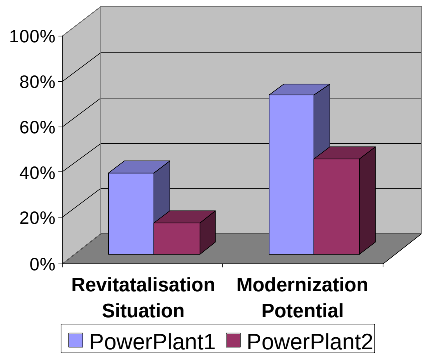


Fig. 7 Revitalisation situation and modernisation potential

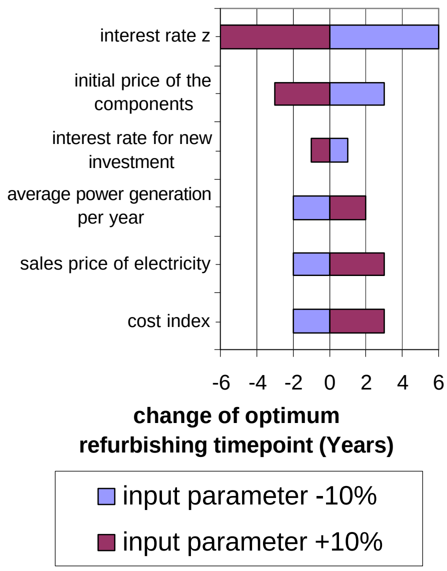


Fig. 8 Sensibility analysis of the economic input parameters

The application of the economic evaluation on different projects have shown the influence of the economic input parameters on the optimum refurbishing time in several sensibility analysis (Fig. 8).

Additionally a detailed analysis of several economic influence parameters has been executed.

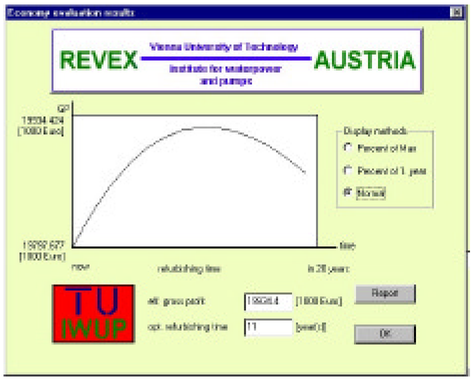


Fig. 9 Sample output of the economic evaluation in REVEX©

As an example the influence of the interest rate on the expected ‚gross profit in dependence on the refurbishing time is shown in Fig. 10.

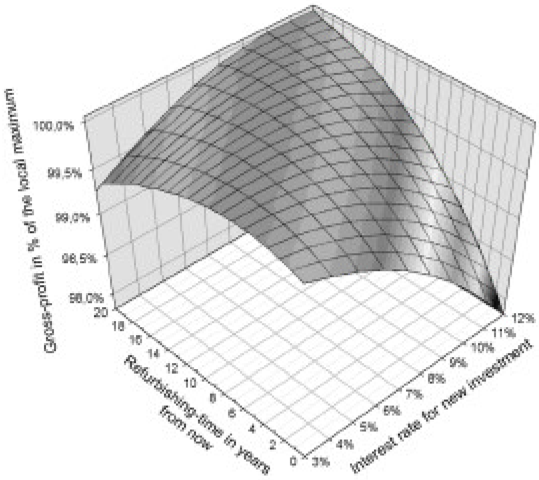


Fig. 10 Gross profit depending on the refurbishing time and the interest rate

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