Asset management partnership goes from strength to strength after 15 years

B. Neijens, Copperleaf Technologies, Canada
C. Hayes, CEATI, Canada

Successful strategic planning for capital investments in existing hydro plants requires the balancing of many factors, including the risks and consequences of equipment failure. In 2001, the US Bureau of Reclamation (USBR), Hydro-Québec (HQ), the US Army Corps of Engineers' Hydroelectric Design Center (HDC), and the Bonneville Power Administration (BPA) partnered to create the Hydropower Asset Management Partnership (hydroAMP), aiming to develop a framework to streamline, simplify, and improve the evaluation and documentation of the condition of hydro equipment. This has been used ever since by a growing number of hydro owners and operators. In 2012 CEATI assumed the programme management role for hydroAMP, which now forms part of the Hydraulic Plant Life Interest Group programme supported by more than 65 hydro utilities around the world.

The Hydropower Asset Management Partnership (hydroAMP) began when representatives from the four organizations who were to become partners met to discuss their respective goals and objectives. The discussion resulted in a collaborative development of hydropower asset management tools related to equipment condition assessments, investment prioritization methods, and business risk evaluations. The Hydropower Asset Management Partnership (hydroAMP) identified the following concerns:

- The majority of critical equipment at hydro plants in North America is near or beyond its design life.
- Equipment reliability contributes significantly to system generation availability.
- The need for significant investment in repairing, refurbishing or replacing existing generation and auxiliary equipment within hydro projects is ongoing and more is anticipated.
- An opportunity exists to increase generation efficiency through investments in improved control systems, operations, and equipment.
- The process for identifying and prioritizing investments needs strengthening.
- Establishment of an objective, consistent, and valid assessment process is critical.
- Equipment condition assessment tools used in the past have been too complex and costly.

Strategic goals

The goal of hydroAMP was to create a framework to streamline, simplify, and improve the evaluation and documentation of the condition of hydro equipment to enhance asset and risk management decision-making. The team recognized that equipment condition assessments support: the development of long-term investment strategies; prioritization of capital investments; coordination of operation and maintenance budgeting processes and practices; and the identification and tracking of performance goals.

Intended users

HydroAMP was developed for use and implementation by any organization developing or operating hydro plants. Therefore, the related tools were designed to be open and flexible, to fit into existing maintenance, planning, budgeting, and decision-making regimes. The processes are also intended to serve multiple users within an organization who may have distinct roles and responsibilities for hydropower asset management.

General methodology

The equipment condition assessment and decision-making process involves three phases, as shown in Fig. 1: Tier 1 assessment, Tier 2 assessment, and a business decision. Tier 1 represents the start of the condition assessment process and culminates in the determination of an equipment Condition Index (CI).

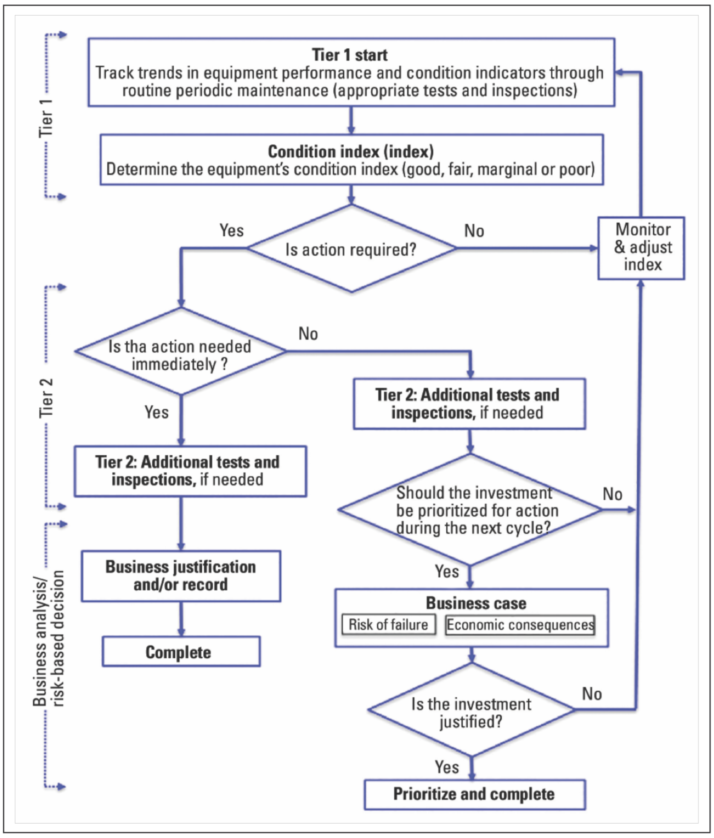
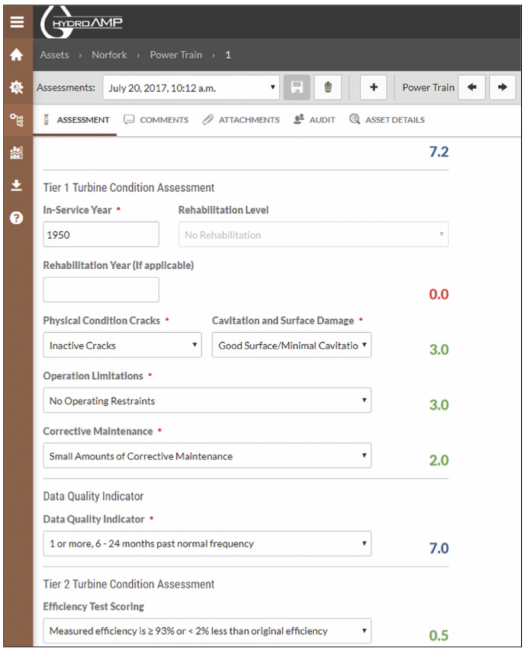


Fig. 1. hydroAMP methodology diagram.

Fig. 2. The hydroAMP condition assessment questionnaire.



The Tier 1 assessment relies on test and inspection results obtained during routine operation and maintenance (O&M) activities or during specific equipment condition reviews or inspections. Each hydroAMP equipment condition assessment methodology specifies relevant CIs, such as equipment age, operational performance, maintenance history, and physical inspections or tests that are evaluated and scored over a narrow set of scores, usually 3 or 4 possible levels of quality. Fig. 2 shows an example of a Tier 1 assessment for a turbine.

Each CI is weighted and then all are added together to compute on overall Tier 1 CI, which ranges numerically between 0 and 10. A condition equipment rating is assigned, based on the CI, the ratings being good, fair, marginal, or poor, as shown in Table 1 below.

Tier 1 tests may indicate abnormal conditions to be addressed immediately, or that can be resolved through standard corrective maintenance solutions. To the extent that Tier 1 tests lead to immediate corrective actions being taken, appropriate adjustments to the condition indicator scores should be made, and the new results used to compute a revised condition index.

As a result of the Tier 1 assessment, additional information may be required to improve the accuracy and reliability of the Tier 1 condition index, or to evaluate the need for more extensive maintenance, rehabilitation, or equipment replacement. If so, one or more Tier 2 inspections, tests, and measurements may be carried out, depending on the specific issue or problem being pursued. These tests are considered non-routine, and may require specialized engineering expertise and/or test equipment to complete. The Tier 2 inspections, tests, and measurements are specifically tailored for the equipment being assessed. An outage and some dismantling of the component under test may also be required. Results of the Tier 2 analysis may either increase or decrease the score of the original Tier 1 CI. Fig. 3 shows the results of annual assessments for a specific asset.

Table 1: Condition ratings based on the hydroAMP Condition Index.

Condition Index (CI)	Condition equipment rating	Definition
8 < Index < 10	Good	There is a high level of confidence that the component will perform well under normal operating conditions. Continue current O&M practices. Repeat condition assessment on normal frequency. Consider performing Tier 2 tests when convenient to provide good base line data for comparison with future tests.
6 < Index < 8	Fair	There is a medium level of confidence that the component will perform well under normal operating conditions. The component may require additional investigations to confirm adequacy. Continue current O&M practices, minimal restrictions to operation and/or minor maintenance may be necessary. Repeat condition assessment on normal frequency. Consider performing Tier 2 tests to provide further insight into equipment condition and adjust CI score as necessary.
3 < Index < 6	Marginal	There is a low level of confidence that the component will perform well under normal operating conditions. The component requires additional investigation to confirm adequacy. Restricted operation and/or non-routine maintenance are necessary. Perform applicable Tier 2 tests and adjust CI score as necessary. Consult with technical specialists. Repeat condition assessment more frequently.
0 < Index < 3	Poor	The component does not perform well under normal operating conditions. Physical signs of serious damage or deterioration are present. Significant restrictions to operation and/or extensive non-routine maintenance are necessary. Perform immediate Tier 2 testing and adjust CI score as necessary. Consult with technical specialists. Repeat condition assessment more frequently.

Equipment condition assessments

Equipment within a hydro plant, whether it is a part of a unit powertrain or provides ancillary support to the plant and its operations, is appropriate for analysis under a condition assessment programme. An unexpected failure can have a significant economic impact because of the high cost of emergency repairs and lost revenues during an extended forced outage. A catastrophic failure could trigger significant adverse safety and environmental consequences.

Determining the current condition of equipment is an essential step in analysing the risk of failure. Equipment condition assessment guides' were developed for the following major equipment and auxiliary components:

- governors;
- turbines;
- generators;
- excitation systems;
- circuit breakers;
- transformers;
- surge arrestors, MOV type;
- batteries;
- compressed air systems;
- cranes;
- emergency closure systems;
- steel penstocks; and,
- balance of plant components.

The guides are not intended to define maintenance practices or describe in detail how inspections, tests, or measurements are to be performed. Utility-specific maintenance policies and procedures should be consulted for such information. However, the guides idenitify a variety of operation, performance and maintenance factors that are useful in assessing and evaluating the condition of the equipment. Not all of these factors are applicable in each situation.

Business decisions

The hydroAMP CI is used as a base for business decisions. In most cases it will be converted into a 'likelihood (or probability) of failure' of the asset, which in conjunction with the 'consequence of the failure' will determine the risk level attached to each asset failure, as shown in Fig. 4.

Expert opinion and asset condition history are both leveraged by predictive analytics models, such as Copperleaf's C55 to convert hydroAMP CIs into predicted degradation curves and likelihood of failure curves, which will provide an asset risk forecast for each asset. Such risk forecasts are then used to determine the optimal intervention time for each asset, and to justify the necessary funding and resourcing required for asset sustainment.

HydroAMP web application

Shortly after the hydroAMP programme began, the need for an Internet-accessible application for recording and tracking hydroAMP information became apparent. BPA, in coordination with the hydroAMP team, developed the original application. As the number of users increased, the need for additional functionality and ongoing support prompted the hydroAMP founders to involve CEATI in the programme. This has resulted in the redevelopment of the application (see Fig. 2) by Copperleaf for CEATI, using modern technology and offering a solid platform for future expansion.

The application contains downloadable copies of all current condition assessment and field inspection guides, provides the ability to configure equipment for each plant or substation managed by the user's organization, includes the capability to input hydroAMP condition assessment data for plant and substation equipment, and generates a series of reports that can be downloaded in a variety of file formats.

Future developments

The wealth of condition data collected with the hydroAMP application can be put to good use in a number of ways, such as the following.

• Comparing the condition index of an asset to its peers (either within a same organization, or across the whole fleet of same type assets within the hydroAMP user base), as shown in Fig. 5.

• Developing asset degradation curves over time based on historical data, as shown in Fig. 6. Many hydro asset operators struggle finding reliable asset degradation information for their key asset types. The pooling of condition data of large asset populations in hydroAMP allows for the development of degradation curves which offer a high degree of confidence. This in turn enables the prediction of the future condition of an asset, a key element required for robust long-term asset investment planning.

• Exploring overall asset health for entire plants or units (see Fig. 7). Such graphs are useful to highlight plants which are in need of urgent attention, and facilitate the rapid identification of trends.

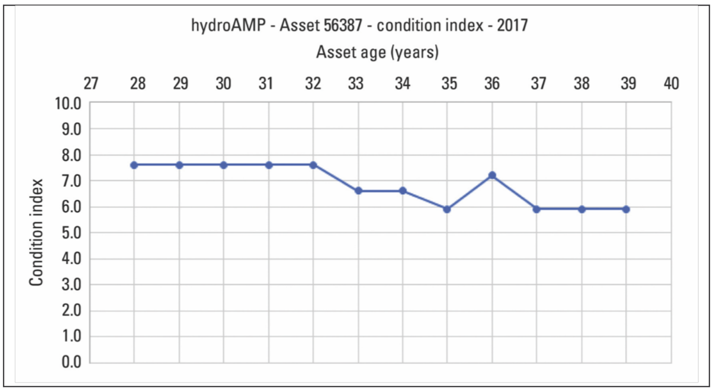


Fig. 3. Results of annual assessments for a specific asset versus asset age.

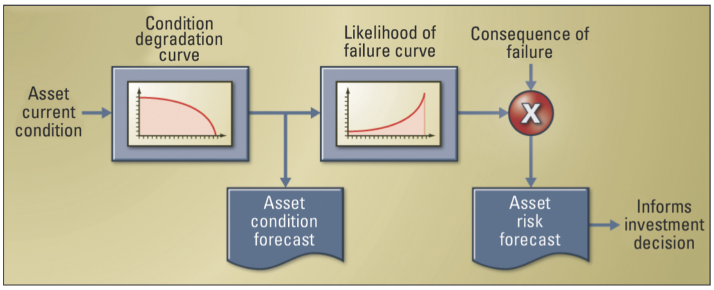


Fig. 4. Using condition data to determine asset risk forecasts.

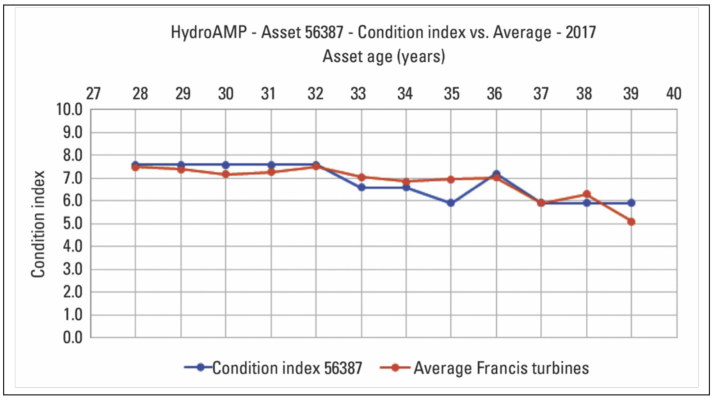


Fig. 5. Evolution of the Condition index of a particular asset, compared with similar assets of the same age.

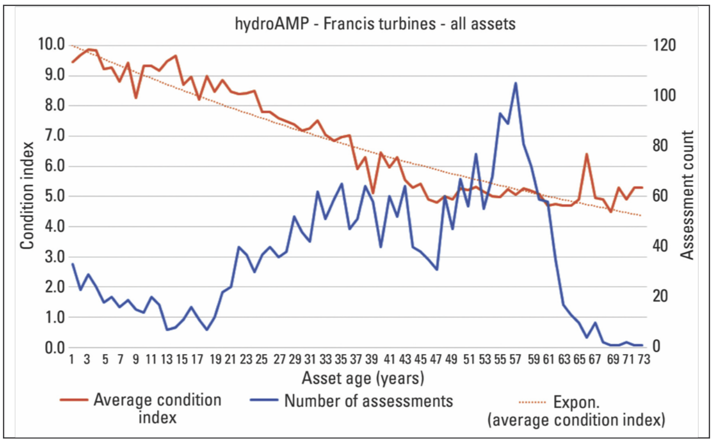


Fig. 6. Average condition index of all Francis turbines by asset age with an exponential trendline. The number of assessments indicates the degree of confidence that can be applied to the degradation data. Refurbished turbines are considered 'new' and their age is reset to zero at the time of refurbishment.

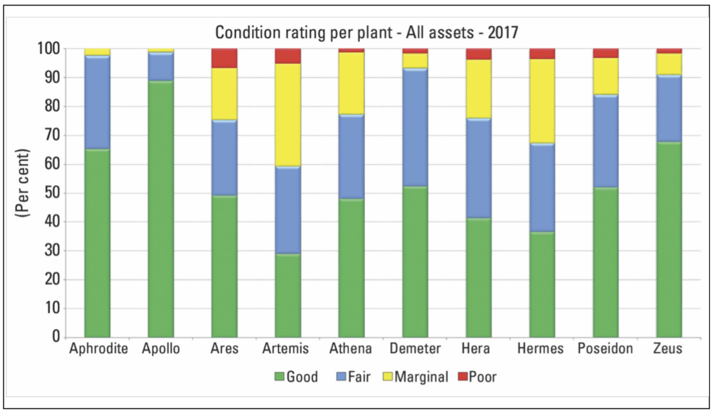


Fig. 7. Aggregate condition rating for entire plants, using the scale defined in the Table.

Conclusion

The hydropower community has long recognized the importance of accurate equipment condition index assessments, in making informed and sound capital investment planning and management decisions. HydroAMP is a collaborative effort that goes a long way to addressing the specific needs of the hydropower asset owners and operators. It is a fundamental step in a robust risk-informed investment planning and decision-making process. ◊

Hydropower utilities interested in joining the Hydraulic Plant Life Interest Group can find the relevant details at: www.ceati.com/collaborative-programs/generation/hplig-hydraulic-plant-life/.

B. Neijens

C. Hayes

Boudewijn Neijens, MEng, MBA is CMO of Copperleaf Technologies. He holds a Master's degree in Mechanical Engineering from the University of Brussels, Belgium, and an MBA from INSEAD in France. He works with large asset-intensive corporations around the world to refine their asset management practices in the areas of asset investment planning and management, decision support systems and risk-based planning models. He is the Chair of the Canadian chapter of the Institute of Asset Management.

Copperleaf Technologies, 2920 Virtual Way No 140, Vancouver, British Columbia V5M 0C4, Canada.

Christopher Hayes, P. Eng, is Vice President of CEATI International. He works with experts and utility leaders in the power industry to develop the CEATI programme, now supported by more than 130 utilities around the world. He oversees programmes relating to generation, transmission, distribution, and security. He is a member of the Professional Engineering Order of Québec and has a Bachelor of Mechanical Engineering degree from McGill University, Canada.

CEATI International, 1010 Sherbrooke St West No 2500, Montréal, Québec H3A 2R7, Canada.