Technical risk management of hydropower plants
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When operating and maintaining a large portfolio of hydropower assets, the challenge for the owner and operator is to decide which risk mitigation investments and maintenance activities should come first, and when. This is especially true when resources in personnel and budgets are limited, and the profitability of the plants must be optimized. The situation requires an efficient and rational prioritization of activities and corresponding allocation of budgets. But how can the right criteria and investment principles be determined, if the overall target is safe, reliable, compliant and economical operation of plants? This article outlines how an asset risk management system can assist in this determination.

Uniper is an international energy company with approximately 11,500 employees and activities in more than 40 countries. The group operates around 180 hydropower plants in Germany and Sweden as well as a number of coal- and gas-fired powerplants, with a total installed generation capacity of about 34 GW, and gas storage sites with a capacity of approximately 7.9 x 109 m3. Its main activities include power generation, gas trading, including a diversified gas portfolio.
Asset risk management system

The Asset Risk Management System follows the principles of ISO 31000 standard, as shown in Figure 2. It is a systematic process for the identification, valuation and management of asset (engineering) risks and performance improvement opportunities, consisting of two primary elements: BowTie and AERO. BowTie supports the identification of risks and is an input into AERO, the main asset risk management process. Other risk identification and management tools and processes (see Figure 1) are run in parallel with BowTie and AERO, but are not addressed in this article.

The objectives of Uniper’s asset risk management process are:

– ensure a safe and compliant operation;
– understand the asset risk profile of the entire portfolio beyond a local site risk perspective;
– ensure the operational business remains within the risk appetite of the company; and,
– optimize risk management activities and resulting investment proposals based on clear priorities regardless of technology and country boundaries.

Identification of risks

The early identification of risks is crucial for an effective management of power generation assets, so that people, the environment and asset value can be protected, and income streams secured. There are various sources for the identification of operational risks. In general, these sources are related to the respective hydropower plant O&M and surveillance programmes, and include, among other things:

– routine visual inspection on periodic rounds (daily, weekly, twice weekly);
– measurements from condition monitoring equipment (equipment sensors, pressure gauges, piezometers, inclinometers, level gauges);
– periodic functional testing of safety relevant discharge devices (bottom outlet, spillway gates, weir or outlet gates, emergency power generators);
– geodetic surveys of dam structures, sounding of the river bed for scour or sedimentation;
– periodic inspections of plant equipment;
– urgent corrective actions (if necessary).

Fig. 2. ISO 31000 Risk management standard principles adopted by Uniper’s Asset Risk Management System.

Fig. 3. Example of a BowTie diagram for a generator (incomplete).
– periodic deep dive investigation and expert reviews of dams and hydraulic structures;
– alerts or notifications from manufacturers;
– incident investigation and root cause analysis; and,
– external audits, such as of insurers.
In addition, Uniper has developed and implemented a structured approach to screen systematically all power generation assets for risks by applying the BowTie methodology.

BowTie is a hazard identification methodology which is widely used in the chemical and petro-chemical industry. It takes its name from the shape of the diagram that is created from the relationship between threats, which could lead to a critical failure (the knot), and resulting consequences, including the available preventive barriers (measures in place), which can reduce the likelihood of the incident occurring, and the available recovery barriers, which help to reduce the impact of the incident.

BowTie provides a powerful visual display (see Figure 3) of these connections between threats, barriers and consequences, and facilitates the identification of missing or ineffective preventive or recovery barriers by answering three fundamental questions of process safety:
– What can go wrong? Identifying the threats.
– What systems are in place to stop things going wrong? Identifying existing barriers.
– Will these systems work effectively when called upon? Assessing effectiveness.

For the major hydropower plant components, such as turbines, generators, transformers, switchyards, gates, different dam types, and so on, Uniper has developed BowTie surveys in which respective plant experts answer questionnaires that enable a fast and effective barrier health check. Some barriers are minimum standard measures for safeguarding an installation, system or component against a specific threat, hence classified as ‘expected’. Others are ‘enhanced’ compared with the reasonably expected level. This classification of barriers is based on widely recognized design principles as well as on the long-term operational experience of Uniper.

In the case that expected barriers are missing or deemed ineffective, a ‘quick-check’ risk assessment will be carried out to assess if this shortcoming could lead to a significant risk, or if it is tolerable or compensatable in some way. A significant risk is recognized as a risk that is beyond the company’s risk appetite, which means that its risk level has exceeded the predefined risk thresholds and is not acceptable any more. When a threshold is exceeded, the risk will be analyzed in more detail as part of the AERO process (see next section and Fig. 6) and a risk mitigation strategy will be developed.

With the development of BowTie-based engineering standards, an integrated and holistic asset risk management process has been implemented.

Analysis and evaluation of risks

All unacceptable risks resulting from the BowTie analysis, and any other identified engineering risks, are fed into Uniper’s AERO process. AERO is an integral part of the Uniper Asset Risk Management system and is intended to manage engineering risks which have the potential to affect the key performance areas of Uniper significantly, namely, the safety of people, the environment, the regulatory compliance, the commercial performance and the company’s reputation. It is designed to allow plant staff to manage engineering risks by evaluating the risk situation and defining the most effective mitigation strategies. The AERO process delivers credible, reliable and consistent risk profiles at plant, group or portfolio level. It also provides a platform for recording and assessing potential opportunity projects that could be implemented to improve the declared asset performance. For the analysis and quantification of risks within AERO, Uniper applies a web-based software called PT-Risk, which was developed in-house. The tool requires users to describe an identified issue, the resulting risk categories affected (safety, environmental, regulatory, cost and reputational), and the corresponding ‘current control measures’ already in place, which are intended to prevent the failure or to reduce the consequences of failure.

In the next step, the risks are quantified based on the actual situation and considering the most likely (not worst case!) failure scenario by assessing probabilities and assumed impact levels. A risk in this context is always defined as: risk = probability x impact.

The software then translates the inputs of probability and impact into a risk score for the risk category assessed, and compares it with predefined risk bandings of the respective risk category, that is, ranges of risk scores that are defined as high, medium (yellow) or low (green) as given in Figure 4.

These risk ranges are different for each risk category and have been annually defined and agreed by Uniper’s Risk Committee (partially consisting of Uniper board members). They reflect the company’s risk appetite (its willingness to tolerate or accept certain risk levels). For example, its risk appetite for safety, environmental and regulatory risks differs to its appetite for cost or reputational risks. Mitigation of high safety, environmental and regulatory risks is expected to be done with urgency. If there is a red risk in any of those three categories, it is either mitigated immediately or operations are stopped. Mitigation of high cost risks, on the other hand, only follows an evaluation of the financial benefits of the investment. The risk score enables Uniper to calculate the business case of a maintenance activity and to compare risks, to decide which one should be given a higher priority.

The failure probability of a component depends on its actual condition, which is usually affected by wear and tear and the quality of maintenance (age is not necessarily a valid criterion). To link failure probabilities with component conditions for the assessment of mechanical and electrical equipment, Uniper applies the ‘bathtub curve’ (see Figure 5), differentiating between normal, inferior, bad and critical conditions, and allocating pre-defined failure probabilities to these conditions, unless there are other more accurate ways to do so.
The software also allows for the assessment of different mitigation strategies to identify the most competitive one. After the risk mitigation strategy has been performed (a mitigation project has been executed), the risk score of the after scenario becomes the new, actual, and now lower, risk level. This risk level then increases in the course of further operation and deterioration of the component along the bathtub curve until it reaches an intolerable risk level again.

In general, all risk (mitigation) projects run through the annual funding process (mid-term planning) in which risk projects are prioritized according to the underlying dominant risk category affected, which should be the respective driver for executing the project. Uniper’s Risk Committee has defined for the asset risk management process that the highest priority is given to projects mitigating safety, environmental and regulatory risks, then cost and reputational risks. For emerging risks that need to be mitigated urgently, the company has also set up an ad-hoc funding process.

When a risk mitigation project has started, the risk status in the software tool PT-Risk is changed from ‘Live’ to ‘Live – Further Control Measures ongoing’, which indicates that the risk is currently being mitigated. This is especially important when it comes to tracking and reporting (see section 7) on the actual risk profiles of plants and portfolio, as the risk status is also displayed in the quarterly risk report generated from the PT-Risk database. As soon as the risk has been mitigated, that is the project has been completed, the risk status in PT-Risk is set back to ‘Live’, and the scoring adjusted to reflect the new risk level. Alternatively, the risk is archived if it was fully mitigated and cannot re-appear.

Ongoing risk review

To ensure that Uniper’s assets are always being operated within the company’s risk appetite, while trying to utilize fully the lifetime of the plant component and optimize the commercial performance of the plant, all risk entries in PT-Risk need to be regularly reviewed and updated by the responsible site experts. This includes continuous monitoring of the associated condition of the component to capture any further progress of deterioration, as well as a re-assessment of the potential failure impact.

Uniper has introduced regular risk review meetings on site between the central risk management department as the owner of the process, and the local site staff as the owner of the risks. During these risk review meetings, the risk status is updated in the PT-Risk database and adjusted according to the current risk level. If a risk is identified as being above the company’s risk appetite, the risk mitigation strategy is activated and the risk status is set back to ‘Live – Further Control Measures ongoing’. This ensures that all risks are continuously monitored and mitigated to ensure the safety and commercial performance of the plant.

Fig. 6. Example of a risk quantification in PT-Risk (AERO), before and after mitigation measures.

Fig. 7. ‘Heat map’ of Uniper’s quarterly Asset Risk report (without details of impact levels and likelihoods).
Risk reporting

The central asset risk management department prepares quarterly risk reports from the PT-Risk database, outlining the highest risks within the various risk categories and summarizing the overall risk situation (see Figure 7). For each risk listed in the report, a short summary of the current risk status is presented. The report is published and distributed to Uniper management for information, so that the actual risk situation of the asset portfolio can be seen by the responsible decision makers for any corrective actions to be taken.

Uniper also applies advanced analytics and business intelligence IT-tools to visualize its asset risk portfolio and to make respective dashboards available online for everyone at Uniper working on, or interested in, this topic.

Conclusion

A risk-based systematic approach in the form of a well-defined asset risk management system clearly supports an effective prioritization of required risk mitigation and maintenance measures, especially for large portfolios. It facilitates an optimal allocation of respective budgets to plants where they are objectively most needed. The systematic approach also supports compliance with regulations, and the transparency this risk management process produces is highly appreciated by insurance companies, at times when insurers are reluctant to insure mixed portfolios, or are under pressure to step out of some sectors of the business.

However, the success of an asset risk management system depends on several factors. For example, it is vital to set up a framework first, which defines a company’s risk aversion and the risk prioritization principles. Tools for the systematic identification of risks are required, and the development of an assessment guideline is crucial for the consistency and comparability of risk assessments. Finally, it is very important to establish a corresponding culture of thinking in “risk dimensions” in the organization, which takes time (AERO was first implemented in 2010, with other methodologies developed and introduced in later years).

In summary, it is not always simple to attach an issue to the actual risk category and describe the potential failure scenario or determine the failure probability. However, a systematic evaluation of probabilities and impacts ensures consistent ranking of the identified risks. Estimating probabilities close to reality protects Uniper against overspending or taking excessive risks (with higher failure rates/incidents).

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