Asset Reliability and Efficiency

This guideline expands on what is expected by the criteria statements in the Hydropower Sustainability Tools (HST) for the Asset Reliability and Efficiency topic, relating to assessment, management, conformance/compliance and outcomes. The good practice criteria are expressed for the operation stage.

In the Hydropower Sustainability Assessment Protocol (HSAP), this topic is addressed in O-5.

The asset reliability and efficiency guideline seeks to ensure that hydropower assets are maintained to deliver optimal performance in the short- and long-term, in accordance with the overall electricity generation and supply strategy of the owner/operator. Asset, in this context, refers to the infrastructure, plant and equipment on which the hydropower station generation operations are reliant. Reliability means that equipment will be available when needed to meet customer demands and may be closely linked to energy security. Efficiency typically relates to the conversion of available energy into electricity, which for a hydropower plant can be as high as 95% depending on a range of factors. Efficiency in this context may also refer to the value of the asset in relation to the costs of running it.

Hydropower asset types relevant to this guidance include: the water storage and conduit system (i.e. the reservoir, intake, head race tunnel, surge shaft, emergency valves, pressure shafts, penstock, main inlet valves); turbines; generators; transformers; the switchyard; and non-generational infrastructure such as land, buildings, roads, bridges, jetties, signage, vehicles, communications systems, and monitoring stations. Transmission infrastructure would also be included insofar as the responsibilities rest with the hydropower facility owner/operator.

Operating hydropower facilities, including associated infrastructure, require regular and systematic assessment and maintenance to ensure adequate reliability and efficiency over time. The consequences of poorly planned and implemented asset management can include: machine failure and loss of power generation; loss in efficiency of the system, which will increase the cost per megawatt of generation; reduced asset life span; public safety issues (e.g. dam failures, trees falling onto power lines, injuries to community members); and environmental incidents (e.g. oil spills into waterways). Infrastructure safety is integrally related to asset management and is addressed more specifically in the Infrastructure Safety topic guideline.

Many civil assets such as dams are required to achieve an effective service life in excess of 100 years. The nominal service life for many major electrical and mechanical hydro assets is typically in the order of 50 years, although modern digital electronic equipment has a nominal service life of only 10 to 20 years. Actual asset life depends on a number of factors including:

- the extent to which the original designs and manufacturing and construction quality address the actual operational duties;
- operating conditions, including environmental factors;
- changes to operational duties over the life of the asset; and
- the adequacy of asset management inspections, functional testing, condition assessment, maintenance, repair, rehabilitation and upgrade regimes.

Assessment

Assessment criterion - Operation Stage: Routine monitoring of asset condition, availability and reliability is being undertaken to identify risks and assess the effectiveness of management measures; and ongoing or emerging asset maintenance and management issues have been identified.

Operating conditions should be continuously monitored and recorded. A number of intrusive inspection and maintenance activities are required in order to achieve the expected asset life. These activities need to be complemented by a well-tailored programme of preventative maintenance, condition monitoring and testing.

Monitoring should inform identification of ongoing and emerging asset maintenance and management issues. Asset maintenance issues may be related to, for example, budget cycles and availability, the availability and capabilities of the workforce, logistical or access difficulties to undertake planned maintenance, or the ability to get parts and spares.

Asset reliability issues could include, for example: start failures and forced or unplanned outages (i.e. the power station stops operating), maintenance-induced failures; or constrained operation due to, for example, temperature or vibration issues. Asset efficiency issues could relate to megawatts (MW) of electricity generation per unit of water flow (m3/s) being lower than design expectations or production targets, or very high maintenance costs in relation to the value of the electricity generated. Root causes could include, for example, normal wear and tear, pitting or abrasion of parts, changes to machinery configuration over time which reduces efficiency, difficulties with valves due to lack of use, rust, corrosion, stresses, material fatigue, and cracks. The results of inspections, condition assessment and maintenance need to be well-documented, stored, and analysed to identify or predict asset condition changes, trends and emerging risks.

Routine monitoring may include visual inspections, testing, measurements, and data collection from instrumentation. Measurements can be obtained through a diverse range of sensors selected for specific risk detection or assurance of optimal running conditions, such as accelerometers for vibration or strain gauges for mechanical stresses. An online condition monitoring system for the generator, turbine and main transformers can be set up to enable live data to be read by system operators at a central control room.

Optimal asset management is based on analysis of technical condition, residual life, risk, profitability, and timing of maintenance and reinvestments. Condition assessments are a key element of optimising asset management and as noted under the Management criterion are the cornerstone of a mature asset management system. These assessments support the development of long-term investment strategies, prioritisation of capital investments, coordination of operations and maintenance (O&M), and identification and tracking of performance goals.

Condition assessments should be designed to achieve objective and repeatable assessments with minimal time and expense for testing, data analysis, reporting and data management. Risks to avoid in undertaking assessments include: inefficient processes; more tests or inspections than is necessary; improper validation or calibration of procedures and results; and a lack of a convenient or consistent method to store, access and utilise data.

Condition assessments typically result in development of a condition index or rating. A view on a particular asset unit or group and the power station as a whole is informed by aggregating individual equipment ratings. Information to inform condition assessments can originate from a wide range of sources and should include: drawings; reports; test results; photos; data monitoring and trend curves; interviews with plant operators and engineers; records of maintenance routines, operational problems and visual inspections; descriptions of condition state; inspection reports; and new measurements. Established evaluation and classification rules should inform views on the condition rating, taking into account equipment age, O&M history, and any other relevant condition indicators. Information quality and confidence in the result should also be rated. A low condition rating or data quality score should lead to further evaluation. More detailed assessments should involve non-routine tests and inspections using specialised expertise and/or instrumentation, resulting in a refined and more accurate asset condition index.

Condition assessment ratings inform refinements to O&M programmes and are an important input to the timing and scale of planned major investments into refurbishments and upgrades. Many other factors should also inform asset investment priorities and decisions, including strategic importance, lost revenues as a result of equipment failure, reliability criticality, forced outage rates, environmental concerns, cost, consequence, and risk. Undertaking or not undertaking a repair or replacement action can be of concern from a technical perspective but may also have legal, regulatory, safety, environmental, and economic consequences. Important analyses to inform business priorities and investment decisions include asset failure or residual life models, analysis of failure probability and associated risks, cost-benefit analyses of maintenance and reinvestment measures. The type of analysis undertaken will depend on the context.

Failure mode identification is an important tool for asset assessment and planning and should inform an asset risk register to capture the key risk issues. Issues arising in practice should be readily identified through the routine O&M activities and analysed with respect to root causes. Records are very important in diagnosing the root causes of faults or failures, informing replacement decisions and determining residual life. Investigations of asset failures or tripping occurrences should address how and why the issue occurred and what can be done to avoid its reoccurrence, with the learnings applied to all similar plant or processes.

Manufacturers criteria, records, experience and history should inform the setting of limiting values for key equipment parameters. Characteristics of identical equipment can vary from unit to unit and unique features can emerge over time based on usage patterns and the particular context, such as environmental or climatic factors. The original equipment manufacturer's recommendations on maximum and minimum permissible parameters for their equipment are often conservative, and so the limits adopted in practice should be informed by good monitoring and analyses accompanied by an understanding of failure modes and risks.

Management

Management criterion - Operation Stage: Measures are in place to address routine monitoring and maintenance requirements of the operating facility in accordance with the overall electricity generation and supply strategy of the owner/operator.

Asset monitoring, maintenance, management and refurbishment requirements depend greatly on the hydropower plant type, setting, usage, age and stresses. Asset management plans should be developed in a systematic manner, addressing appropriate levels (asset portfolio, power station, asset type) and both short-term and long-term needs.

Management plans, guidelines, procedures, and detailed work instructions should be addressed with respect to each of the specific types of assets, as listed in the introduction to this guidance. Routine requirements and detailed work instructions will be specific to the asset type and are typically a mix of inspections and actions that help ensure optimal asset performance and prevent major issues arising. For example, routine requirements for water storage and conduit systems could include: regular testing of operation of conduit isolation system equipment (e.g. intake gates, valves, excess flow device, surge equipment); periodic physical inspections to look at condition, silt deposition, rust, erosion, abnormalities; leakage inspections, testing and treatment; painting inspections and repainting; replacements of deteriorated valve seals; purification and testing of hydraulic system oil; and clearing and maintenance of the trash rack or intake gate filter.

Asset management data should be recorded, managed and reported in a manner that supports accessibility by various parties for their information and decision-making needs. Operating hydropower facilities and organisations should ensure that their equipment condition data is contained in a centralised database in a standardised format. This database should allow for centralised data entry, storage, and retrieval, as well as individual power station and portfolio level analysis. Data should be available (where possible) in real-time and web-accessible. The database should include a comprehensive list of assets, all input records that inform condition assessments, and readily enable generation of reports.

The asset database should link into, or be embedded within, a Computerised Maintenance Management System (CMMS) that addresses day-to-day monitoring and maintenance activities. A CMMS aids planning through scheduling, produces job tickets, work orders and instructions for operational staff, and records actions taken, inspection and assessment findings, and asset performance. The CMMS should enable supporting documentation for a condition assessment (e.g. test reports, photographs, operation and maintenance records) to be attached to each work order so that historical knowledge is readily available. The CMMS should also enable reports to be routinely generated as appropriate for decision-makers at various levels in the business.

Asset management plans and processes for an operating hydropower facility should ideally be embedded within a corporate asset management system. Benchmark requirements for asset management can be guided by the international standard ISO 55001 and relate to: the organisational context and objectives for asset management; the responsible parties; relevant plans; supporting systems and processes (e.g. communications, human resources); operations (e.g. maintenance procedures); and performance evaluation and support.

A corporate asset management policy should document big picture issues such as business goals, strategies, constraints and risk appetite, which have a bearing on the asset management approach at an individual facility within the corporation's portfolio. The corporate policy should identify and establish the overall objectives that the business is intending to achieve, taking into consideration stakeholder expectations, regulatory compliance, social and cultural obligations, and business risk appetite. This vision is normally developed at the board level in an overall business context. Corporate objectives for assets might include, for example, to increase efficiency, achieve cost savings, manage usage, and ensure safe operation.

A corporate asset management plan should establish the framework for the business in its approach to asset management. This plan would typically: document information about the company and the hydropower infrastructure; list assets managed within the asset management system; list current infrastructure projects; set the asset values and current performance levels; present the target asset values (short-term and long-term economic value) and performance targets (level of availability, water collection); outline the main risks and opportunities related to the operation of the infrastructure; and define the roles and responsibilities of the various stakeholders (owner, asset manager, operator, energy manager).

The asset management approach should be established in the asset policy and asset management plan. A common starting approach to asset management is to use a fixed-time maintenance strategy, often informed by the recommendations of the original equipment manufacturers. A more mature asset management approach should be based on asset condition assessments as described under the Assessment criterion of this guidance, centred on risk assessment and mitigation informed by asset failure mode and root cause analyses. This approach seeks to provide improved plant performance at a reduced maintenance cost and a lower risk exposure profile. International good practice is based on a risk approach tailored to the risk tolerance of the individual business.

The asset management plan should address asset life cycle planning. A life cycle plan should record estimates of asset life, routine or major maintenance costs and time periods, and upgrade or replacement costs and time periods. The asset life cycle plan should include: identification of issues and risks over time; updates and changes in management approaches over time as assets age; foreseeable changes that will be required for maintenance; and a clear understanding of the difference between failure and end-of-life. Asset renewal decisions can be complicated by considerable uncertainties relating to technical condition, the expected remaining life of assets, and future market demands. Timing of major works should take into account when other plants can meet the market demand for electricity alongside other factors such as resource availability. Life extension actions can help postpone comprehensive renewal and this may be profitable provided that delays do not lead to major failures with high consequential costs.

Asset management should be accompanied by a resource development and capability strategy to ensure that asset management requirements can be appropriately supported. Human resources supporting a corporate asset management system include: on-site plant staff who work with equipment daily and have a direct role in performing routine maintenance and the equipment condition assessments; plant or facility managers who support plant maintenance, rehabilitation, and replacement decisions, and evaluate equipment condition assessment data and trends; technical staff (engineers, economists, environmentalists, biologists and technical specialists) who undertake more detailed supporting analyses and risk assessments; and asset managers who prioritise competing investment needs, analyse business cases and justifications for investment decisions, and support decisions that consider trade-offs between competing needs or conflicting requirements.

Conformance/Compliance

Conformance/Compliance criterion - Operation Stage: Processes and objectives relating to asset maintenance and management have been and are on track to be met with no major non-compliances or non-conformances, and any asset related commitments have been or are on track to be met.

Assessment processes and management measures relating to asset management should be compliant with relevant legal and administrative requirements. The asset management system should identify all internal standards, procedures or guidelines as well as all relevant national and international standards or licence conditions applicable to the assets. Applicable legislation and permits may relate to, for example: operation and maintenance of cranes, hoists and lifts; pressure vessels; and chemicals and flammable substances. Legislated requirements may include, for example, registration of particular assets, certification by third parties, and particular forms of record keeping.

To demonstrate conformance, the asset-related measures implemented should be consistent with what is in the company policies and plans. Asset management commitments may be expressed in policies of the owner/operator or company statements made publicly available or within management plans. Variations to commitments should be well-justified and approved by relevant authorities, with appropriate stakeholder liaison. Conformance with requirements of the asset management plans and reliability and efficiency expectations should be systematically checked, including the completion of routine and special monitoring and maintenance tasks, and the ongoing recording and updating of asset condition. A minor non-conformance might be delayed submission of a monitoring report; a major non-conformance might be neglecting to undertake essential maintenance works on an asset.

Outcomes

Outcomes criterion - Operation Stage: Asset reliability and efficiency performance is in line with the objectives of the owner/operator and any asset performance guarantees with only minor gaps.

To ensure outcomes are met, it is essential that the objectives of the owner/operator for the assets are clearly expressed. These may relate to, for example: targets for availability, reliability, and efficiency; asset life targets; asset life cycle cost targets; and safety-related objectives. A hydropower plant may also have asset performance guarantees embedded into contracts. Performance guarantees may relate to electricity generation availability and reliability, and (depending on the capabilities of the power station) also ancillary services that support the security and stability of the electricity grid (e.g. frequency control, spinning reserve, operating reserve, black start capability).

An evidence-based approach should demonstrate asset reliability and efficiency performance. Monitoring reports and data should clearly track performance against objectives and capture incidents. Examples of evidence can include records of asset performance, asset reliability assessments, information on asset efficiency, information on comparative equipment and system performance, and information on the operational efficiency of the individual power station (or groups of power stations) in the context of the broader system and relevant market arrangements. Evidence may be collected by the owner/operator or through independent inspections and benchmarking studies. Evidence should also show that the full range of maintenance issues are being addressed and that the systems used to manage the maintenance programme are in place and effective.