Condition Assessment Manual

Appendix 1.03 – Guide for Control/Shut-Off Valve Condition Assessment

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1.0 General

This Guide is for condition assessment of the major valves along with their operating system at a hydropower plant, which are installed in penstocks or large conduits to cut off or control the turbine generating flow. Unforeseen failure of the control/shut-off valves can have a substantial impact on power generation and revenues due to an extended forced outage; under emergency situation of load rejection coincidence with wicket gate malfunction, the failure of shut-off valve could cause catastrophic threats of human lives and asset damages resulting from penstock rapture and plant flooding (reference to the Shut-off Valve Best Practices). Therefore, it is important to maintain an updated condition assessment of the control/shut-off valves and plan accordingly. A control/shut-off valve condition assessment is essential to estimate the economic lifespan and potential risk of failure, and to evaluate the benefits and cost of control/shut-off valve upgrading.

For any type of plant major valve system, the following three-step analyses are necessary to arrive at a control/shut-off valve condition indicator:

1) What parts should be included for control/shut-off valve condition assessment and which parts are more important than others (parts and their weighting factors)?

2) What metrics/parameters should be investigated for quantitative condition assessment and which ones are more important than others (condition parameters and their weighting factors)?

3) How to assign numerical scores to the control/shut-off valves (rating criteria)?

This Appendix provides guides to answer the above questions, which can be applied to all control/shut-off valves. The condition assessment is performed on individual control/shut-off valves in a plant, because even the originally identical control/shut-off valves may have experienced different Operation & Maintenance (O&M) histories and would arrive at different values of condition indicators. Due to the uniqueness of each individual control/shut-off valve, the guides provided in this Appendix cannot quantify all factors that affect individual control/shut-off valve condition. Mitigating factors not included in this guide may trigger testing and further evaluation to determine the final score of the control/shut-off valve condition and to make the decision of control/shut-off valve replacement or rehabilitation.

This Appendix is not intended to define valve maintenance practices or describe in detail inspections, tests, or measurements. Utility-specific maintenance policies and procedures must be consulted for such information.

2.0 Constituent Parts Analysis

The components of a control/shut-off valve system include the valve body and internals, valve operator which may include electric and/or hydraulic power, and structural supports. If any part does not exist in a particular control/shut-off valve, this part will be excluded from scoring mechanism by inputting "NA" into the Table. The effect of one part exclusion is usually insignificant to justify any adjustment for the weighting factors of other control/shut-off valve parts.

3.0 Metrics for Control/shut-off valve Condition Assessment

As listed in Table 1, the following five condition parameters are considered for condition assessment of control/shut-off valve parts:

- The Physical Condition
- The Age
- The Installed Technology Level
- The Operating Restrictions
- The Maintenance Requirement

These five condition parameters are scored based on the previous testing and measurements, historical O&M records, original design drawings, previous rehabilitation feasibility study reports if conducted, interviews with plant staff and some limited inspections. It is noticed that there is a certain level of relevance between the age and physical condition, maintenance needs, or some operating restrictions. However, as a benchmarking condition assessment without specific testing and measurements conducted on site, these five parameters are regarded as providing the basis for assessing the condition of control/shut-off valve parts.

In addition, the Data Quality Indicator, as an independent metric, is to reflect the quality of available information and the confidence on the information used for the condition assessment. In some cases, data may be missing, out-of-date, or of questionable integrity, and any of these situations could affect the results of condition assessment. The scores of data quality are determined by the on-site evaluators for each assessed part/item to indicate the information and data availability, integrity and accuracy, and the confidence on the given condition ratings (MWH 2010).

4.0 Weighting Factors

There are two categories of weighting factors in Table 1. It is recognized that some condition parameters affect the control/shut-off valve condition to a greater or lesser degree than other parameters; also some parts are more or less important than other parts to an entire control/shut-off valve. These weighting factors should be pre-determined by consensus among experienced hydropower mechanical engineers and plant O&M experts. Once they are determined for each type of control/shut-off valve, they should be largely fixed from plant to plant for the same type of control/shut-off valve, except for special designs found in a control/shut-off valve where the weighting factors have to be adjusted. In this case, the adjustment of weighting factors must be conducted by HAP core process development team. The range of absolute values of weighting factors won't affect the Condition Indicator of a control/shut-off valve, which is the weighted summation of all scores assigned to the control/shut-off valve parts and five condition parameters.

Table 1: Typical Control/Shut-off Valve Condition Assessment & Scoring - XXX Hydropower Plant

Control/Shut-off Valve for Unit ___	Taxonomy ID	Physical Condition Score	Age Score	Installed Technology Score	Operating Restrictions Score	Maintenance Requirement Score	Data Quality Score	Weighting Factors for Parts
Valve	3.5.1							2.0
Valve Operator Equipment	3.5.2							2.0
Structural/Supports	3.5.3							1.0
Electric/Hydraulic Power System	3.5.4							1.0
Weighting Factors for Condition Parameters		2.0	1.0	1.0	1.0	1.5	Data Quality -->	*0.00*
							Condition Indicator -->	***0.00***

5.0 Rating Criteria

Physical Condition - Rating Criteria for Control/shut-off valve Parts

Physical Condition of control/shut-off valve parts refers to those features that are observable or detected through measurement and testing, including some observed performance. It includes the observation of the valve body exterior and interior, the disc, rotor, plug, or gate, the valve operator, the valve connection to the penstock, and valve support. The Best Practices of

Control/shut-off valve Condition Assessment can assist in evaluating the control/shut-off valve condition.

For HAP site assessment, it is important to conduct interviews and discussions with plant personnel in order to score the physical condition of control/shut-off valve parts. The results of all related information are analyzed and applied to Charts 1a, 1b and 1c to assign the condition scores of control/shut-off valve parts.

Chart 1a Control/Shut-off Valve Physical Condition Rating Criteria	
Physical Condition Description	**Physical Condition Score**
Limited corrosion on disk/plug and water passage; coating is in good condition; seals and seats are in good condition and properly adjusted with no or minimal leakage, bearing/pivot point lubrication is in good condition; the bypass is in good condition; valve is regularly exercised.	**8 – 10**
Moderate corrosion on disk/plug and water passage; coating is in adequate condition; seals and seats are in adequate condition with minimal leakage; bearing/pivot point lubrication is in good condition; the bypass is in good condition; valve is regularly exercised.	**5 – 7**
Large areas of corrosion on disk/plug and water passage; coating is less than adequate; seals and seats have some damage with minor leakage; bearing/pivot point lubrication is in adequate condition; the bypass has moderate corrosion; valve is regularly exercised.	**3 – 4**
Severe corrosion on disk/plug and water passage; coating is poor; seals and seats are damaged allowing excessive leakage; bearing/pivot point lubrication is not functioning properly; the bypass has excessive corrosion; there is severe chattering, vibration, or binding during operation; the valve is either rarely exercised or is excessively exercised (i.e., ≥ 50 cycles per year).	**0 – 2**

Chart 1b Control/Shut-off Valve Operator, Electric/Hydraulic Power System Physical Condition Rating Criteria	
Physical Condition Description	**Physical Condition Score**
Seals, stems, cylinders, hydraulic system, position indicators, and controls are in good condition; backup power is available and tested regularly; slow-down mode has been tested and verified; pressure differential indicators up/downstream are operational and tested; operational testing performed on annual basis; the system is exercised frequently.	**8 – 10**
Seals, stems, cylinders, hydraulic system, position indicators, and controls are updated or in good condition; backup power is available; slow-down mode functions but needs a minor adjustment; pressure differential indicators up/downstream are operational but not calibrated; the system is exercised frequently.	**5 – 7**
Seals, stems, cylinders, hydraulic system, position indicators, and controls are in fair condition; backup power is not regularly tested; slow-down mode functions but needs a minor adjustment; pressure differential indicators up/downstream are operational and tested; the cycle of operation time has changed slightly; the system is exercised rarely.	**3 – 4**
Seals, stems, cylinders, hydraulic system, gate position indicators, and controls are in poor condition; backup power is not available or not reliable; slow-down mode and limit switches are out of adjustment; pressure differential indicators up/downstream are not functioning; the cycle of operation time has changed significantly; the system is never exercised.	**0 – 2**

Chart 1c Control/Shut-off Valve Structural/Supports Physical Condition Rating Criteria	
Physical Condition Description	**Physical Condition Score**
Coating is intact with little or no evidence of corrosion. Fasteners in excellent condition. Concrete in excellent condition.	**8 – 10**
Coatings is mostly intact with minor corrosion. Fasteners intact with some corrosion. Concrete intact with minor cracking.	**5 – 7**
Coating is more than 50% missing and moderate corrosion on most steel parts. Fastners corroded. Concrete cracked and small areas spalled.	**3 – 4**
Coating is severely compromised and corrosion is severe on all steel parts. Fasteners are severely corroded and one or more is missing. Concrete appears severely compromised by cracks and deterioration.	**0 – 2**

Age - Rating Criteria for Control/shut-off valve Parts

Age scoring is relatively more objective than other condition parameters. The detailed scoring criteria developed in Chart 2 allow the age score to be automatically generated in the HAP Database by the actual years of the installed part.

Chart 2 Age Rating Criteria for Control/Shut-off Valve Parts	
Age of Equipment	**Age Score**
< 20 Years	**8 – 10**
20-35 Years	**5 – 7**
35-60 Years	**3 – 4**
> 60 Years	**0 – 2**

Installed Technology Level – Rating Criteria for Control/shut-off valve Parts

The Installed Technology Level indicates advancement levels of designing, machining, installation and materials, which may affect the unit and plant performance. Outdated technology may bring difficulties for spare parts supply and become a prolonged outage when it fails.

Scoring the Installed Technology Level requires historic knowledge of control/shut-off valve technology advancement and familiarity with the current control/shut-off valve manufacturing industry. High head valves of pre-1940 construction with cast one piece bodies may be susceptible to cracking of the body if the valve is subjected to very high loads. Valves of modern design (post 1950) generally have an expected service life in excess of 75 years subjected to proper and routine maintenance. Wearing of seals or bearings, which was a serious maintenance problem for pre-1950s valves, has been mitigated through the development of corrosion and wear resistant materials. Even modern valves that are infrequently operated will have a greater occurrence and frequency of problems. With the use of computers to model stresses and deflections in valves, they have become lighter with thinner walls, resulting in ultimate factors of safety that are not as high as with valves fabricated before the 1970s (ASCE 2007).

In addition, the competence, professionalism and reputation of the original suppliers could also imply the installed technology levels. Compared to those from large and well-known manufacturers, the valve parts supplied by small and unnamed companies would get lower scores.

Chart 3 Control/Shut-off Valve Technology Rating Criteria	
Technology Levels of the Parts/Items	**Score for Installed Technology Level**
The technology has not been changed significantly since the valve was installed; and the installed technology was supplied by brand name companies with great reputation.	**8 – 10**
The technology has been advanced but no problem to supply the matching parts in next 5-10 years, or the technology change has little effect on the efficiency and reliability of power generation (but may reduce the cost of replacement). The installed technology was supplied by medium companies with good reputation.	**4 – 7**
The installed technology has been phased out, it is a problem to supply parts in reasonable order time, or the technology change has significantly improved the efficiency and reliability of power generation. The installed technology was supplied by small companies with bad reputation.	**0 – 3**

Operating Restrictions - Rating Criteria for Control/shut-off valve Parts

Operational limitations play a role in determining the serviceability of control/shut-off valve. The control/shut-off valve operating restrictions may be sourced from the original design and current condition of control/shut-off valve parts. The operating ranges may be constrained due to the limited original design ranges for the flow and head, and/or currently deteriorated control/shut-off valve physical condition (e.g. severe vibrations or cavitation noise).

Chart 4 describes the ratings of control/shut-off valve operating restrictions.

Chart 4 Control/Shut-off Valve Operating Restrictions Rating Criteria	
Operating Restrictions or Off-Design Conditions	**Score for Operating Restrictions**
The design standard has no changes, and the original design has no constraints on the required operation. Tested as Required; no known design or operational deficiencies.	**8 – 10**
Minimal restraints: Operations to avoid minor rough zones; operation range can be expanded with revised equipment selection and design. No known design and operational deficiencies.	**5 – 7**
Moderate restraints: Operations to avoid large rough zones with high vibration. The operation range and performance can be significantly improved with revised equipment selection and design.	**3 – 4**
Severe limitations: The equipment does not meet the operational criteria or not tested as required or has a known design and operational deficiency.	**0 – 2**

Maintenance Requirement – Rating Criteria for Control/Shut-off Valve Parts

The amount of corrective maintenance that either has been or must be performed is an indication of the control/shut-off valve condition. No corrective maintenance is an indication that the control/shut-off valve is in good shape. Severe corrective maintenance requires scheduled or forced outages to perform.

Other factors to consider for maintenance scoring include:

- The need of maintenance is increasing with time or problems are reoccurring;
- Previous failures related to the control/shut-off valve parts;
- Failures and problems of control/shut-off valve parts with similar design.

The results of control/shut-off valve maintenance history (including routine maintenance and corrective maintenance) are analyzed and applied to Chart 5 to score the control/shut-off valve parts.

Chart 5 Control/Shut-off Valve Maintenance Requirement Rating Criteria	
Amounts of Corrective Maintenance	**Maintenance Requirement Score**
Minimum level (normal condition): A small amount of routine preventive maintenance is required. No corrective maintenance.	**9 – 10**
Low level: Small amounts of corrective maintenance. Repairs that could be completed during a unit preventive maintenance outage that is scheduled on a periodic basis.	**7 – 8**
Moderate level: Some corrective maintenance that causes extensions of unit preventive maintenance outages.	**5 – 6**
Significant/Extensive level: Significant additional and corrective maintenance is required; forced outage occurs and outages are extended due to maintenance problems (e.g., corrosion caused leaks).	**3 – 4**
Severe level: Severe corrective maintenance that requires scheduled or forced outages. Repeated forced outages, frequent repairs, abnormal wear to components, and/or labor-intensive maintenance is required.	**0 – 2**

Data Quality – Rating Criteria for Control/Shut-off Valve Parts

The Data quality scores reflect the quality of the inspection, test, and measurement results to evaluate the condition of control/shut-off valve parts. The more current and complete inspection, testing, and measurement results, the higher the Data Quality scores. The frequency of normal testing is as recommended by the organization. Reasonable efforts should be made to perform visual inspections and data collection (measurements, tests, operation logs, maintenance records, design drawings, previous assessment reports and etc.). However, when data is unavailable to score a condition parameter properly, it may be assumed that the condition is "Good" or numerically equal to some mid-range number 3-7. Meanwhile, the Data Quality score is graded low to recognize the poor or missing data.

Qualified personnel should make a subjective determination for the Data Quality scores, considering as many factors as possible. The suggested criteria for scoring the Data Quality of control/shut-off valve parts are developed in Chart 6.

Chart 6 Control/Shut-off Valve Data Quality Rating Criteria	
Years Since Last Condition Assessment	**Data Quality Score**
<8 years	**8 – 10**
8-17 years	**5 – 7**
17-25 years	**3 – 4**
>25 years	**0 – 2**

6.0 Control/Shut-off Valve System and Data Quality Indicators

In Table 1, the final condition score of the control/shut-off valves, i.e., the Condition Indicator, *CI*, can be calculated as follows:

$$CI = \frac{\sum_{K=1,M}^{J=1,5} S_C(K,J) \times F(K) \times F(J)}{\sum_{K=1,M}^{J=1,5} F(K) \times F(J)} \tag{1}$$

The control/shut-off valves Data Quality Indicator, *DI*, will be the weighted summation of all Data Quality scores received for its associated parts/items:

$$DI = \frac{\sum_{K=1,M} S_D(K) \times F(K)}{\sum_{K=1,M} F(K)} \tag{2}$$

Here M = the total number of parts/items associated with the control/shut-off valves; K = the identification No. of control/shut-off valve parts (from 1 to M); J = the identification No. of condition parameters (from 1 to 5, respectively for physical condition, age,…); $S_C(K, J)$ = the condition score of the control/shut-off valves part for one of 5 condition parameters; $S_D(K)$ = the data quality score for a part; $F(J)$ = the weighting factor for a condition parameter; $F(K)$ = the weighting factor for control/shut-off valve.

The calculated Condition Indicator from equation (1) may be adjusted by the results of internal inspections and specific testing results that would be performed, since the specific control/shut-off valve testing would more directly reveal the condition of the control/shut-off valve.

7.0 Reference

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