# Condition Assessment Manual

## *Appendix 1.08 – Guide for Governor Condition Assessment*




Revision 1.0, 12/09/2011

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6283
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

and

MESA ASSOCIATES, INC.
Chattanooga, TN 37402

# Contents

## 1.0 General

Unforeseen failure of the governor can have a substantial impact on power generation and revenues due to a extended forced outage. Therefore, it is important to maintain a current assessment of the condition of the governor and plan accordingly. A governor condition assessment is essential to estimate the economic lifespan and potential risk of failure, and to evaluate the benefits and cost of governor upgrading.

For any type of governor, the following three-step analyses are necessary to arrive at a governor condition indicator:

1) What parts should be included for a governor 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 governor parts (rating criteria)?

This Appendix provides guides to answer the above questions, which can be applied to all governors. The condition assessment is performed on individual governors in a plant, because even the originally identical governors 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 governor, the guides provided in this Appendix cannot quantify all factors that affect individual governor condition. Mitigating factors not included in this guide may trigger testing and further evaluation to determine the final score of the governor condition and to make the decision of governor replacement or rehabilitation.

This Appendix is not intended to define governor 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

For the four major types of governors (i.e., mechanical, mechanical-hydraulic, analog, and digital), their constituent parts are analyzed and listed in Table 1 (references to HAP Taxonomy). If any part (e.g., Double Regulating Device) does not exist in a particular governor, 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 governor parts.

## 3.0 Metrics for Governor Condition Assessment

As listed in Table 1, the following five condition parameters are considered for condition assessment of turbine and turbine 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 governor parts.

In addition, the Data Quality Indicator, as an independent metrics, 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 governor condition to a greater or lesser degree than other parameters; also some parts are more or less important than other parts to an entire governor. 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 governor, they should be largely fixed from plant to plant for the same type of governor, except for special designs found in a governor 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 governor, which is the weighted summation of all scores that assigned to the governor parts and five condition parameters.

**Table 1: Typical Governor Condition Assessment & Scoring**

**- XXX Hydropower Plant (Unit #)**

| Governor 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 |
|---|---|---|---|---|---|---|---|---|
| Oil Pressure System | 4.1.2.1 | | | | | | | 3.0 |
| Flow Distributing Valves | 4.1.2.2 | | | | | | | 4.0 |
| Control System | 4.1.2.3 | | | | | | | 5.0 |
| Speed Sensing Device | 4.1.2.4 | | | | | | | 2.0 |
| Feedback Device | 4.1.2.5 | | | | | | | 1.0 |
| Double Regulating Device | 4.1.2.6 | | | | | | | 2.0 |
| Weighting Factors for Condition Parameters | | 2.0 | 1.0 | 1.5 | 1.0 | 1.0 | Data Quality --> | *0.00* |
| | | | | | | | Condition Indicator --> | *0.00* |

## 5.0 Rating Criteria

Physical Condition - Rating Criteria for Governor Parts

Physical Condition of governor parts refers to those features that are observable or detected through measurement and testing, including some observed performance. It includes pump vibration and noise, oil loss, looseness of pins and linkages, and sticking of valves. The Best Practices of Governor Condition Assesment can assist in evaluating the governor condition.

For HAP site assessment, it is important to conduct interviews and discussions with plant personnel in order to score the physical condition of governor parts. The results of all related

information are analyzed and applied to Chart 1 to assign the condition scores of governor parts.

| Chart 1 Governor Physical Condition Rating Criteria | |
|---|---|
| **Observation and Inspection Results** | **Physical Condition Score** |
| No damaged or significantly worn parts have even been found by previous disassembly physical inspection. No significant increase on leakage rate from original value. Off-line and on-line response and stability normal, governor free from hunting, accuracy of frequency within < 0.2 Hz, synchronization time within norm, and able to remote start. | **8 – 10** |
| Damaged or worn parts found and replaced. Small increase in the leakage rate. Off-line and on-line response and stability fair, occasional hunting problems, accuracy of frequency and synchronization time outside the norm, or remote start is difficult. | **4 – 7** |
| Damaged or worn parts found and not replaced as appropriate. Leakage rate has doubled (or more). Off-line and on-line response and stability poor, reoccurring hunting problems, difficulty in synchronization or unable to remote start. | **0 – 3** |

Age - Rating Criteria for Governor Parts

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

| Chart 2 Age Rating Criteria for Governor Parts | | | |
|---|---|---|---|
| **Age for Mechanical-hydraulic Governor System** | **Age for Analog Governor System** | **Age for Digital Governor System** | **Age Score** |
| < 25 Years | < 20 Years | < 10 Years | **8 – 10** |
| 25-40 Years | 20 to 30 Years | 10 to 15 Years | **4 – 7** |
| > 40 Years | > 30 Years | > 15 Years | **0 – 3** |

Installed Technology Level – Rating Criteria for Governor Parts

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

Scoring the Installed Technology Level requires historic knowledge of governor technology advancement and familiarity with the current governor manufacturing industry. 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 governor parts supplied by small and unnamed companies would get lower scores.

| Chart 3 Governor Technology Rating Criteria | |
|---|---|
| **Technology Levels of the Parts/Items** | **Score for Installed Technology Level** |
| The technology has not been changed significantly since the governor was installed; all necessary mechanical and electronic parts are available from original supplier; and the original supplier is a brand name company with great professional reputation. | **8 – 10** |
| The mechanical and electronic parts are no longer available from original supplier and must be obtained from alternative suppliers. | **5 – 7** |
| The electronic and mechanical parts are not available at all and/or some mechanical parts must be reverse-engineered and manufactured by alternative suppliers. | **3 – 4** |
| The mechanical and electronic parts are not available at all and there are significant obstacles to successful reverse-engineering of the mechanical parts. | **0 – 2** |

Operating Restrictions - Rating Criteria for Governor Parts

The governor operating restrictions refer to the limitations on normal operation caused by the tendency of the governor to hunt. Hunting is an unstable condition in which the governor can't maintain frequency at an acceptable level when operating off line. Off-line hunting is usually the first and possibly the only sign of a problem with a governor. But , off-line hunting can also be a symptom of a variety of problems. The most common cause of off-line hunting is misadjustment of the dashpot. If the dashpot needle is too far open, there is not enough compensation and the governor will hunt. Excessive friction in the governor mechanism or the turbine wicket gate mechanism can also cause hunting. The on-line hunting is not common, it is the result of bad signal from PMG or hydraulic problem. In sum, if the automatic synchronizer will not synchcronize the unit because of excessive hunting then that is a problem, but further check is needed to find if it is the governor caused this operating restriction.

Chart 4 describes the ratings of governor operating restrictions.

| Chart 4 Governor 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 and operational efficiencies. | **8 – 10** |
| Minimal restraints: Special operational requirements are needed to avoid minor maintenance issues. The operation range can be expanded with revised equipment selection and design. No known design and operational efficiencies. | **5 – 7** |
| Moderate restraints: Special operational requirements are needed to avoid major maintenance issues. The operation range and performance can be significantly improved with revised equipment selection and design. | **3 – 4** |
| Severe limitations: The equipment do 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 Turbine Parts

The amount of corrective maintenance that either has been or must be performed is an indication of the governor condition. No corrective maintenance is an indication that the governor 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 governor parts;
- Failures and problems of governor parts with similar design.

The results of governor maintenance history (including routine maintenance and corrective maintenance) are analyzed and applied to Chart 5 to score the governor parts.

| Chart 5 Governor Maintenance Requirement Rating Criteria | |
|---|---|
| **Historical Maintenance Records** | **Maintenance Requirement Score** |
| Normal preventative and corrective maintenance (<50 hours/year/unit) or no significant increase in preventive and corrective maintenance (less than 1.5 times of baseline, as established by maintenance records). | **8 – 10** |
| Significant increase (over 1.5 times of baseline) in preventative maintenance, but no significant increase in corrective maintenance. | **5 – 7** |
| Significant increase (over 1.5 times of baseline) in corrective maintenance, otherwise operational constraints would occur. | **3 – 4** |
| Repeated corrective maintenance to avoid operational constraints. | **0 – 2** |

Data Quality – Rating Criteria for Governor Parts

The Data quality scores reflect the quality of the inspection, test, and measurement results to evaluate the condition of governor 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 governor parts are developed in Chart 6.

**Chart 6 Governor Data Quality Rating Criteria**

| Data Availability, Integrity and Accuracy | Data Quality Score |
|---|---|
| High: The maintenance policies and procedures were followed by the plant and the routine inspections, tests and measurement were performed within normal frequency in the plant. The required data and information are available to the assessment team through all means of site visits, possible visual inspections and interviews with experienced plant staff. | **8 – 10** |
| Medium: One or more of routine inspections, tests and measurement were completed 6-24 months past the normal frequency, or small portion of required data, information and documents are not available to the assessment team. | **5 – 7** |
| Low: One or more of routine inspections, tests and measurement were completed 24-36 months past the normal frequency, or some of results are not available. | **3 – 4** |
| Very Low: One or more of required inspections, tests and measurement were completed >36 months past the normal frequency, or significant portion of results are not available. | **0 – 2** |

## 6.0 Governor Condition and Data Quality Indicators

In Table 1, the final condition score of the governor, i.e., the Condition Indicator, *CI*, can be calculated as follows:

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

The governor Data Quality Indicator, *DI*, will be the weighted summation of all Data Quality scores received for its associated parts/items:

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

Here $M$ = the total number of parts/items associated with a governor; $K$ = the identification No. of governor 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 a governor 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 a governor part.

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 governor testing, such as the efficiency/index test and paint film quality test, would more directly reveal the condition of the governor.

## 7.0 Reference

EPRI (2000), Hydro Life Extension Modernization Guide: Volume 2: Hydromechanical Equipment, Palo Alto, CA: August 2000. TR-112350-V2.

MWH (2010). Final Report of Hydropower Modernization Initiative Asset Investment Planning Program, MWH prepared for U.S. Army Corps of Engineers Northwest Division, Hydroelectric Design center, October 21, 2010.

USACE (2001). Major Rehabilitation Evaluation Report, Center Hill Power Plant, prepared by U.S. Army Corps of Engineers, March 2001.

HAP Team (2011a). HAP Best Practice Category of Hydropower Unit and Plant Efficiency Improvement, prepared by Mesa, HPPi and ORNL.

HAP Team (2011b). HAP Condition Assessment Manual, prepared by ORNL, Mesa and HPPi.

TVA (2010). Enterprise Asset Management (EAM) Asset database Modification and Unique Identification of Structures, Systems, and Components.

Reclamation (2002). Mechanical Governors for Hydroelectric Units. Facilities, Instructions, Standards, and Techniques. Vol. 2-3, Prepared by U.S. Department of the Interior, Bureau of Reclamation, July 2002.

March (2011). “Best Practice” Guidelines for Hydro Performance Processes, by Patrick March, Charles Almquist and Paul Wolff, Hydro Vision Conference, July 2011.

USACE (1985). Engineer Manual, No. 1110-2-1701. Engineering and Design – HYDROPOWER, US Army Corps of Engineers.

HydroAMP(2006)- Hydropower Asset Management-Using Condition Assessments and Risk-Based Economic Analyses. Appendix E- Equipment Condition Assessment Guides.

For overall questions
please contact:

Brennan T. Smith, Ph.D., P.E.
Water Power Program Manager
Oak Ridge National Laboratory
865-241-5160
smithbt@ornl.gov

or

Qin Fen (Katherine) Zhang, Ph. D., P.E.
Hydropower Engineer
Oak Ridge National Laboratory
865-576-2921
zhangq1@ornl.gov