September 2006

Hydro Plant Risk Assessment Guide

Appendix E1: Generator Condition Assessment

E1.1 GENERAL

Hydroelectric generators are key components in the power train at hydroelectric powerplants and are appropriate for analysis under a condition assessment program. Unexpected generator failure can have a significant economic impact due to the high cost of emergency repairs and lost revenues during an extended forced outage.

Determining the present condition of a generator is an essential step in analyzing the risk of failure. This appendix provides a process for arriving at a Generator Condition Index which may be used to develop a business case addressing risk of failure, economic consequences, and other factors.

E1.2 SCOPE / APPLICATION

The condition assessment methodology outlined in this appendix applies to hydroelectric generators, motor/generators, and motors rated 2 MW (megawatts) or higher. The condition assessment primarily focuses on the generator stator winding and core, rotor, and field and amortisseur windings. Auxiliary components such as fans, coolers, fire suppression systems, generator protection relays, etc. are not considered during this assessment.

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

E1.3 CONDITION AND DATA QUALITY INDICATORS, AND GENERATOR CONDITION INDEX

This appendix describes the condition indicators generally regarded by hydro plant engineers as providing the initial basis for assessing generator condition. The following indicators are used to separately evaluate the condition of the stator and rotor:

- Physical Inspection
- Insulation Resistance and Polarization Index (stator and field windings)
- Operation & Maintenance History
- Age

These condition indicators are initially evaluated using Tier 1 inspections, tests, and measurements, which are conducted by utility staff or contractors over the course of time and as a part of routine maintenance activities. Numerical scores are assigned to each stator and rotor condition indicator, which are then weighted and summed to determine the Stator and Rotor Condition Indices. The lower of the two indices is selected to represent the overall Generator Condition Index.

An additional stand-alone indicator is used to reflect the quality of the information available for scoring the generator condition indicators. In some cases, data may be missing, out-of-date, or of questionable integrity. Any of these situations could affect the accuracy of the associated condition indicator scores as well as the validity of the overall Condition Index. Given the potential impact of poor or missing data, the Data Quality Indicator is used as a means of evaluating and recording confidence in the final Generator Condition Index.

Additional information regarding generator condition may be necessary to improve the accuracy and reliability of the Generator Condition Index. Therefore, in addition to the Tier 1 condition indicators, this appendix describes a "toolbox" of Tier 2 inspections, tests, and measurements that may be applied to the Stator and Rotor Condition Indices, depending on the specific issue or problem being addressed. Tier 2 tests are considered non-routine. However, if Tier 2 data is readily available, it may be used to supplement the Tier 1 assessment. Alternatively, Tier 2 tests may be deliberately performed to address Tier 1 findings. Results of the Tier 2 analysis may either increase or decrease the score of the Generator Condition Index. The Data Quality Indicator score may also be revised during the Tier 2 assessment to reflect the availability of additional information or test data.

The Generator Condition Index may indicate the need for immediate corrective actions and/or follow-up Tier 2 testing. The Generator Condition Index may also be used as an input to a computer model that assesses risk and performs economic analyses.

Note: A severely negative result of ANY inspection, test, or measurement may be adequate in itself to require immediate de-energization or prevent re-energization of the generator, regardless of the Generator Condition Index score.

E1.4 INSPECTIONS, TESTS, AND MEASUREMENTS

Inspections, tests, and measurements should be conducted and analyzed by staff suitably trained and experienced in generator diagnostics. Qualified staff that is competent in these routine procedures may conduct the basic tests and inspections. More complex inspections and measurements may require a generator diagnostics expert.

Inspections, tests, and measurements should be performed on a frequency that provides the accurate and current information needed by the assessment.

Generator condition assessment may cause concerns that justify more frequent monitoring. Utilities should consider the possibility of taking more frequent measurements or installing on-line monitoring systems that will continuously track critical parameters. This will provide

additional data for condition assessment and establish a certain amount of reassurance as generator alternatives are being explored.
Details of the inspection, testing, and measurement methods and intervals are described in technical references specific to the electric utility.

E1.5 SCORING

Condition indicator scoring is somewhat subjective, relying on the experience and opinions of plant staff and generator experts. Relative terms such as “Results Normal” and “Degradation” refer to results that are compared to industry accepted levels; or to baseline or previously acceptable levels on this equipment; or to equipment of similar design, construction, or age operating in a similar environment.

E1.6 WEIGHTING FACTORS

Weighting factors used in the condition assessment methodology recognize that some Condition Indicators affect the Generator Condition Index to a greater or lesser degree than other indicators. These weighting factors were arrived at by consensus among generator design and maintenance personnel with extensive experience.

E1.7 MITIGATING FACTORS

Every generator is unique and, therefore, the methodology described in this guide cannot quantify all factors that affect individual generator condition. If the Generator Condition Index triggers significant follow-up actions (e.g., major repairs or a Tier 2 assessment), it may be prudent to first have the index reviewed by generator experts. Mitigating factors specific to the utility may affect the final Generator Condition Index and the final decision on generator replacement or rehabilitation.

E1.8 DOCUMENTATION

Substantiating documentation is essential to support findings of the assessment, particularly where a Tier 1 condition indicator score is less than 3 (i.e., less than normal) or where a Tier 2 test results in subtractions to the Generator Condition Index. Test reports, photographs, O & M records, and other documentation should accompany the Generator Condition Assessment Summary Form.

E1.9 CONDITION ASSESSMENT METHODOLOGY

The condition assessment methodology consists of analyzing each condition indicator individually to arrive at a condition indicator score. The scores are weighted and summed to determine the Condition Index. Condition Indices are developed separately for the stator and rotor. The lower of the Stator and Rotor Condition Indices is used to arrive at an overall

Generator Condition Index. The Generator Condition Index is applied to the Generator Condition-Based Alternatives, Table 24, to determine the recommended course of action. The stator condition assessment focuses on the stator winding and core. Stator winding condition is evaluated using Tier 1 and Tier 2 tests. Assessment of the stator core is considered to be non-routine, and therefore, a Tier 2 evaluation. Rotor condition assessment comprises the rotor, and field and amortisseur windings. Rotor components are evaluated using both Tier 1 and Tier 2 tests.

Reasonable efforts should be made to perform Tier 1 inspections, tests, and measurements. However, when data is unavailable to properly score a condition indicator, it may be assumed that the score is "Good" or numerically equal to some mid-range number such as 2. This strategy must be used judiciously to prevent erroneous results and conclusions. In recognition of the potential impact of poor or missing data, a separate Data Quality Indicator is rated as a means of evaluating and recording confidence in the final Generator Condition Index.

E1.10 TIER 1 – INSPECTIONS, TESTS, AND MEASUREMENTS

Tier 1 tests include those inspections, tests, and measurements that are routinely accomplished as part of normal operation and maintenance, or are readily discernible by examination of existing data. Tier 1 test results are quantified below as condition indicators that are weighted and summed to arrive at a Condition Index. Tier 1 tests may indicate abnormal conditions that can be resolved with standard corrective maintenance solutions. To the extent that Tier 1 tests result in immediate corrective maintenance actions being taken by plant staff, then adjustments to the condition indicators should be reflected and the new results used when computing the overall Tier 1 Condition Index. Tier 1 test results may also indicate the need for additional investigation, categorized as Tier 2 tests.

E1.11 STATOR CONDITION INDICATORS

Stator Condition Indicator 1 – Operation & Maintenance History

During operation, large synchronous generators are continuously subjected to electrical, mechanical, thermal, and environmental stresses. These stresses act and interact in complex ways to degrade the machine's components and reduce its useful life. Deterioration of the stator winding insulation is a leading factor for determining the serviceability of hydroelectric generators. Unexpected stator winding failure can result in forced outages and costly emergency repairs.

Operation and maintenance history may provide a useful indication of stator condition. The operation and maintenance history of the generator should be reviewed by qualified personnel to make a subjective determination of scoring that encompasses as many operation and maintenance factors as possible under this indicator. Factors to consider include:

- Maintenance needs are increasing with time or problems are re-occurring;
- Spare parts are becoming unavailable;
- Frequent starts and stops;
- Rapid loading ramp rates are used;

- Operating outside of voltage rating (either higher or lower);
- Sustained overloading;
- Frequent rough-zone crossings;
- Close-in lightning strikes;
- Out-of-phase breaker closings;
- Unbalanced phase operation;
- Previous failures on this equipment related to the stator winding or core;
- Failures or problems on equipment of similar design, construction, or age operating in a similar environment.

Results of stator winding O & M history are analyzed and applied to Table 1 to arrive at an appropriate Stator Condition Indicator Score.

Table 1 – Stator Winding Operation & Maintenance History Scoring

Results	Stator Condition Indicator Score
Operation and maintenance normal.	3
Some abnormal operating conditions experienced and/or additional maintenance above normal occurring.	2
Significant operation outside normal and/or significant additional maintenance is required; forced outage occurs; outages are regularly extended due to maintenance problems; similar units are problematic.	1
Repeated forced outages; maintenance not cost effective; major electrical or mechanical failures; similar units have reached end-of-life.	0

Stator Condition Indicator 2 – Physical Inspection

Several types of stator winding problems can be detected during the course of physical inspections, such as insulation cracks, bulging or puffy coils, surface corona, contamination, carbon tracks, winding movement, loose bracing and blocking, and loose wedges or slot fillers. Qualified personnel should make a subjective determination of scoring that encompasses as many inspection factors as possible under this indicator. Negligible evidence of aging, damage, and/or deterioration would lead to a "normal" rating, whereas a minor amount of wear and tear would be rated as "some deterioration." If the deterioration observed is very obvious and widespread, a rating of "significant deterioration" is appropriate. At a minimum, the following areas should be inspected and the condition evaluated:

- Stator winding;
- Stator winding wedges, packing, blocking, and bracing;
- Circuit ring bus;
- Main and neutral leads.

Results of the stator winding physical inspection are analyzed and applied to Table 2 to arrive at a Stator Condition Indicator Score.

Table 2 – Stator Winding Physical Inspection Scoring Results	Stator Condition Indicator Score
Inspection results are normal.	3
Inspection shows some deterioration.	2
Inspection shows significant deterioration.	1
Inspection shows complete or imminent failure of stator winding components.	0

Stator Condition Indicator 3 – Insulation Resistance and Polarization Index

Insulation resistance is defined as the quotient of the applied direct voltage over the measured current ($R = V/I$). For a high capacitance specimen such as a generator stator winding, an applied voltage step will result in a measured current that decays exponentially with time. Because of this time-dependency, insulation resistance is normally calculated and recorded one minute after the test voltage is applied. Insulation resistance measurements combine both surface and volume resistances, and are mainly used to detect moisture absorption, conductive contamination, degree of cure, and cracks or fissures. Insulation resistance tests are sensitive to specimen temperature and are often normalized to a standard temperature (typically 40°C) for analysis. Humidity and surface contamination can also affect the measurement. The insulation resistance of good insulation may range from hundreds to thousands of megaohms. Comparison of individual phases and trending over time are the best means of evaluating insulation condition.

A polarization index test is similar to the insulation resistance test except that current readings are taken at two time intervals, normally one and ten minutes after application of the voltage step. The quotient of these two current readings (I_1/I_{10}) is termed the polarization index and gives an indication of insulation dryness, contamination, cure, and mechanical integrity. Since the polarization index is the ratio of two measurements made under identical conditions, it is less sensitive to temperature variations than is insulation resistance. However, normal polarization indices vary significantly for different types of insulation systems depending on the electrical properties of the constituent dielectric materials, making it difficult to define acceptable polarization index criteria. Therefore, trending of measurements over time and comparison between phases are typically necessary to assess insulation condition.

Stator winding insulation resistance and polarization index test results should be analyzed and applied to Table 3 to arrive at a Stator Condition Indicator Score.

Table 3 – Stator Winding Insulation Resistance and Polarization Index Scoring	
Results	**Stator Condition Indicator Score**
Results are normal and similar to previous tests.	3
Results indicate minor decrease in insulation resistance or polarization index (e.g., factor of 2 decrease).	2
Results indicate significant decrease in insulation resistance or polarization index (e.g., factor of 10 decrease).	1
Insulation resistance or polarization index is below minimum acceptable values.	0

Stator Condition Indicator 4 – Winding Age

The age of the generator stator winding is an important factor to consider when identifying candidates for replacement. Age is one indicator of remaining life and upgrade potential to state-of-the-art materials and designs. The design life of a stator winding rated 6.9 kV or higher is typically 25 to 35 years. For lower voltage windings, the design life is typically 35 years or more. It is important to recognize, however, that although age may be a useful indicator, the actual service life that can be realized varies widely depending on the specific equipment manufacturer and date of manufacture; the insulation system design, materials, and production methods; the quality of installation; and the generator's operation and maintenance history.

The stator winding age should be determined and applied to Table 4 to arrive at an appropriate Stator Condition Indicator Score.

Table 4 – Stator Winding Age Scoring	
Age	**Stator Condition Indicator Score**
< 20 years	3
≥ 20 and < 30 years	2
≥ 30 and < 40 years	1
≥ 40 years	0

E1.12 TIER 1 – STATOR CONDITION INDEX CALCULATIONS

Enter the stator condition indicator scores from the tables above into the Stator Condition Assessment Summary form at the end of this document. Multiply each stator indicator score by its respective Weighting Factor, and sum the Total Scores to arrive at the Tier 1 Stator Condition

Index. Attach supporting documentation. The Stator Condition Index may be adjusted by the Tier 2 stator inspections, tests, and measurements described later in this document.

E1.13 TIER 1 – STATOR DATA QUALITY INDICATOR

Stator Data Quality Indicator – Quality of Inspections, Tests, and Measurements

The Stator Data Quality Indicator reflects the quality of the inspection, test and measurement results used to evaluate the stator condition under Tier 1. The more current and complete the results are, the higher the rating for this indicator. The normal testing frequency is defined as the organization's recommended frequency for performing the specific test or inspection.

Qualified personnel should make a subjective determination of scoring that encompasses as many factors as possible under this indicator. Results are analyzed and applied to Table 5 to arrive at an appropriate Stator Data Quality Indicator Score.

Table 5 – Stator Data Quality Scoring

Results	Stator Data Quality Indicator Score
All Tier 1 inspections, tests and measurements were completed within the normal testing frequency and the results are reliable.	10
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 6 and < 24 months past the normal testing frequency and results are reliable.	7
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 24 and < 36 months past the normal testing frequency, or some of the results are not available or are of questionable integrity.	4
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 36 months past the normal frequency, or no results are available or many are of questionable integrity.	0

Enter the Stator Data Quality Indicator Score from Table 5 into the Stator Condition Assessment Summary form at the end of this document.

E1.14 ROTOR CONDITION INDICATORS

Rotor Condition Indicator 1 – Operation & Maintenance History

Operation and maintenance history may provide a useful indication of generator rotor condition. The operation and maintenance history of the rotor should be reviewed by qualified personnel to make a subjective determination of scoring that encompasses as many operation and maintenance factors as possible under this indicator. Factors to consider include:

- Maintenance needs increasing with time or problems are re-occurring;
- Spare parts are becoming unavailable;
- Operating outside of voltage rating (either higher or lower);
- Sustained overloading;
- Frequent rough-zone crossings;
- Out-of-phase breaker closings;
- Number of times unit has been subjected to over speed or runaway (usually associated with load rejection);
- Previous failures on this equipment related to the rotor or field winding;
- Failures or problems on equipment of similar design, construction, or age operating in a similar environment.

Results of rotor O & M history are analyzed and applied to Table 6 to arrive at an appropriate Rotor Condition Indicator Score.

Table 6 – Rotor Operation & Maintenance History Scoring

Results	Rotor Condition Indicator Score
Operation and maintenance normal.	3
Some abnormal operating conditions experienced and/or additional maintenance above normal is required.	2
Significant operation outside normal and/or significant additional maintenance is required; forced outage occurs; outages are regularly extended due to maintenance problems; similar units are problematic.	1
Repeated forced outages; maintenance not cost effective; major electrical or mechanical failures; similar units have reached end-of-life.	0

Rotor Condition Indicator 2 – Physical Inspection

Several types of rotor problems can be detected during the course of physical inspections, such as overheating, loose and vibrating components, impact damage, and contamination. Qualified personnel should make a subjective determination of scoring that encompasses as many inspection factors as possible under this indicator. The following areas should be inspected and the deterioration should be evaluated:

- Rotor hub, radial arms, and rim;
- Field poles, keys, collars, and pole faces;
- Field windings and interpole connections;
- Field winding leads;
- Amortisseur winding bars, shorting straps, and inter-connections;
- Rim-mounted fan blades.

Results of the rotor physical inspection are analyzed and applied to Table 7 to arrive at a Rotor Condition Indicator Score.

Table 7 – Rotor Physical Inspection Scoring

Results	Rotor Condition Indicator Score
Inspection results are normal.	3
Inspection shows some deterioration.	2
Inspection shows significant deterioration.	1
Inspection shows complete or imminent failure of field winding components.	0

Rotor Condition Indicator 3 – Insulation Resistance and Polarization Index

Refer to "Stator Condition Indicator 3 – Insulation Resistance and Polarization Index" in section E1.11 above for a detailed description of insulation resistance and polarization index measurements.

Results of the insulation resistance and polarization index tests are analyzed and applied to Table 8 to arrive at a Rotor Condition Indicator Score.

Table 8 – Field Winding Insulation Resistance and Polarization Index Scoring

Results	Rotor Condition Indicator Score
Results are normal and similar to previous tests.	3
Results indicate minor decrease in insulation resistance or polarization index (e.g., factor of 2 decrease).	2
Results indicate significant decrease in insulation resistance or polarization index (e.g., factor of 10 decrease).	1
Insulation resistance or polarization index is below minimum acceptable values.	0

Rotor Condition Indicator 4 – Field Winding Age

The age of the generator field winding is an important factor to consider when identifying candidates for replacement. Age is one indicator of remaining life and upgrade potential to state-of-the-art materials and designs. The design life (or life expectancy) of the insulation of field windings is 50 to 60 years. Although age is a useful indicator of remaining life and upgrade potential, it is also important to recognize that the actual service life that can be realized varies widely depending on the specific equipment manufacturer and date of manufacture; the insulation system design, materials, and production methods; the quality of installation; and the generator's operation and maintenance history.

The age of the field winding should be determined and applied to Table 9 to arrive at an appropriate Rotor Condition Indicator Score.

Table 9 – Field Winding Age Scoring

Age	Rotor Condition Indicator Score
< 20 years	3
≥ 20 and < 30 years	2
≥ 30 and < 40 years	1
≥ 40 years	0

E1.15 TIER 1 – ROTOR CONDITION INDEX CALCULATIONS

Enter the rotor condition indicator scores from the tables above into the Rotor Condition Assessment Summary form at the end of this document. Multiply each indicator score by its respective Weighting Factor, and sum the Total Scores to arrive at the Tier 1 Rotor Condition Index. Attach supporting documentation. The Rotor Condition Index may be adjusted by the Tier 2 rotor inspections, tests, and measurements described later in this document.

E1.16 TIER 1 – ROTOR DATA QUALITY INDICATOR

Rotor Data Quality Indicator – Quality of Inspections, Tests, and Measurements

The Rotor Data Quality Indicator reflects the quality of the inspection, test and measurement results used to evaluate the rotor condition under Tier 1. The more current and complete the inspections, tests and measurements, the higher the rating for this indicator. The normal testing frequency is defined as the organization's recommended frequency for performing the specific test or inspection.

Qualified personnel should make a subjective determination of scoring that encompasses as many factors as possible under this indicator. Results are analyzed and applied to Table 10 to arrive at an appropriate Rotor Data Quality Indicator Score.

Table 10 – Rotor Data Quality Scoring

Results	Rotor Data Quality Indicator Score
All Tier 1 inspections, tests and measurements were completed within the normal testing frequency and the results are reliable.	10
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 6 and < 24 months past the normal testing frequency.	7
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 24 and < 36 months past the normal testing frequency, or some of the results are not available.	4
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 36 months past the normal frequency, or no results are available.	0

Enter the Rotor Data Quality Indicator Score from Table 10 into the Rotor Condition Assessment Summary form at the end of this document.

E1.17 TIER 2 – STATOR INSPECTIONS, TESTS, AND MEASUREMENTS

Tier 2 inspections, tests, and measurements generally require specialized equipment or expertise, may be intrusive, or may require an outage to perform. A Tier 2 assessment is not considered routine. Tier 2 inspections are intended to affect the Generator Stator Condition Index established using Tier 1 tests as well as confirm or disprove the need for more extensive maintenance, rehabilitation, or generator replacement.

Note that there are many tests that can provide information about the various aspects of stator condition. The choice of which tests to apply should be made based on known information obtained via review of O & M history, physical inspection, other test results, and company standards as well as the Tier 1 assessment. Many of the following Tier 2 tests are used to detect or confirm a similar defect or state of deterioration. In the event that more than one Tier 2 tests are performed to assess the same problem or concern, then the test with the largest adjustment shall be used to recalculate the Stator Condition Index. It is important to avoid adjusting the Condition Index downward twice or more simply because multiple tests are completed for the same suspected problem. Since the Tier 2 tests are being performed by and/or coordinated with knowledgeable technical staff, the decision as to which test is more significant and how different tests overlap is left to the experts.

For Tier 2 assessments performed, apply only the appropriate adjustment factors per the instructions above and recalculate the Stator Generator Condition Index using the Generator Condition Assessment Summary form at the end of this document. An adjustment to the Data Quality Indicator score may be appropriate if additional information or test results were obtained during the Tier 2 assessment.

Test T2.S1: Ramped Voltage Test

To conduct this test, an automatic high-voltage power supply (i.e., ramped voltage test set) is used to linearly increase the applied direct voltage from zero up to some maximum value at a constant ramp rate, typically 1 to 2 kV per minute. The current response versus applied voltage is measured and plotted, and the results are used to evaluate the condition of the insulation by noting deviations from the normal shape of the test curve. Any departure from a smooth curve could be an indication of insulation problems. Because the maximum test voltage is above the normal operating stress, the ramped voltage test also serves as a high-potential withstand test.

Ramped voltage test results are analyzed and applied to Table 11 to arrive at a Stator Condition Index score adjustment.

Table 11 – Ramped Voltage Test Scoring

Test Results	Adjustment to Stator Condition Index
Smooth, linear curve.	Add 0.5
Curve slightly nonlinear, similar to previous test results.*	No Change
Curve less linear than previous test results.*	Subtract 0.5
Curve significantly less linear than previous test results.*	Subtract 1.0
Test stopped early to avoid breakdown.	Subtract 2.0
Failure during test.	Subtract 5.0

*If no previous test results are available, compare to results of similar machines or to typical results.

Test T2.S2: Partial Discharge Measurements

Partial discharges are localized ionizations of the gaseous space surrounding or within a solid insulation. When the electric stress in the gas exceeds a critical value, a transient ionization, or partial discharge, occurs. The ionized gas contains electrons, ions, excited molecules, and free radicals. These chemically reactive species can affect and degrade the adjacent solid insulation. Although the damage caused by a single partial discharge (PD) event is minute, the cumulative effect of many discharges can eventually lead to insulation failure.

There are several potential sites of partial discharges in high-voltage generator stator windings, such as between the surface of the slot portion of the winding and the grounded stator core, at

either boundary of the voltage stress grading coating in the end turn area, in the winding overhang region where potential differences exist between adjacent coils separated by small air spaces, and internal to the insulation within voids, delaminations, or other defects.
PD measuring equipment and data analysis methods have been developed to quantify the level of discharge activity and determine the source. Measurements may be made either on-line or off-line, and a variety of detection techniques are possible (e.g., corona probe, PDA, EMI). Since discharge measurements are greatly influenced by the specific measuring technique, the PD instrument manufacturer should be consulted to determine appropriate evaluation criteria.

Partial discharge test results are analyzed and applied to Table 12 to arrive at a Stator Condition Index score adjustment.

Table 12 – Partial Discharge Test Scoring

Test Results	Adjustment to Stator Condition Index
Low PD readings throughout the generator.	Add 0.5
Few in number and low in magnitude.	No Change
Numerous high PD readings.	Subtract 0.5
Widespread and abnormally high PD readings.	Subtract 1.0

Test T2.S3: Dissipation (or Power) Factor Measurements

The dissipation factor, or tan δ, represents the losses in an insulation tested under sinusoidal voltage conditions. (Alternately, the power factor = cos θ is used to measure insulation losses. Typically, the numerical difference between tan δ and cos θ is negligible so that the terms dissipation factor and power factor are often used interchangeably.) Absolute values of tan δ as well as changes with respect to voltage are used to assess insulation quality and condition. When performing the test, several tan δ measurements are made over a range of applied voltages. For example, a typical test schedule would involve making measurements from 0.25 Un (where Un equals the rated phase-to-neutral voltage of the winding) through 1.25 Un, increasing the test voltage in increments of 0.25 Un. The tip-up, or Δ tan δ, is calculated by subtracting tan δ measured at 0.25 Un from tan δ at 1.0 Un. Relatively high values of tan δ and tip-up generally indicate the presence of voids, delaminations, or high conductivity.

Normal tan δ measurements may vary depending on several factors, such as the type of dielectric materials comprising the insulation, the effect of the end winding voltage stress grading treatment, and specimen temperature and humidity. Given the difficulty in establishing absolute limits for tan δ measurements, trending over time and/or comparisons among identical machines are generally needed to analyze and interpret dissipation factor values.

Dissipation factor results are analyzed and applied to Table 13 to arrive at a Stator Condition Index score adjustment.

Table 13 – Dissipation Factor Scoring	
Test Results	**Adjustment to Stator Condition Index**
Tan δ and tip-up are below expected values.	Add 0.5
Tan δ and tip-up are equal to expected values.	No Change
Tan δ or tip-up slightly exceed expected values.	Subtract 0.5
Tan δ or tip-up somewhat exceed expected values or have increased since previous test.	Subtract 1.0
Tan δ or tip-up significantly exceed expected values or have increased sharply since previous test.	Subtract 2.0

Test T2.S4: Ozone Monitoring

The presence of ozone in an air-cooled hydrogenerator stator housing is usually an indication that high intensity electrical discharges are occurring in the machine. Discharges between the surfaces of the slot portion of the generator stator winding and the grounded stator core are referred to as slot discharges and result from defective or deteriorated semi-conductive slot treatment or because the stator coils are loose in their slots. Discharges which occur at either boundary of the voltage stress grading coating in the end turn area of the stator winding are often called grading coating discharges. Grading coating discharges normally result from deficiencies in the voltage stress grading system. If the resistivity of the voltage grading treatment is too high, discharges occur at the interface between the grading treatment and the semi-conductive slot paint. If the resistivity is too low, discharges occur at the upper boundary of the stress grading treatment, i.e., away from the stator core. Electrical activity can also occur in the end winding region where high potential differences exist, such as between adjacent line- and neutral-end coils or between line-end coils of different phases. These discharges are known as end winding discharges. End winding discharges vary according to winding design, geometry and spacing between coils, the type of surface treatment, and end winding cleanliness. Stator windings can also experience internal discharges due to voids in the groundwall insulation. These discharges are not likely to cause elevated ozone levels.

All types of external discharges can cause air to ionize, producing ozone and other damaging by-products. In addition to the risk of a stator winding insulation failure resulting from intense electrical discharges, damage to the ferrous and rubber materials which are exposed to ozone can also be extremely serious. The following components are particularly susceptible to ozone: the iron stator core, brake ring, rotor shaft, hub, and rim laminations; air cooler fins and gaskets; unpainted water piping, and other exposed surfaces. Furthermore, normal leakage of stator housing air into the powerplant can result in increased background ozone levels in the plant work areas, prompting concern for worker health and safety.

Ozone levels may vary depending on the particular location at which the measurement is taken within the machine, as well as generator terminal voltage, loading, temperature and relative humidity. Therefore, to the extent possible, repeat ozone measurements should be made under the same general conditions.

Ozone results are analyzed and applied to Table 14 to arrive at a Stator Condition Index score adjustment.

Table 14 – Ozone Scoring

Test Results	**Adjustment to Stator Condition Index**
Ozone levels < 0.05 ppm.	Add 0.5
Ozone levels ≥ 0.05 and < 0.1 ppm.	No Change
Ozone levels ≥ 0.1 and < 1.0 ppm.	Subtract 1.0
Ozone levels ≥ 1.0 ppm.	Subtract 2.0

Test T2.S5: Black Out Test

This test is generally performed on generators with stator windings rated 6900 volts and above since machines with lower ratings are not likely to experience surface discharges during normal operation. The black out test may be performed with either the rotor in place or removed. However, removing the rotor improves visibility of surface discharges in the slot region. The test is typically conducted in the evening with the powerhouse lights off. A black plastic covering may be placed over the air housing to help eliminate outside light. An individual coil, group of coils, complete phase, or the entire stator winding is energized at rated voltage or slightly above while observers positioned inside the unit look for visual evidence of electrical discharges. Active areas of corona are noted with respect to slot number and location.

Black out test results are analyzed and applied to Table 15 to arrive at a Stator Condition Index score adjustment.

Table 15 – Black Out Test Scoring

Test Results	**Adjustment to Stator Condition Index**
Negligible corona.	Add 0.5
Few locations and minor intensity.	No Change
Several locations and moderate intensity.	Subtract 1.0
Widespread, intense corona.	Subtract 2.0

Test T2.S6: High-Potential Withstand Test

High-potential withstand tests are typically performed to provide some assurance that the winding insulation has a minimum level of electrical strength. Because the inherent withstand capability of sound insulation is well above the usual proof test value, failure during a test at an appropriate voltage indicates the insulation is unsuitable for service. Withstand tests are intended to search for flaws in the material and for manufacturing defects, and to demonstrate in a practical manner that the insulation has a minimum level of electrical integrity. A primary requirement of such a test is that it should be discerning and effective in detecting serious flaws at or below the minimum specified strength without damaging sound insulation. The applied test voltage may be power frequency, very low frequency (VLF), or direct voltage.

Stator winding high-potential withstand test results are analyzed and applied to Table 16 to arrive at a Stator Condition Index score adjustment.

Table 16 – Stator Winding High-Potential Withstand Test Scoring

Test Results	Adjustment to Stator Condition Index
Passed withstand test.	Add 0.5
Failed withstand test.	Subtract 5.0

Test T2.S7: Stator Core Inspection

A stator core physical inspection may be done with the rotor in place although it is more convenient to examine the core with the rotor removed. The stator core should be examined for looseness and shifting. Core looseness should be checked with the knife test. Stator through bolt torque may also be checked. Any broken core laminations, laminations which protrude into the air gap, signs of fretting corrosion, bent core duct separators, or other evidence of core damage should be noted. Interlaminar insulation faults may result in severe overheating which could damage the stator winding at that location. Generally, defects at the core surface are easily observed while defects in the slot area or in the back iron are not detectible visually. If inspection panels are present on the stator frame wrapper, they should be removed to allow inspection of the back iron and stator frame.

Stator core inspection results are analyzed and applied to Table 17 to arrive at a Stator Condition Index score adjustment.

Table 17 – Stator Core Inspection Scoring	
Test Results	**Adjustment to Stator Condition Index**
Core condition appears very good.	Add 0.5
No indication of core damage or deterioration.	No Change
Minor core damage or deterioration.	Subtract 0.5
Moderate core damage or deterioration.	Subtract 1.0
Significant core damage or deterioration.	Subtract 2.0

Test T2.S8: Wedge Tightness Evaluation

Stator windings are wedged into the core slots and subjected to positive radial pressure to protect the winding from vibration-induced damage during normal operation and to keep coils/bars from being forced out of the slots during phase-to-phase short circuit conditions. This evaluation is used to determine the condition of the stator winding wedge system. The wedge system should be examined closely for loose, broken, or burnt wedges. To perform a comprehensive assessment with the rotor in place, one or two pole pieces must be removed in order to access the entire length of the stator core and the rotor must be rotated manually in order to inspect all wedges in every slot. A partial evaluation may be conducted by inspecting only those wedges that are within reach between the rotor poles. The wedge evaluation procedure requires careful visual inspection of the wedging system, including wedges and slot packing materials. The wedge system may be further examined by tapping the wedges with a blunt metallic instrument which rings or vibrates when hit against a solidly wedged slot. Loose wedges produce a dull sound when tapped. Commercial wedge tightness measuring tools are also available. Wedge systems utilizing under-wedge ripple springs may be evaluated using a depth gauge to measure the ripple spring compression. Regardless of the specific evaluation method used, wedge system condition is assessed based on the overall percentage of loose wedges as well as the number and location of loose wedges in any given slot.

Stator core inspection results are analyzed and applied to Table 18 to arrive at a Stator Condition Index score adjustment.

Table 18 – Wedge Tightness Scoring	
Test Results	**Adjustment to Stator Condition Index**
Rewedging completed within last < 5 years and no indication of loose wedges.	Add 0.5
No indication of loose wedges.	No Change
Few loose wedges.	Subtract 0.5
Numerous loose wedges.	Subtract 1.0
Widespread loose wedges.	Subtract 2.0

Test T2.S9: Core Loop Test

The stator core loop test, also known as the ring test or rated flux test, is performed on motor or generator stators to evaluate the integrity of the core laminations. Core damage may be caused by ingress of foreign bodies into the stator bore, excessive vibrations, or deterioration of the lamination insulation due to overheating or other aging processes. Inadvertent core damage may also occur during rewedging or removal of the rotor and/or stator coils. A bearing failure may also cause the rotor to rub and damage the stator core. The core loop test is used to detect damage, assess its severity, and indicate whether repair is required.

The loop test is made by wrapping an excitation winding around the stator core and frame. A 60-Hz voltage is applied to the winding sufficient to induce a flux approximately equal to the rated operating flux density and produce normal axial voltage between laminations. Defective areas of the core or tooth insulation appear as "hot spots' that can be detected via infrared thermal imaging. An area of iron exhibiting a temperature equal to or greater than 5 °C above the average core temperature is generally considered to be a hot spot.

Core loop test results are analyzed and applied to Table 19 to arrive at a Stator Condition Index score adjustment.

Table 19 – Core Loop Test Scoring	
Test Results	**Adjustment to Stator Condition Index**
No visible hot spots.	Add 0.5
One warm spot < 5 °C.	No Change
Two or more warm spots < 5 °C, or one hot spot ≥ 5 °C and < 10 °C.	Subtract 0.5
Two or more hot spots ≥ 5 °C and < 10 °C.	Subtract 1.0
One or more hot spots ≥ 10 °C.	Subtract 2.0

Test T2.S10: EL CID Test

The Electromagnetic Core Imperfection Detector (EL CID) test is used to detect and evaluate known or suspected damage to the stator core lamination insulation. The main advantage of the EL CID test over the rated flux test is that it requires a much smaller capacity power supply for the excitation winding, since only 3 to 4 percent of rated flux needs to be induced in the core. The EL CID test operates on the basis that eddy currents will flow through failed or significantly aged core insulation. Using a special "Chattock coil," a voltage signal is obtained that is proportional to the magnitude of eddy current flowing between laminations. The measured voltage is fed to a signal processor what gives an output in mA (milliamperes) that represents the axial component of the measured voltage. Relatively high readings indicate faulty insulation. The manufacturer of the EL CID test equipment states that output readings above 100 mA indicate significant core shorting.

EL CID test results are analyzed and applied to Table 20 to arrive at a Stator Condition Index score adjustment.

Table 20 – EL CID Test Scoring

Test Results	Adjustment to Stator Condition Index
No readings > 50 mA.	Add 0.5
No readings > 100 mA.	No Change
One reading > 100 mA and ≤ 200 mA.	Subtract 0.5
Two or more readings > 100 mA and ≤ 200 mA.	Subtract 1.0
One or more readings > 200 mA.	Subtract 2.0

Test T2.S11: Other Specialized Diagnostic Tests

Additional tests such as winding dissection, capacitance measurements, core bolt insulation resistance, winding conductor resistance measurements, and others may be applied to evaluate specific stator winding or core problems. Some of these diagnostic tests may be considered to be of an investigative research nature. When conclusive results from other diagnostic tests are available, they may be used to make an appropriate adjustment to the Stator Condition Index.

E1.18 TIER 2 – STATOR CONDITION INDEX CALCULATIONS

Enter the Tier 2 adjustments from the tables above into the Generator Condition Assessment Summary form at the end of this guide. Subtract the sum of these adjustments from the Tier 1 Stator Condition Index to arrive at the Net Stator Condition Index. Attach supporting documentation. An adjustment to the Data Quality Indicator score may be appropriate if additional information or test results were obtained during the Tier 2 assessment.

E1.19 TIER 2 – ROTOR INSPECTIONS, TESTS, AND MEASUREMENTS

Tier 2 inspections, tests, and measurements generally require specialized equipment or expertise, may be intrusive, or may require an outage to perform. A Tier 2 assessment is not considered routine. Tier 2 inspections are intended to affect the Rotor Condition Index number established using Tier 1 tests as well as confirm or disprove the need for more extensive maintenance, rehabilitation, or generator replacement.

Note that there are many tests that can provide information about the various aspects of rotor condition. The choice of which tests to apply should be made based on known information obtained via review of O & M history, physical inspection, other test results, and company standards as well as the Tier 1 assessment. Many of the following Tier 2 tests are used to detect or confirm a similar defect or state of deterioration. In the event that more than one Tier 2 tests are performed to assess the same problem or concern, then the test with the largest adjustment shall be used to recalculate the Rotor Condition Index. It is important to avoid adjusting the Condition Index downward twice or more simply because multiple tests are completed for the same suspected problem. Since the Tier 2 tests are being performed by and/or coordinated with knowledgeable technical staff, the decision as to which test is more significant and how different tests overlap is left to the experts.

For Tier 2 assessments performed, apply only the appropriate adjustment factors per the instructions above and recalculate the Rotor Generator Condition Index using the Generator Condition Assessment Summary form at the end of this document.

Test T2.R1: High-Potential Withstand

High-potential withstand tests are typically performed to provide some assurance that the winding insulation has a minimum level of electrical strength. Because the inherent withstand capability of sound insulation is well above the usual proof test value, failure during a test at an appropriate voltage indicates the insulation is unsuitable for service. Withstand tests are intended to search for flaws in the material and for manufacturing defects, and to demonstrate in a practical manner that the insulation has a minimum level of electrical integrity. A primary requirement of such a test is that is should be discerning and effective in detecting serious flaws at or below the minimum specified strength without damaging sound insulation. The applied test voltage may be power frequency, very low frequency (VLF), or direct voltage.

Field winding high-potential withstand test results are analyzed and applied to Table 21 to arrive at a Rotor Condition Index score adjustment.

Table 21 – Field Winding High-Potential Withstand Test Scoring

Test Results	Adjustment to Rotor Condition Index
Passed withstand test.	Add 0.5
Failed withstand test.	Subtract 5.0

Test T2.R2: AC Pole Drop Test

This test is performed on salient pole rotors to detect shorted turns in the field winding. The winding is energized at 120 V, 60 Hz and the voltage drop across each pole is measured. Poles with appreciably lower voltage drops may have shorted turns. The voltage drop across the immediately adjacent poles may be low as well due to the influence of the defective pole on the magnetic circuits of the adjacent poles.

AC pole drop test results are analyzed and applied to Table 22 to arrive at a Rotor Condition Index score adjustment.

Table 22 – AC Pole Drop Test Scoring

Test Results	Adjustment to Rotor Condition Index
Poles reinsulated within last < 10 years.	Add 0.5
No indication of shorted turns.	No Change
One pole with one shorted turn.	Subtract 0.5
Two or more poles with one shorted turn.	Subtract 1.0
One or more poles with multiple shorted turns.	Subtract 2.0

Test T2.R3: Field Winding AC Impedance

Due to the appreciable centrifugal forces that act on a rotor winding at rated speed, certain shorted turns may only be apparent when the rotor is revolving at or near rated speed. An impedance test can be performed while the machine is being shut down or brought up to speed to detect shorted turns that are only present under centrifugal forces. To perform the test, a 120 V, 60 Hz power supply is applied to the winding through the collector rings. The applied voltage and current are measured and the impedance is calculated over a range of rotational speeds.

Field winding ac impedance test results are analyzed and applied to Table 23 to arrive at a Rotor Condition Index score adjustment.

Table 23 – Field Winding AC Impedance Scoring

Test Results	Adjustment to Rotor Condition Index
Difference between readings taken at rated speed and standstill is < 5%. No abrupt changes.	Add 0.5
Difference between readings taken at rated speed and standstill is ≥ 5% and < 10%. No abrupt changes.	No Change
Difference between readings taken at rated speed and standstill is ≥ 5% and < 10%, with abrupt change ≥ 5%.	Subtract 1.0
Difference between readings taken at rated speed and standstill is ≥ 10% and abrupt change is ≥ 5%.	Subtract 2.0

Test T2.R4: Other Specialized Diagnostic Tests

Additional tests such as DC resistance measurements, temperature scanning, etc. may be applied to evaluate specific rotor problems. Some of these diagnostic tests may be considered to be of an investigative research nature. When conclusive results from other diagnostic tests are available, they may be used to make an appropriate adjustment to the Rotor Condition Index.

E1.20 TIER 2 – ROTOR CONDITION INDEX CALCULATIONS

Enter the Tier 2 adjustments from the tables above into the Generator Condition Assessment Summary form at the end of this guide. Subtract the sum of these adjustments from the Tier 1 Rotor Condition Index to arrive at the Net Rotor Condition Index. Attach supporting documentation. An adjustment to the Data Quality Indicator score may be appropriate if additional information or test results were obtained during the Tier 2 assessment.

E1.21 GENERATOR CONDITION INDEX CALCULATIONS

Choose the lower of the Net Stator Condition Index and Net Rotor Condition Index to represent the overall Generator Condition Index. Record the Data Quality Indicator score associated with the chosen Condition Index. Suggested alternatives for follow-up action, based on the Generator Condition Index, are described in the Generator Condition-Based Alternatives located in Table 24.

E1.22 GENERATOR CONDITION-BASED ALTERNATIVES

The Generator Condition Index – either modified by Tier 2 tests or not – may be sufficient for decision-making regarding generator alternatives. The Index is also suitable for use in a risk-and-economic analysis model. Where it is desired to consider alternatives based solely on generator condition, the Generator Condition Index may be directly applied to the Generator Condition-Based Alternatives table (Table 24).

Table 24 – Generator Condition-Based Alternatives

Generator Condition Index	Suggested Course of Action
≥ 7.0 and ≤ 10 (Good)	Continue O & M without restriction. Repeat condition assessment as needed.
≥ 3.0 and < 7 (Fair)	Continue operation but reevaluate O & M practices. Consider using appropriate Tier 2 tests. Repeat condition assessment process as needed.
≥ 0 and < 3.0 (Poor)	Immediate evaluation including additional Tier 2 testing. Consultation with experts. Adjust O & M as prudent. Begin replacement/rehabilitation process.

GENERATOR
TIER 1 CONDITION ASSESSMENT SUMMARY

Date: __________________________ Location: ____

Gen. Identifier: ____________ Gen. Manufacturer: ___________________ Yr. Mfd.: __________

Stator Winding Manufacturer: _____________________ Yr. Winding Installed: ______________

Stator Insulation Type: _________________ MVA: ________ PF: ______ Voltage: ____________

Field Winding Manufacturer: ______________________ Yr. Winding Installed: ______________

Field Insulation Type: ___________________ Current: ______________ Voltage: _____________

Part A: Calculate the Tier 1 Stator Condition Index

Tier 1 Generator Stator Condition Summary
(For instructions on indicator scoring, please refer to condition assessment guide)

No.	Condition Indicator	Score ×	Weighting Factor =	Total Score
1	O & M History *(Score must be 0, 1, 2, or 3)*		1.18	
2	Physical Inspection *(Score must be 0, 1, 2, or 3)*		1.18	
3	Insulation Resistance and Polarization Index *(Score must be 0, 1, 2, or 3)*		0.58	
4	Winding Age *(Score must be 0, 1, 2, or 3)*		0.39	
	Tier 1 Stator Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*			

Tier 1 Stator Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	

Evaluator: _____________________________ Technical Review: _____________________________

Management Review: ___________________ Copies to: _____________________________________

Part B: Calculate the Tier 1 Rotor Condition Index

Tier 1 Generator Rotor Condition Summary
(For instructions on indicator scoring, please refer to condition assessment guide)

No.	Condition Indicator	Score ×	Weighting Factor =	Total Score
1	O & M History *(Score must be 0, 1, 2, or 3)*		1.18	
2	Physical Inspection *(Score must be 0, 1, 2, or 3)*		1.18	
3	Insulation Resistance and Polarization Index *(Score must be 0, 1, 2, or 3)*		0.58	
4	Winding Age *(Score must be 0, 1, 2, or 3)*		0.39	
	Tier 1 Rotor Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*			

Tier 1 Rotor Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	

Evaluator: ______________________ Technical Review: ______________________

Management Review: ______________ Copies to: ____________________________

Part C: Determine the Tier 1 Generator (Stator and Rotor) Condition Index

To determine the Tier 1 Generator (Stator and Rotor) Condition Index, choose the lower of the Tier 1 Stator Condition Index and the Tier 1 Rotor Condition Index. Record the Data Quality Indicator associated with the chosen Condition Index.

Generator Condition Index _____________

Data Quality Indicator _________________

(Attach supporting documentation.)

Generator Condition-Based Alternatives	
Generator Condition Index	**Suggested Course of Action**
≥ 7.0 and ≤ 10 (Good)	Continue O & M without restriction. Repeat condition assessment as needed.
≥ 3.0 and < 7 (Fair)	Continue operation but reevaluate O & M practices. Consider using appropriate Tier 2 tests. Repeat condition assessment process as needed.
≥ 0 and < 3.0 (Poor)	Immediate evaluation including additional Tier 2 testing. Consultation with experts. Adjust O & M as prudent. Begin replacement/rehabilitation process.

GENERATOR
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: __________________________ Location: ____

Gen. Identifier: ___________ Gen. Manufacturer: ___________________ Yr. Mfd.: _________

Stator Winding Manufacturer: _____________________ Yr. Winding Installed: _____________

Stator Insulation Type: ________________ MVA: _______ PF: ______ Voltage: ___________

Field Winding Manufacturer: ______________________ Yr. Winding Installed: _____________

Field Insulation Type: ___________________ Current: _____________ Voltage: ____________

Part A: Calculate the Tier 2 Stator Condition Index

Tier 2 Stator Condition Summary		
No.	**Tier 2 Test**	**Adjustment to Tier 1 Stator Condition Index**
T2.S1	Ramped Voltage Test	
T2.S2	Partial Discharge Measurements	
T2.S3	Dissipation Factor Measurements	
T2.S4	Ozone Monitoring	
T2.S5	Black Out Test	
T2.S6	High-Potential Withstand Test	
T2.S7	Stator Core Inspection	
T2.S8	Wedge Tightness Evaluation	
T2.S9	Core Loop Test	
T2.S10	EL CID Test	
T2.S11	Other Specialized Diagnostic Tests	
Tier 2 Adjustments to Stator Condition Index (Sum of individual Adjustments)		

Tier 2 Stator Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	

To calculate the Net Stator Condition Index *(Value should be between 0 and 10)*, subtract the Tier 2 Adjustments from the Tier 1 Stator Condition Index:

Tier 1 Stator Condition Index __________

minus **Tier 2 Stator Adjustments** __________ = ________________

Net Stator Condition Index

Part B: Calculate the Tier 2 Rotor Condition Index

Tier 2 Rotor Condition Summary		
No.	**Tier 2 Test**	**Adjustment to Tier 1 Rotor Condition Index**
T2.R1	High-Potential Withstand Test	
T2.R2	AC Pole Drop Test	
T2.R3	Field Winding AC Impedance	
T2.R4	Other Specialized Diagnostic Tests	
Tier 2 Adjustments to Rotor Condition Index (Sum of individual Adjustments)		

Tier 2 Rotor Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	

To calculate the Net Rotor Condition Index *(Value should be between 0 and 10)*, subtract the Tier 2 Adjustments from the Tier 1 Rotor Condition Index:

Tier 1 Rotor Condition Index __________

minus **Tier 2 Rotor Adjustments** __________ = ________________

Net Rotor Condition Index

Part C: Determine the Tier 2 Generator (Stator and Rotor) Condition Index

To determine the Net Generator (Stator and Rotor) Condition Index *(Value should be between 0 and 10)*, choose the lower of the Net Stator Condition Index and the Net Rotor Condition Index. Record the Data Quality Indicator associated with the chosen Condition Index:

Net Generator Condition Index _____________

Data Quality Indicator ______________

Evaluator: __________________________ Technical Review: __________________________

Management Review: _________________ Copies to: _________________________________

(Attach supporting documentation.)

EXAMPLE

GENERATOR
TIER 1 CONDITION ASSESSMENT SUMMARY

Date: 6-25-03 **Location:** Yellowtail Powerplant

Gen. Identifier: Unit **Gen. Manufacturer:** Westinghouse **Yr. Mfd.:** 1965

Stator Winding Manufacturer: National Electric Coil **Yr. Winding Installed:** 1983

Stator Insulation Type: Epoxilated Resin **MVA:** 65,789 kVA **Voltage:** 13.8 kV

Part A: Calculate the Tier 1 Stator Condition Index

Tier 1 Generator Stator Condition Summary
(For instructions on indicator scoring, please refer to condition assessment guide)

No.	Condition Indicator	Score ×	Weighting Factor =	Total Score
1	O & M History *(Score must be 0, 1, 2, or 3)*	2	1.18	2.36
2	Physical Inspection *(Score must be 0, 1, 2, or 3)*	3	1.18	3.54
3	Insulation Resistance and Polarization Index *(Score must be 0, 1, 2, or 3)*	2	0.58	1.16
4	Winding Age *(Score must be 0, 1, 2, or 3)*	2	0.39	0.78
	Tier 1 Stator Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*			7.84

Tier 1 Stator Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	7

Part B: Calculate the Tier 1 Rotor Condition Index

Tier 1 Generator Rotor Condition Summary
(For instructions on indicator scoring, please refer to condition assessment guide)

No.	Condition Indicator	Score ×	Weighting Factor =	Total Score
1	O & M History *(Score must be 0, 1, 2, or 3)*	3	1.18	3.54
2	Physical Inspection *(Score must be 0, 1, 2, or 3)*	3	1.18	3.54
3	Insulation Resistance and Polarization Index *(Score must be 0, 1, 2, or 3)*	3	0.58	1.74
4	Winding Age *(Score must be 0, 1, 2, or 3)*	3	0.39	1.17
	Tier 1 Rotor Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*			10.00

Tier 1 Rotor Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	4

Part C: Determine the Tier 1 Generator (Stator and Rotor) Condition Index

To determine the Tier 1 Generator (Stator and Rotor) Condition Index *(Value should be between 0 and 10)*, choose the lower of the Tier 1 Stator Condition Index and the Tier 1 Rotor Condition Index. Record the Data Quality Indicator associated with the chosen Condition Index:

Generator Condition Index _____7.84__________

Data Quality Indicator ______7__________

Evaluator: Armand Bird, Acting Electrical Foreman_ Technical Review: Tom Manni_________

Management Review: _________________ Copies to: _________________________________

(Attach supporting documentation.)

Supporting Documentation

Date: 6-25-03 **Location:** Yellowtail Powerplant

Gen. Identifier: Unit **Gen. Manufacturer:** Westinghouse **Yr. Mfd.:** 1965

Stator Winding Manufacturer: National Electric Coil **Yr. Winding Installed:** 1983

Stator Insulation Type: Epoxilated Resin **MVA:** 65,789 kVA **Voltage:** 13.8 kV

Unit 1 Stator was given a rating of 2 on O & M History for the following reasons: Yellowtail is a remotely-controlled peaking plant with frequent use of AGC, thus resulting in fast ramp rates, frequent rough zone crossings, and abnormally high numbers of starts and stops.

Records of quadrennial ramp tests indicate "snaking" which has been associated with possible delamination of the strands in the winding. The most recent ramp tests are acceptable and show no increasing signs of deterioration.

Coupling capacitors have been installed to monitor partial discharge, but results have been questioned on their value.

Insulation resistance or polarization index testing is not performed at Yellowtail, but D. C. Ramp testing is performed on a quadrennial schedule. The results of this test have indicated that no substantial increase in leakage is occurring. The resulting score of 2 is because the testing was not performed, but no abnormal results would be anticipated.

Winding age was rated at 2 because the winding is on the border line between 20 and 30 years. Also, with the rapid ramp rates and abnormal starts and stops the winding is being subjected to thermal stresses undetectable by inspection or test.