EPRI Generator R&D – Part II

Highlights of Generator Research Projects from 2019 - 2023, including 2024 planned projects and proposed 2025 research.

Bill Moore, P.E.
Sr. Technical Executive, EPRI

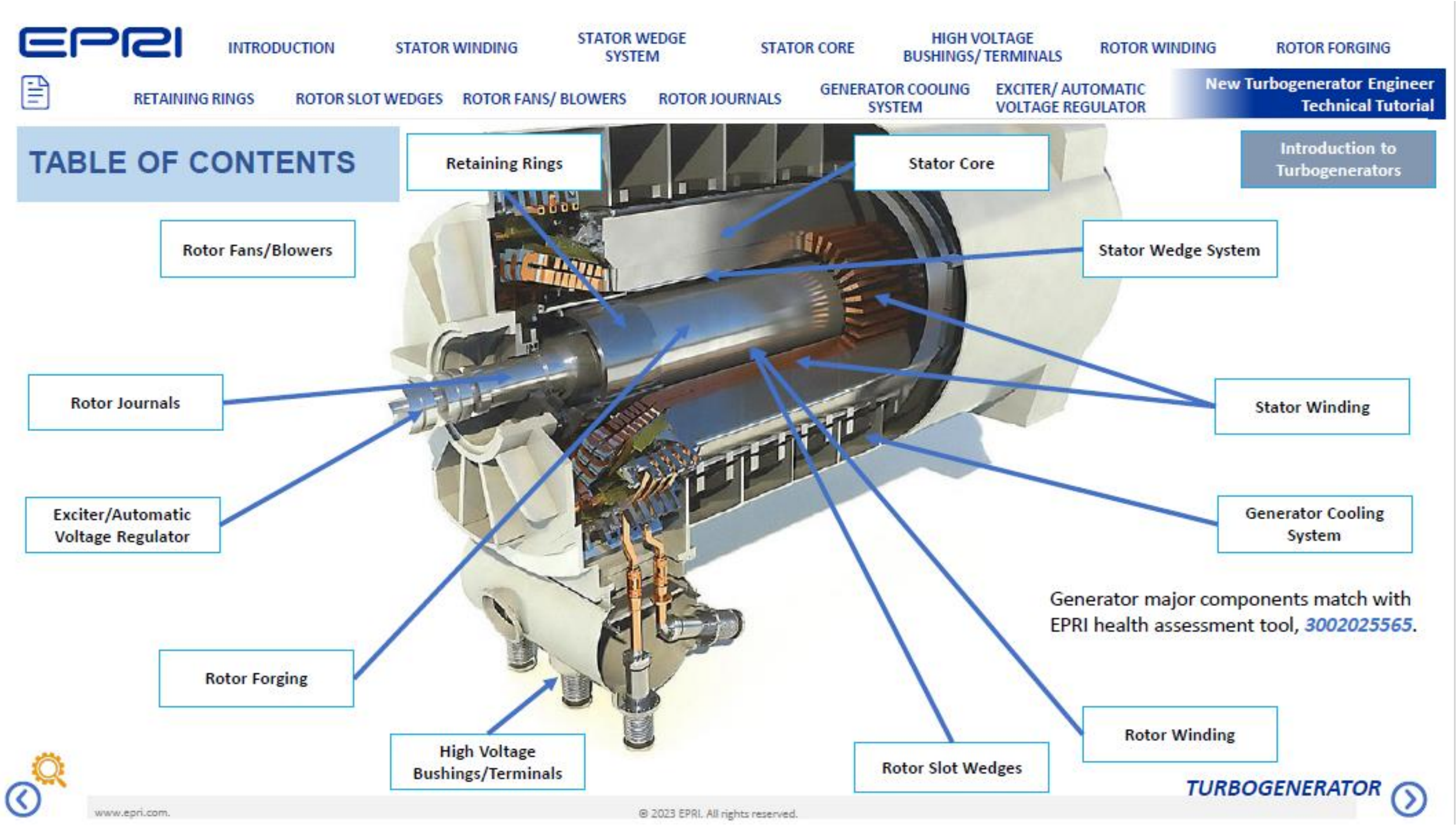
IRMC
June, 2024

www.epri.com

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Agenda

- Company Background
- EPRI Research – How to Get It
- Brief Highlights of 2019 IRMC Presentation
- R&D Completed 2020-2023, in progress for 2024 and plans for 2025



© 2024 Electric Power Research Institute, Inc. All rights reserved.

Company Background – Unique History

EPRI Company Background

- EPRI has about 450 members around the globe in approximately 30 countries.
- International Members make up nearly 30% of EPRI's total funding.
- In the U.S. EPRI members generated about 90% of the total electricity produced.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

EPRI is perhaps, best known for….

COLLABORATION

EPRI has a collaborative approach. The R&D:

- Leverages member research dollars
- Connects members to global network of peers
- Assists in accelerating deployment of technology
- Helps to mitigate the risk/uncertainty of “going it alone”

INDEPENDENCE/OBJECTIVITY

EPRI’s independent research is guided by our mission to benefit the public. We offer:

- Objective solutions
- A proven track record
- Scientifically based research that can be trusted

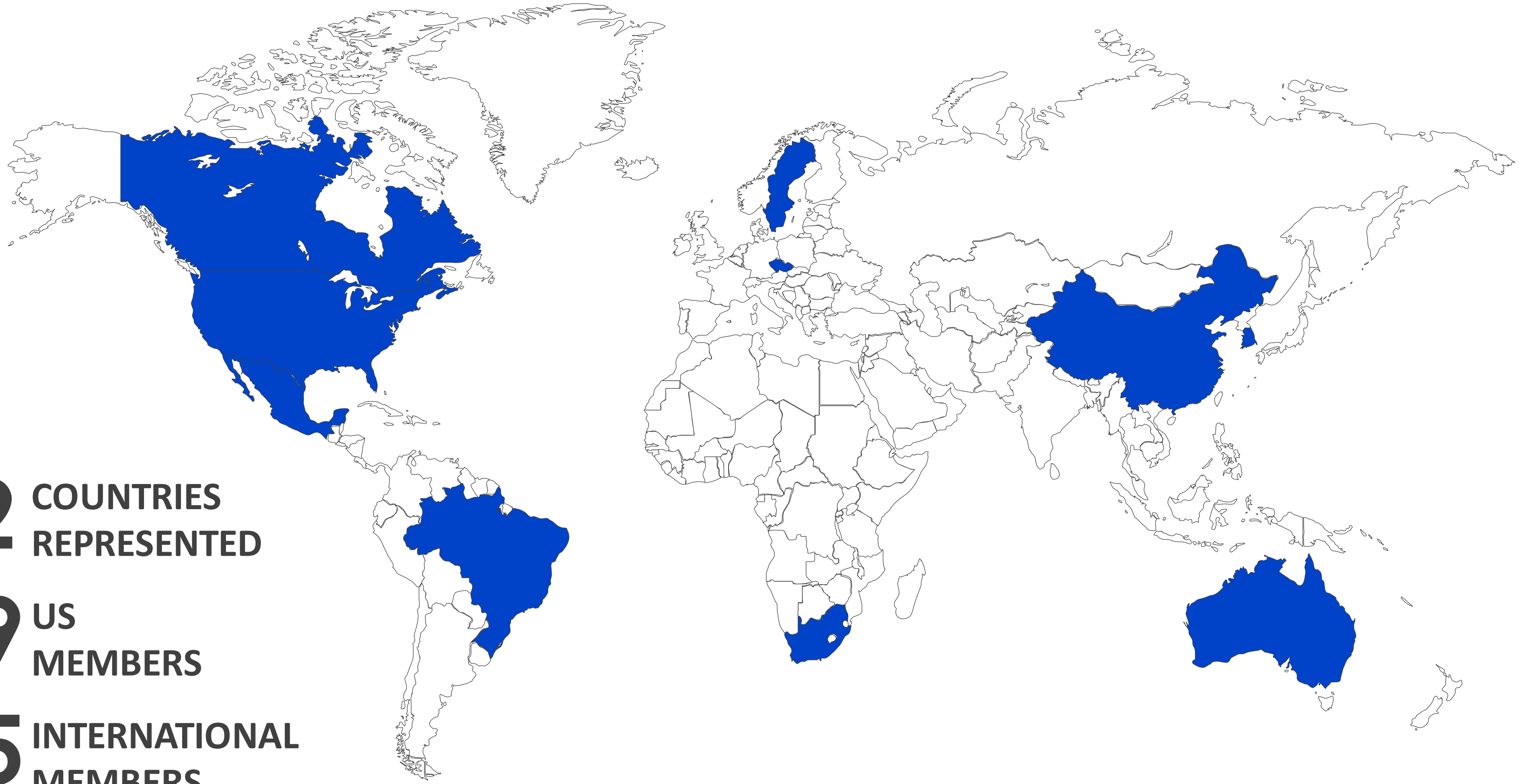
EXPERTISE

For more than 50 years, EPRI has been applying R&D to help solve real challenges. With EPRI, our members can:

- Reduce expenses and increase productivity
- Be more resilient today and better prepared for tomorrow
- Access an industry repository of collective experiences, technical expertise, and training resources
- Extend member staff and make member teams more robust and more confident
- Benchmark, learn and share best practices
- Increase awareness of challenges that others are facing and possible alternate solutions to challenges our members may be facing
- Save time and money troubleshooting problems EPRI and its stakeholders have seen before

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Generator & Auxiliary Systems Program 220 Membership



12 COUNTRIES REPRESENTED

29 US MEMBERS

25 INTERNATIONAL MEMBERS

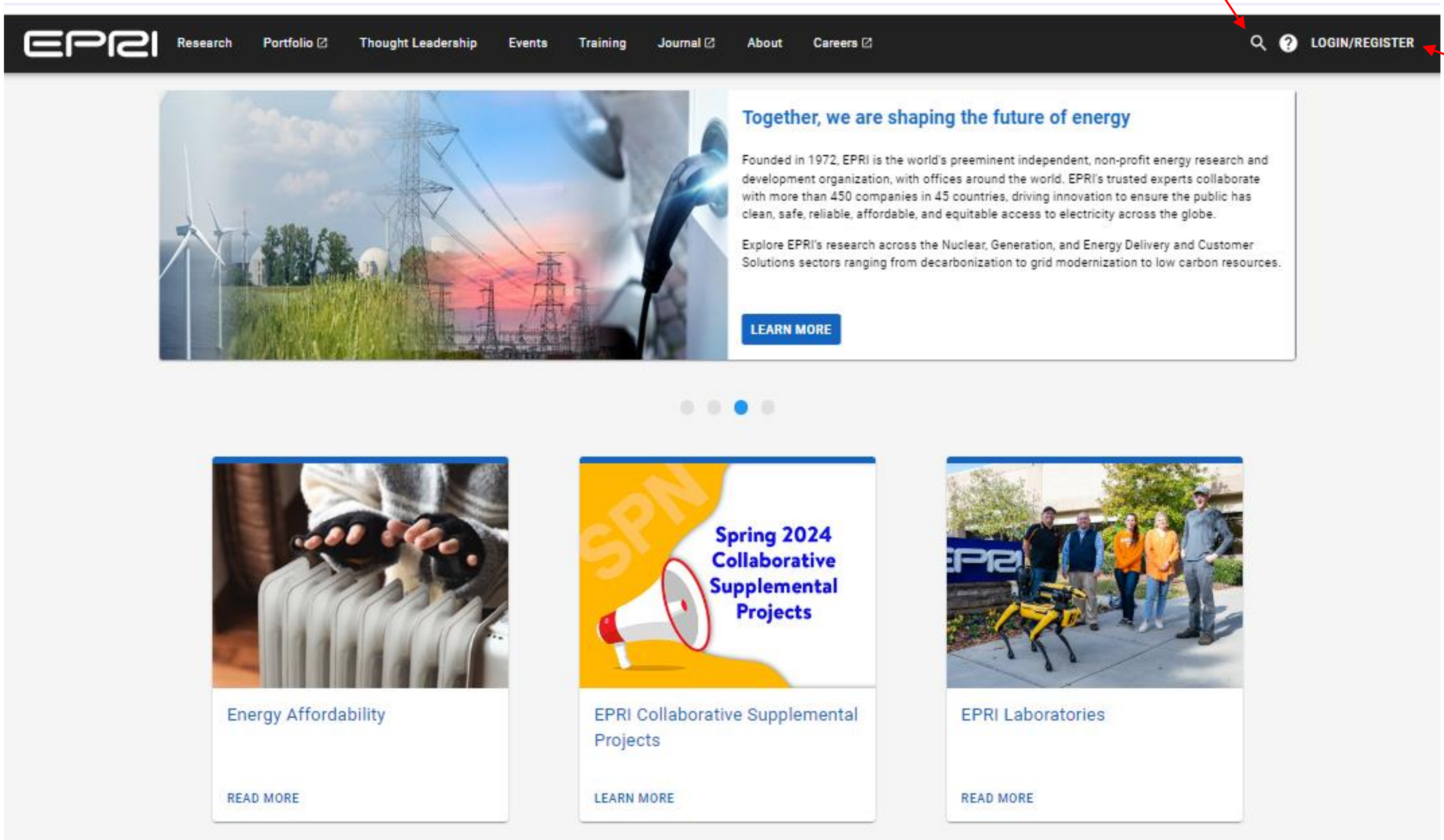
54 TOTAL US AND INTERNATIONAL PARTICIPANTS

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Research Information – How to Get it

EPRI Website www.epri.com

Use the search icon for locating any EPRI report. Some research is available to public and can be immediately downloaded from here.

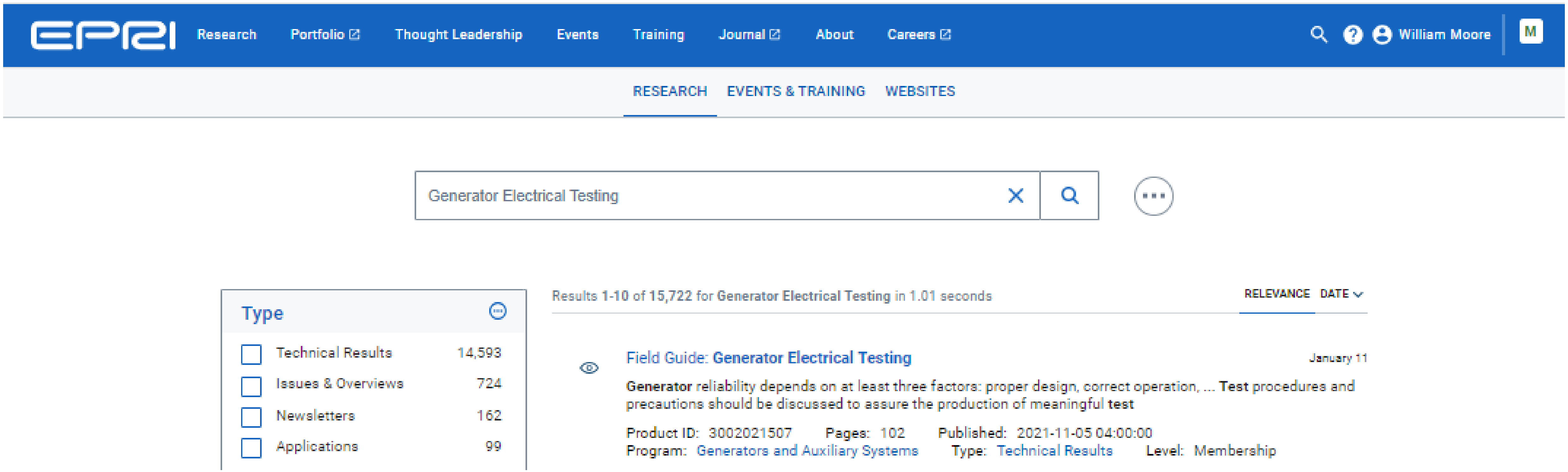


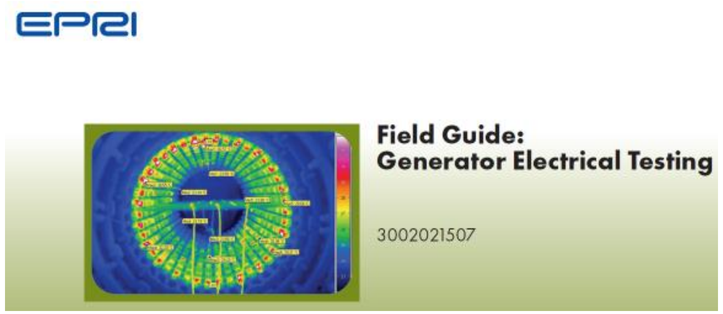
EPRI Members can login and immediately download needed research.

If a member signs on the top bar turns blue.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

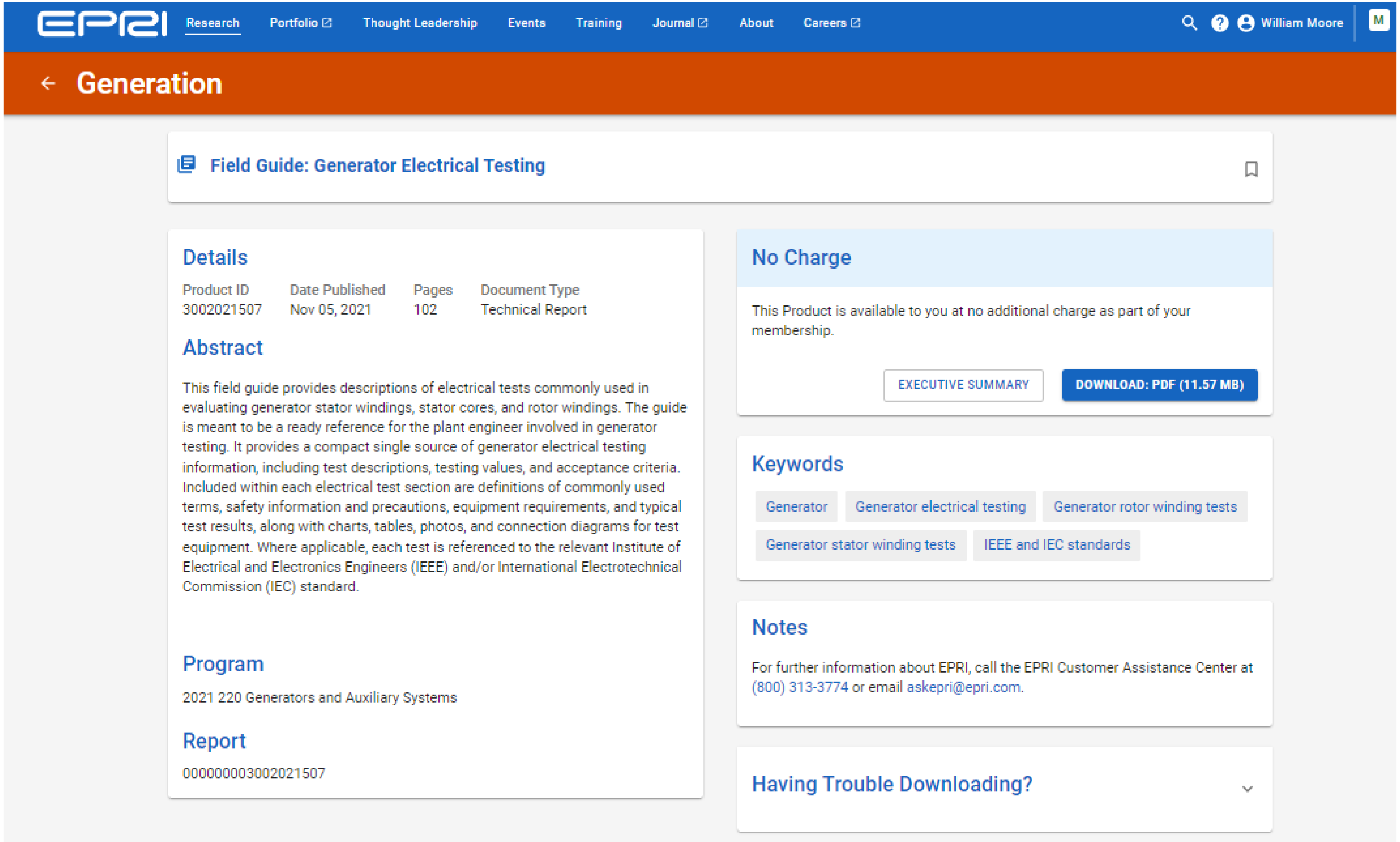
Example of Research to Download





© 2024 Electric Power Research Institute, Inc. All rights reserved.

EPRI Member Research



© 2024 Electric Power Research Institute, Inc. All rights reserved.

Generator Research Available for <u>Non-Members</u>

- 1009855 Core Overheating Risk (2006)
- 1007441 Repair & Test Guide (2002) Free!
- 1004951 Optimized Maintenance of Generator Rotors
- 106640 Retain Ring Failure at Comanche (1996)
- 1025335 Generator Fan/Blower Design/Inspect/Maintenance
- GS-6936 Surge Protection of Generators (1990)
- 1012216 On-line Monitoring & Cond Assess (2006)
- 1008351 Effects of Flexible Ops on Generators (2004)
- 1022588 Motoring of a Synchronous Generator (2011)
- 1020233 Digital Fault Recorders (2010)
- 1004556 Tools for Exciter, VR, Field Ground (2002)
- 3002002902 Converting to a Synchronous Condenser (2014)
- 3002018611 Shaft Voltage Monitoring Guide (2020)

These reports are publicly available and are downloadable at www.epri.com

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Quick EPRI Generator Research Reference List

EPRI Program 220 Reference List
Generator & Auxiliary Systems

Generator Fundamentals (especially for New Engineers)
- 3002030027 Turbogenerator Tutorial Part 2 (2024)
- 3002027376 Turbogenerator Tutorial Part 1(2023)
- 3002021507 Field guide: Gen Electrical Testing (2021)
- 1023848 Field guide: Visual Inspection of Gen (2012)
- EL-5036-V1 Electric Generators Volume 1 – (1988)

Stator Core, Frame and Foundation
- 3002024052 Stator Core Insp, Test, Repair and Replace (2022)
- 3002025432 Monitoring Back of Core Arcing (2022)
- 1009855 Core Overheating Risk (2006) Free!
- 1008378 Stator Core Assessment (2203)

Stator Winding and Support
- 3002027372 Generator Stator Flex Connection (2023)
- 3002027374 Generator Stator Main Lead (2023)
- 3002018610 Best Practices for Stator Rewinds (2021)
- 3002018669 Stator Wedge Tightness Test Guide (2020)
- 3002016240 Stator Endwinding Bump Test (2019)
- 1021774 Stator Winding Vibration Tutorial (2011)
- 1014909 Stator Winding Coil Insulation Repair (2008)
- 1014908 Stator Winding Hipot Testing (2008)

Stator Water Cooling
- 3002021515 Chemical Cleaning (2022)
- 3002019747 SCWS Chemistry Sourcebook (2021)
- 3002016241 Layup Guide for the SCWS (2019)
- 3002000420 TG Guidelines Volume 4 – SCWS (2013)

Bushings
- 1016787 Bushing Installation and Maintenance Guide (2008)

Generator Monitoring
- 3002024097 Rotor Ground Detection – Online (2022)
- 3002018611 Shaft Voltage Monitoring Guide (2020)
- 3002014447 Continuous On-Line Monitoring (COLM) (2020)
- 1012216 On-line Monitoring & Cond Assess (2006) Free!

Generator NDE
- 3002027378 Generator NDE Field Guide (2023)

Generator Flexibility
- 3002021520 Gen Flex Ops – Comprehensive Report (2021)
- 3002021533 Nuclear Generator Flexible Operation (2021)
- 3002013652 Outage Intervals for Gen in Flex Ops (2018)
- 1008351 Effects of Flexible Ops on Generators (2004) Free!

Failures Modes, FMEAs
- 3002016225 Generator Sensor Gap Analysis (2019)
- 3002013631 Gen FMEA with Sensor Identification (2018)
- 3002007010 Decisions after Abnormal Operation (2016)
- 3002000441 Combined Cycle Gen Failures (2013)
- 1022588 Motoring of a Syn Generator (2011) Free!

Exciters, Bearings, Collector Assemblies and AVR's
- 3002027375 Generator Collector System Guide (2023)
- 3002021510 Exciter Maintenance Guide (2021)
- 1026566 Field Guide: Bearing Damage Mechanisms (2012)
- 1024804 Synchronous Gen Voltage Reg Basics (2012)
- 1021775 Excitation – Volume 7 (2011)
- 1020233 Digital Fault Recorders (2010) Free!
- 1004556 Tools for Exciter, VR, Field Ground (2002) Free!

Auxiliary Systems including Hydrogen, Seal Oil, Water Cooling
- 3002030034 SF6 on Generator Material (2024)
- 3002024096 Instrument Transformers (2023)
- 3002024120 Generator Hydrogen Best Practices (2022)

Email bgmoore@epri.com for active download file.

This one page-list on this slide and the next slide identifies close to 100 research reports, maintenance guides, training tutorials, failure mode spreadsheets.

Research is segregated by topic (major components, testing, etc.)

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Quick EPRI Generator Research Reference List

Rotor Winding
- 3002013649 Brazing Best Practices (2018)
- 3002013650 On-line Detection of Rotor Arcing (2018)
- 3002004969 Best Practice Generator Rotor Rewinds (2015)
- 3002008541 Rotor Arcing: Theory & Simulation (2016)
- 1004951 Optimized Maintenance of Gen Rotors – Free!

Rotor Shaft
- 1011679 – Torsional Vib Interact with the Grid (2005) Free!

Rotor Retaining Rings
- 3002013650 On-line Detection of Rotor Arcing (2018)
- 3002006238 Damage to Generator Retaining Rings (2015)
- 3002003589 Inspection of 18.18 Generator Ret Rings (2014)
- 1007001 RR Cracking at Port Washing Unit 1 (2002)
- 106640 Retain Ring Failure at Comanche (1996) Free!

Rotor Fans/Blowers
- 1025335 Generator Fan/Blower Design/Inspect/Maintain Free!

Generator Health
- 3002025565 Generator Health Assessment Tool v1.3 (2022)
- 3002021506 Hydrogenerator Health Assessment Tool (2021)
- 3002013612 Generator Robotic Inspection & Test (2018)

Generator Protection
- 3002024098 Stator Ground Protection (2023)
- GS-6936 Surge Protection of Generators (1990) Free!

Generator Testing
- 3002024099 Rotor Ground Detection: Offline (2022)
- 3002021507 Generator Electrical Testing Field Guide (2021)
- 3002021509 Field Guide: EMI Hand-held Sniffer (2021)
- 3002018669 Stator Wedge Tightness Test Guide (2020)
- 3002016240 Stator Endwinding Bump Test (2019)
- 1025330 H2 System: Volume 3 (2012)
- 1023497 Current and Voltage Transformers (2011)

Bus Systems
- 3002000707 – Lessons Learned Bus Inspections (2013) Free!
- 1015057 – Bus Maintenance Guide (NMAC) (2007) Free!

Hydrogenerators
- 3002027379 Hydrogenerator Tutorial Part I (2023)
- 3002021506 Hydro Gen Health Assessment Tool (2022)
- 3002021540 Hydrogenerator Rewind Best Practices (2021)
- 3002019569 COLM Quick Guide Hydrogenerators (2020)
- 3002014639 Field Pole Attachment Cracking (2018)
- 3002011185 Flexible Operation of Hydropower Plants (2017)

Vibration
- 3002016244 ST & Gen Vibration Diagnostic Guide (2019)

EPRI Web-based Tools
- T-G Outage Guidelines https://turbgenoutageguide.epri.com/
- T-G Risk Mgmt Resource https://tgrisk.epri.com/
- Bearing Action Advisor https://bearingaction.epri.com/

Program 220 Home Link
- https://www.epri.com/research/programs/113174
- Visit the link above to find the P220 Generator Resource Navigator – A visual search tool by Generator Component

Note: Some of the older reports shown here are publicly available for free to non-members. Others are available only to members. Click on the live link or go to www.epri.com and enter the report number. ***Program 220 has over 200 "deliverables" on many topics. If you don't see what you are looking for here, go to www.epri.com and search under the topic you are interested in.***

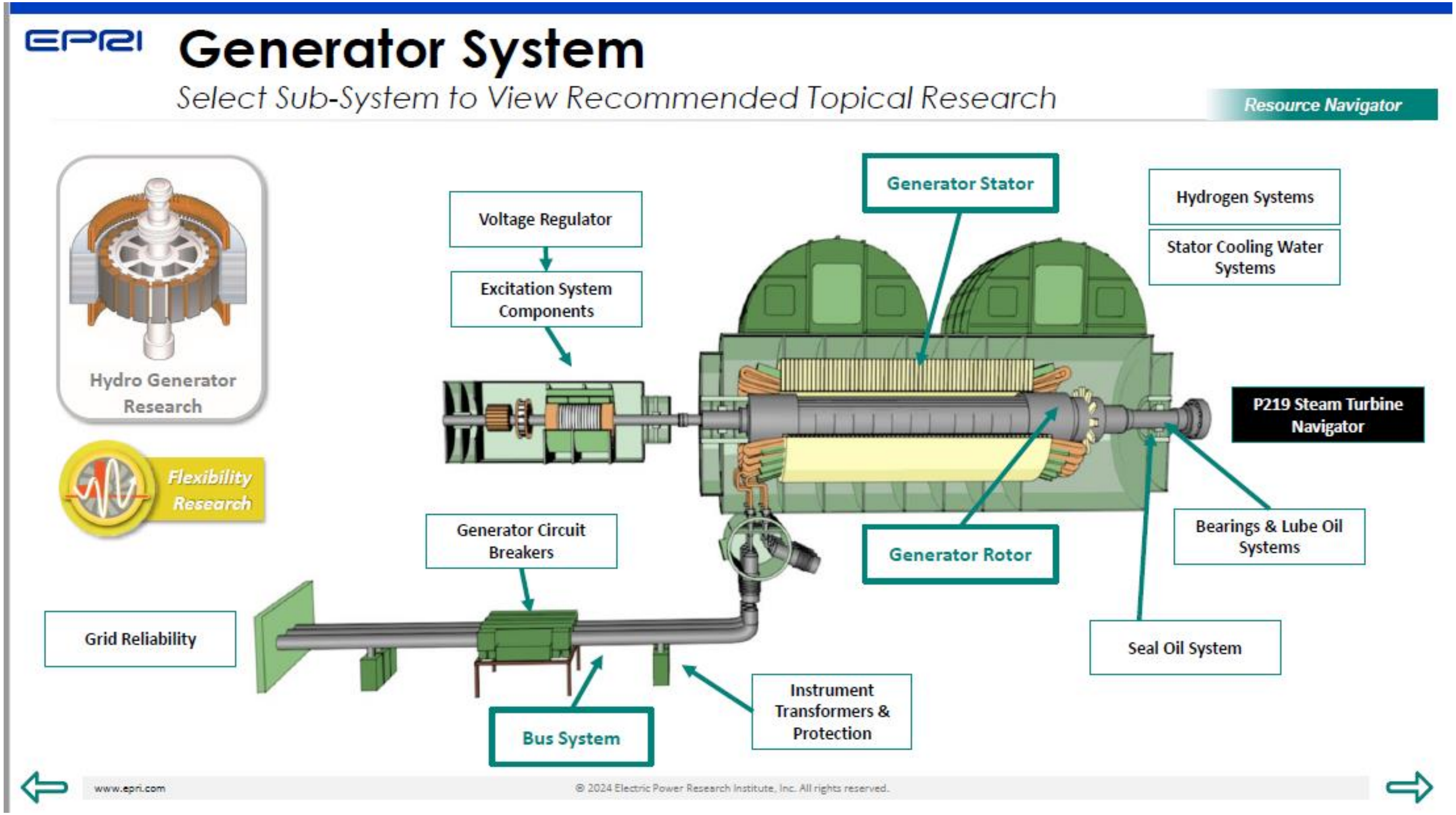
Email bgmoore@epri.com for active download file

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Another Way to Look for EPRI Research

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Generator Resource Navigator



© 2024 Electric Power Research Institute, Inc. All rights reserved.

Generator Resource Navigator

EPRI | Generator Rotor (Field) | Retaining Rings | Rotor Fans/ Blowers | Stator | Bearing & Lube / Seal Oil System | Generator Cooling Systems | Excitation Systems | Electrical Auxiliary Systems | Generator O&M | HYDRO

Sub-categories | Stator Winding | Stator Wedge System | Stator Core | High Voltage Bushings | Foundation | *Resource Navigator*

Stator

3002025565 Generator Health Assessment Tool (GHA) v1.3

3002016225 Generator Sensor Gap Analysis

3002013631 Generator FMEA with Sensor Detection Identification

3002014447 Continuous On-Line Monitoring (COLM): Generators

Recently Released:

3002027372 Generator Stator Flex Connection Technical Summary

3002027374 Generator Stator Main Lead Technical Summary

RISKS | INSPECTION | REPAIR

3002021507 Field Guide: Generator Electrical Testing

3002016240 Generator Stator Endwinding Bump Test Guide

3002014692 Theoretical Limits of Generator Stator End Winding Vibration – Analytical Basis: Part 2 Connection End with Phase Leads Between Coil Ends and Parallel Ring Conductors

3002011428 Interpretation of an Electromagnetic Signature Analysis Test (EMSA) Conducted as an Application of the EPRI Frequency Domain Model for Large Machines

1021773 Very Low Frequency (VLF) Hipot Testing of Rotating Machine Stator Winding Insulation

1000376 Testing of Stator Windings for Thermal Aging

1021774 Generator Stator Endwinding Vibration Guide: Tutorial

www.epri.com

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Email bgmoore@epri.com for active download file

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Turbine Generator Users Group Meetings

Summer TGUG sessions will be hybrid (virtual + in-person)

Denver, CO
Marriott Tech Center
August 12-16, 2024

Registration is Open

https://epri.app.box.com/folder/249409674114

Winter TGUG sessions will be in-person

Orlando, FL

January 13-17, 2024

Traditional 4.5 day agenda with workshop, OEM session, and user's group

Registration to open in October 2024

Interested in Presenting? Send title & name to bgmoore@epri.com

© 2024 Electric Power Research Institute, Inc. All rights reserved.

GMUG (Generator Monitoring User Group)

- Ad hoc group, once per month
- All invited (members, other utilities, OEMs, suppliers)
- Discuss Generator Monitoring
- Focus has been on EMI/EMSA but has and will include other topics
- Recognize industry "saves" where monitoring results prevent generator component failures
- Highlight diagnostic methods, charts and standards to enhance interpretation
- Presentations welcome

© 2024 Electric Power Research Institute, Inc. All rights reserved.

2024 Generator & Auxiliary Systems Webcast Schedule

	Topic	EPRI Lead	Date (10:00am EDT U.S. unless noted)
1	P220 International Advisory Meeting Broadcast	Prescott	February 21
2	Collector System Maintenance	Moore	March 7
3	Generator Nondestructive Examination	Moore	April 11
4	Main Lead and Flex Connections	Moore	May 2
5	P220 Webcast on 2025 Research Proposals	Prescott	June 6
6	Overspeed Testing Best Practices	Steele	**July 9**
7	Turbine Generator User Group Session Broadcasts		August 12-16
8	P220 International Advisory Meeting Broadcast	Prescott	September 25
9	Stator DC Leakage Testing	Moore	October 17
10	Generator Overhaul Benchmarking Survey Results	Moore	November 21

MEMBERS CAN VIEW ALL PAST PROGRAM RECORDINGS AND CONTENT HERE ➔
https://www.epri.com/research/programs/113174/events

© 2024 Electric Power Research Institute, Inc. All rights reserved.

2019 IRMC Presentation Highlights

2019 Agenda – EPRI Generator Research Program

- **Introductory Overview of EPRI**

- **Past Generator Reliability Issues and EPRI Value Added**
  – Rotor Dovetail Cracking TIL 1292
  – Stator Bar Water Leaks
  – Stator Endwinding Vibration
  – Retaining Ring Corrosion Cracking (18.5)

- **Present Generator Reliability Issues and Current EPRI Activity**
  – 2018 Projects Completed

- **Future Generator Issues**
  – 2019 Research in Progress

© 2024 Electric Power Research Institute, Inc. All rights reserved.

2020

Generator Stator Wedge Testing Guide - 3002018669

Industry Issue/Project Description

- Many stator wedge testing methods utilizing different wedge designs & varying acceptance criteria with no clear, comprehensive guidance. Goal was to provide an industry guide on recommended stator wedge tightness testing methods and acceptance criteria, covering all methods and designs.

Some Takeaways

- Survey indicated about half of respondents prefer manual testing and about half electronic
- Although 53% were satisfied with robotic wedge tightness testing, 12% were not satisfied and more had minor concerns (18% said results were inaccurate)
- 63% of EPRI survey respondents indicated that a full rewedge should be done when between 20 to 30% of wedges are found to be loose. The same survey indicated that end wedge looseness is an important finding, and often is a driver for a partial rewedge.

Figure 6. Wedge tap test for tightness

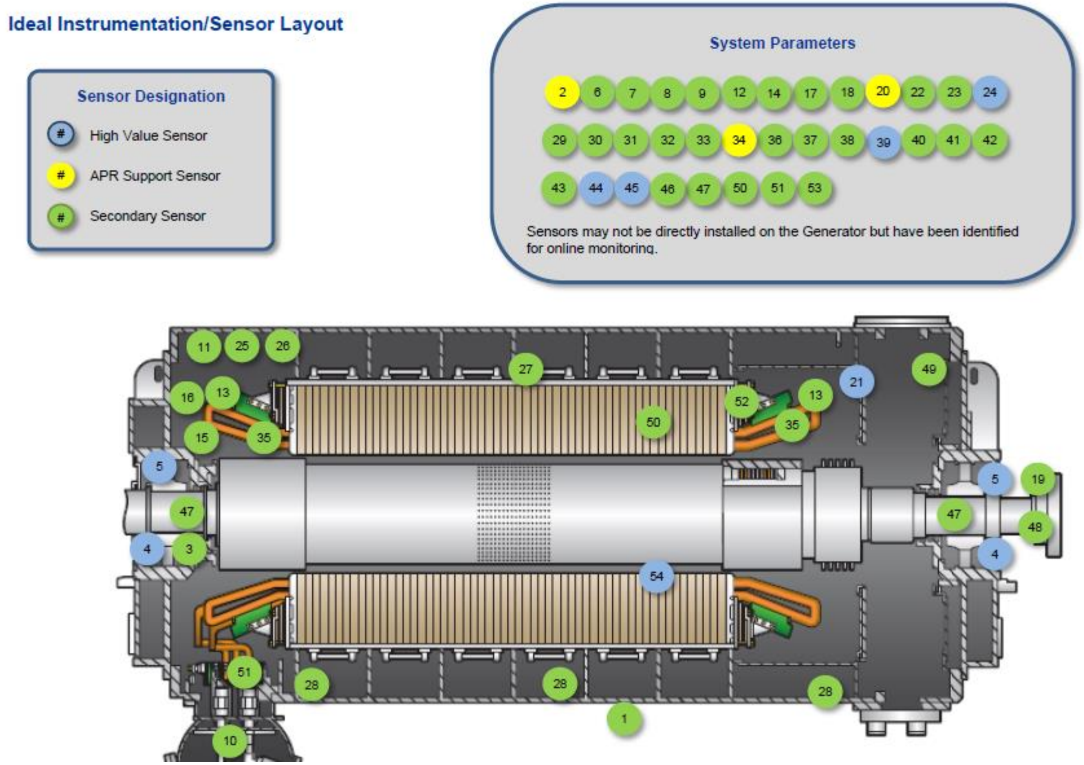
Table 1. Stator wedge test criteria and recommended action

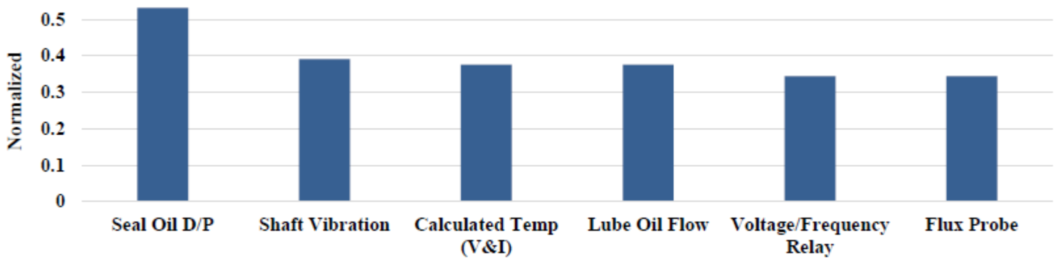
Finding	Wedges Adjacent?	Slot or End Wedge?	No Action	Replace Affected Wedges	Re A
One wedge tested loose	No	Either	X		
Two wedges tested loose	No	Either	X		
Two wedges in one slot tested loose	Yes	Slot	X		
Two wedges in one slot tested loose	Yes	End		X	
Three or more wedges in one slot tested loose	No	Slot	X		
Three or more wedges in one slot tested loose	Yes	Either		X	
Less than 20% wedges tested loose overall with no	No	Either	X		

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Turbogenerator COLM Quick Guide - 3002014447

- COLM (Continuous Online Monitoring Guide) for turbo generators
- Prioritizes sensor applications for air-cooled, hydrogen-cooled and water-cooled generators
- Good, first read document when deciding what generator monitoring you may need.





© 2024 Electric Power Research Institute, Inc. All rights reserved.

Hydrogenerator COLM Quick Guide - 3002019569

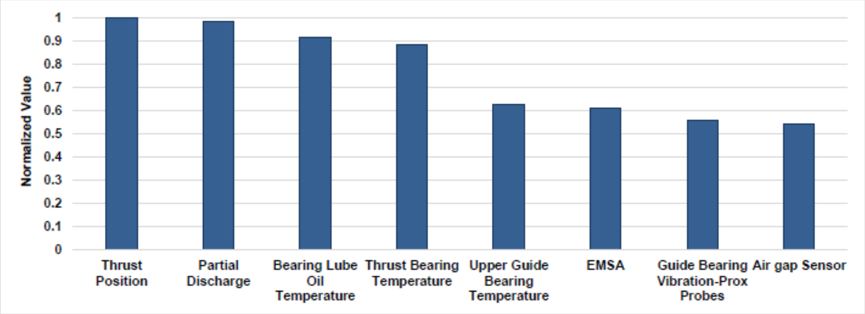
- COLM (Continuous Online Monitoring Guide) for hydro generators

- Prioritizes sensor applications for salient pole machines

- Good, first to read document when deciding what generator monitoring you may need.

Ideal Sensor Layout

Sensor No.	Sensor Technology	Sensor No.	Sensor Technology	Sensor No.	Sensor Technology
1	Air gap sensor	14	Cooling water flow	27	Temperature sensors (winding, air)
2	APR – excitation current	15	Thrust bearing vibration – proximity probes	28	Thermography
3	APR – instrumentation	16	Creep indicator	29	Thrust bearing temperature
4	APR – pressure thrust position	17	Electromagnetic signature analysis (EMSA)	30	Thrust position
5	APR – V, I, MVAR, winding temperature	18	Flux probe	31	Upper guide bearing temperature
6	Bearing lube oil pressure transmitter	19	Foundation vibration – proximity probes	32	Upper guide bearing vibration – proximity probes
7	Bearing lube oil temperature	20	Guide bearing vibration – proximity probes	33	Vibration – end coil
8	Brake travel – proximity probe	21	HP lift supply pressure	34	Vibration stator frame – proximity probes
9	Brush monitor	22	Partial discharge analysis	35	Vibration upper/lower brackets – proximity probes
10	CLR inlet and outlet air temperature sensors	23	Pressure of air supply header	36	Vibration upper/lower brackets – proximity probes
11	CLR outlet pressure sensor	24	Proximity probe – radial growth	37	Ambient air temperature
12	Cooler differential pressure	25	Stator frame vibration – proximity probes		
13	APR – cooler performance monitoring – air inlet out temperature, water inlet outlet temperature, water flow or DP, P, VAR	26	Strainer differential transmitter		



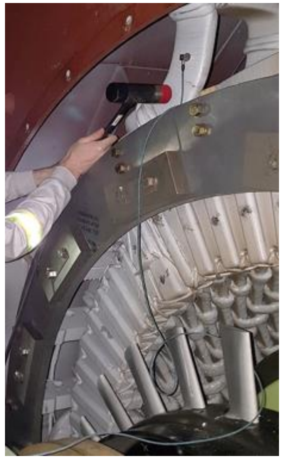
NOTES

Normalized value is determined from the quantity of degradation influences detected in the PMBD and the detectability (high/medium/low) for each of them.

© 2024 Electric Power Research Institute, Inc. All rights reserved.
EPRI

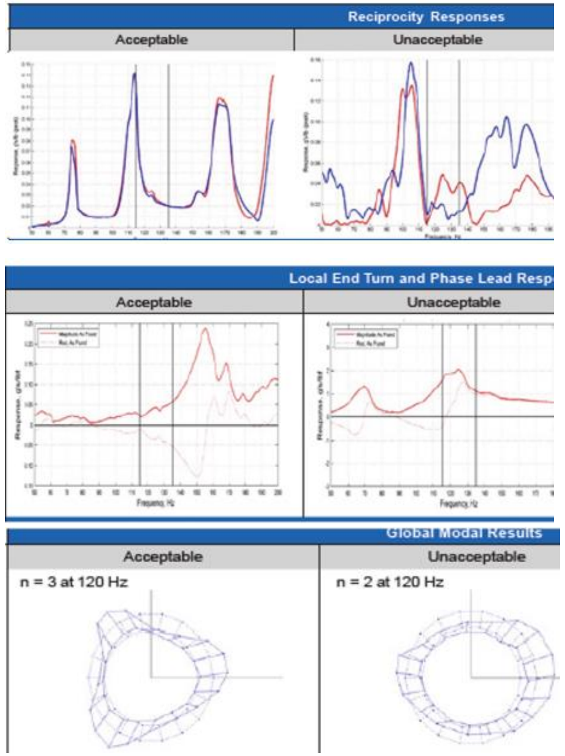
Stator End Winding Bump Test Guide

#3002016240



Industry Issue/Project Description

- Bump Testing is becoming a common maintenance test to identify susceptibility to high vibration with the stator endwinding and phase leads, but different manufacturers have different test methods, different acceptance criteria, and different corrective action approaches. Goal was to develop a clear guide to describe proper method of performing a bump test, identify appropriate acceptance criteria and offer guidance on interpretation and corrective action approaches.



Some Takeaways

- Three Parts of Bump Test
  - Reciprocity test
  - Individual coil response
  - Modal Analysis
- Guide clearly identifies acceptance criteria
- Repair approaches and tuning included

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Stator Cooling Water System Layup Guide

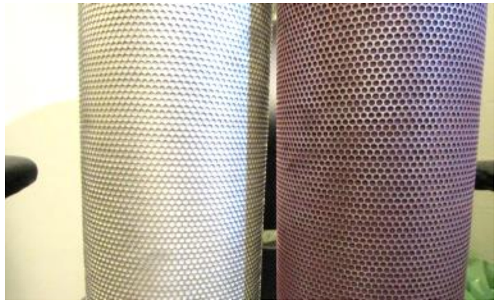
#3002016241

Industry Issue/Project Description

- Improper layup of the generator SCWS is a key factor in oxide plugging of the stator bar copper hollow conductors, filters and strainers causing load reduction, runback, chemical cleaning costs, and shut down events. Goal was to provide most current guidance for proper short-term & long- term layup and communicate the consequences if proper layup approach is not followed.

Some Takeaways

- Shut down 4 days or more, drain & blow dry
- Some members would only gravity drain – does not work. Others would run water circulation pumps once every 24 hours. Had water chemistry problems coming back from outage.
- 17% of members surveyed had water left in stagnant longer than 4 days.



EPRI RESOURCES

Bill Moore, *Technical Executive*
704.595.2584, bgmoore@epri.com

EPRI thanks the following contributors and advisors, who reviewed the report and provided feedback:

P. Breaker	New Brunswick Power Corporation
L. Chetwynd	SvoBaTech
R. Chetwynd	National Electric Coil
V. Fernagut	Électricité de France
D. Fischli	Duke Energy
R. Jones	Duke Energy
K. Liao	Ontario Power Generation
R. Moyers	Tennessee Valley Authority
M. Mura	EPRI
K. O'Dowd	Exelon Corporation
M. Norman	Tennessee Valley Authority
M. Parker	Tennessee Valley Authority
B. Ritchie	Luminant
M. Saul	Exelon Corporation
J. Schooley	Southern Nuclear Operating Company
R. Schooley	Southern Nuclear Operating Company
S. Shulder	EPRI
S. Simon	Institute of Nuclear Power Operations
G. Yeboah	American Electric Power
J. Wieters	Electric Power Research Institute
D. Withers	Arizona Public Service
D. Yager	SaskPower

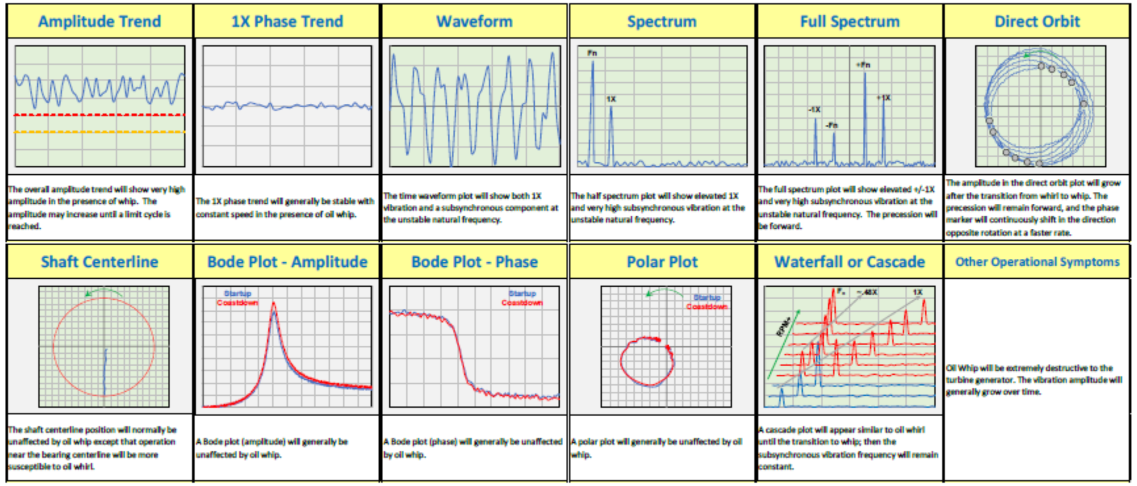
© 2024 Electric Power Research Institute, Inc. All rights reserved.

ST & Gen Bearing Vibration Diagnostic

#3002016244

Oil Whip

Oil Whirl will transition to Oil Whip when the whirl frequency reaches the first natural frequency. The subsynchronous vibration will lock onto the unstable natural frequency and will not continue to increase with the rotor speed. The subsynchronous vibration will increase and can be damaging.



Key Diagnostic Indicators

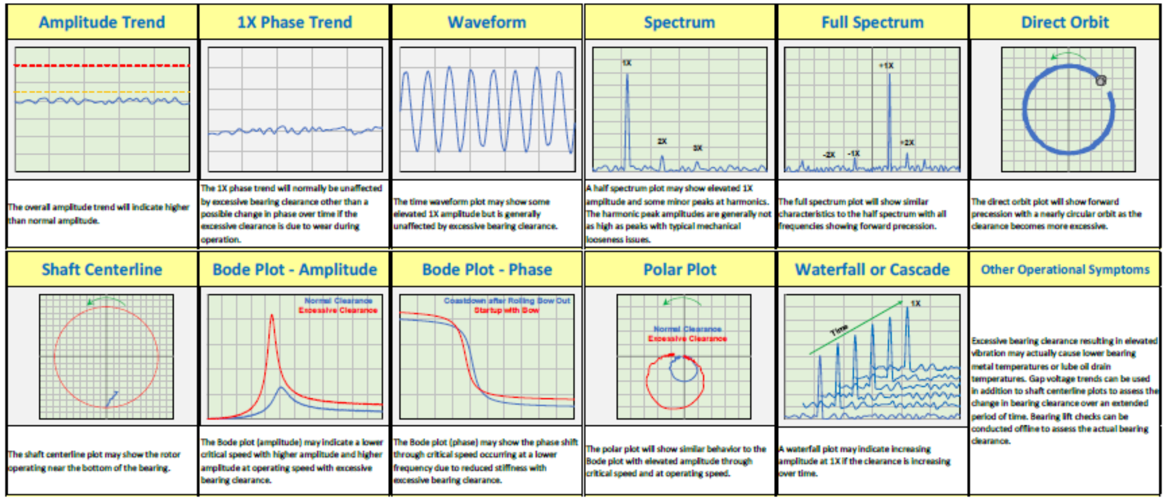
- Subsynchronous vibration at the first forward, damped natural frequency of the rotor bearing system
- Varying amplitude of the subsynchronous vibration
- Sensitivity to bearing oil supply temperature

Potential Causes

- Inadequate rotor-bearing system design (low damping)
- Excessive bearing clearance
- Operating >2 times an unstable natural frequency prone to oil whirl

Excessive Bearing Clearance

Excessive bearing clearance may be caused by design or maintenance issues. Other causes could be a loss of Babbitt material on the bearing liner or pads. This can increase the vibration amplitude if the clearance is due to wear during operation from the change in the bearing stiffness and damping coefficients.



Key Diagnostic Indicators

- Excessive 1X amplitude
- Shaft operating near the bottom of the bearing in the shaft centerline plot that decreases as the clearance increases
- Lower than expected critical speed

Potential Causes

- Bearing design, manufacturing, or setup deficiencies
- Excessive bearing wear due to oil contamination, ESD or overloading

Quick Guide includes diagnostic evaluations for 18 different operational conditions. Two are shown above.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Generator FMEA & Sensor "Gap Analysis"

#3002016225 & 3002013631

Industry Issue/Project Description

- There are generator failure modes still undetectable while unit is in operation, or not monitored on your generator. Goal was to develop Failure Modes & Effects Excel Spreadsheet downloadable to members giving the system generator engineer the ability to customize and identify top impact failure modes based on existing unit monitoring.

Some Takeaways

- FMEA excel spreadsheet that identifies the TRL (Technical Readiness Level) of specific monitoring sensor applications. A risk priority number can be calculated for a specific generator issue.

	Generator Type	Failure Location	SEV	Cause	PROB	Remedy	Monitoring Technology	TRL	Monitoring Technology Classificati	DET for FM, Effect, Caus	Sensor	Sensor Location	Exam	Exam Result	DET	RPN
2	Common	Stator Winding				Confirmation of the ground fault is required by isolating the stator winding from the system and performing an	Temperature	10	OLC	Effect	Thermocouple	Coil Water Inlet & Outlet	Sum Stator Winding Temperature High	Increase		
3	Common	Stator Winding		Conductor Bar Temperature High	10	If using a core monitor, validate the alarm and reduce load immediately until all stator winding temperature alarms are cleared. Verify the presence of this condition and record all pertinent load and temperature data for analysis and correction of the problem.	Inspection	10	OFL	FM Effect	Visual	Stator Winding	Visual examination to identify dusting (particles) from insulation and/or discoloration due to overheating; look for signs of greasing caused by dusting plus oil mixed with particles	Abnormal		
4	Common	Stator Winding	9	Stator Terminal	6		Pyrolysis Evaluation	10	OLC	Effect	Core Monitor	Ion chamber	Generator Condition (Core Monitor)	Abnormal	2	108
6	Common	Stator Winding		Machine specification/design margin, manufacturing	5	Limit the incident of switching surges to winding, if possible. In poorly made windings the initial high partial discharge may be an indicator of poor resin impregnation. In rewinds specify dedicated turn insulation if the failed winding did not have such insulation.	Electromagnetic Signature Analysis	9	OLR	Cause	Current Transformer	Generator Neutral	Turn-to-turn electrical surges	Abnormal		
7	Common	Stator Winding					Temperature	10	OLC	Cause	RTD	Embedded in stator slots	Sum any bar temperature above normal	Increase		
8	Common	Stator Winding		Turn-to-Turn Electrical Surges	3		Temperature	10	OLC	Cause	RTD or Thermocouple	Stator terminal	Any terminal temperature above normal	Increase		
9	Air-Cooled	Stator Winding					Temperature	10	OLC	Cause	RTD or Thermocouple	H2 Hot Gas	Hydrogen Hot Gas Discharge Temperature Increase	Increase		

© 2024 Electric Power Research Institute, Inc. All rights reserved.
EPRI

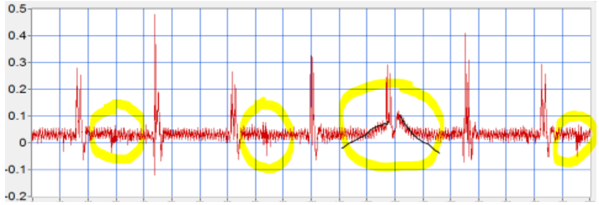
Shaft Voltage Monitoring Quick Guide #3002018611

Industry Issue/Project Description

- Newer Shaft Voltage Monitoring equipment installed with more and more data results, but a guide offering interpretation of those signal results not available. Objective to capture experience from Owners & Key Contractors and Develop “Malady Plot” for reference that identifies frequencies, patterns, action levels, and associated reliability issues.

Some Takeaways

- 100% of respondents check shaft voltage levels. Weekly checks are done by 45% of respondents, whereas 27% check monthly and the rest check intermittently.
- Use of carbon brushes, braided rope, and copper straps are divided almost equally.
- 64% of respondents reported bearing damage traced back to issues with shaft grounding.
- Wide variety of shaft voltage alert levels.
  - 25% of respondents have alert levels (not to exceed) set at 10 V and 10 A.
  - 10% have alert levels at 6 V and 1 A.
  - 20% have alert levels at 3 V
  - 10% have 1 V as an “ investigation level.”
  - The rest of respondents did not have specific alert levels or were unsure of what they were.



EPRI RESOURCES

Bill Moore, *Technical Executive*
704.595.2584, bgmoore@epri.com

EPRI thanks the following contributors to this guide:

D. Agnew	New Brunswick Power
G. Carlin	Nova Scotia Power
A. Datillo	LG&E/KU
D. Fischli	Duke Energy
R. Ilie	Israel Electric
S. Purushothaman	FM Global
M. Sasic	IRIS Power
K. Smith	Duke Energy
E. Wheeler	National Grid
S. Xu	FM Global
D. Yager	SaskPower
G. Yeboah	American Electric Power
M. Young	SRP
R. Zulak	Exelon

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Use of SFRA* to Detect Rotor J-Strap Cracking - #3002019653

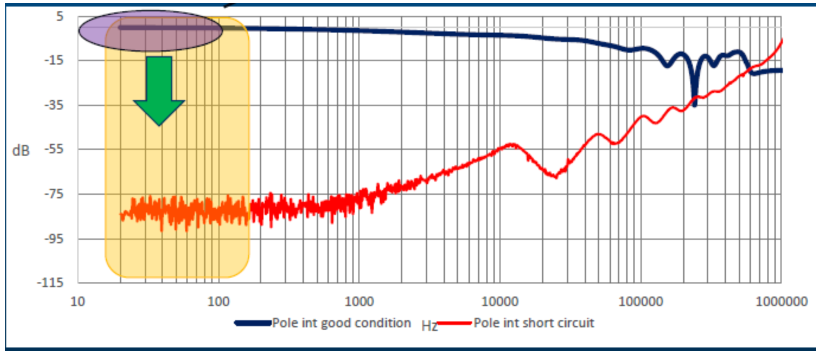
Industry Issue/Project Description

- Forced outages from J-Strap & Pole Crossover open circuits commonly occur. Goal to build on past SFRA experience developed on transformer testing and identify cracking of rotor conductors before open circuit. Simulate J-Strap cracking & repeated SFRA testing.

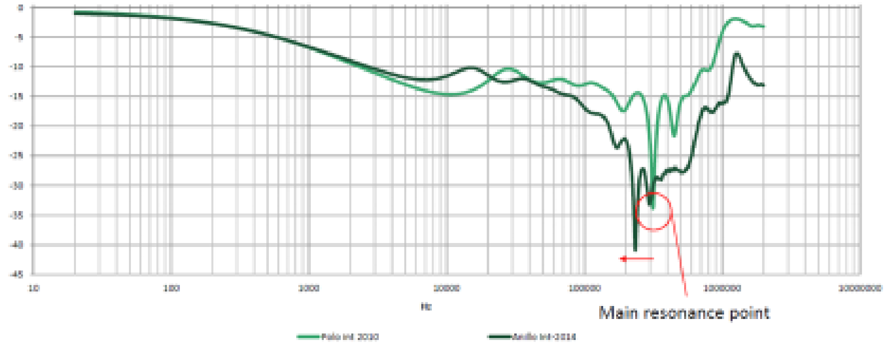
Some Takeaways

- Easy to identify rotor ground faults.
- Easy to identify shorted turns.
- More research needed on SFRA.

Cracked J-Strap above & Severed & Tested Below



Rotor Winding Ground – GMUG 2019 - CFE



Rotor Turn Short – GMUG 2018 - CFE

*SFRA – Sweep Frequency Response Analysis

© 2024 Electric Power Research Institute, Inc. All rights reserved.
EPRI

2021

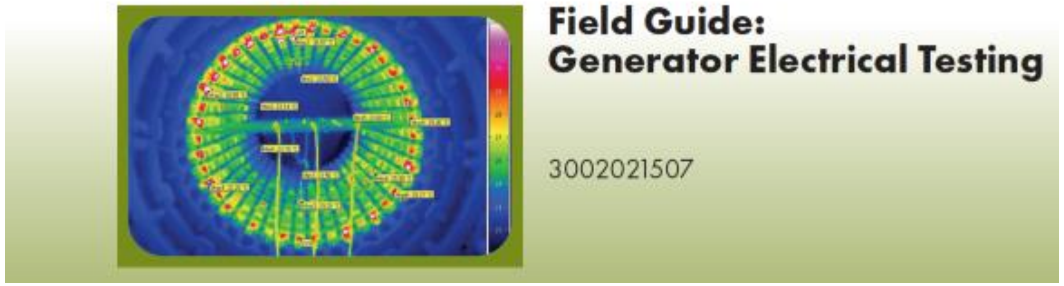
Field Guide for Generator Electrical Testing- #3002021507

Industry Issue/Project Description

- Generator Off-Line Testing is Complicated with Many Types of Tests, Different Voltage Levels, and Different Acceptance Criteria. Member Utility Engineers requested a handy reference guide.

Some Takeaways

- Thirty-One (31) of the most common generator electrical tests are described including test setup, connections, test values, acceptance criteria and IEEE/IEC standard reference.
- Key reference document to facilitate generator testing. Field Guide has all the necessary essentials in one place. IEEE and IEC references provided for deeper dive, if needed.



2.27 Rotor DC high potential Test

Background

The DC high potential test is an over-potential test. The voltage applied is substantially higher than the operating voltage and the expectation is that if the winding does not fail as a result of this test, it is not likely to fail soon after return to service, due to insulation aging. Rotor windings are more frequently tested using alternating voltage, but direct voltage test can be performed. Rotors of higher rated voltage (≥ 400 V dc) may have a silicon carbide coating inside the slot armor. This coating causes tracking problems when high DC voltages are applied, so the AC test is recommended.

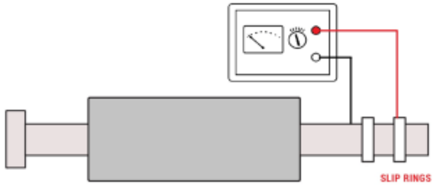


Figure 2.27-1 Rotor winding DC Hipot connection

Test Method

The DC voltage is applied between one slip ring and the rotor forging. Recommended test voltage is 1500 V dc for one minute. All safety precautions listed in Section 2.3 should be followed.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

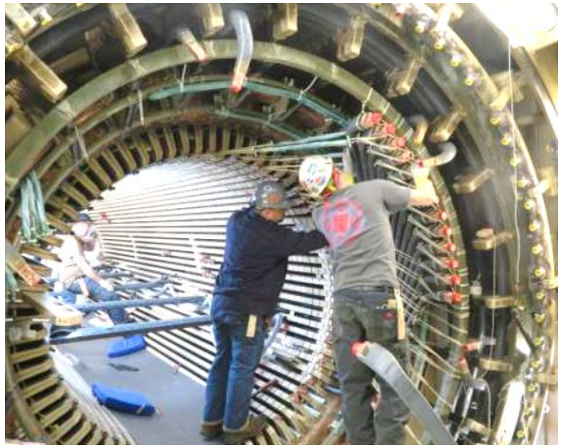
Best Practices for Generator Stator Rewinds #3002018610

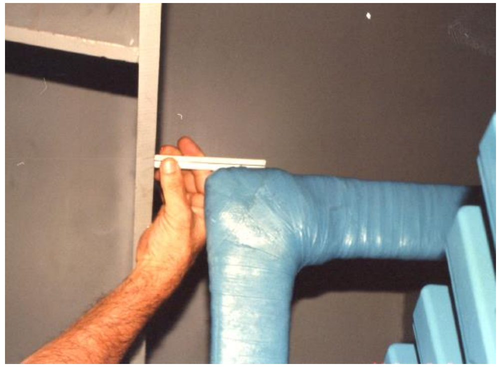
Industry Issue/Project Description

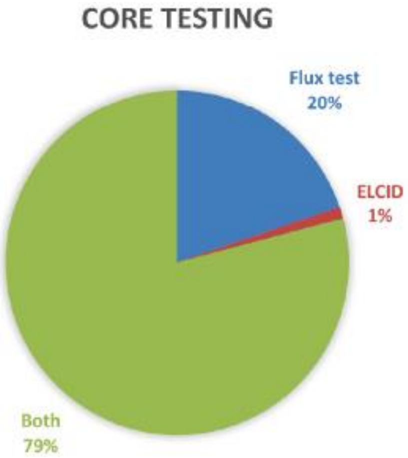
- Problems and issues can occur during generator rewinds. It's a complicated process, requiring skill and expertise. Included actions are to conduct worldwide survey of past rewind issues and experiences and gather collective industry expertise.
- Key issues discussed include 3rd Party Rewind Experience, Core Evaluation – Biggest Risk – Must know condition, Stator Bar Epoxy Impregnation, Voids, Test Results, Bars in Storage – How to Evaluate, PD Values After Rewind

Some Takeaways

- Description of best practices, from start to finish. Key document for everyone involved in a Generator Rewind.
- See top best and worst practices to right.







Rank	Focal Point	% Vote
1	Good specification	34
2	Internal/third-party oversight at factory and during rewind	25
3	Adequate testing throughout manufacturing process	17
4	Checking 100% of coils in dummy core before shipping	8
5	Final testing on site	8
6	Type testing of sample bars	8

- **Also include a list of absolute Worst Practices**
  - Not purchasing spare bars
  - Not settling technical exceptions before start of rewind
  - Not checking coil shape in mock stator core before shipment
  - Not enough oversight at different stages of manufacture & rewind
  - Many more

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Stator Water Cooling System Chemistry Sourcebook 3002019747

Industry Issue/Project Description

- Perceived "gaps" between plant chemists and generator SME in the area of SWCS and Water Chemistry. Goal was to provide a common document that bridged those gaps.

Some Takeaways

- Document bridges the knowledge gaps between Water Chemistry Experts and Generator Subject Matter Experts and provides the most up to date advice for Generator Stator Water Cooling Systems.
- Provides separate chapters for each type of SWCS, whether low DO, high DO, alkaline.
- Provides troubleshooting guide in each chapter.

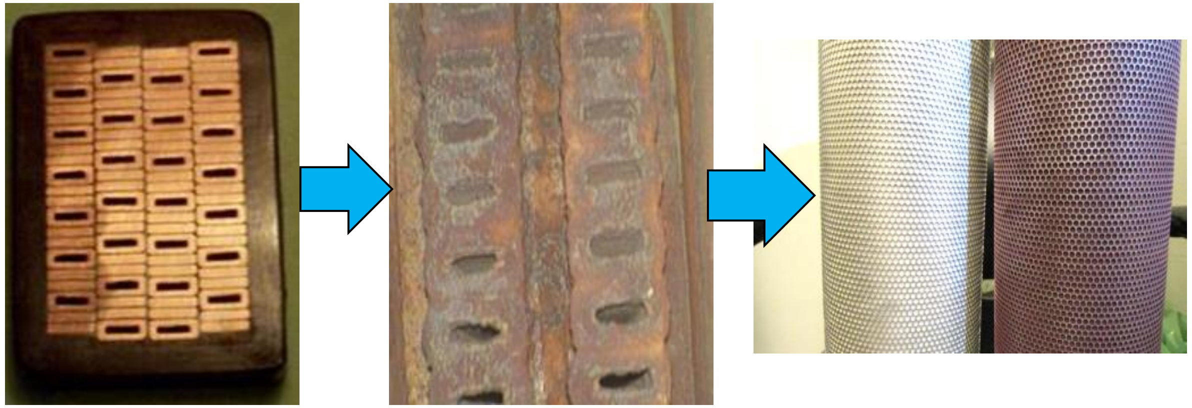


Table 3-4
General Troubleshooting Actions that Could be Taken to Address Non-Conforming Dissolved Oxygen Concentration in Low Dissolved Oxygen Stator Water Cooling System [3-1]

Action No.	Symptoms	Probable Causes	Short-Term Action	Long-Term Action
1	DO increases 10 ppb above normal	Air in-leakage	Increase cover gas pressure and/or flow Check cover gas purity Check system for possible locations for air in-leakage Swap pumps if pump leakage is suspected	Repair leaks Replace pump seals
2	DO increases to 50 ppb	Air in-leakage	Same as #1 Review inlet to outlet ΔT, coil to coil ΔT, and ΔP data for possible increases. Reduce loads if increases are observed. Schedule SWCS shutdown for repairs	Same as #1 Discuss with vendor to schedule inspection Clean SWCS Replace resin
		Air ingress following outage due to aerated		

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Field Guide: Detection of EMI Using a Handheld Sniffer - #3002021509

Industry Issue/Project Description

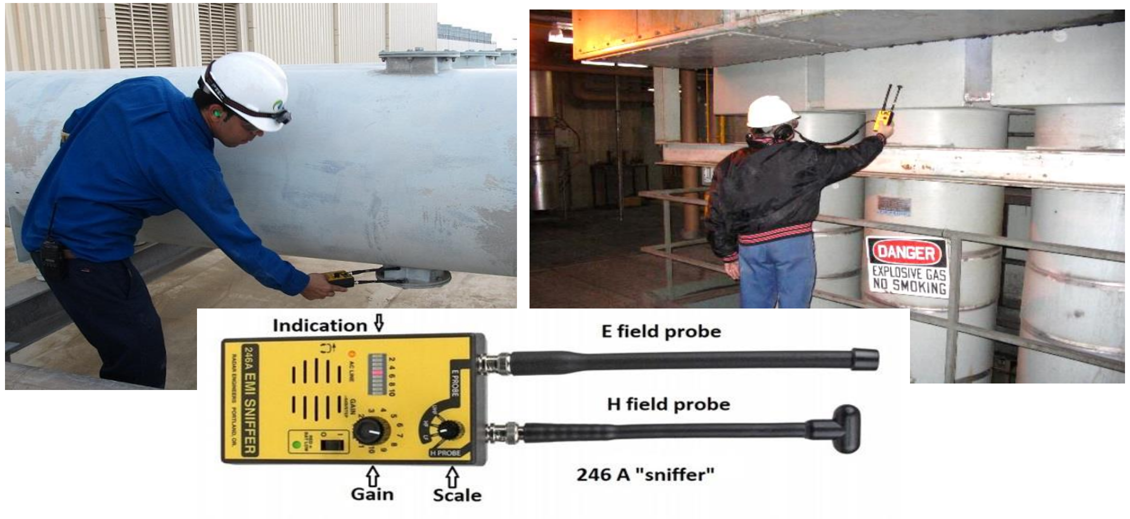
- Localized EMI testing can provide additional troubleshooting information to identify a generator, exciter, or isophase bus issue; especially related to arcing and sparking. Goal was to develop a practical field guide to help users understand the use of this tool, with specific troubleshooting approaches.

Some Takeaways

- Methods to use the "sniffer" are included in the field guide.
- Many case histories, with specific settings are shown.

Embedded in Field Guide

- Audio files of specific issues are included in the document
- Bouncing carbon brushes
  - Play mp3 file below
- IPB broken bolts arcing
  - Play mp3 file below
- 8 more



Testing of the Isophase Bus with the handheld EMI/EMSA Sniffer. This handy device can provide instant feedback on many developing failure modes for this component.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

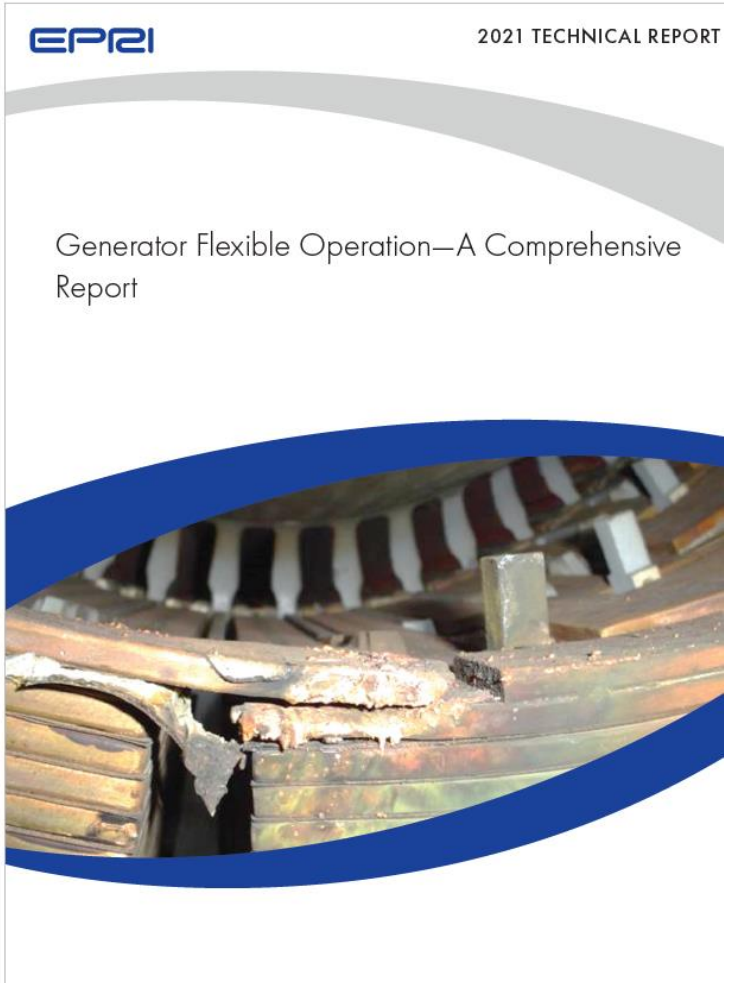
Generator Flexible Operations – A Comprehensive Report-#3002021520

Industry Issue/Project Description

- More and more units are operating flexibly, now. Continued concerns about premature aging and fatigue failure of critical components leading to forced outages. Goal to develop comprehensive technical report that covers the effects of Flexible Operation on the Generator – BOTH the Rotor and Stator.

Some Takeaways

- All-in-one source for the impact of flexible operation on the generator. Includes results of 2020 Base Research Project on Stator Winding #3002018667 & combine previous recent work done on Rotor #3002013652 and other older, EPRI reports, #1008351 & #3002000045 on flexibility



© 2024 Electric Power Research Institute, Inc. All rights reserved.

Nuclear Generator Flexible Operation-#3002021533

Industry Issue/Project Description

- Nuclear Plant Generators are operating in a “flexible mode” more and more for a variety of reasons. Effects of “flexible operation” on Nuclear Plant Generators not fully understood. Goal to provide improved understanding of who is operating Nuclear Plant Generators in a flexible mode, what types of flexible operation others are using, and the potential impacts of operation in that mode.

Some Takeaways - Survey Preliminary Results – 15 Utilities, Worldwide

- **Do your Nuclear generators operate flexibly?**
  - International outside North America – **80% Yes**
  - Canada – **33% Yes**
  - **US – 26% Yes**
- **What is primary mode of flexible operation?**
  - Load Cycling ranging from 20% load drop to 40% **up to 80% (100-20-100)**
- **What is frequency of load cycling?**
  - Most responded seasonally, some on weekends, and one does this almost every day (influenced or driven by Hydro, Wind, Festivals)

Nuclear Generator Flexible Operation

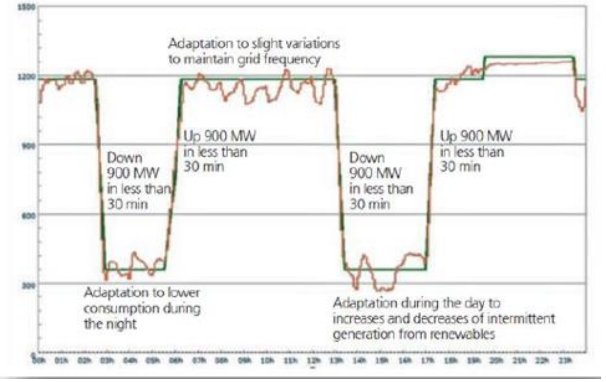
Technical Brief — Generators and Auxiliary Systems and Flexible Power Operations

Background and Introduction

In the last several years, there has been significant interest and industry activity in flexible power operation. The Electric Power Research Institute (EPRI) has been a key player in this activity through various workshops, research reports, and technical readiness assessments. Flexible operation can be defined, in the simplest fashion, as any type of operation that is not steady, baseload operation.

For the electrical generator in a power plant, the major types of specific flexible operation are speed cycling (also called *start-stop operation*), load cycling (also called *load following*), frequency control (FC), and reactive power control. Speed cycling can be referred to as 100-0-100, meaning that the generator is operating at 100% of its rated output and rated speed, then is brought down to 0% rated output and standstill, then brought back up to 100% rated load and speed again. That is one speed cycle or one start-stop. The load is also cycled, but the emphasis is on the speed in this case going to standstill. Alternatively, a typical load cycle

Figure 1. Generator stator coil shown with abraded copper strands and ground insulation due to repeated-load cycling. The support block that abraded into the coil is not shown. [1]



© 2024 Electric Power Research Institute, Inc. All rights reserved.

Exciter System Maintenance Guide-#3002021510

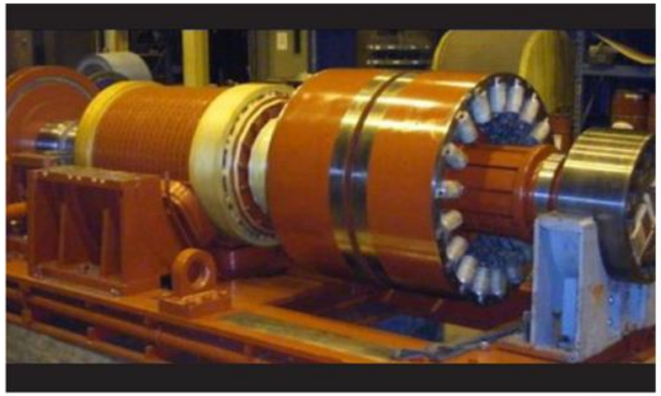
Industry Issue/Project Description

- At least once a year, we hear of a major failure of a brushless exciter. Brushless exciters continue to fail In-Service and sometimes, forced outage time can be lengthy; especially without a spare brushless exciter or a temporary mobile exciter Component obsolescence and the many subtle design configuration differences make exciter spares more difficult.

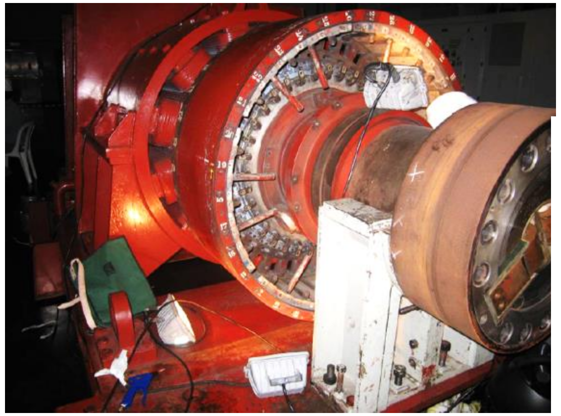
Some Takeaways

- Goal of this project was to identify and communicate key failure modes and important maintenance recommendations related to the brushless exciter and provide that information in an easy to read, fully illustrated, technical brochure.
- Includes outage inspection information as well as all-important diode wheel component maintenance (fuses and diodes).

GENERATOR EXCITER SYSTEM
MAINTENANCE GUIDE



October 2021



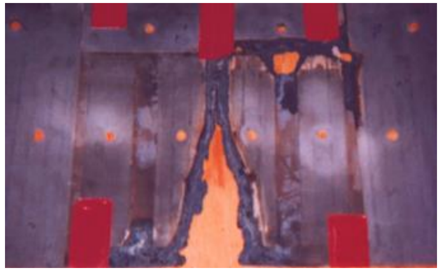


Table of Contents

EPRI Project Manager
B. Moore

© 2024 Electric Power Research Institute, Inc. All rights reserved.

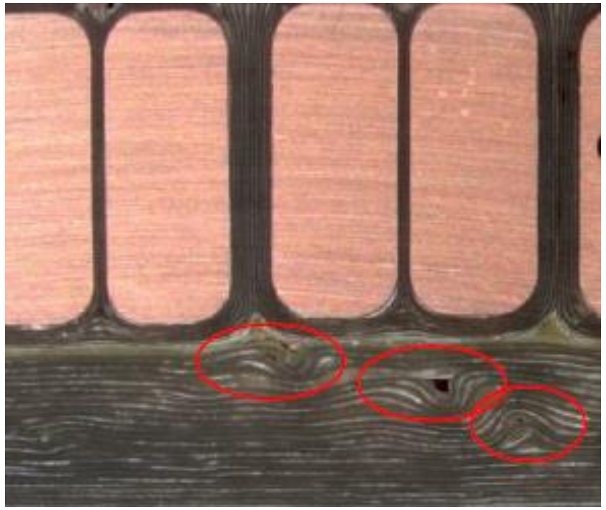
Hydrogenerator Rewind Best Practices #3002021540

Industry Issue/Project Description

- Problems and issues can occur during Hydrogenerator rewinds. It’s a complicated process, requiring skill and expertise. Goal to provide a reference on best practices, specific to hydrogenerator rewinds.

Some Takeaways

- Survey done with included results on best and worst practices. Description of Best Practices, from Start to Finish. Leverage previous work done on EPRI’s “Best Practices for Rotor Rewinds” 3002004969 and turbogenerator project “Best Practices for Stator Rewinds-Turbogenerators.” Conduct Hydrogenerator rewind specific survey on best practices. Key document highlights past rewind issues and offers important guidance to best practices for Hydrogenerator Rewinds.



© 2024 Electric Power Research Institute, Inc. All rights reserved.

2022

Stator Core Inspection, Test, Repair & Replace - 3002024052

Industry Issue/Project Description

- Industry core inspection and test documents offered different testing approaches, different test times and sometimes different standards were referenced.

Some Takeaways

- This is a very good, high quality, reference for anything related to generator stator cores. A member can use it as a first-stop sourcebook for core related questions involved with design, testing, maintenance or repair aspects. Also includes other reference standards. This research provides a one-source referral document to cover nearly everything related to the stator core, including design basics, common failure modes, inspection, testing, repair, replacement and case histories. 125-page report.

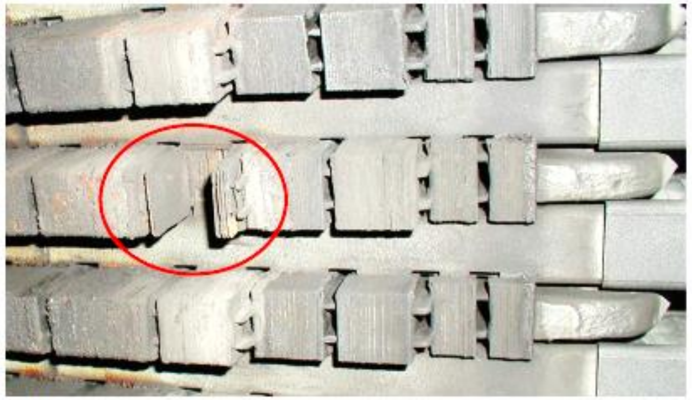
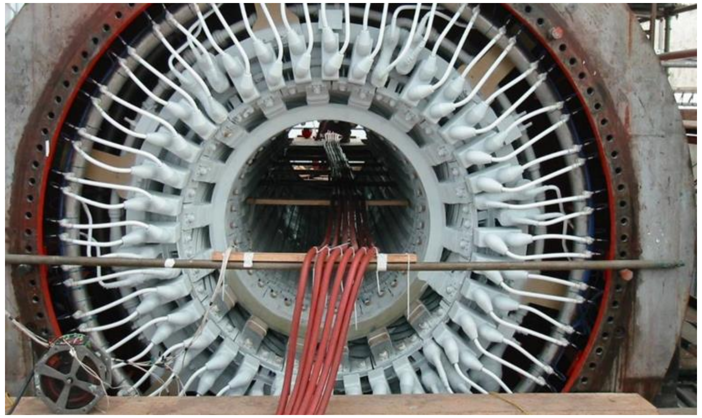


Figure 4-2
Missing stator tooth. Only a few laminations in the core packet adjacent to the core vent space blocks are still intact.



How long should the core loop or core ring flux test be run?   What is the acceptance criteria? Should it be done at full, rated flux, or some percent of rated flux? What is SMCAS? (Top photo of stator core damage in report. Bottom photo shows core loop test. Other case histories included along with design & testing specifics.)

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Rotor Ground Faults: Online Detection and Diagnosis - 3002024097

Industry Issue/Project Description

- Owners want to know the best approaches to determine if a rotor ground exists, and then the best response. This shorter technical update focuses on online detection and diagnosis of rotor ground faults. Background between turn shorts and ground faults are presented, along with the pro's and con's of various online detection approaches. Recent and past EPRI Surveys are included related to equipment monitored and indicated alarm action. The guide includes past case history discussions of previous rotor ground faults.

Some Takeaways

- Important document to understand the best ways to detect online rotor ground faults, and also to decide the most common approach others take when they occur. The majority of owners alarm only and shut down at the best opportunity. Other survey results included as well.
- The information in this report is best used by plant and corporate engineers responsible for maintaining and improving reliability of their generators including ensuring proper procedural actions are in place when a ground fault is indicated online.

Two cases of extensive damage from ground faults.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

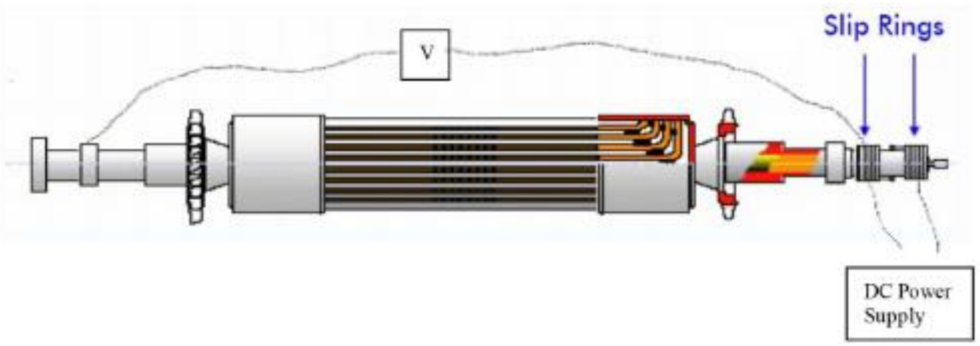
Rotor Ground Faults: Offline Detection & Diagnosis - 3002024099

Industry Issue/Project Description

- This project focused on offline detection and diagnosis of rotor ground faults. If you have an indication online, then you must come offline to investigate and repair it (if confirmed). The research covers the best tests and approaches to detect and identify the location of the ground offline, or if it cannot be identified, the approach to disassembly.

Some Takeaways

- Include discussion of accepted approaches to investigating and repairing a rotor ground. Both split voltage and rotor current tests are described. A flow chart is also included to support guidance in this area. If you do not have specific procedures to follow when a ground is identified, these reports provide assistance and guidance.



Split Voltage Test (above) and Flow chart (below) for offline rotor ground fault below.

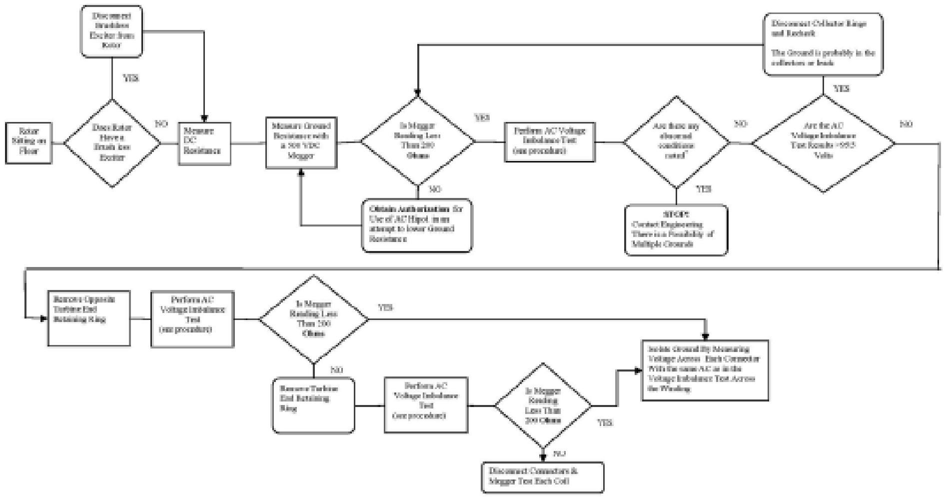


Figure C-1
Rotor ground location flow chart. (This chart can help guide personnel to take the right action when performing testing and trying to locate a rotor ground with the unit stationary.)

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Best Practices for Chemical Cleaning of W-C Stator Bars - 3002021515

Industry Issue/Project Description

- This document is a compilation of Best Practices in the area of performing chemical cleaning on water-cooled generators. It includes discussion of both on-line and off-line cleaning, as well as the best chemicals and techniques to use. It offers recommendations for pre- and post-cleaning activities as well.

Some Takeaways

- The white paper is an easy-to-read reference for everything related to cooling water flow restriction and chemical cleaning. Familiarity with its contents may help if copper oxide buildup and plugging occurs in stator bars, filters or strainers. It can provide important steps to take, before the situation becomes urgent as well as the best approach to take in resolving the issue.
- Take early action! Detect adverse trends early: actively monitor relevant parameters. Determine actual need / urgency for cleaning. Contact specialist company right away and start preparations. If possible, determine and eliminate likely root cause before start.
- Find and eliminate root cause
- Have cleaning procedures and a standing PO ready – Allows for Fast Response

Report Cover page. Includes both online and offline chemical cleaning best practices.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Generator Hydrogen Best Practices - 3002024120

Industry Issue/Project Description

- This project includes the identification of Best Practices involved with Generator Hydrogen Cooling Gas. The document covers H2 gas basics, CO2, Argon, purging, filling, fast degas, purity, dew point, dryers, H2 leaks and detection methods and other topics. It also documents past, known, industry events and lessons learned from those events.

Some Takeaways

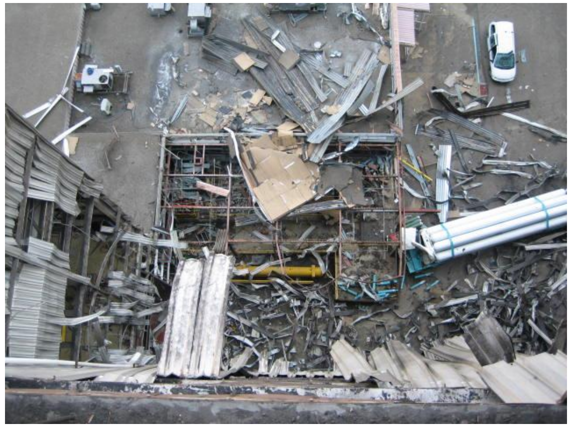
- A comparison of your company's current practices against that which is outlined in this project, may identify some needed changes and could prevent a H2 explosion, equipment damage or personnel injury. H2 leak detection and correction approaches discussed may also be of benefit.

May 4th, Australia Coal Fired Unit

https://www.csenergy.com.au/news/cs-energy-releases- photo-of-unit-c4

Aug 8th, South Africa

https://www.dailymaverick.co.za/article/2021-08-09-eskom- confirms-explosion-at-medupi-days-after-station-comes- onstream-investigations-under-way/



© 2024 Electric Power Research Institute, Inc. All rights reserved.
EPRI

Generator Health Assessment Tool Upgrade to V1.3 - 3002025565

Industry Issue/Project Description

- This project involved an upgrade to the GHAT (Generator Health Assessment Tool) first published in 2021. Aging and weighting factors were adjusted for several generator component categories. Generator auxiliary component categories & questions were expanded. Additional failure modes included. Key questions for evaluation were clarified.

Some Takeaways

- The output of this tool can be used by maintenance and operational personnel to identify generator components at higher risk of failing and take pre-emptive action in the form of more frequent inspection and testing or even repair and replacement.

Utility: **Draft EPRI Generator Fast Track Health Assessment**
Test Copy 16

Add A Unit

Unit	Last Evaluated	Unit Weighted Risk Summary	Stator Winding	Stator Wedge System	Stator Core	High Voltage Bushings/ Terminals	Rotor Winding	Rotor Forging	Retaining Rings	Rotor Slot Wedges	Rotor Fans/ Blowers	Rotor Journals/ Bearings	Generator Auxilary Systems	Generator Cooling System	Exciter/ Automatic Voltage Regulator	Risk Tolerance Index
41	9/14/2022	26%	40%	27%	37%	32%	15%	76%	5%	39%	35%	29%	29%	24%	8%	Average
2	9/14/2022	19%	25%	50%	4%	59%	18%	22%	26%	18%	3%	30%	33%	17%	17%	Average
3	8/23/2022	24%	30%	89%	24%	49%	23%	26%	3%	31%	4%	55%	69%	51%	35%	Conservativ
4	9/14/2022	24%	39%	67%	17%	27%	15%	23%	14%	18%	37%	49%	23%	25%	67%	Average
M	9/14/2022	49%	64%	56%	65%	51%	49%	31%	45%	35%	100%	23%	82%	28%	62%	Average

Snapshot of Generator Health Assessment Tool (GHAT) V1.3.
For
Turbogenerators

© 2024 Electric Power Research Institute, Inc. All rights reserved.

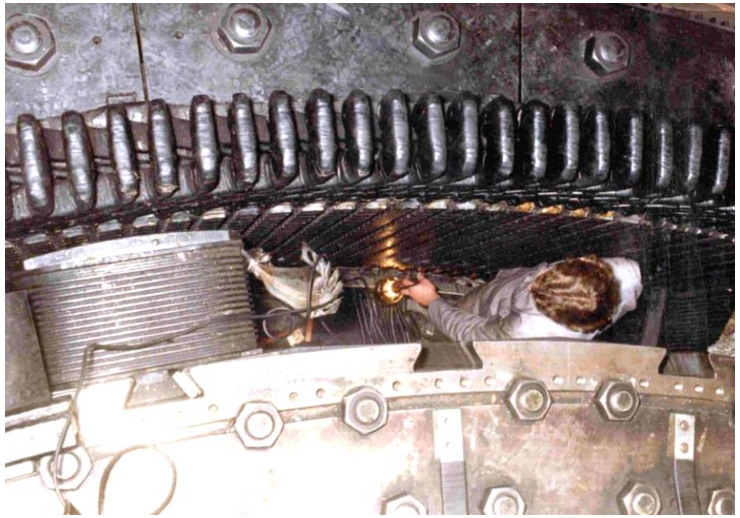
Hydrogenerator Health Assessment Tool – 3002021506

Industry Issue/Project Description

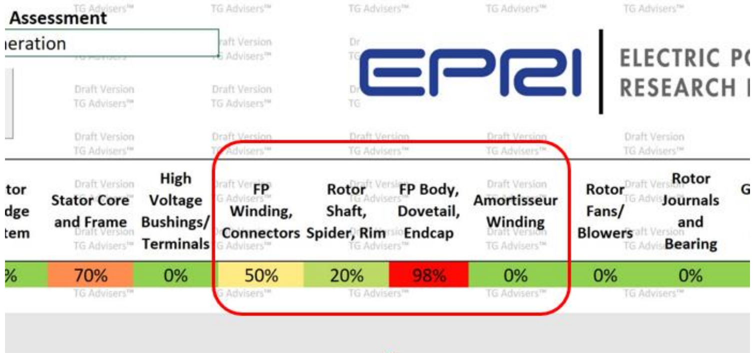
- In a recent EPRI survey, only 21% of respondents indicated their company had a Formal Methodology for Evaluating Generator Health. Develop a simple, first level, health assessment tool for generator owners. Identify key questions to evaluate health. Provide easy to see color coding. Ability to examine one unit or entire fleet. Ability to convey concerns to management

Some Takeaways

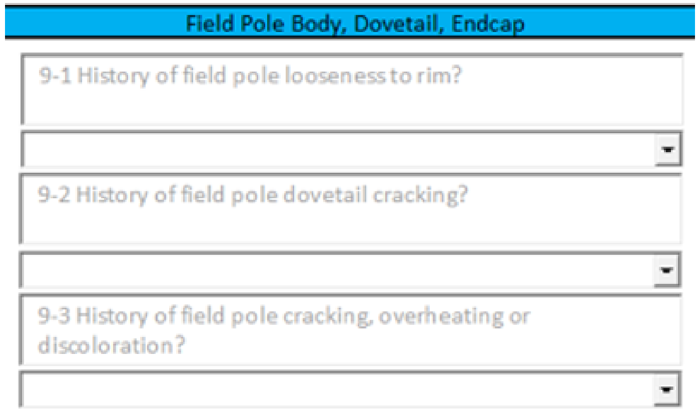
- Simple tool (Excel Spreadsheet) for first level health assessment of single generator or entire fleet. If concerns are evident, a more intensive health assessment can then be done on any major component.



Do I know the condition of my hydrogenerator stator core? Should it be replaced when I rewind the generator? Photo shows ELCID done with field pole removed to evaluate core condition.



Key Component Differences for Hydros versus Turbos have been recognized and incorporated.



Key questions asked to evaluate each major component.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Seal Oil System Maintenance Guide - #3002021517

Project Description

- This research provides common troubleshooting steps to resolve seal oil maintenance and operational issues including oil leaks into the generator, excessive H2 gas leaks out, seal issues and more. The documents provides an in-depth background discussion on seal oil system design & operation, and covers three major OEM designs, GE, S-W, Alstom (triple seal). It can be used in combinations with the workbook, also published in 2022.

Some Takeaways

- The main document along with the workbook can be an important reference guide for understanding and troubleshooting issues with seal oil systems. The technical aspect can help identify failure modes and keep the system in the best operating condition. Technical guide include the following:
- System Design Basis, Function, and Component Description
- Actions for Emergency Response/Abnormal Condition
- Standard Operation, Testing, & Maintenance
- Design-Specific Technical Information
- Lessons Learned & Case Studies

Table D-1
Fault chart

#/Severity	Condition	Indications
1	Hydrogen sealing has been lost	Loud hissing sound issuing from bearing cavities. Rapid measurable loss of H2 pressure (order of 1+ p H2 gas detected in bearing cavities and/or ASDT ro DP-SO between approximately 0–2 psid (0–13.8 kI
2	Loss of ac power or Unavailability of multiple sources of seal oil	Loss of ac power and/or Loss of multiple seal oil pumps Multiple pump differential pressure alarm sounds (or) Multiple pump motor ammeter alarm sounds, "emergency seal oil pump running" alarm sounds
3	Seal oil pressure unstable	One or more regulators and/or relief valves at seal o DP-SO fluctuating cyclically between near zero to > H2 gas detected in bearing cavities and/or ASDT ro
4	Seal oil pressure marginal	Slow, measurable loss of H2 pressure (order of 1+ p H2 gas detected in bearing cavities and/or ASDT Ro DP-SO between approximately 2–3 psid
5	Seal oil pressure sufficient but either differential is drifting or there is a sudden change of main, backup, or H-side oil supply pressure	Seal oil supply pressure steady but very high, OR Seal oil differential pressure drifting with generator g OR Sudden reduction of seal oil supply pressure for main
6	Loss of single seal oil pump	Seal oil pump(s) stopped confirmed stopped by field Pump differential pressure alarm sounds, Pump motor ammeter alarm sounds,

Fault Chart in Guide for Troubleshooting

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Enhanced Monitoring for Back of Core Arcing - #3002025432

Project Description

- This Supplemental Project funded by seven major utilities focused on identifying new ways of monitoring back of core arcing and burning. Most funders owned a specific OEM generator with this issue and were concerned with long term reliability. Project first stage involved installation of probes to monitor arcing activity. 2nd stage involve installation of shaft voltage continuous monitor.

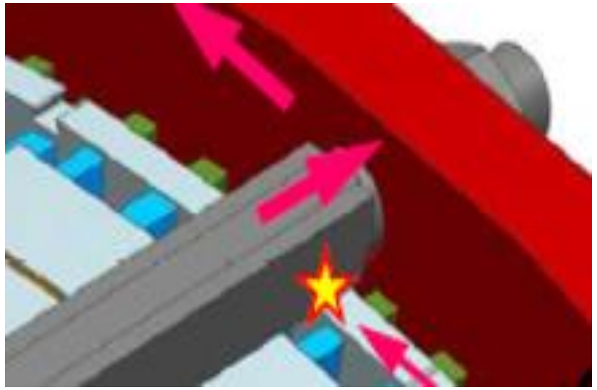



Photo of first unit failed & typical arc location above. TGUG 2017. Progression of arc damage on host unit below.

Some Takeaways

- Supplemental project funders can benefit by reviewing the research done to date, including both online monitoring which provided information on operating regimes associated with higher damage, and other monitoring equipment that may provide further insight into online recognition of core burning activity.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

2023

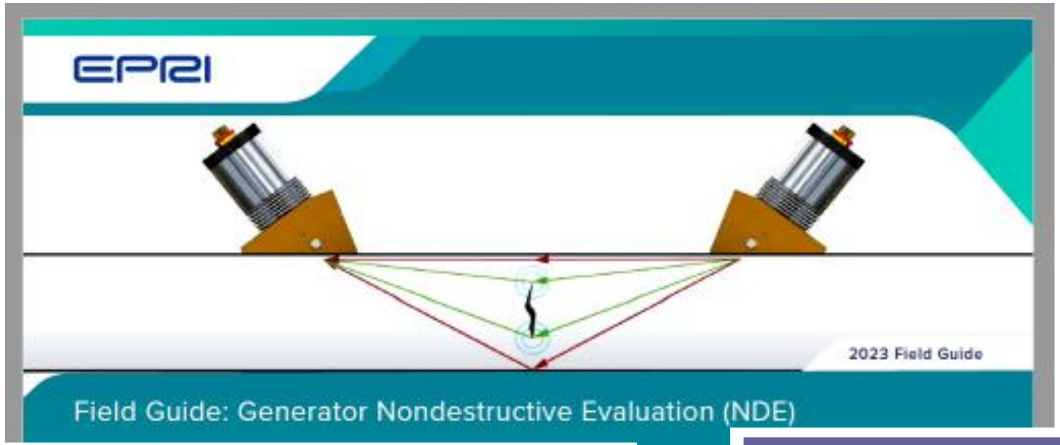
Generator NDE Field Guide - 3002027378 - Published 2023

Industry Issue/Project Description

- This pocket field guide is 167 pages and 80 figures of detailed NDE information – all specifically applied to the generator. It is color coded to provide easy reference and sorted by component including NDE for generator rotors, stators, and exciters. A separate section with in-depth discussion on different types of NDE technology is included with major sections on MT, PT, ET, and UT.

Some Takeaways

- Incredibly valuable and easy to use reference the next time generator NDE is required at your plant or on one of your units. This document should be a valuable reference to all outage managers and engineering personnel involved in generators. A webcast is planned for Members on April 11 at 10 am eastern to cover the highlights of this field guide.



Contents

Table 3. Preferred NDE techniques for rotating parts

COMPONENT	FAILURE MECHANISM(S)	NDE METHOD					
ROTATING PARTS		VT	MT	PT	ET	UT	RT
Coupling Bolts	Fatigue cracking, thread flattening	X	X			X	
Rotor Slot Wedges	Fretting, arcing	X		X			

Generator NDE Field Guide showing cover page, content description and small section of handy reference table. 3002027378 (2023)

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Collector System Maintenance Guide - 3002027375 - Published 2023

Industry Issue/Project Description

- This guide includes a single source and reference for key information related to inspection, testing, maintenance, operation, monitoring and repairs of generator collector assemblies, including the housing, slip rings, carbon brushes, brush holders, stub shaft and more. Essential information has been gathered and assembled into one “go-to” document. Fully illustrated, this guide also covers this generator auxiliary component in great detail. Failure modes and methods to prevent failures are included, as well as all the latest inspection, testing and monitoring methods.

Some Takeaways

- The guide provides a convenient one-stop source for information on maintaining the reliability of collector systems, including slip rings and brush rigging. A webcast is planned for Members on March 7 at 10 am eastern. Highlights of the guide will be presented.

Table of Contents

6. Inspections and Corrective Actions

Table 3 lists findings and recommendations for corrective actions.

Table 3. Findings and recommendations for corrective actions

Finding	Action
Excessive brush wear	Check spring pressure, electrical connections, and brush grade. Calculate brush wear rate. Measure ring runout. The TIR of the collector ring surfaces is to be no more than 0.0127 mm (0.0005 in.) and with a surface finish of 0.0002 mm (0.000008 in.) or better.
Uneven brush wear	Inspect the position of the brush holder mount, the brush holder, and the ease of movement of the brush. Brush holders should be aligned into a radial position and be spaced 3.3 mm (0.13 in.) from the surface of the collector ring. Check the spring according to the manufacturer's recommendation to ensure that consistent pressure is being applied.
Evidence of selectivity (poor current sharing)	Ensure that all brushes are free to move in the holder. Inspect the springs for consistent pressure. Perform current measurements on the brush pigtails to determine how the current is being shared. Inspect the collector surface finish and for excessive wear of the spiral groove.
Sparking	Verify that slip ring runout is within specifications and brushes are not bouncing on rings.
Photographing	Check control logic to ensure that the exciter breaker is closed only when the machine is at speed.

7. Failure Modes

Carbon Dust Accumulation

Collector systems are susceptible to failure by means of carbon dust accumulation. As the brushes wear, they produce a carbon dust that when deposited in an area can create an electrical path, either to ground or to the opposite polarity ring. Routine inspection and cleaning can prevent electrical faults due to brush dust accumulation. Figure 20 shows carbon dust buildup in the brush holder.

Figure 20. Carbon dust in brush holder

Insulation Failure

Figure 21 shows a crack in the ground insulation of the collector ring. This allows a path to ground and can be detected by an insulation resistance test. Other insulated regions that should be

Cascading Brush Failure (Selectivity)

A cascading brush failure occurs when brush contact is lost on one or more brushes resulting in higher current density for the remaining brushes. This exacerbates the problem and leads to more brush failures. Consistent inspection of the brush wear and the functionality of the spring and brush holder will mitigate the potential for failure (see Figure 22).

Figure 22. Selective action illustrated by discolored copper pigtail

Inadequate Spring Pressure

A broken, detached, or twisted constant force spring can fail to

EPRI RESOURCES

Bill Moore, *Sr. Technical Executive, Project Manager*
980.229.6308, bgmoore@epri.com

The following contributed to and/or reviewed this report:

J. Baker	Prairie State Energy Campus
J. Clapper	Tennessee Valley Authority
R. Gray	Duke Energy
G. Carlin	Nova Scotia Powe
B. Devinck	First National Operation & Maintenance Company
J. Green	Duke Energy
C. Keathley	Ameren
E. Prescott	EPRI
K. Simmons	Tennessee Valley Authority
M. Young	Salt River Project

Generators and Auxiliary Systems

3002027375

Images above from guide showing contents, partial table of inspection and correction actions, failure mode section and PAG contributing members. Just a small portion of this jam-packed maintenance guide.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Generator Stator Flex Connection - 3002027372 - Published 2023

Industry Issue/Project Description

- This technical brief covers essential information related to generator stator flex connections including, past industry failures, design configuration, failure modes, inspection and testing approaches along with repair and replacement discussion. Although the primary discussion is on the GE design, different designs from different OEMs are identified along with current advisories and bulletins on this component. Key degradation mechanisms are included.

Some Takeaways

- The document provides up to date discussion on all aspects of the generator stator flex connection design component. A webcast for Members, May 2, 2024, will discuss highlights of this technical brief.

Table of Contents

Figure 17. Complete flex connection replacement showing new, silver insulated copper leaves, new bolting plates, new bolts, and lock plates installed

EPRI RESOURCES

Bill Moore, *Sr. Technical Executive*
980.229.6308, bgmoore@epri.com

The following contributed to and/or reviewed this report:

J. Clapper	Tennessee Valley Authority
D. Coleman	Duke Energy
K. O'Dowd	Constellation
J. Green	Duke Energy
J. Phelps	Southern Company
E. Prescott	EPRI
K. Simmons	Tennessee Valley Authority
N. Trainer	Constellation
D. Withers	Palo Verde
S. Xu	FM Global

Images from 3003027372 Published in 2023 including table of contents, industry failures, component location, replacements and PAG review team.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

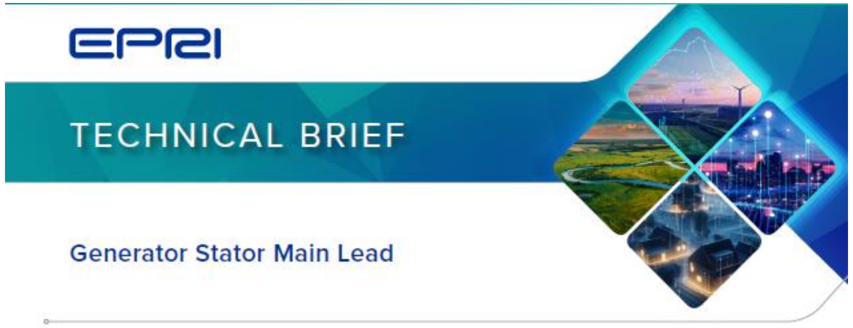
Generator Stator Main Lead Connections- 3002027374

Industry Issue/Project Description

- This technical brief covers important design, inspection, testing, repair and replacement aspects of this important generator component. This component, which connects the stator winding to the bushings consist of a brazed copper pipe that is susceptible to cracking. This design is primarily found on modular-style generators.

Some Takeaways

- Important information on appropriate non-destructive inspection is included in this document. Any member who has a Siemens Energy modular generator should review this information. A webcast for P220 Members is planned for May 2, 2024, at 10 am eastern. This topic will be combined with discussion of the stator flex connections, mentioned in the previous slide.



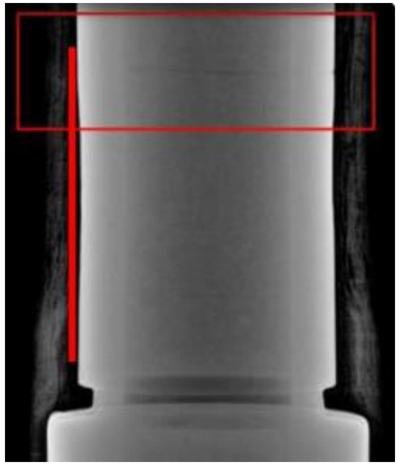
EXECUTIVE SUMMARY

Generator stator main leads on Siemens Energy modular[1] generators provide a connection from the stator windings (specifically the parallel rings) to the generator bushings. The leads are made from copper pipe and are brazed to a flange that is bolted to a bushing flange. The hollow copper pipe provides a path for hydrogen cooling gas to the hydrogen-cooled bushing, and the copper conduit provides the pathway for voltage and current to exit the generator. Failures have occurred on this type of main lead copper pipe connection. The original main lead brazed joint design can crack and separate in service, leading to a ground fault. This failure can include copper contamination and potential damage to other areas of the generator. One failure event was presented in August 2022 at an EPRI Generator workshop meeting and is shown in Figure 1.

This generator was placed into service in 2004, and had about 18 years of operation, approximately 1,200 starts, and 108,000 service hours around the time of the failure. Reportedly, six failures have occurred with this design. The Original Equipment Manufacturer (OEM) has issued a bulletin to replace these main leads with a new upgraded design. This technical brief will discuss, in more detail, aspects of this component design, including more details about the failure shown in Figure 1, other industry experience, and OEM recommendations.

1 Modular generators represent a style of generators developed by Siemens Energy that have the same design with the same diameters but come in varying lengths at different power outputs.

Figure 1. Photo of main lead failure. EPRI TGUG Generator Workshop Presentation, "Wise County ST Generator Main Lead Failure, Stephen M. Bates, August 15, 2022. [4]



Cover page and images from the Generator Stator Main Lead publication, 3002027374. Images include an in-service failure, stripping of insulation for UT and a radiographic image.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

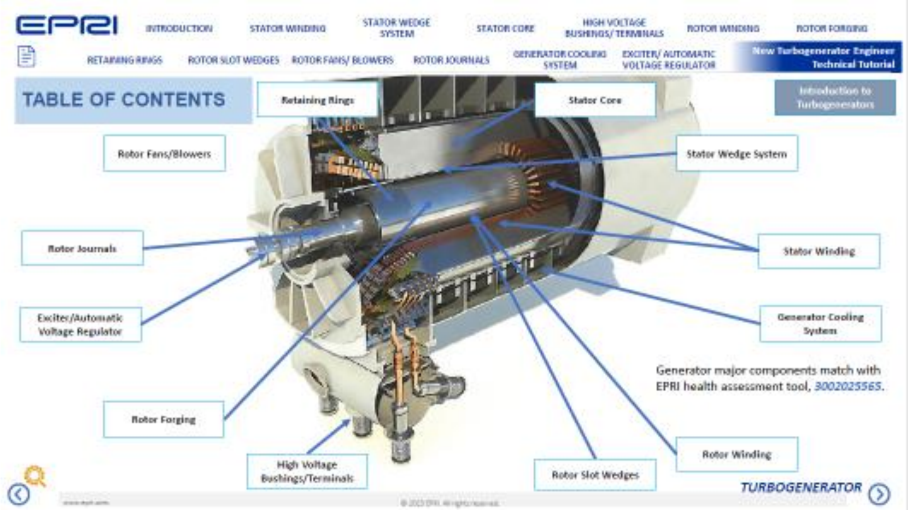
Turbogenerator Tutorial – Design & Construction Part 1 – 3002027376

Industry Issue/Project Description

- Part 1 of this Adobe PDF Interactive tutorial on turbogenerator design and construction was published in early 2023. The tutorial focuses on major generator, exciter and auxiliary system components, describing and illustrating their configuration and design purpose. The tutorial major sections coincide with major generator components and are aligned with EPRI's Generator Health Assessment Tool GHAT (3002025565).

Some Takeaways

- This easy point and click file is very informative and provides a solid foundation for any generator engineer or Subject Matter Expert searching for specific information on a particular component.



Tutorial provides a great learning opportunity for new engineers involved in generators. 3002027376 (2023)

© 2024 Electric Power Research Institute, Inc. All rights reserved.

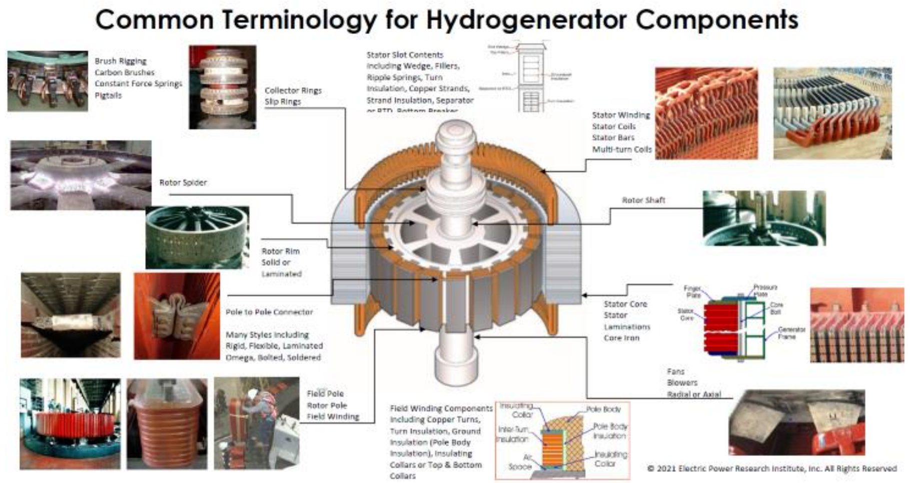
Hydrogenerator Tutorial - Design & Construction Part 1 - 3002027379

Industry Issue/Project Description

- Part 1 of this Adobe PDF Interactive tutorial on **hydro** generator design and construction was published in early 2023. The tutorial focuses on major hydrogenerator, exciter and auxiliary system components, describing and illustrating their configuration and design purpose. The tutorial major sections coincide with major hydrogenerator components and are aligned with EPRI's **Hydro** Generator Health Assessment Tool HGHAT (3002021506).

Some Takeaways

- This easy point and click file is very informative and provides a solid foundation for any generator engineer or Subject Matter Expert searching for specific information on a particular component.



Tutorial provides a great learning opportunity for new engineers involved in generators. 3002027379 (2023)

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Instrument Transformer Guide – 3002024096

Industry Issue/Project Description

- 86-page technical update report that provides fundamental information on Instrument transformers (ITs) and the important role they play as part of the generator. The topic includes both current transformers (CTs) and voltage transformers (VTs) describing how they help to protect power plant electrical equipment. Known failure modes are discussed as well as timing for replacements. Industry resources and standards that involve ITs also included.

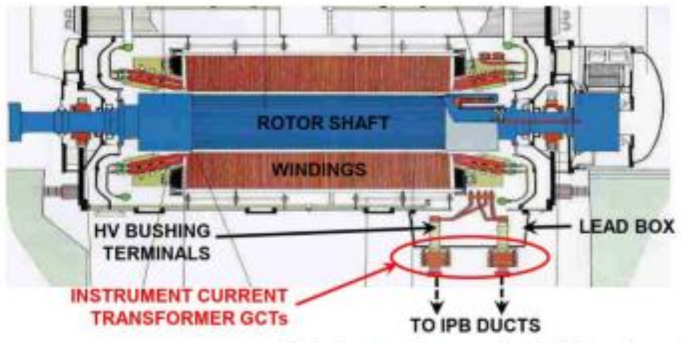
Some Takeaways

- This document will provide to engineering and plant personnel the basic understanding of ITs used on main generators and generator auxiliary systems. It also provides an up-to-date list of available suppliers that may be leveraged when replacement is needed. The report also includes application, testing, and maintenance of CTs and VTs.

Instrument Transformer Guide for Generators

3002024096

Technical Update, March 2023



Typical construction approaches for CTs are shown in Figure 5-3.

Open Construction

Encapsulated In Resin

Images from 30020246 showing typical location of generator CTs, type of construction and common heat damage failure mode.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Stator Ground Fault Protection – 3002024098

Industry Issue/Project Description

- This 56-page technical update report describes industry experience with close-to-neutral generator stator ground faults and the evolution of stator ground protection schemes.

Some Takeaways

- The document is intended for engineers, plant management, and plant equipment owners and the report gives readers information to consider when planning upgrades to the stator ground protection at their facilities.

Ground fault failures shown in 3002024098.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

2024 Projects (In progress)

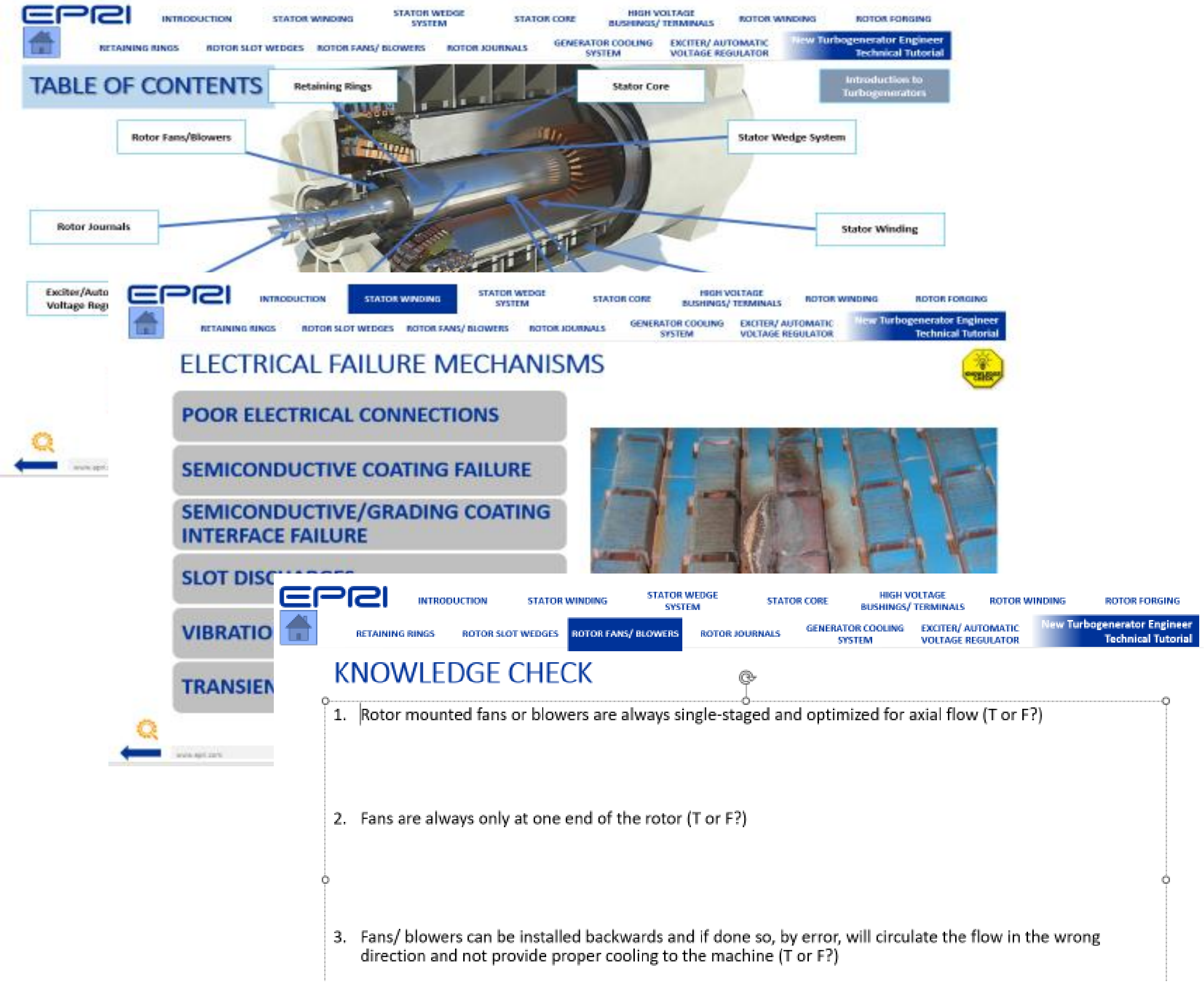
Turbogenerator Tutorial - Failure Mechanisms – Part 2 – 3002030027 - Published

Industry Issue/Project Description

- This Part 2 turbogenerator tutorial will pick up where Part 1 left off. It will be of similar nature as Part 1, but focus on Generator, exciter and auxiliary equipment failure modes. These are described and categorized by generator component, consistent with the EPRI Generator Health Assessment Tool (GHAT). Also included are inspection and testing activities to help prevent the failures identified.

Some Takeaways

- The tutorial will be very informative and comprehensive about generator failure modes, inspection and testing. Extremely easy to use and jump to specific generator components, EPRI recommends that any newer generator engineer go through the tutorial. Categorization by generator component is the same as Part 1 (Design) and the GHAT, providing consistency in naming, searching and finding. Knowledge check" questions in each category help assure understanding.



Images from Part 2 Turbogenerator Tutorial, to be published by Year End 2024. Similar format to Part 1 on Design & Construction.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

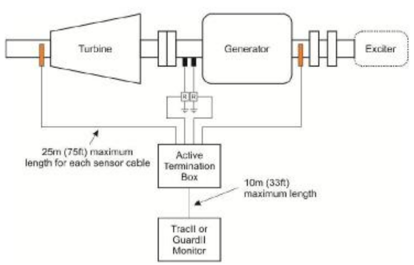
Continuous Monitoring Sourcebook for Turbogenerators-In Progress

Industry Issue/Project Description

- Generator Monitoring is critical to long term reliability and availability of the generator. Often, at TGUG or other conferences, there are specific presentations and references on a specific monitoring device, a new technology, or a new approach towards generator monitoring. There is a need for a comprehensive Generator Monitoring Sourcebook that covers ALL key generator online, continuous monitoring technologies. Topics in this sourcebook would include EMSA, Flux Probe, Core Condition Monitor, Partial Discharge, Shaft Voltage, SLMS, Carbon Brush Monitoring, Dew Point Monitoring, End Winding Vibration Sensors, and more. Also included will be the basics of temperature, pressure, vibration and more. OEM offered packages such as Siemens Gen Advisor and GE GHM systems would be discussed as well.

Some Takeaways

- This one-stop generator monitoring source book will provide members with the latest information on successful generator monitoring. From fundamentals to advanced technology systems, the sourcebook will be organized to easily find information about what a Member wants to monitor, why a particular component should be monitored, pro's and con's of monitoring and more. The output of this project will be in the form of a Field Guide due by Year End 2024.



New TurboGenerator Monitoring Sourcebook be a "one-stop" reference for generator monitoring.

© 2024 Electric Power Research Institute, Inc. All rights reserved.
EPRI

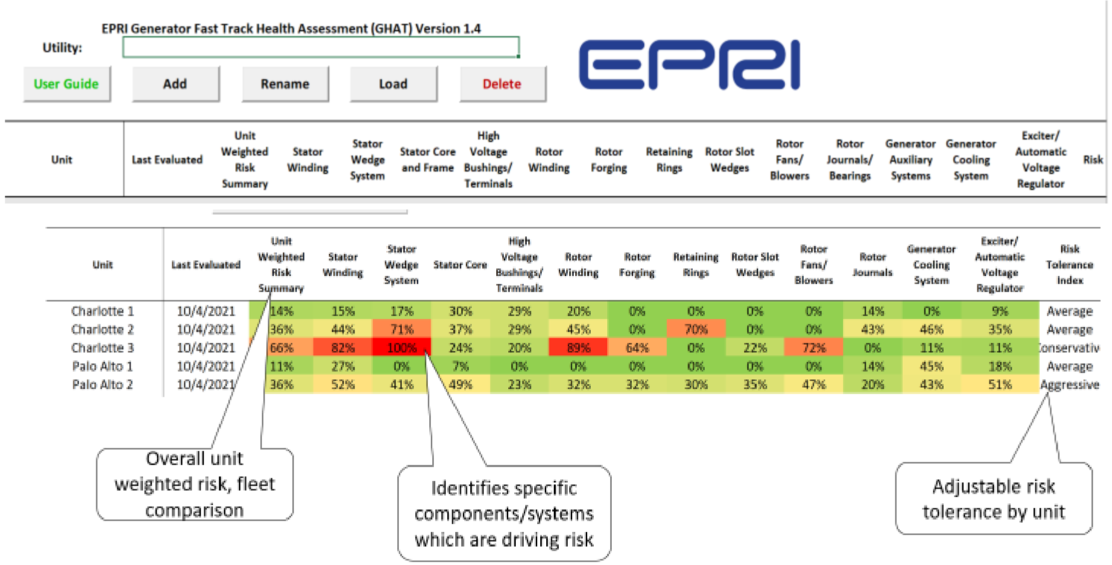
GHAT Generator Health Tool Assessment V1.4-Published-3002030030

Industry Issue/Project Description

- This deliverable will include a significant upgrade to EPRI's Generator Health Assessment Tool (GHAT). The deliverable will be labeled "Version 1.4 and includes over a dozen software improvements, such as those listed below. It will also include a Word Template for categorizing key generator component information, prior to filling out the Excel spreadsheet tool.

Some Takeaways

- The Generator Health Assessment Tool (GHAT V1.4) in Excel is easy to use and provides a consistent method for evaluating generators based on known failure modes, inspection findings and test results. Improvements made with each version based on feedback of over 200 generators evaluated. Version 1.4 and Word Template expected available by Year End 2024.



Unit	Last Evaluated	Unit Weighted Risk Summary	Stator Winding	Stator Wedge System	Stator Core	High Voltage Bushings/ Terminals	Rotor Winding	Rotor Forging	Retaining Rings	Rotor Slot Wedges	Rotor Fans/ Blowers	Rotor Journals	Generator Cooling System	Exciter/ Automatic Voltage Regulator	Risk Tolerance Index
Charlotte 1	10/4/2021	14%	15%	17%	30%	29%	20%	0%	0%	0%	0%	14%	0%	9%	Average
Charlotte 2	10/4/2021	36%	44%	71%	37%	29%	45%	0%	70%	0%	0%	43%	46%	35%	Average
Charlotte 3	10/4/2021	66%	82%	100%	24%	20%	89%	64%	0%	22%	72%	0%	11%	11%	onservativ
Palo Alto 1	10/4/2021	11%	27%	0%	7%	0%	0%	0%	0%	0%	0%	14%	45%	18%	Average
Palo Alto 2	10/4/2021	36%	52%	41%	49%	23%	32%	32%	30%	35%	47%	20%	43%	51%	Aggressive

New GHAT Version 1.4 in Excel shown above.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

GVPI Generator Stator Windings: A Technical Assessment-In Progress

Industry Issue/Project Description

- GVPI windings have been a popular, lower cost alternative to individually manufactured stator epoxy- mica bars.
- Recently, there have been some failures which are raising concerns with present designs. Coupling that with earlier issues by one manufacturer that resulted in a discontinuation of this approach, the current status of this technology should be discussed from a technical approach. Advances have also been made in repairing and rewinding these machines, once referred to as a "throw-away" if a failure occurs.
- The scope of this project will be to describe how GVPI stator windings are made, cover the design differences with Single or Individual Bar VPI windings, include a discussion and use of internal slip planes, cover recent failures with GVPI windings and discuss pro's and cons of this technology compared with resin rich made coils and single bar VPI approaches. The latest approaches on repairs and rewinds would be covered as well.

Some Takeaways

- Owners with GVPI generators will benefit from a document that provides fundamental information on the design, manufacture and installation of GVPI windings, including a summary of recent operation issues. Advances and experience with repairs of GVPI windings will be included. Publication in the form of a technical update is scheduled by year end 2024.

Photo of GVPI bar "ridge" concern in 2022 EPRI Generator Workshop presentation by Duke Energy

GVPI Stator Bar Failure 2022 TGUG by D. Fischli, Duke Energy

Failure & Rewind of a GVPI Generator – EPRI Australia Workshop, 2015 by W. Moore

© 2024 Electric Power Research Institute, Inc. All rights reserved.

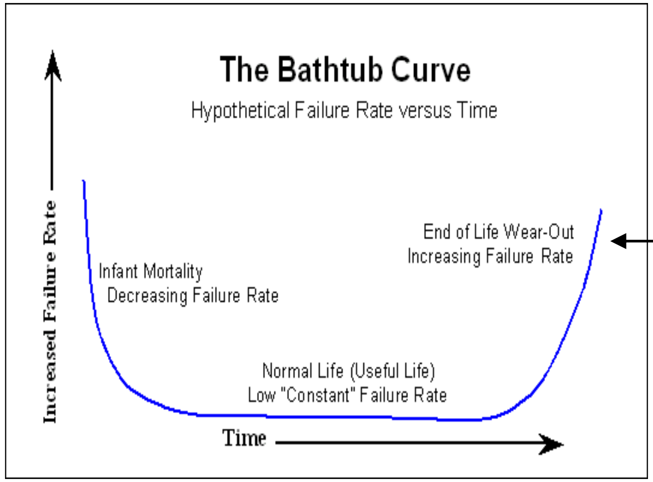
Considerations for Justifying Generator Rewinds-In Progress

Industry Issue/Project Description

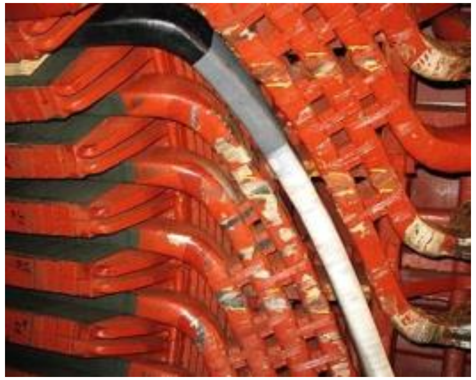
- When should I rewind my generator? This is a question many ask. The correct answer is “right before it is ready to catastrophically fail!” That way, the owner has managed to get the most life out of the generator that an owner can get. Unfortunately, that exact point in a generator’s life – the time JUST BEFORE it is ready to fail - is almost impossible to predict. Many generators are rewound AFTER failure, but that is too late, and often results in longer schedules and higher costs. Surprisingly, there is little guidance in this area.

Some Takeaways

- There are, however, principles that can be evaluated when considering a rewind of a generator. This research will discuss the key factors involved, including visual inspection results, test results, industry data and more. This is an important topic in the industry, and one that EPRI should have ready guidance available to our members. That will be the goal of this research including simplified decision trees to provide input on this important question.



Ideal rewind point



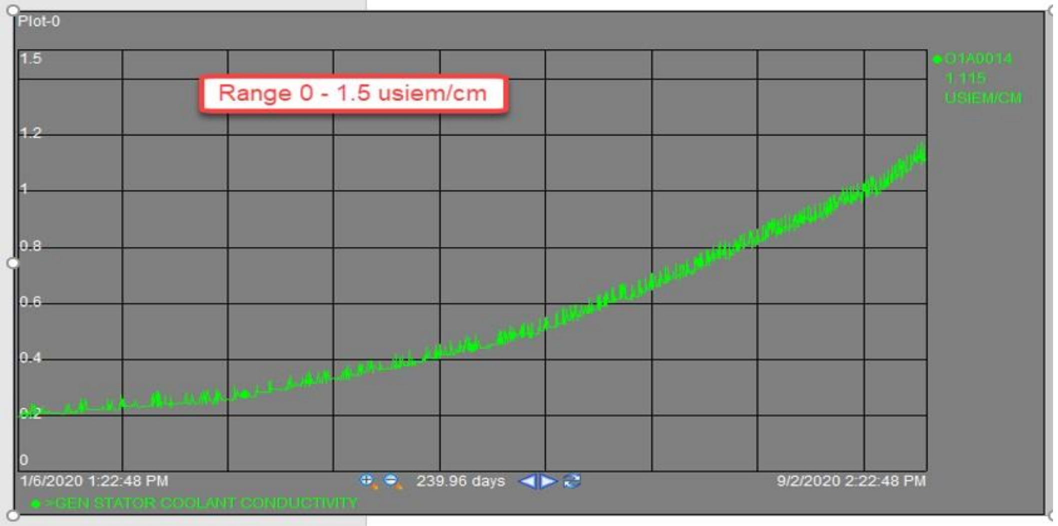
Ideally, the perfect rewind time is just immediately before “end of life” as shown in the bathtub curve at the top. Perhaps it is after a leak repair is done, or a single bar is replaced, as in the first two photos directly above. The factors that go into this decision (3rd photo) will be fully explored and documented in this research effort. This technical report is planned for publication by Year End 2024.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Preventing Early Resin Demineralizer Exhaustion-In Progress

Industry Issue/Project Description

- This project will provide a robust technical "quick guide" related to early resin demineralization exhaustion. Several Members have struggled with this issue recently, and some still are. As noted by the increasing conductivity curve on the right, Members wonder if their resin will last until the next refueling cycle. This effort will look at the many reasons for demineralizer exhaustion, offering potential actions and solutions.



EPRI Member conductivity trend and section from troubleshooting table from Water Chemistry Sourcebook.

Dresden 2	2012	Conductivity increase	0.3				Suspected air inleakage but could not find source	Anion resin exhausted due to carbonates	Replaced resin online	Long term issue with increasing conductivity trends each cycle. Installed online chemistry instrument skid at both units.

Some Takeaways

- This document will provide an in-depth reference source for issues and recommended actions related to early demineralizer exhaustion before the next refueling cycle.

© 2024 Electric Power Research Institute, Inc. All rights reserved.
EPRI

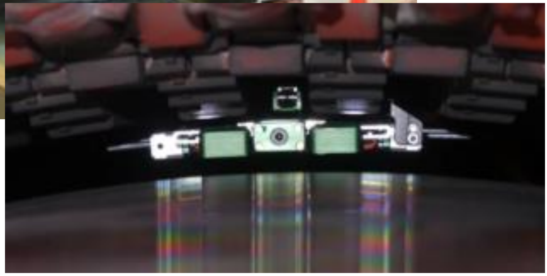
Overhaul Benchmark Study-In Progress

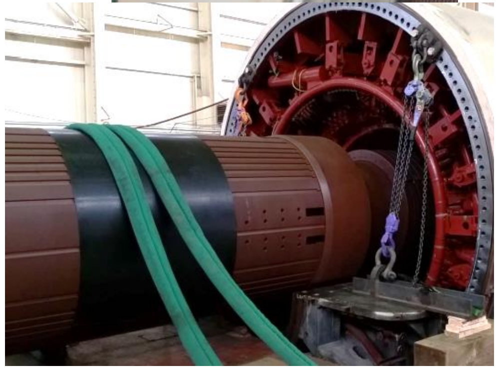
Industry Issue/Project Description

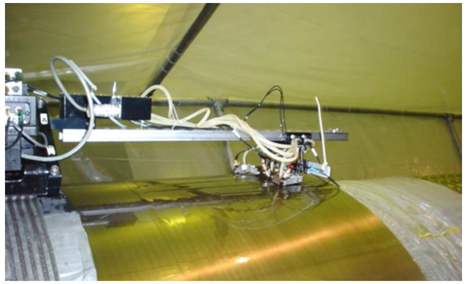
- Depending upon Member response, this study is expected to provide current information on practices involving generator overhaul schedules and timing. Key questions on this survey include:
  - What are the frequencies (duration and interval length) of your minor, medium and major overhauls?
  - Are these intervals determined using time basis or are they set based on condition assessment findings?
  - What are the typical inspection and testing activities you include in each?
  - What sequence are you using for outage planning? Minor then major? Minor then medium or major? Other? Are you aligning with centerline and turbine components? (for example, minor with a turbine valve or HGPI, and a major with the turbine centerline major?)
  - What technologies are you using to attempt to extend these outages or forego outages? Have these technologies been successful in extending outages?
  - What is your periodicity on retaining ring NDE? Do you align your main power transformer with your overhauls, or do you have another frequency specified for the transformers?

Some Takeaways

- A survey to P220 members was sent out late 2023. Several responses have been received but more are needed. A reminder will be sent out in early 2024. A webcast to update Members on the results of this survey is scheduled for November 21, 2024 at 10 am.







Generator Major Overhaul May Involve Rotor/Field Removal or a robotic inspection may suffice.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

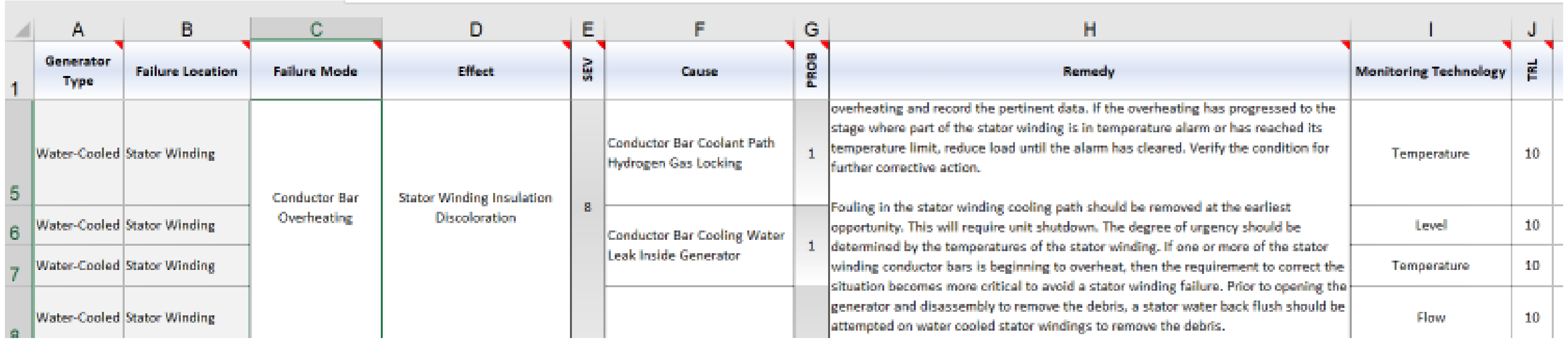
FMEA of Specific Generator Model-In Progress

Industry Issue/Project Description

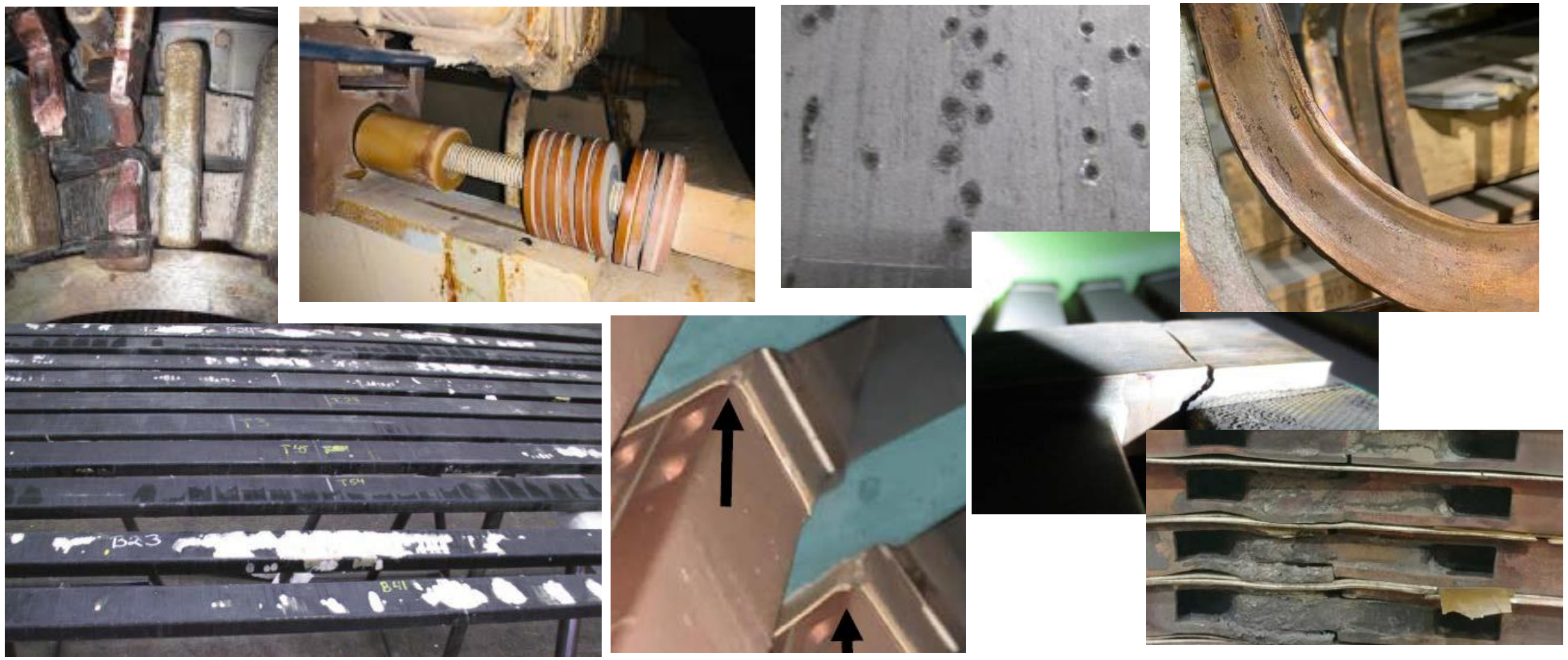
- The scope of this project will be to apply EPRI's previously developed Generator FMEA (Failure Mode Effects Analysis) Tool (3002023631) to <u>one specific generator model.</u> A likely focus will be the WY23Z Alstom Top Air Style Generator. Machine-specific failure mechanisms will be identified and made specific in the FMEA Tool. Such known failure modes as phase lead cracking, end winding looseness, vibration sparking, rotor turn collapsing, partial discharge, slot liner cracking, pole crossover cracking and rotor end turn brazed joint cracking will be identified and highlighted.

Some Takeaways

- Owners of WY23A model generators will benefit having available a specific FMEA spreadsheet developed for this particular generator. This effort will provide the foundation for doing similar efforts on other specific generator models.



	A	B	C	D	E	F	G	H	I	J
1	Generator Type	Failure Location	Failure Mode	Effect	SEV	Cause	PROB	Remedy	Monitoring Technology	TRL
5	Water-Cooled	Stator Winding	Conductor Bar Overheating	Stator Winding Insulation Discoloration	8	Conductor Bar Coolant Path Hydrogen Gas Locking	1	overheating and record the pertinent data. If the overheating has progressed to the stage where part of the stator winding is in temperature alarm or has reached its temperature limit, reduce load until the alarm has cleared. Verify the condition for further corrective action.	Temperature	10
6	Water-Cooled	Stator Winding				Conductor Bar Cooling Water Leak Inside Generator	1	Fouling in the stator winding cooling path should be removed at the earliest opportunity. This will require unit shutdown. The degree of urgency should be determined by the temperatures of the stator winding. If one or more of the stator winding conductor bars is beginning to overheat, then the requirement to correct the situation becomes more critical to avoid a stator winding failure. Prior to opening the generator and disassembly to remove the debris, a stator water back flush should be attempted on water cooled stator windings to remove the debris.	Level	10
7	Water-Cooled	Stator Winding							Temperature	10
8	Water-Cooled	Stator Winding							Flow	10



The images above include a snapshot of a portion of the EPRI FMEA Spreadsheet Tool (3002013631) along with many different failure modes on one generator model type.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

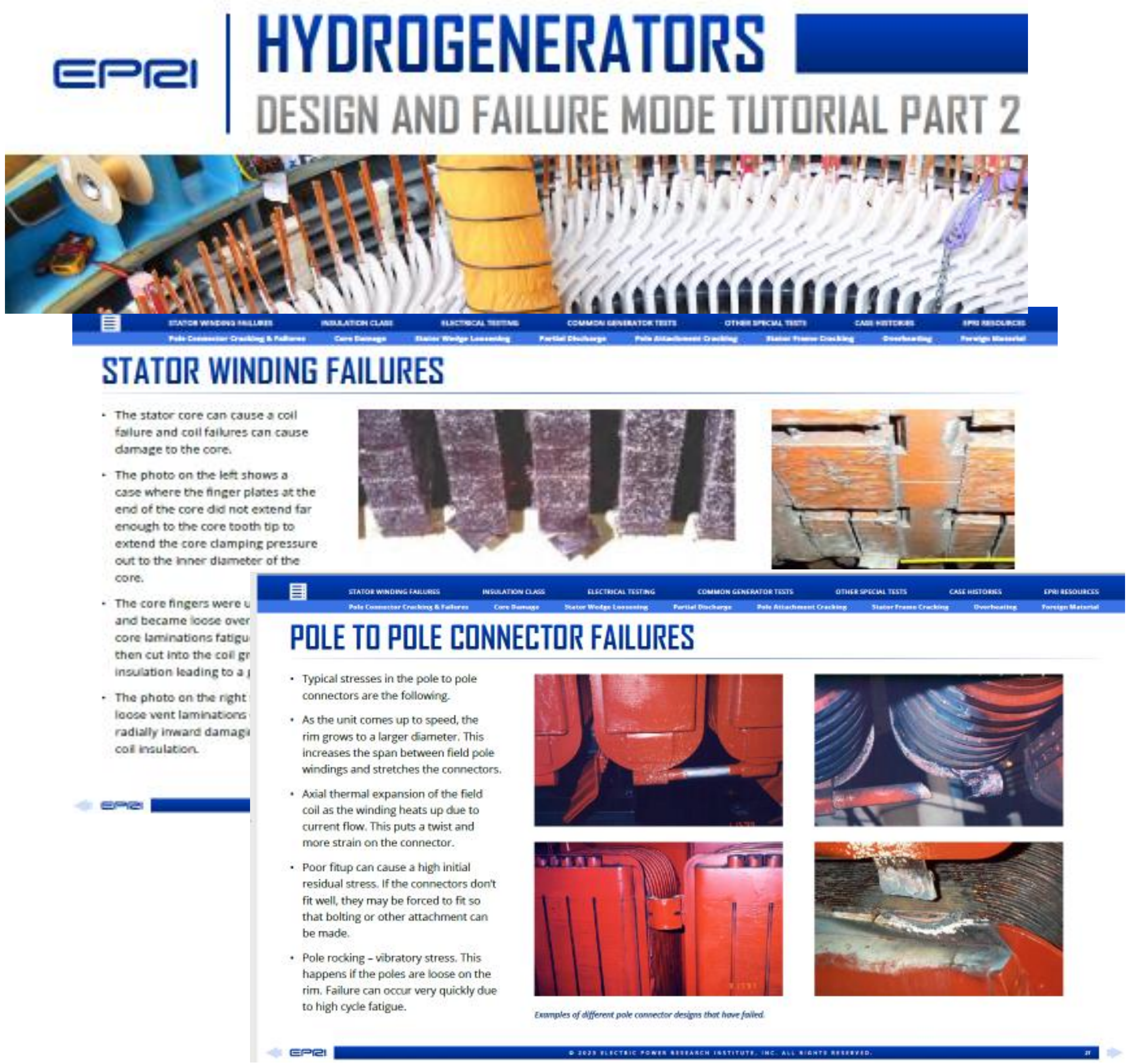
Hydrogenerator Tutorial-Failures Modes & Testing–Part 2-In Progress

Industry Issue/Project Description

- This Part 2 hydro generator tutorial will pick up where Part 1 left off. It will be of similar nature as Part 1, but focus on hydro generators, exciters and auxiliary equipment failure modes. These are described and categorized by generator component, consistent with the EPRI Hydro Generator Health Assessment Tool (HGHAT). Also included are inspection and testing activities to help prevent the failures identified.

Some Takeaways

- This tutorial will be very informative and will provide owners a solid foundation related to knowledge of hydro generator failure modes and inspection and testing. EPRI recommends that any newer hydro generator engineer go through the tutorial. Categorization by generator component is the same as Part 1 (Design & Construction) and the HGHAT (Hydro Generator Health Assessment Tool), providing consistency in naming, search and find.



Images from Part 2 Hydro generator Tutorial, to be published by Year End 2024. Similar format to Part 1 on Design & Construction.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

2025 Projects (future)

Stator Winding Uprate Considerations

Industry Issue/Project Description

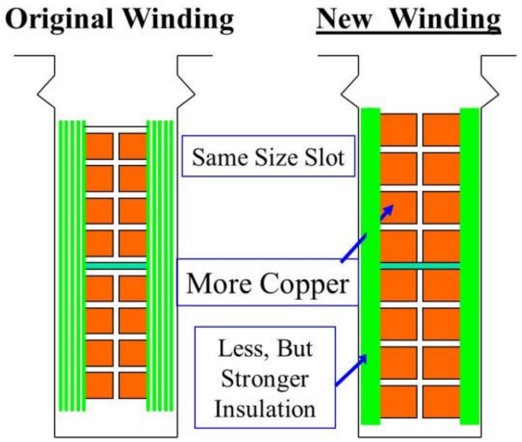
- This deliverable will provide an insight into how stator winding uprates are evaluated. With the recent uprate and upgrade industry focus, this unique and specific focus on the generator stator winding should be of value to engineers involved in this type of project. Fundamental concepts such as evaluation I^2R losses, strand eddy current losses and circulating current losses will be discussed. The importance of Roebel transposition determination will be made, including nuances for hydrogenerator stator windings. Series connection designs will be included as well. Factors that should be addressed when changing design, such as GVPI to non-GVPI, will be included.
- Decision process important – going back to OEM. What are key questions to ask. Uprate study – Nuclear – OEM. Must evaluate all components. Example – flex links.

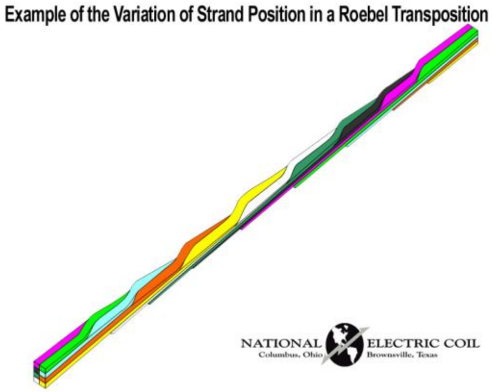
Member Benefits

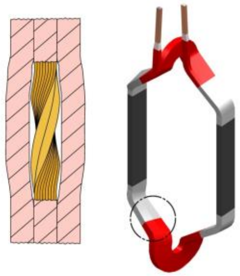
- The published technical update will assist generator SME's and system engineers involved in plant uprates and upgrades. It will be helpful in understanding bid offerings for new stator rewinds with help to compare the benefits and risks of different solicitations.

Deliverable Format

- Technical Brief, White Paper, Quick Guide
- Published by Year End 2025







© 2024 Electric Power Research Institute, Inc. All rights reserved.

FME (Foreign Material Exclusion) for Generators

Industry Issue/Project Description

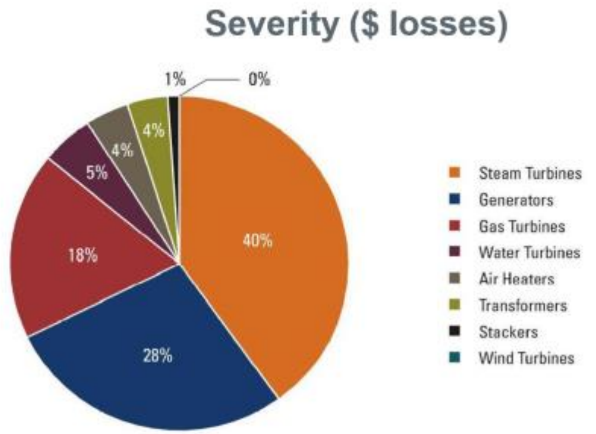
- In a 2023 presentation by FM Global, the generator ranked #2 in industry losses from foreign object damage. Additionally, EPRI has been made aware of recent, multiple instances of foreign object intrusion resulting in contamination and magnetic termites. FME (Foreign Material Exclusion) had been a significant problem that EPRI provided input on in the early 2,000's, but issues continue to occur. Also, the popularity of 3rd party contractors in charge of FME for generator rewinds, has increased.
-

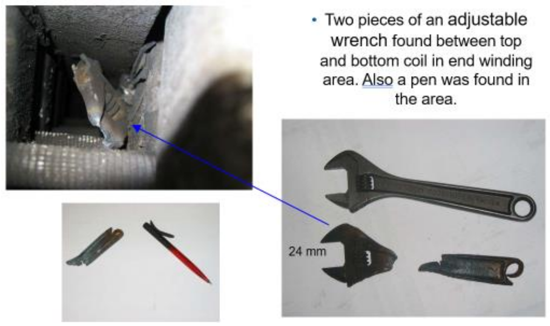
Member Benefits

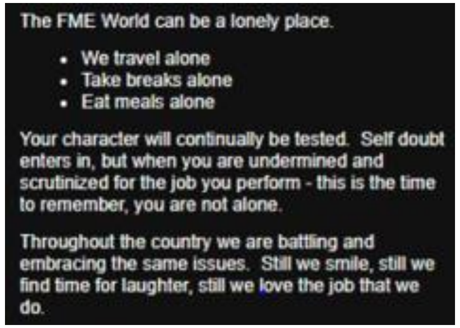
- This deliverable will be a quick guide focusing on the essentials and importance of FME, especially in the area of generator rewinds. Best Practices for essential FME will be identified. Past case histories will be covered including details about magnetic termites.

Deliverable Format

- Technical Update
- Published by Year End 2025







© 2024 Electric Power Research Institute, Inc. All rights reserved.

Stator Core Remaining Useful Life (RUL) Evaluation

Industry Issue/Project Description

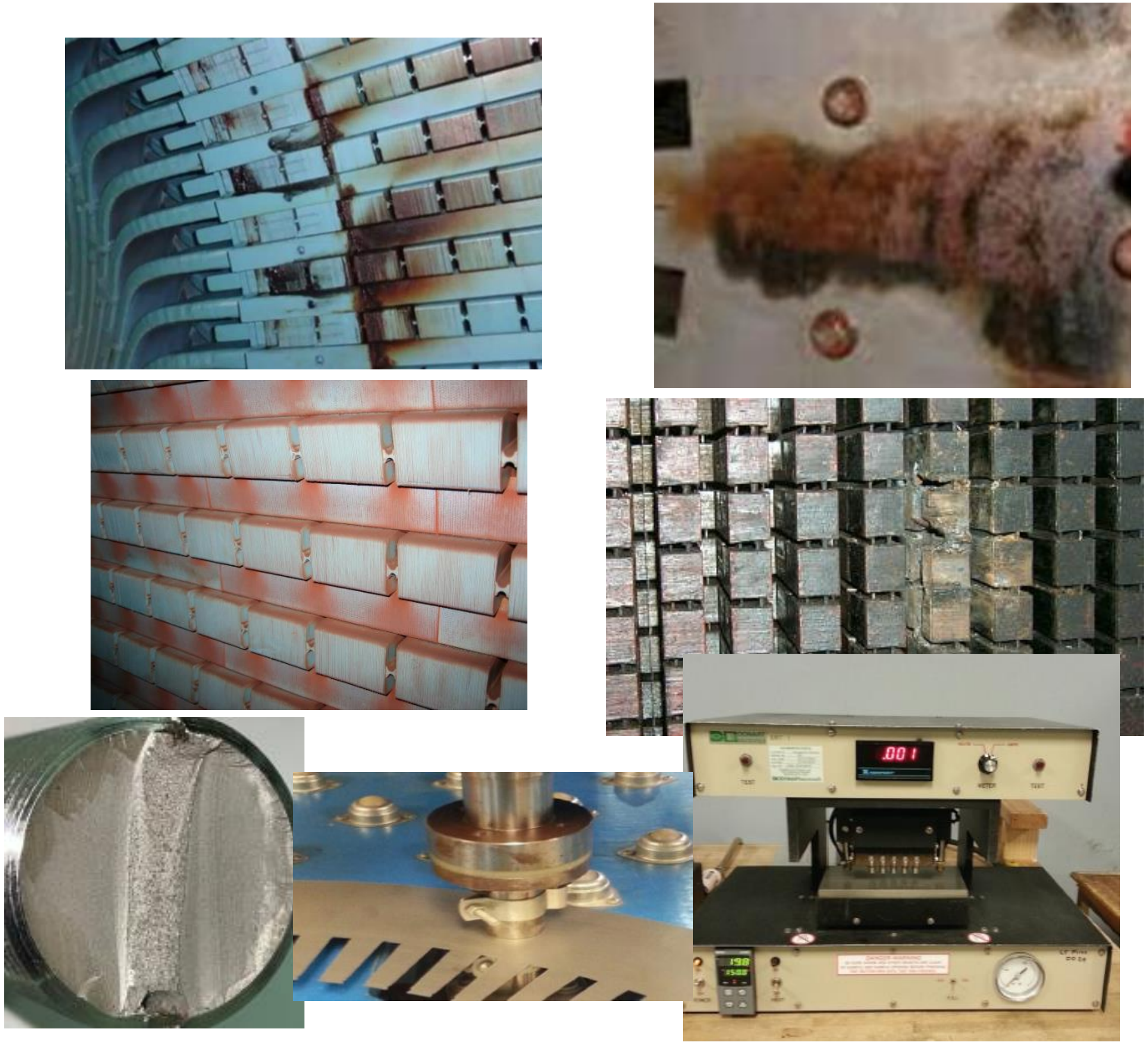
- How long will my core last? Sure, I can test it now with ELCID Core Loop and other methods, but these don't provide indication of RUL (Remaining Useful Life)
- As cores age, and a stator rewind is done, should I keep my core as (especially on the 2^{nd} rewind) or should I replace it? What are the pro's and con's?
- Lead Time. Data.
- Worst thing in the world is to put a new winding in an old core. Westinghouse? Automatically replace?
- Franklin Test – Insulation properties. Epstein test- magnetic properties.

Member Benefits

- The research, only at conceptual infancy, may provide methods to better evaluate RUL for stator cores.

Deliverable Format

- Technical Update
- May include testing/lab experiments
- Published by Year End 2025



© 2024 Electric Power Research Institute, Inc. All rights reserved.

Continuous Monitoring Sourcebook for Hydrogenerators

Industry Need

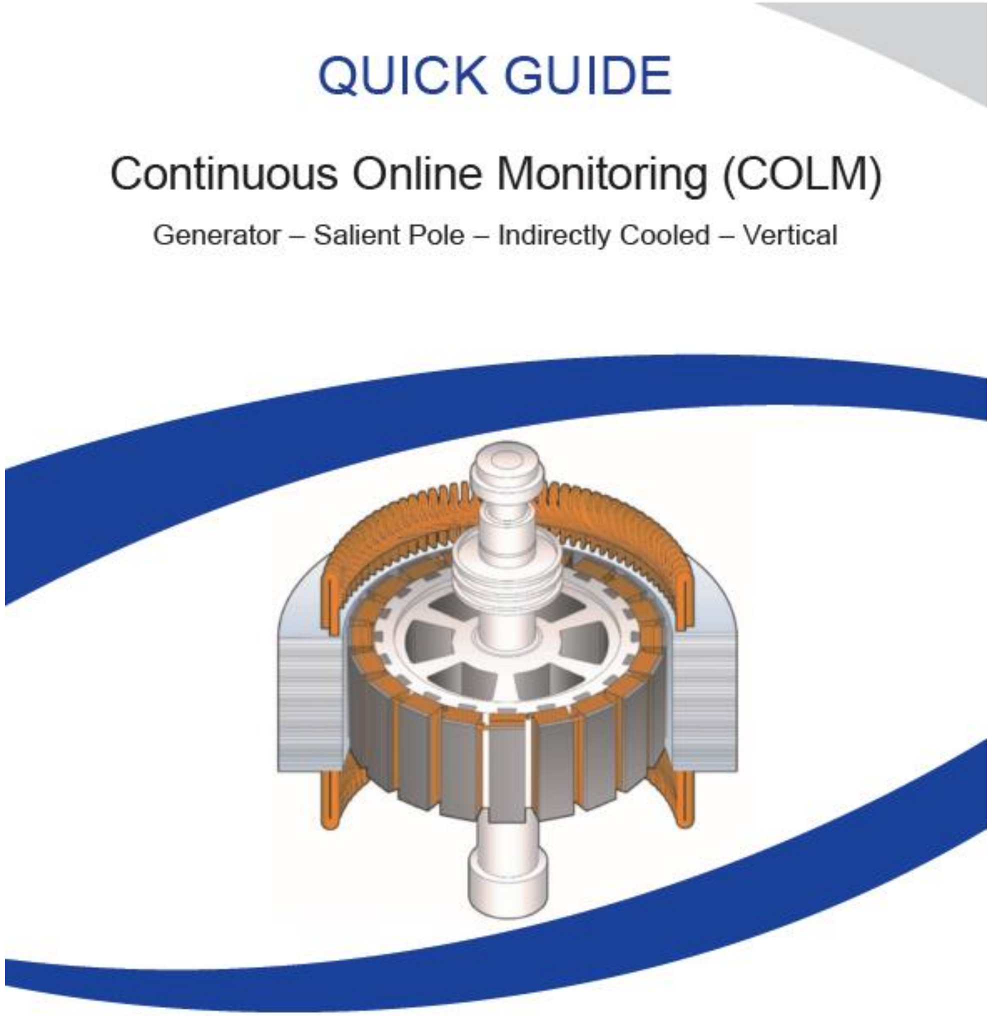
- Hydrogenerator Monitoring is critical to long term reliability and availability of the generator. Often, we have specific presentations and references on a specific monitoring device, a unique technology, or one singular approach towards a specific generator component or condition.

Member Benefits

- This project would include the latest developments in continuous, online monitoring that are essential but also unique to hydrogenerators. The field guide would be a comprehensive effort to include all key sensors and monitoring systems unique to hydros. Other, more specialized diagnostic areas would be included along with the essentials of temperature and vibration. This Field Guide will significantly build on and go deeper and farther than the EPRI COLM series.

Deliverable Format

- "Field Guide"
- Published by Year End 2025



New Hydro Generator Monitoring Sourcebook will build on and go deeper than the COLM Quick Guide Series.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Vibration Sparking in Air-Cooled Generators

Industry Issue/Project Description

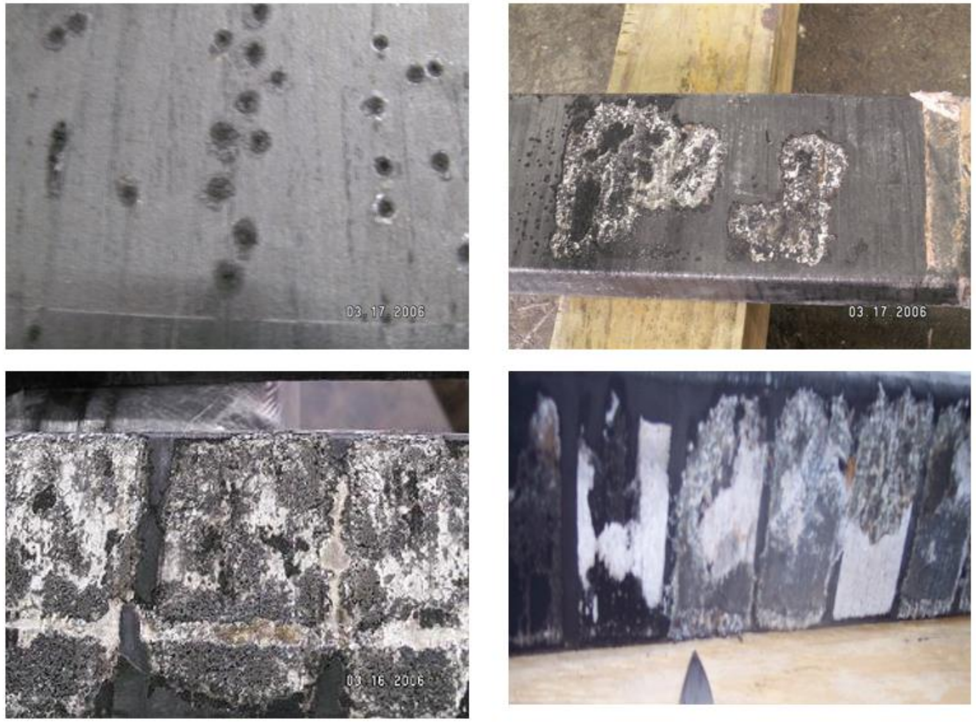
- Vibration sparking is a particularly “fast acting” failure mode, compromising the stator bar ground insulation, usually resulting in a ground fault. One of the first industry failures occurred in the 2007 time-frame. Somewhat specific to certain air-cooled generators these failures led to many premature stator rewinds The problem has recently surfaced again on air-cooled Nuclear generators with water-cooled windings.

Member Benefits

- The scope of this project will focus on several key areas:
  - Determination if EMI testing can identify vibration sparking in progress
  - Investigate new developments and possible repair solutions in the case of known generator vibration sparking/spark erosion. The research will encompass the past learnings of this failure mode, but also focus on new repair options, such as in-situ repair and replacement of top bar round packing with side ripple springs.

Deliverable Format

- Technical Update
- Published by Year End 2025



The four photos above show the rapid progression of Vibration Sparking on a Stator Bar. Top Left – initial stage, Top right 2nd stage, Bottom left-3rd stage, Bottom Right-Failure of Ground Insulation

© 2024 Electric Power Research Institute, Inc. All rights reserved.

Bolted Connections in Generators

Industry Need

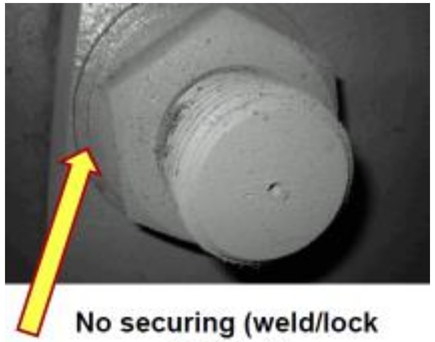
- Bolted connections in generators are found in many locations, including those with a mechanical focus such as through bolts, building bolts, end shield bolts, frame foot bolting, bearing pedestal, fan bolts, cooler bolting and more. There are also those with a combined mechanical and electrical contact need, including flex connection bolts, bus bar bolting, brushless exciter riser bolts. With the variety of bolting applications, materials and torquing requirements, it is no wonder that bolts loosen and/or fail to provide good electrical contact. Also, what is the best approach to silver plating for good electrical contact, and the influences of gaskets and O-rings and locking (prick punch and lockplate). Many facets of this topic.

Member Benefits

- This reference would compliment the recently published Steam Turbine Bolting Maintenance Guide. It would provide a ready reference for generator bolting maintenance, covering both mechanical and electrical aspects.

Deliverable Format

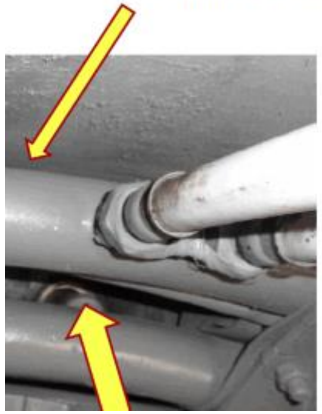
- Technical Update
- Published by Year End 2025

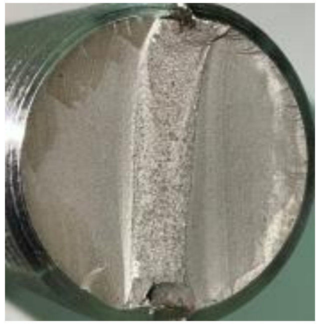


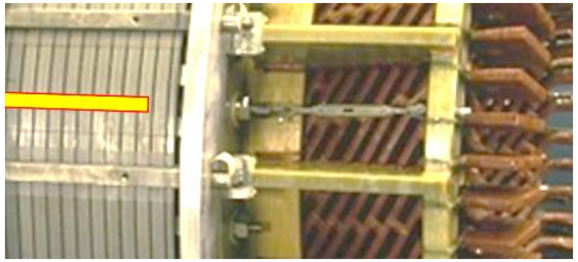
No securing (weld/lock plate/...)

Missing nut
(10-12 O'clocks seen from Turbine)

Difficult physical access







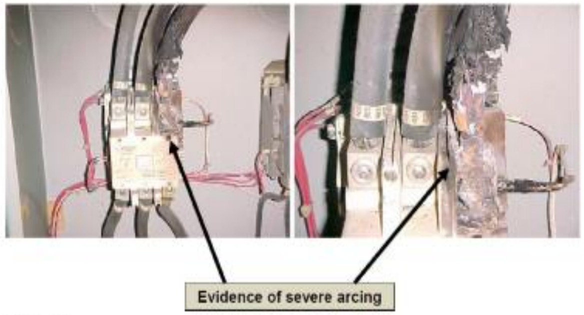


Figure 7-1
An example of a connection failure

© 2024 Electric Power Research Institute, Inc. All rights reserved.

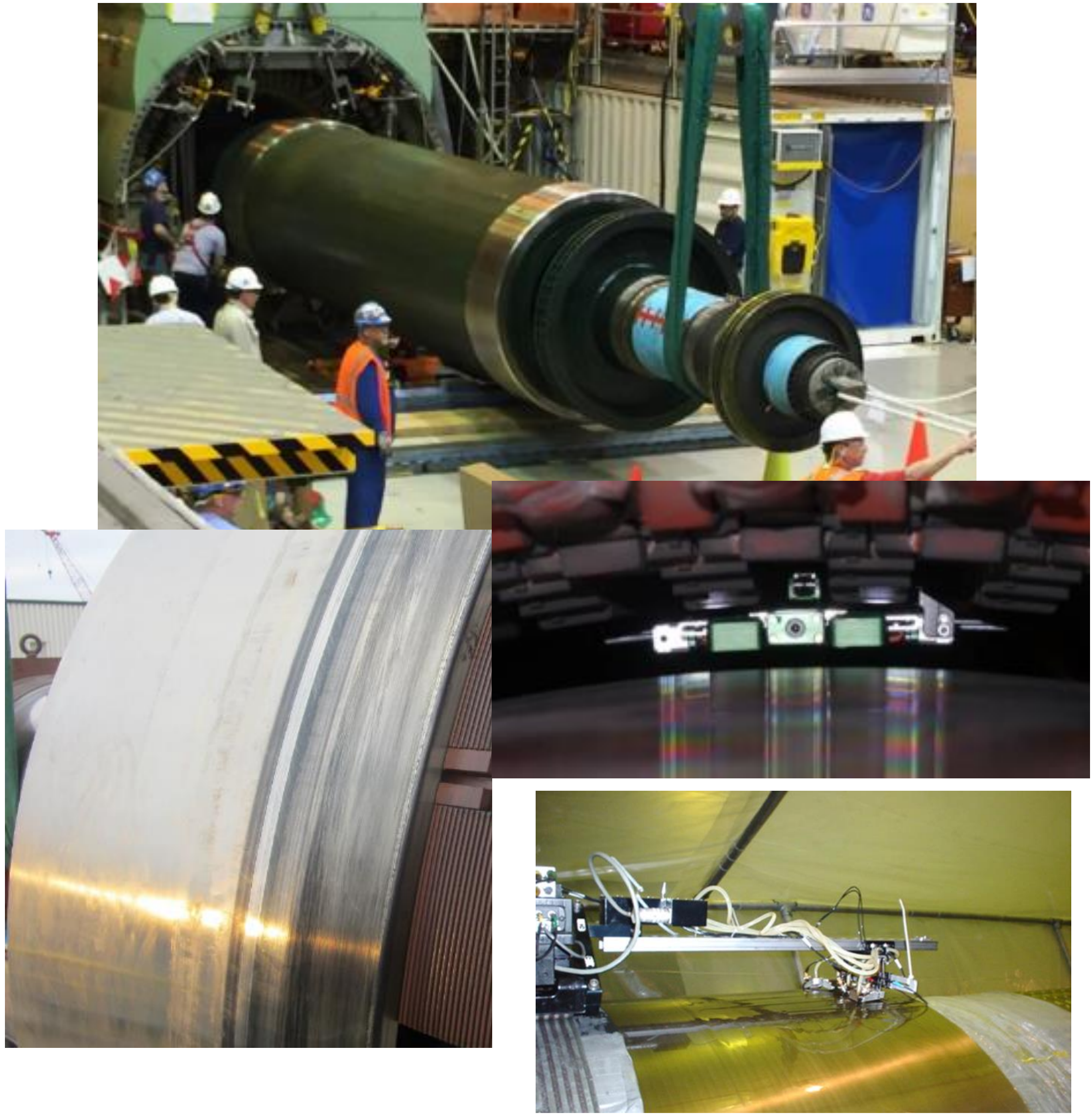
Overhaul Benchmark Study

Deliverable Description

- Provide detailed study results from an in-depth survey about overhaul duration, interval timing and scope. The surveys are back in-house and the results are being analyzed and will be presented in a P220 webcast later on this year. The information could prove of value to members by formalizing a detailed deliverable report of the results. The study will provide current information on practices involving generator overhaul schedules and timing. Key questions on this survey include:
  - What are the frequencies (duration and interval length) of your minor, medium and major overhauls?
  - Are these intervals determined using time basis or are they set based on condition assessment findings?
  - What are the typical inspection and testing activities you include in each?
  - What sequence are you using for outage planning? Minor then major? Minor then medium or major? Other? Are you aligning with centerline and turbine components? (for example, minor with a turbine valve or HGPI, and a major with the turbine centerline major?)
  - What technologies are you using to attempt to extend these outages or forego outages? Have these technologies been successful in extending outages?
  - What is your periodicity on retaining ring NDE? Do you align your main power transformer with your overhauls, or do you have another frequency specified for the transformers?

Member Benefits

- A webcast to update Members on the results of this survey is scheduled for November 21, 2024, at 10 am. However, more details and a downloadable deliverable report available to member, would provide excellent bench marking comparisons. Publish by mid-year, 2025. Technical update format. If you haven't filled out a survey and would like to there is still time. Email bgmoore@epri.com



Generator Major Overhaul May Involve Rotor/Field Removal or a robotic inspection may suffice.

© 2024 Electric Power Research Institute, Inc. All rights reserved.

BESS Impact on Turbogenerators

Industry Need

- What are the specific impacts (positive or negative) of battery plants on the generator. For renewables, such as wind and solar, the lack of inertia of these inverter-based resources (IBR) can impact the stability and/or frequency control of large prime movers. Are battery plants similar, or do they offer additional benefits or concerns? Does the rapid increase in BESS (Battery Energy Storage Systems) raise concerns for existing generators? Read of a case where a nearby batter storage plant was instrumental in keeping a generator online.

Member Benefits

- Pro’s and con’s of newly installed battery plants, from a generator perspective, will be summarized.

Deliverable Format

- Technical Brief
- Published by Year End 2025

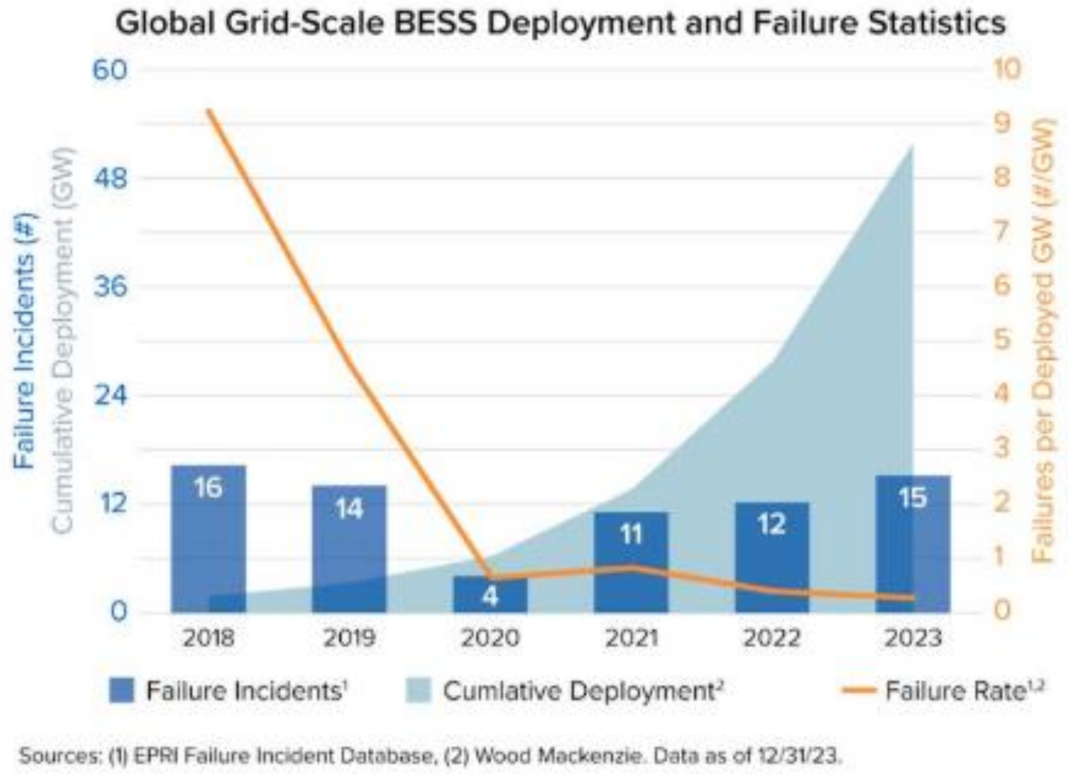


Figure 1. *Global Grid-Scale BESS Deployment and Failure Statistics*

© 2024 Electric Power Research Institute, Inc. All rights reserved.

H2 Leak Monitoring for Stator Water Cooled Generators

Industry Need

- Units operating with H2 leaks are a high concern for possible explosion or catastrophic failure. If H2 leak is to atmosphere, it is usually identifiable. First steps is to make sure H2 does not pocket or accumulate, so forced ventilation is helpful. A leak to the H2O system however, can be more problematic. SLMS limit versus other limits.

Member Benefits

- Summarize facts about these leak detection systems. Identify what improvements are needed. Review past case histories.

Deliverable Format

- Technical Update. Year End 2025.

© 2024 Electric Power Research Institute, Inc. All rights reserved.
EPRI

Questions? Ideas for EPRI Research?

© 2024 Electric Power Research Institute, Inc. All rights reserved.

TOGETHER...SHAPING THE FUTURE OF ENERGY®

www.epri.com

© 2024 Electric Power Research Institute, Inc. All rights reserved.