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Generator Maintenance Update

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Exceptional Market Changes & Asset Trends



- Wind and Solar, Renewables, are first deployed assets – greater cycling of other assets
- Hydro is considered a renewable by most, but excluded as a renewable by some, making it's fit in the market awkward – maintenance priority and budget
- Older & smaller nuclear units are being considered for decommissioning – greater dependence on other assets
- Older smaller coal shutdown. Larger later model coal being run to failure – minimal planned maintenance and budget
- Low cost of gas made modern simple cycle and combined cycle units a work horse – recent cost volatility, more cycling

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Generator Inspection



- Traditional Inspection Outages - disassembled generator, rotor removed; time & cost intensive
- Visual Inspection – most cost effective maintenance tool



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Tremendous Advancements – Optical Technology



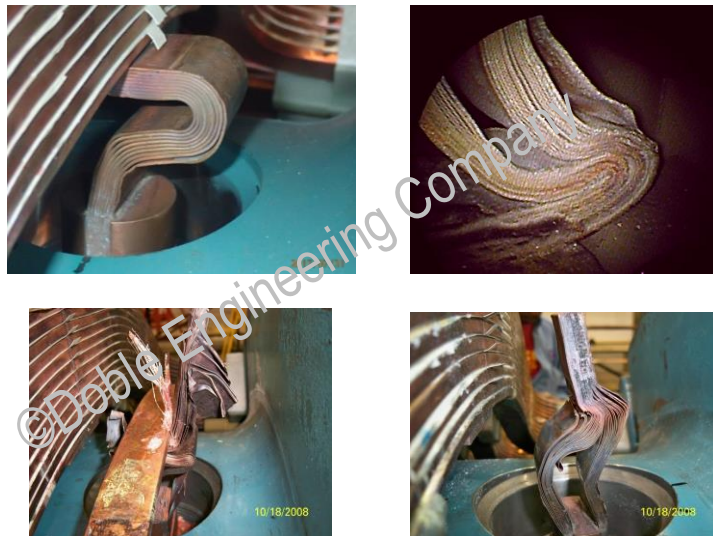
- Borescope - size, clarity, color, and measuring



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Borescope Value Example – Main Rotor Lead



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Common Generator Maintenance Activities

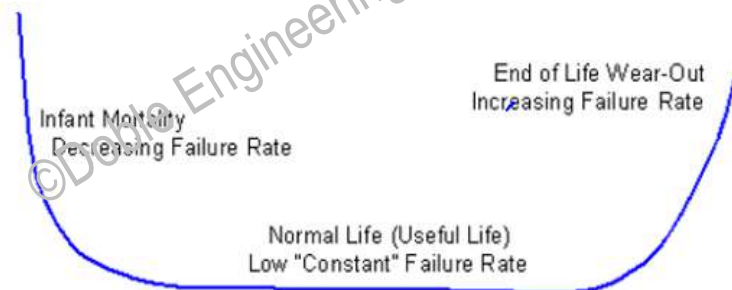


MAINTENANCE ACTIVITY	SHOWS	FREQUENCY
Dielectric Absorption	Winding cleanliness	Major Outage
Polarization Index (PI)	Winding cleanliness/moisture	Major and Minor Outage Cycles
Power Factor	Insulation integrity	Major Outage Cycle
Partial Discharge (PD)	Coil tightness; insulation integrity	On-line or Outage Cycle
Megger	Integrity of Insulation	Major and Minor Outage Cycles
Blackout	Corona suppression integrity	Rewind
Resistance	Integrity of joints and connections	Major and Minor Outage Cycles
Flux Probe	Rotor winding shorts	On-line, Rewind
Rotor Impedance	Rotor winding shorts	Rewind
Ground Fault	Rotor Ground	Continuous
Split Voltage	Location of rotor grounds	As Needed
Voltage Drop	Presence of shorted turns	Major Outage Cycle
El Cid	Integrity of stator core	Major Outage Cycle
Core Loop	Integrity of stator core	Major Outage Cycle
Bolt Torque	Stator core looseness	Major Outage Cycle
Ultrasonic	Cracks, defects in forgings	Major Outage Cycle
Temperature Monitoring	Normal/abnormal operation	On-line and Continuous
Dye Penetrant	Cracks, defects in forgings	Major Outage Cycle
Eddy Current	Cracks, defects in forgings	Major Outage Cycle
Magnetic Particle	Cracks, defects in forgings	Major Outage Cycle
Wedge Mapping	Stator winding tightness	Major Outage Cycle
Hi-Pot	Insulation integrity	Major Outage Cycle
Vibration	Rotor imbalance	Monthly and On-line
Visual Inspection	Normal/Abnormal Performance	As Available
Oil Chemistry and Count	Bearing oil contamination	Twice Yearly

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- The “Bathtub Curve” is typically used as a visual model to illustrate the three key periods of product failure



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Infant Mortality Examples



- Pole to Pole Crossover Connectors
- Many different shapes, sizes, and configurations
- Numerous early life failures – primarily due to insufficient flexibility



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Normal and End of Life Periods



- **Normal Life**
 - Hopefully boring, but not unimportant!
 - Importance of outage reports and trending
- **End of Life**
 - What is the plan?
 - Sources of Insight and Guidance
 - Past Outage Reports and Trended Data
 - Other Users, User Groups, & On Line Forums
 - Experienced Consultants
 - Trusted Vendors – Independents, OEM
 - Specifications
 - “Bull Pen”

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Stator Vibration and Resonance



- Vibration & Resonance – **NOT THE SAME**
- Flux - creates steady state pounding forces
- Pounding forces often lead to looseness / movement



Dusting



Greasing

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Resonance



- Symptom – Exceptional / Very High Vibration
- Frequency Response & Modal Testing – “Bump Testing”
- Exclusion Zones
 - 115 to 135 Hz for 60 Hz generators
 - 95 to 115 Hz for 50 Hz generators



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Example – Resonance Consequences & Solutions

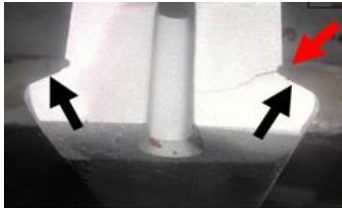


Resonant Exclusion
Zones
60 HZ – 115HZ to 135HZ
50 HZ – 95HZ to 115HZ



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Speed and Load Cycling Consequences



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Turbo and Hydro Maintenance Similarities & Differences



More similarities than differences?

- Stator
 - Commonality of air cooled machines – PD & Dirt
 - Core, coils and insulation system are very similar
 - More bars than multi turn coils in Turbo
 - More Roebel transpositions in Turbo than twist transpositions
 - Bars more common in Hydro
- Rotor
 - More differences primarily related to design, size, & speed

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Conclusions



- Well planned & executed maintenance is as important as ever!
- Incorporate new technologies.
- Identify & adapt to new maintenance challenges from operational and generator design changes
- Document & trend maintenance data and findings
- Better utilize available sources of insight and guidance
 - Other Users & User Groups
 - Experienced Consultants
 - Trusted Independent and OEM Service Providers

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QUESTIONS



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