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## Balance of Plant Maintenance Planning

AWEA Project Performance  
&  
Reliability Workshop

Mike Moore  
Shermco Industries

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## Key Learning Objectives

- Discuss Some Statistics
- Discuss Maintenance Planning
  - Generator Breakers
  - Power Cables
  - Oil Filled Transformers
  - Collector Substation
- Standards
- Challenges for the Wind Industry



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## Historical Electric Losses by Asset Type

Source: Factory Mutual Global (1991 – 2000)

Equipment	Number	Gross \$ Millions
Transformers	1,000	492
Cable/Wiring/Bus	893	362
Switchgear/Circuit Breakers	602	254
Generators	174	166
Motors	580	145
Misc. Electrical Apparatus	261	49
TOTAL	3,510	1,467

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## Lingo

- Reliability
  - The ability of a system to perform and maintain its functions in routine circumstances, as well as hostile or unexpected circumstances.
- Acceptance for Service
  - Testing performed on a system, lots of manufactured mechanical/electrical parts, or products prior to its placement into service to verify it is safe for placement into service and will operate per its intended design.

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## Lingo

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- Preventive Maintenance
  - Care and servicing by personnel for the purpose of maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects.

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## Lingo

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- Predictive Maintenance
  - (**PdM**) techniques help determine the condition of in-service equipment in order to predict when maintenance should be performed. This approach offers cost savings over routine or time-based “Preventive Maintenance, because tasks are performed only when warranted.

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## Generator Breaker

- **Periodic Maintenance (Weekly/Monthly/Annually)**

- **Visual Inspection**

- Anchorage
- Connections - Grounding & Conductors
- Mechanical Operation
- Infrared Inspections
- Ultrasound Inspections



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## Generator Breaker

- **Periodic Maintenance (Every Two Years)**

- **Visual Inspection**

- Anchorage
- Connections - Grounding & Conductors
- Mechanical Operation



- **Electrical Testing**

- Over-Current Protective Devices
- Insulation Resistance
- Contact Resistance
- Control Device Operation



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## Generator Step-Up Transformer

- **Periodic Maintenance (Monthly/Quarterly/Annually)**

- **Visual Inspection**

- Anchorage
- Connections - Grounding & Conductors
- Mechanical Operation of Oil Immersed Switches
- Infrared Inspection
- Oil/Headspace Leaks
- Headspace/Nitrogen Blanket

- **Electrical Testing**

- Control Devices

- **Insulating Oil Sampling & Analysis**

- Oil Quality
- DGA



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## Generator Step-Up Transformer

- **Periodic Maintenance (Every Three Years)**

- **Visual Inspection**

- Anchorage
- Connections - Grounding & Conductors
- Oil/Headspace Leaks

- **Electrical Insulation Testing**

- Power Factor/Dissipation Power Factor
- Turns Ratio (TTR)
- Winding Resistance
- Insulation Resistance

- **Insulating Oil Sampling & Analysis**

- Oil Quality
- DGA
- Furanic Compounds



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## Collector Power Cables

- **Periodic Maintenance (Annually)**

- **Visual Inspection**

- Anchorage
- Connections - Grounding & Conductors
- Bends/Radius
- Exposed Terminations
  - Visual Inspection
  - Infrared Inspection
  - “On-Line” Partial Discharge Sampling
  - Ultrasound Inspection



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## Collector Power Cables

- **Periodic Maintenance (Every Three Years)**

- **Visual Inspection**

- Anchorage
- Connections - Grounding & Conductors
- Bends/Radius
- Terminations

- **Electrical Testing**

- \*Very Low Frequency (VLF)
- Tan Delta
- Power Factor/Dissipation Power Factor
- “Off-Line” Partial Discharge



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## Collector Substation

- **Periodic Maintenance (Weekly/Monthly/Quarterly)**

- **Visual Inspection**

- Anchorage
    - Connections - Grounding & Conductors
    - Event Recorders
    - Collector Terminations
    - Station Batteries
    - Station Service
    - Transformers
      - Oil Levels
      - Winding Temperatures
      - Oil Temperatures
      - Headspace/Nitrogen Blanket
      - Arresters/Bushings
    - MV/HV Breaker Operations
    - Outdoor Bus/Structures



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## Collector Substation

- **Periodic Maintenance (Annually)**

- **Visual Inspection**

- All Previous Inspections (Weekly/Monthly/Quarterly)

- **Electrical Test**

- Infrared Inspection
    - “On-Line” Partial Discharge Sampling
    - Ultrasound Inspection
    - Battery Testing/Load-bank
    - Protective Relay Testing / Electrical Operation of Devices
    - NERC/FERC Compliance Testing & Maintenance

- **Insulating Oil Sampling & Analysis (Transformer & Tap changer)**

- Oil Quality
    - DGA



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## Collector Substation

- **Periodic Maintenance (Every Three Years)**
  - **Visual Inspection**
    - All Previous Inspections (Weekly/Monthly/Quarterly)
  - **Electrical Test**
    - All Previous Inspections (Annuals)
    - Medium /High Voltage SF6 Circuit Breaker Testing & Maintenance
    - Main Substation Transformer Testing & Maintenance
    - NERC/FERC Compliance Testing & Maintenance
  - **Insulating Oil Sampling & Analysis (Transformer & Tap changer)**
    - Oil Quality
    - DGA
    - \*Furanic Compounds (Transformer Only)



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## Standards & Program Development

- Develop maintenance programs off of national consensus standards to bring credibility and reliability to the program.
  - IEEE 902-1998 (Yellow Book)
    - Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems
  - NFPA 70B
    - Recommended Practice for Electrical Equipment Maintenance
  - ANSI/NETA MTS-2007
    - International Electrical Testing Association's Maintenance Testing Specifications
    - Approved American National Standard (ANSI)
    - Annex B - Offers guidelines for the frequency of maintenance tests

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## Standards & Program Development

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- Develop maintenance programs off of national consensus standards to bring “safety” to the program.
  - NFPA 70E – Standard for Electrical safety in the Workplace
    - Chapter 2 – Safety Related Maintenance Practices
  - Write a safety- or reliability-based electrical acceptance testing plan for all new equipment to ensure that installation meets applicable codes, standards and safely operates as designed by the manufacturer
  - Develop an electrical maintenance plan for existing and service-aged electrical equipment that evaluates and trends insulation systems, mechanical operation and over-current protective devices for proper operation

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## Standards & Program Development

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- Develop maintenance programs off of national consensus standards to bring “safety” to the program. (cont.)
  - NFPA 70E – Standard for Electrical safety in the Workplace
    - Chapter 2 – Safety Related Maintenance Practices
  - Institute practices like “First Trip” to give site managers a real world look at equipment operating speeds
  - Validate all over-current protective devices with the most recent coordination study settings

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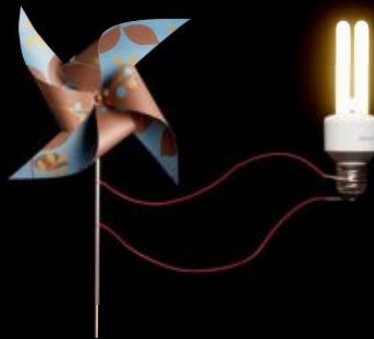
## Challenges for Wind Energy

- Wind energy equipment and systems presents unique hazards for electrical work:
  - Extreme heat/cold
  - Mechanical hazards
  - Multiple power sources
  - Worker fatigue
  - Personnel challenges
  - Elevated Working
  - High incident energy at many locations in the collector



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## Questions?



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Thank You