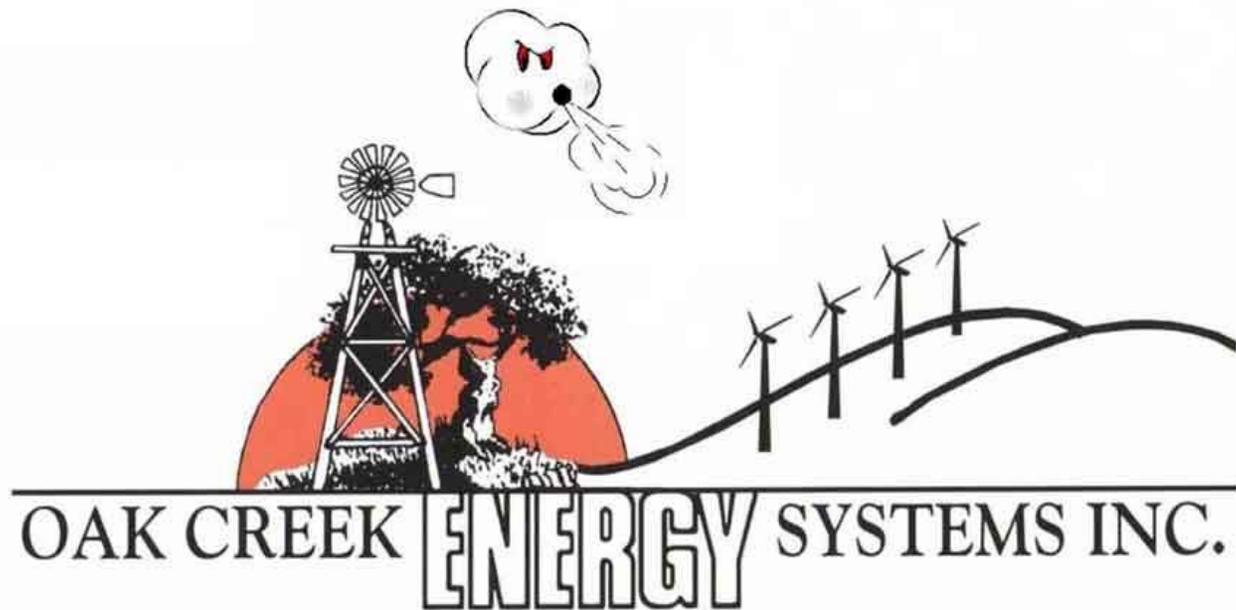


Generator & Electric System Reliability

Hal Romanowitz

Wind Turbine Reliability Workshop
Albuquerque
October 3, 2006



Overview

- **Increased Use of Lower Speed Generators Can Increase WTG Reliability**
- **Generator Reliability can be Very High**
- **Attention to Details is Important**

Major Impacts on Generator Reliability

- **Insulation Life**
- **Bearing Life**
- **Slip Rings & Brushes**
- **Iron Damage After Winding Ground**
- **Rewinding Issues**

What Kills Insulation

- **Cracks or Voids in Magnet Wire Insulation**
- **Dirt or Dust Accumulates**
- **Moisture Appears**
- **Failure Occurs**
- **Avoid Failure by Eliminating Causes**

What Causes Insulation Cracks & Voids

- **Original Magnet Wire Insulation Voids**
- **Thermal Ageing**
- **Mechanical Shock**

Type of Generator Coil Makes a Difference

- **Random Wound Coils Most Common**
- Round Magnet Wire with Many Turns
- Difficult to Impossible to Control Turns Lay
- Early and Late Turns Can Touch
- Risk of High Voltage on Adjacent Turns

- **Form Wound Coils for Larger Generators**
- Rectangular Magnet Wire
- Single Turn Per Layer Feasible
- Excellent Management of Adjacent Turn Volts
- Excellent Opportunity for Supplemental Insulation

Resin Insulation

- **High Solids Resin Very Common Now**
- **Warm Wound Magnet Structure Dips**
- **Vacuum Impregnation**
- **Slot Length Makes a Difference**

Coil, Slot & Winding Design for Inverter Use

- **Low Surge Impedance Design Helps**
- **Must Allow for Surge Voltage in Inverter Use**

Mechanical Bracing Important

- **Current Surge Stress is Significant**
- **Rotating Mechanical Stress**
- **Cold – Hot – Cold Expansion**
- **Key is to Brace Appropriately**
- **Important to Extra Insulate End Turns**

Impact of Temperature on Insulation Life

- **10C Rule is Key**
- **+10C Operation = ½ X Life**
- **-10C Operation = 2 X Life**
- **Thermal Ageing Leads to Insulation Cracks**
- **Class F Insulation at Class B Rise Benefit**

Manage Dirt & Dust

- **Open Dripproof Generator is Higher Risk**
- **Filtered Air Open Generator Mid Risk**
- **Totally Enclosed Generator Much Lower Risk**

Water Cooled Totally Enclosed

- **Water Cooled Totally Enclosed is an effective way to make Large Generators Totally Enclosed**
- **Leak Prevention Design is Important**
- **Must Change Coolant Regularly**
- **Bad Coolant = Bad Cooling = Hot Generator**

Manage Moisture & Condensation

- **Increasingly Important As Generator Ages**
- **Modest Heating Prevents Most Condensation**
- **In-Winding Heat is Best**

High Impedance Ground is Beneficial

- **Avoids Iron Damage @ Ground Fault**
- **Allows Orderly Planned Shutdown @ Ground**
- **Permitted by Code**
- **Requires Simple Monitoring**
- **Oak Creek considers it Very Successful**
- **Used Widely with Large Generators**

Bearing Life Issues

- **Proper Lubrication**
- **Stray Currents**
- **False Brinelling**
- **Bearing Fits**

Bearing Lubrication

- **Lubricated for Life Bearings are Not!**
- Unless Life is Less Than 5 Years
- **Oil is the Critical Lubricant**
- **Grease is Oil in a Soap Carrier**
- **Sealed Bearings Can Be Relubricated In Place**
- Fresh Grease in Cavity is Effective Lubricant
- Danger in Over Pressuring Lubricant Into Seal & Popping

Slip Rings & Brushes

- **Brush & Slip Ring Design is a Black Art**
- Humidity, Load, & Speed are Critical Factors
- What Works One Place May Not Work in Another

- **Slip Ring Runout & Surface Condition Important**

- **Arc Damage of Slip Ring Grows Exponentially**
- Address Issues Early & Often

Permanent Magnets are Great - But

- **Mechanical Design is Important**
- **Over Temperature Kills Magnets**
- **Over Current Kills Magnets**
- **Potential for Greatly Improved Designs**
- **Potential for Greatly Improved Performance**