Factors Influencing Wind Turbine Reliability in Pitch System Designs

2006 Wind Turbine Reliability Workshop

Hosted by:
Sandia National Laboratories
In Association with:
National Renewable Energy Laboratory (NREL)
American Wind Energy Association (AWEA)

Albuquerque, NM 3 and 4 October, 2006
MLS Electrosystem LLC

- Joint Venture Founded in 2000
- Focused on Electric Servo Pitch Control
- Experience with Servo Pitch Since 1996
- Expanding Operations to Support Growth
  - Seneca, PA
    - Engineering and Development Labs
    - Electronics and Electrical System Assembly
  - Houston, TX
    - Mechanical Applications and Design Engineering
    - Mechanical Assembly for Pitch and Yaw Gears
Importance of Reliability

• It’s All About the ROI
  – Exceeding Production Expectations
  – Beating Availability Targets
  – Reliability of Sub-Systems is Key to Availability and ROI
The Language of Reliability

• For Wind Turbine Sub-Systems That Means:
  – Reliability: Things That Don’t Break (High MTBF)
  – Durability: Time Between Maintenance Intervals
  – Predictability: Maintenance At Favorable Times
  – Serviceability: Short Time For Maintenance/Repair
  – Accessibility: Few Restrictions On Getting There
Full Span Blade Pitch Sub-System Basics

- Follows Blade Pitch Angle Demands from the Turbine Control System
- Provides Varying Degrees of Speed and Power Regulation
- Can Provide Load Mitigation
  - Tower
  - Drive Train
  - Blade Fatigue
- Can Provide Real-Time Blade Root and Other Load Data
- Part of Grid Loss Ride Through Strategy
- Is the Aerodynamic Brake to Stop the Turbine – Critical Safety Function
Full Span Blade Pitch Sub-System Basics

- Market Technology Trends
  - Increasing Dynamic Response
  - Increasing Sophistication of Command and Control Processing

Time

- Blade Fatigue Mitigation
- Embedded Blade Strain
- Dynamic Loads Mitigation
- Rotor Speed Regulation
- Optimize Angle for Stall Regulation
- Barometric Compensation
Full Span Blade Pitch Sub-System Basics

Not An Industrial Application!

- Outdoor or Semi-Outdoor Environment
- Restricted Access
- Lightning Strikes
- Other Electrostatic Discharges
- AC Mains Supply Transients
- Rotational Forces
- Fatigue Cycles > $2 \times 10^8$ (30 Years)
Full Span Blade Pitch Sub-System Basics

- Full Span Blade Pitch Actuator Types
  - Conventional Hydraulic
  - Servo Hydraulic
  - Thyristor Electric
  - Servo Electric
Full Span Blade Pitch Actuator Types

- Standard Hydraulic
  - Widely Deployed
  - Well Suited to the Early Objectives for Pitch
  - Low Initial Cost
  - Very Rugged and Reliable If Maintained
  - Maintenance Interval 6 Months to 1 Year
  - Well Established Support Infrastructure and Organizations
Thyristor Electric
- Most Widely Deployed Electric Pitch Type
- Low Response 50 to 60 Hz Torque Response
- Low Maintenance - In Principle
- Uses Sophisticated Electronic Controls
Full Span Blade Pitch Actuator Types

- Servo Hydraulic
  - Response Suitable to Achieve Latest Pitch Objectives: 90 to 200 Hz Torque Response
  - Performance Sensitive to Maintenance
  - Reliability Sensitive to Maintenance
  - Very High Maintenance: 2 to 6 Month Intervals
  - Uses Sophisticated Electronic Controls
Full Span Blade Pitch Actuator Types

- Servo Electric
  - Newer Technology in the Wind: Late 90s
  - Response Suitable to Achieve Latest Pitch Objectives: 300 to 500 Hz Torque Response
  - Low Maintenance: In Principle
  - High Reliability: In Principle
  - Uses Sophisticated Electronic Controls
Factors Influencing Reliability in Design

- Electrical and Electronics Related
  - Components Rated for -40 to +85°C or Better
  - Capacitor Circuit Design for Durability
    - Low Operating Ambient Compared to Part Rating
    - Use of Tantalum Capacitors
    - Extended Life Electrolytic Parts
    - Applied Voltage Low Percentage of Rated
    - Ripple Current Low Percentage of Rated
    - Power Films in High Power Switching Circuits
Factors Influencing Reliability in Design

• Electrical and Electronics Related
  – Optocouplers Circuit Design Durability
    • Conservative CTR – Margin for Lifetime Drift
    • High dV/dt rated parts
  – Protecting Circuits from Damaging Transients
    • PCB Layout and Circuit Design Techniques
      – Construct Faraday Cages in PCB Layers
      – Hand Place Parts and Signal Routing
      – Y-Capacitors on Isolation Barriers
Factors Influencing Reliability in Design

• Electrical and Electronics Related
  – System Packaging and Assembly Practices
    • Learn from Aircraft and Automotive Techniques
    • Laced Cable Harnesses
    • High Vibration Automotive Connectors
    • Thread Lock or Prevailing Torque Fasteners
    • Mechanical Stabilization of Electronic Parts
Factors Influencing Reliability in Design

- Electrical and Electronics Related
  - Protection of Power Switching Electronics
    • Fast Bridge High Current Detector - 5 μSec
    • Survive Direct Shorts and Ground Fault to Output Stage
  - Exceed EMC Transient Immunity Standards
    • IEC Level IV+ EFT Burst – No Fault
    • IEC Level IV+ Surge – No Fault
    • IEC Level IV+ ESD – No Fault
Factors Influencing Reliability in Design

• Electrical and Electronics Related
  – Environmental Protection – Equipment Enclosures
    • Pressure Compensation
    • Anti-Condensation System
    • Conformal Coating and Trace Spacing on PCBs
      – Allowance for Non-Conductive Pollution
      – Permits Condensation
Factors Influencing Reliability in Design

- Electrical and Electronics Related
  - Temperature Management of Equipment Enclosures
    - Circulation to Maintain Uniform Temperatures
    - Comfortable Temperature Rise at Full Rated Load
    - Identify and Validate Hot Spots

Temperature Validation
Factors Influencing Reliability in Design

- Durability of Emergency Power – Batteries
  - Approved for Aircraft and Air Transport
  - 5 to 10 Year Service Life
  - Charging Techniques
  - “High Rate” Construction
  - Initial Capacity
  - Validation of Supply
Factors Influencing Reliability in Design

- Durability of Emergency Power – Batteries
  - Validation Testing
  - Production Testing

Battery Internal Resistance vs Temperature
Factors Influencing Reliability in Design

- Preventative Maintenance up to 30 Years
  - Scheduling Maintenance
    - Batteries 5 Years
    - Motor Brushes Typically 5 to 10 Years
      - Measure First of Fleet After 2 Years
      - Establish Replacement Schedule
    - Cooling Fans 10 Years
  - Predicting Maintenance
    - Detect Battery Maintenance Several Months Before Need
    - Extend Maintenance to 6 to 10 Years
    - Monitor Temperature Rise for Given Conditions
Factors Influencing Reliability in Pitch System Designs

- Reliability = Availability = ROI
- Pitch Systems Present Special Design Challenges
- Increasing Response and Performance Demands
  - Challenges “Conventional” Pitch System Types
  - Requires Newer Servo Based Approaches
- Availability Driven Design Techniques In Servo Pitch Systems