MLS Electrosystem
Mechanical Linkage Solutions

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

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Importance of Reliability

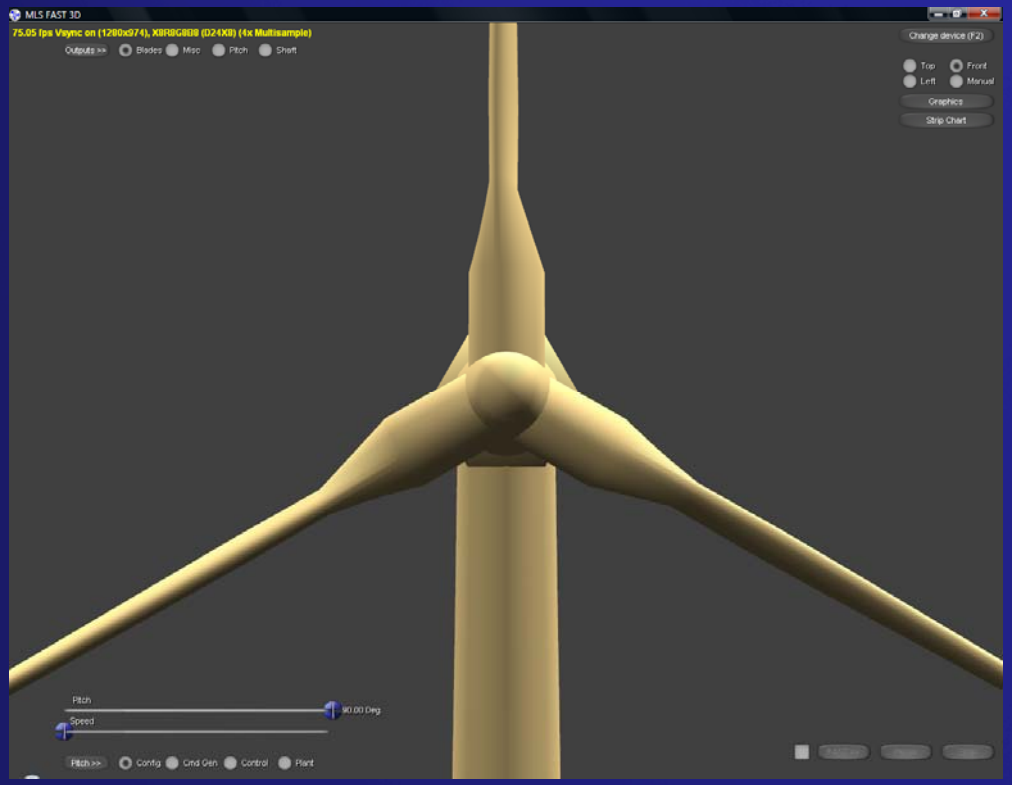
- It's All About the ROI
  - Exceeding Production Expectations
  - Beating Availability Targets
  - Reliability of Sub-Systems is Key to Availability and ROI

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

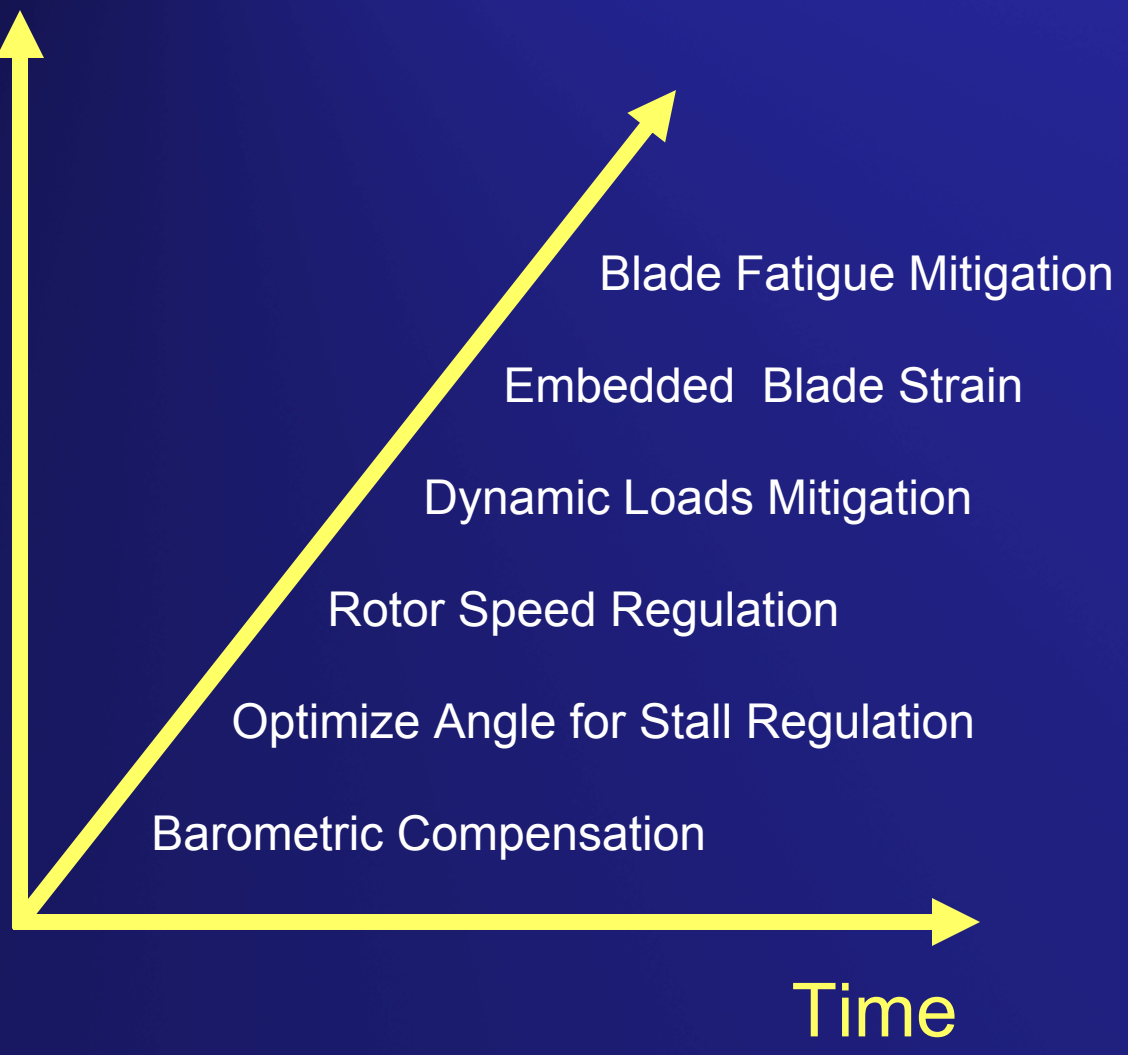
Full Span Blade Pitch Sub-System Basics

- 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

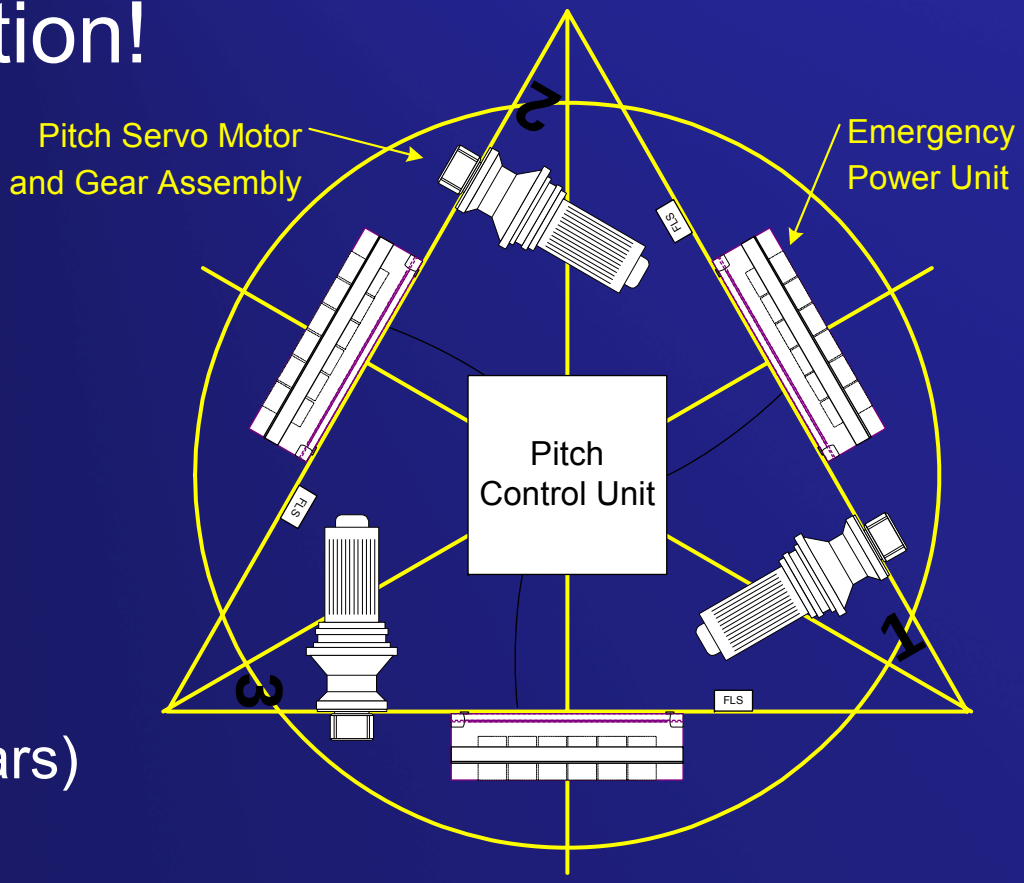
- Market Technology Trends
  - Increasing Dynamic Response
  - Increasing Sophistication of Command and Control Processing



Full Span Blade Pitch Sub-System Basics

Not An Industrial Application!

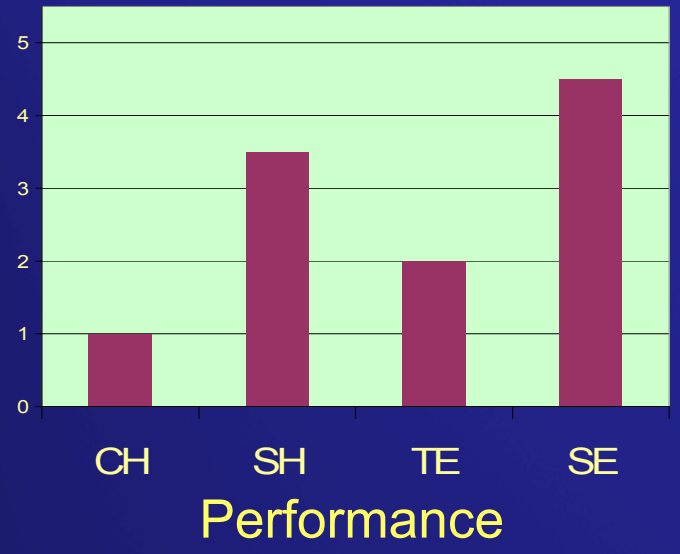
- Outdoor or Semi-Outdoor Environment
- Restricted Access
- Lightning Strikes
- Other Electrostatic Discharges
- AC Mains Supply Transients
- Rotational Forces
- Fatigue Cycles > 2 x 10^8 (30 Years)

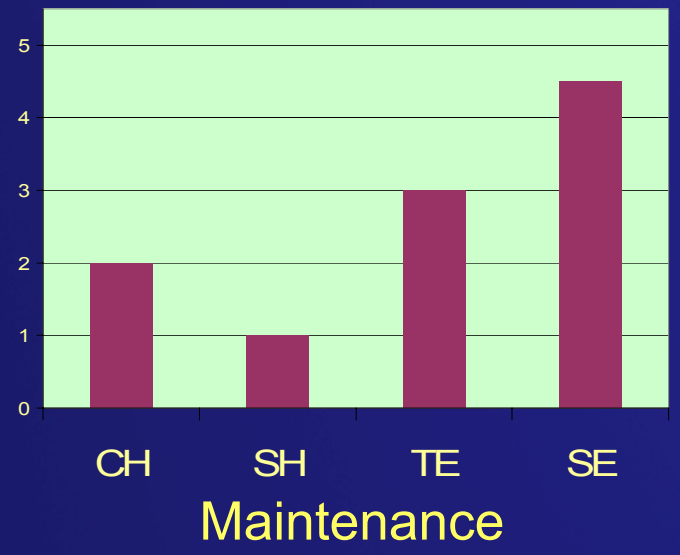


Typical Pitch System Hub Layout

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

Full Span Blade Pitch Actuator Types

- 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

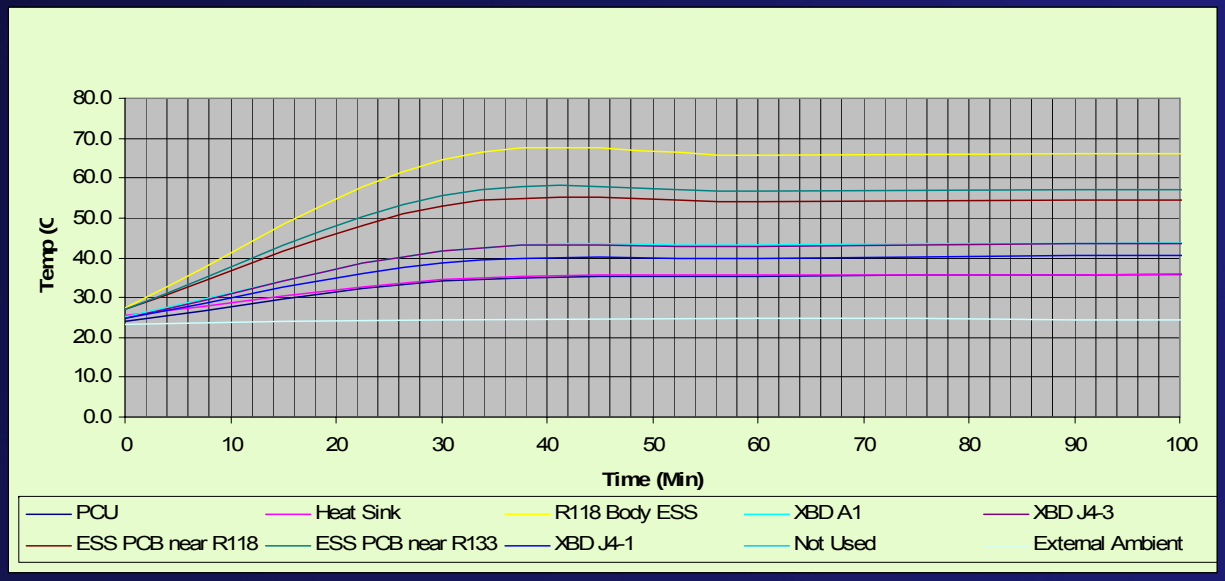
- Electrical and Electronics Related
  - Protection of Power Switching Electronics
    - Fast Bridge High Current Detector - 5 µSec
    - Survive Direct Shorts and Ground Fault to Output Stage
  - Exceed EMC Transient Immunity Standards
    - IEC Level IV+ EFT Burst – No Fault
    - IEC Level IV+ Surge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



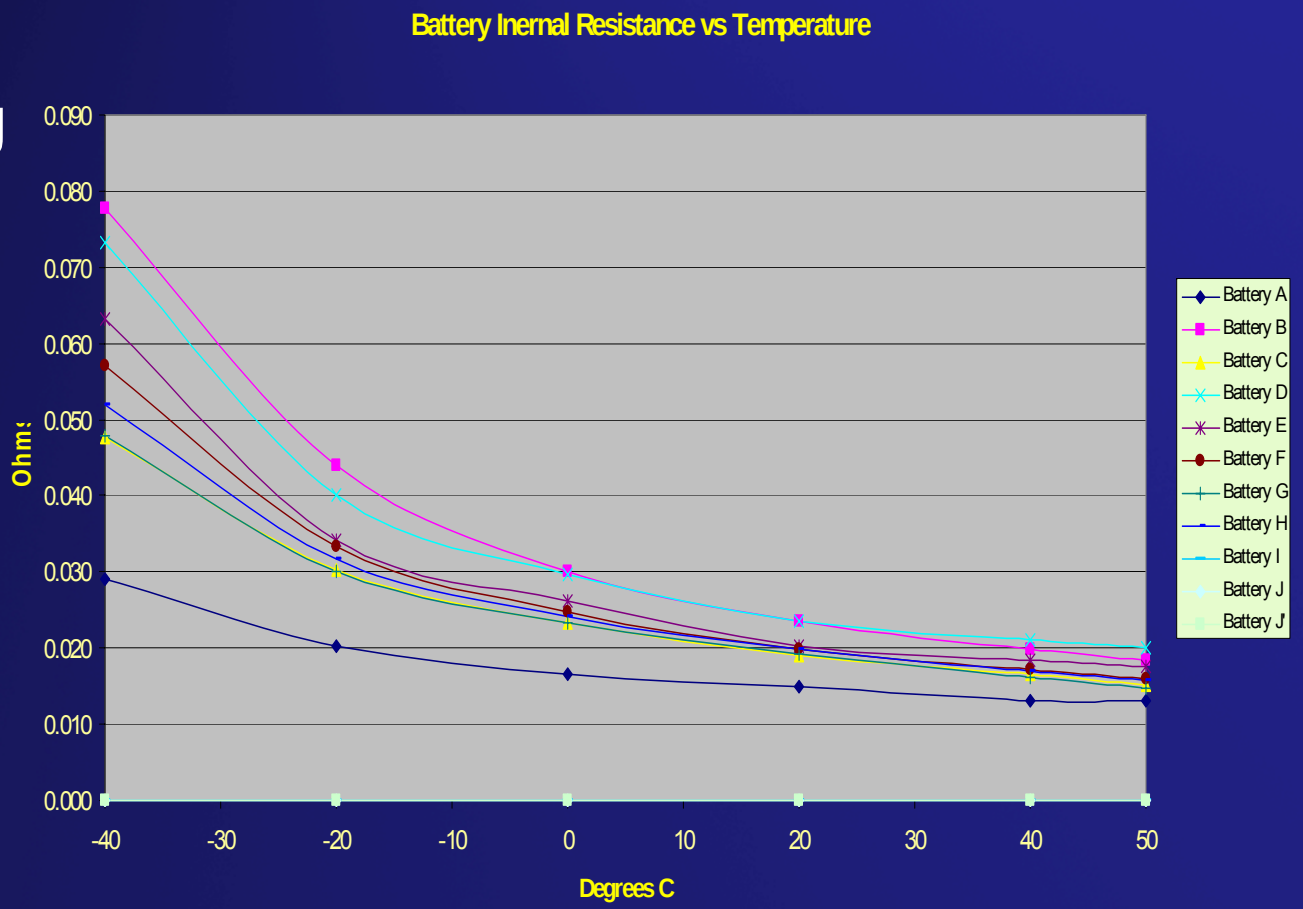
Temperature Validation

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



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