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# **Grainger CEME/IEEE Workshop - Technology Roadmap for Large Electrical Machines**

## **Modeling Tools**

Scott Sudhoff

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# Modeling Aspects

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- Categories
  - Electrical Simulation
  - Magnetic Analysis
  - Structural Analysis
  - Thermal Analysis
  - Computational Fluid Dynamics
  
- Applications
  - Design
  - Analysis

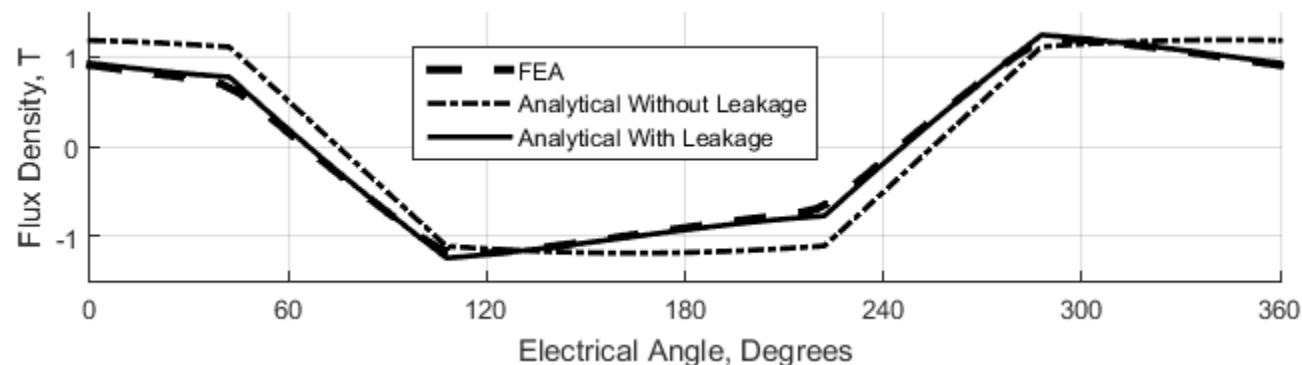
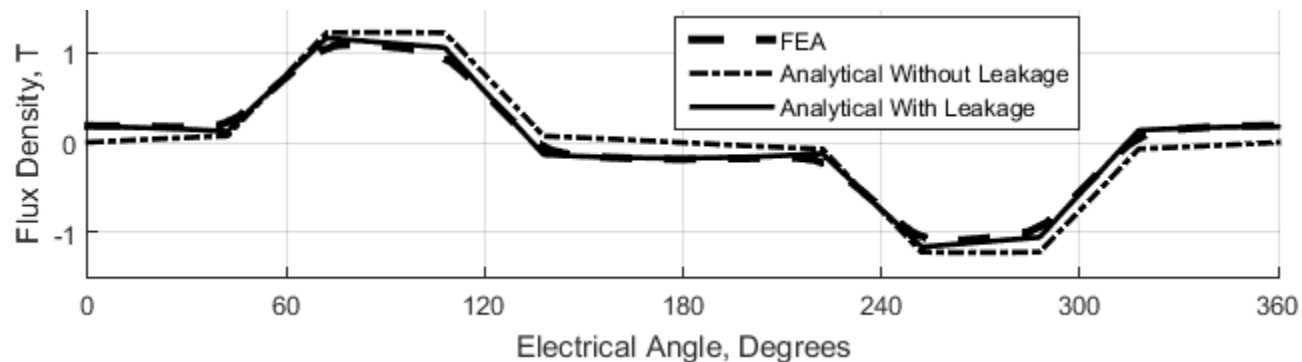
# Electrical Simulation

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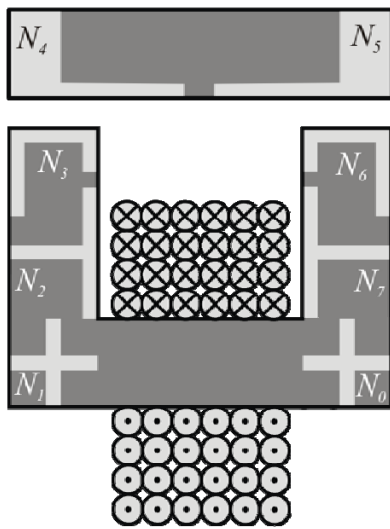
- Categories
  - State-Variable Based Approach
  - Resistor-Companion Based Approaches
  - Hardware-in-the-Loop
  - Power-Hardware-in-the-Loop
  - Real Time Digital Simulators
  - Distributed Heterogeneous Simulation

# Magnetic Analysis – Analyticalish Methods

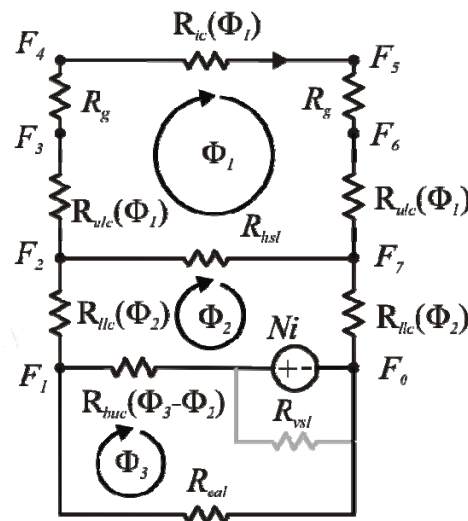
- Direct solution of Maxwell's equations
- Magneto-static analysis of radial field using Ampere's Law



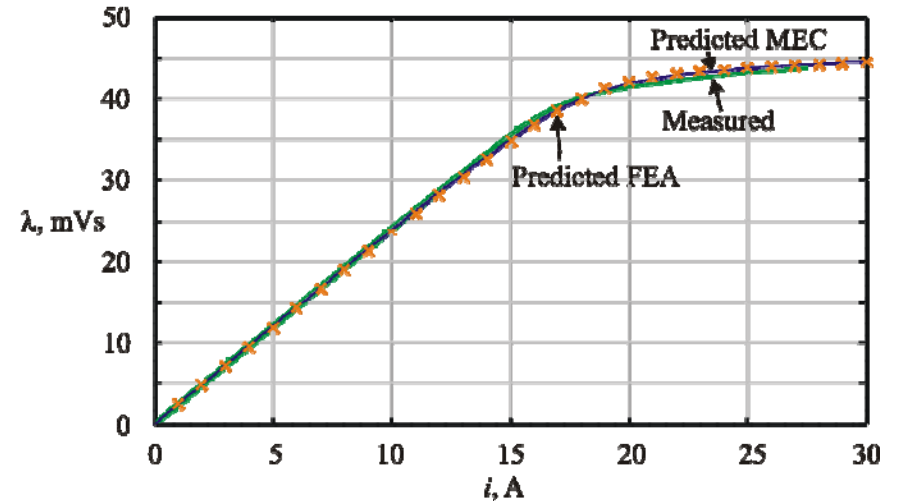
# Magnetic Analysis – Magnetic Equivalent Circuits



(a) cross section showing nodes



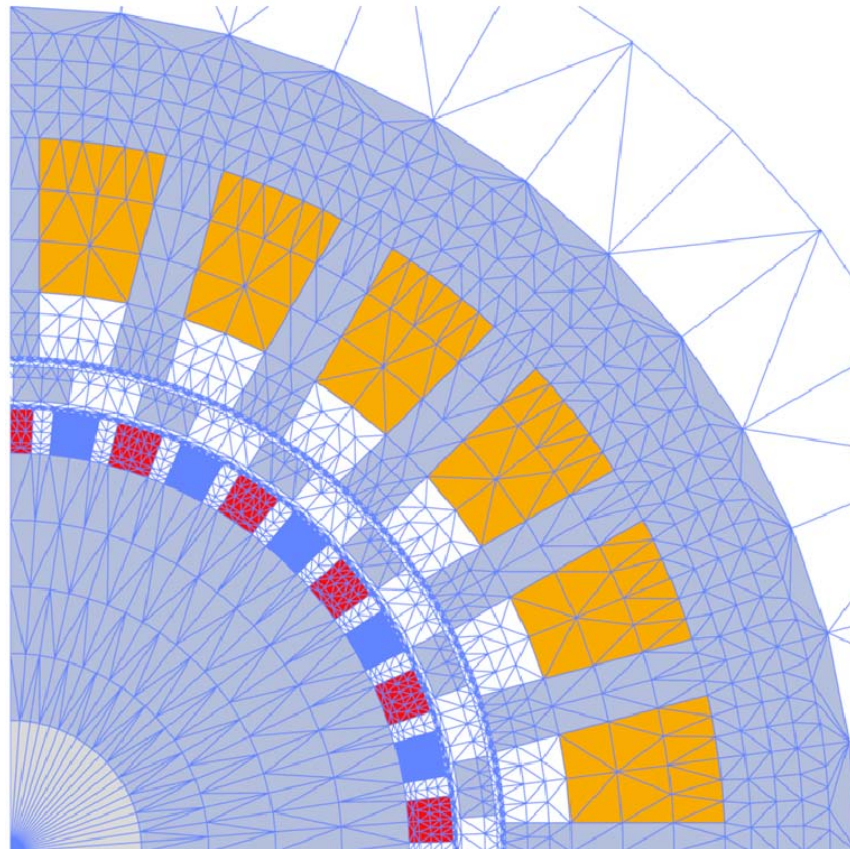
(b) magnetic equivalent circuit



# Magnetic Analysis – Finite Element Analysis

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- Computational Strategies
  - Graphical Processing Units
- Structured Mesh FEA



# Magnetic Analysis – Other Methods

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- Boundary Element Methods
  - Analytical*ish* solution for 2D problems
- Method of Moments

# Structural Analysis

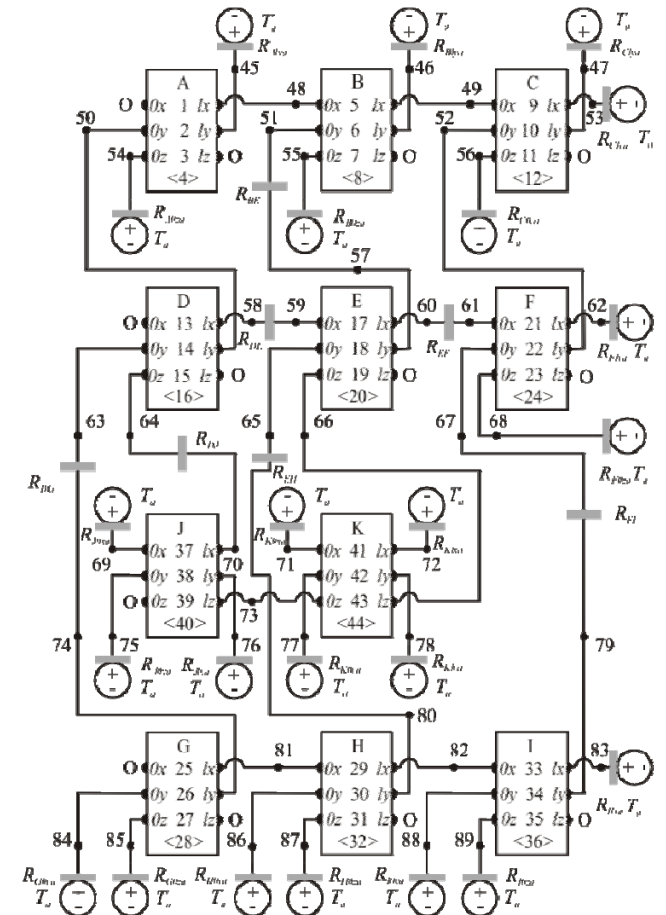
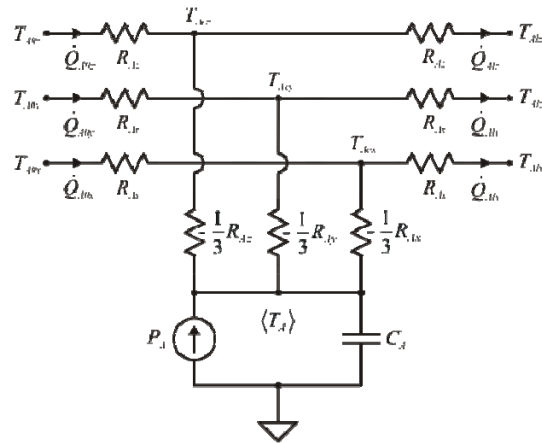
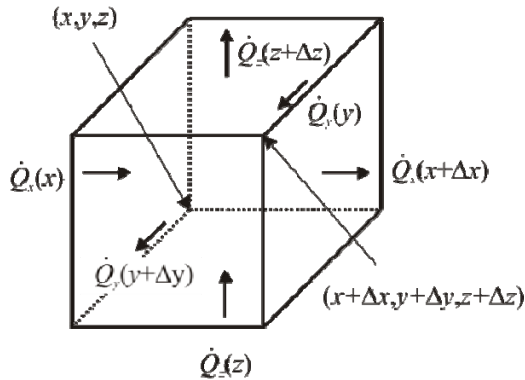
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- Particularly Important for High-Speed Machines



# Thermal Analysis

- Strictly Speaking Needs CFD
- Thermal Equivalent Circuits
- Thermal FEA



# Computational Fluid Dynamics

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- Extremely difficult problem
- Combinations of turbulent and laminar flow make this problem challenging