Estimation of Model Parameters Using Limited Data for the Simulation of Electric Power Systems

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Presentation Roadmap

- Embedded Simulator Overview
- Mathematical Modeling and Algorithm Development

Embedded Simulator Overview

Why use embedded simulation?

Embedded Simulator Overview

Why use embedded simulation?

- Train control room operators
- Evaluate trainee performance
- Verify control logic
- Develop and validate best practice operating procedures
- Study plant responses to “what-if” scenarios

Embedded Simulator Overview

Simulator Implementation

- Utilizes standard Ovation toolset
- Flexibility – algorithms developed as they are needed
- Models use same graphic icons as Ovation control system graphics
- No 3rd party resource specialization required
- Allows for plant measurements where there is no physical sensor

Embedded Simulator Overview

Simulator Flexibility

- An Ovation Embedded Simulator can range in terms of fidelity depending on need and application
- Migration from tie-back to a much higher fidelity is realizable
  - Can be done on an incremental basis
- “Multi-use” algorithms

Embedded Simulator Overview

- Models predict and output based on an input
  - Steady state relationships
  - Dynamics relationships
- Process variable steady-state values
  - Process variables at an equilibrium (operating point)
  - Rate of change with respect to time is zero
  - Described by algebraic equations
- Process variable dynamics
  - Time varying response
  - Described by differential equations
  - Concept of state variable

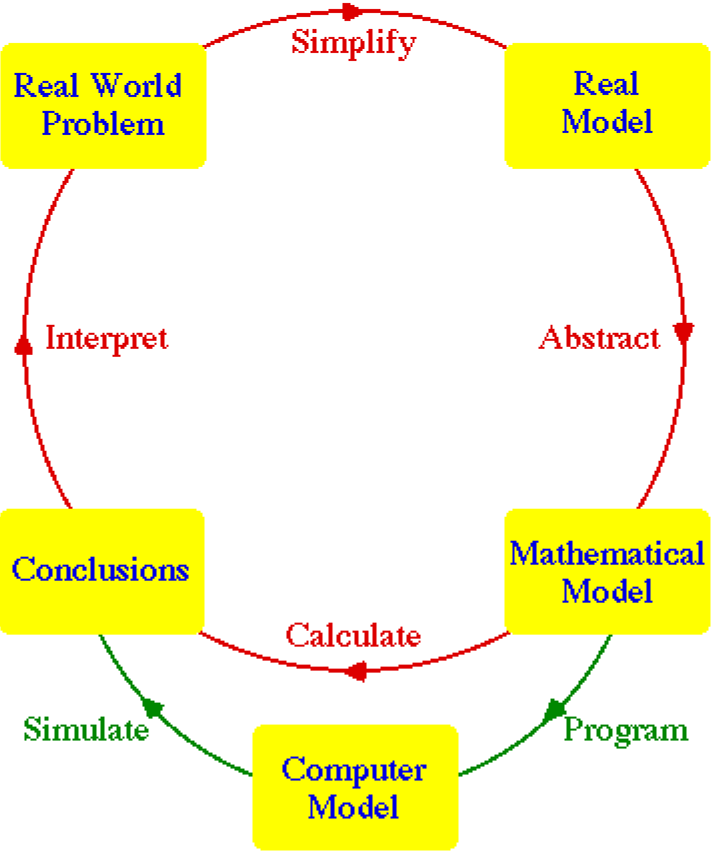
Embedded Simulator Overview

- First principles models
  - Based on the laws of physics
  - Conservation of mass and energy
  - Parameters have physical meaning
  - Non-linear for practical purposes
- Empirical models
  - Less fidelity than first principles
  - Data driven models
- Transfer function models
  - Lead/Lag, ARX etc.
  - Tend to be linear

Mathematical Modeling and Algorithm Development

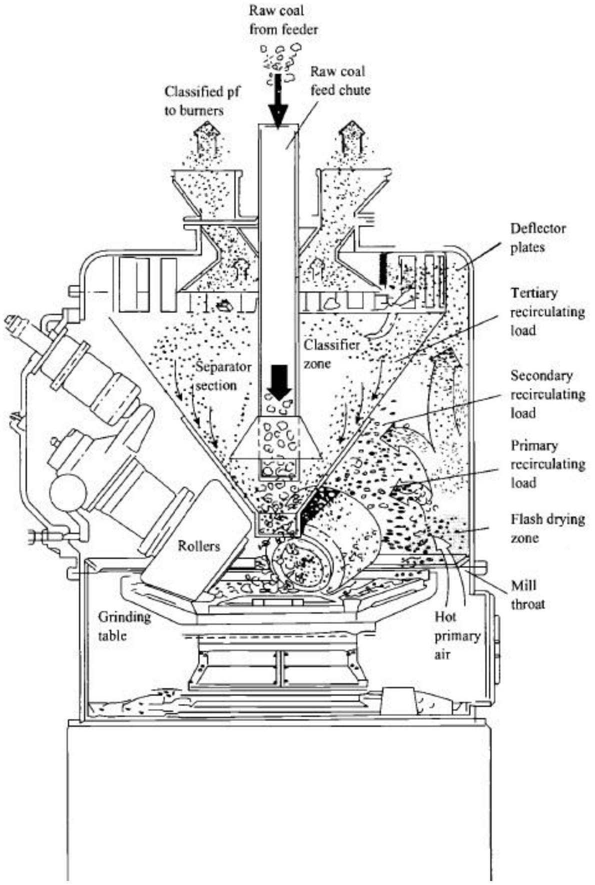
Mathematical Modeling and Algorithm Development

- What is mathematical modeling?
- Modeling can be challenging due to lack of real data.
- Simplifications are made to create a realistic model.
- The model fidelity can be determined by the user to accommodate the desired application.



Mathematical Modeling and Algorithm Development

- Equipment is first researched using technical literature to develop and understanding of the model.
- The research findings are compared to available data to properly reduced the model complexity.
- <u>Example</u>: Consider the pulverizer shown to the right.



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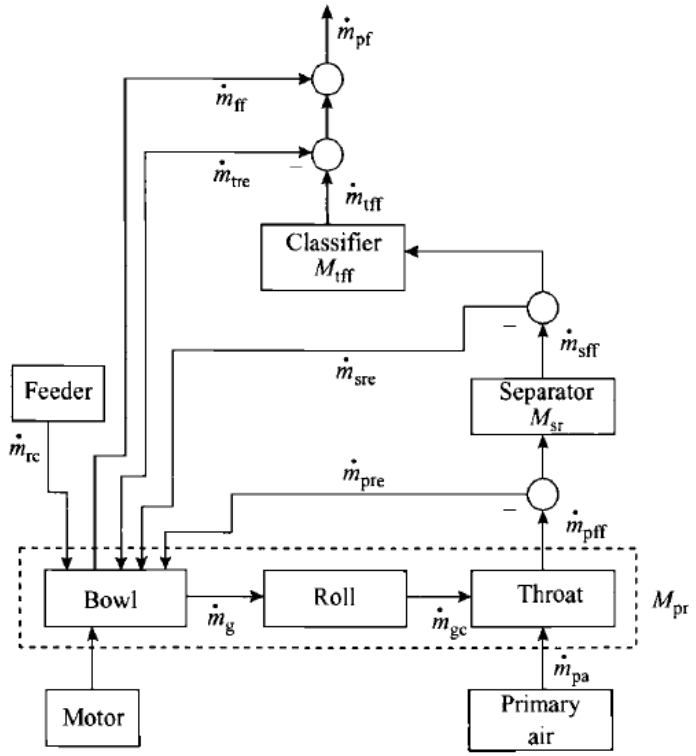
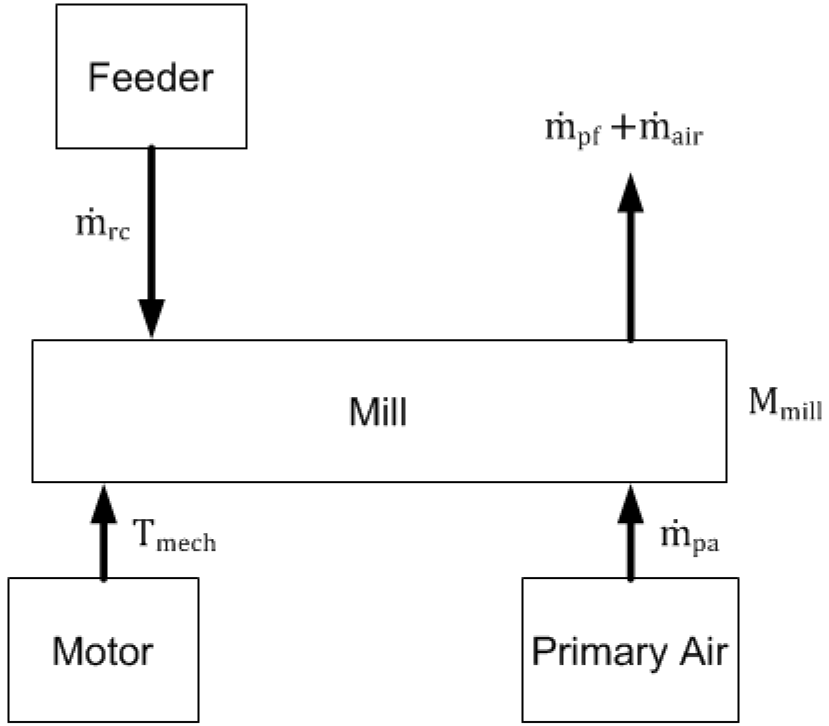
Mathematical Modeling and Algorithm Development

Research Model



Simplified Model



Mathematical Modeling and Algorithm Development

Major Difficulty

- Models must be reduced to a user friendly version due to difficulties such as
  - Limited knowledge of the engineer
  - Limited data
  - Complexity

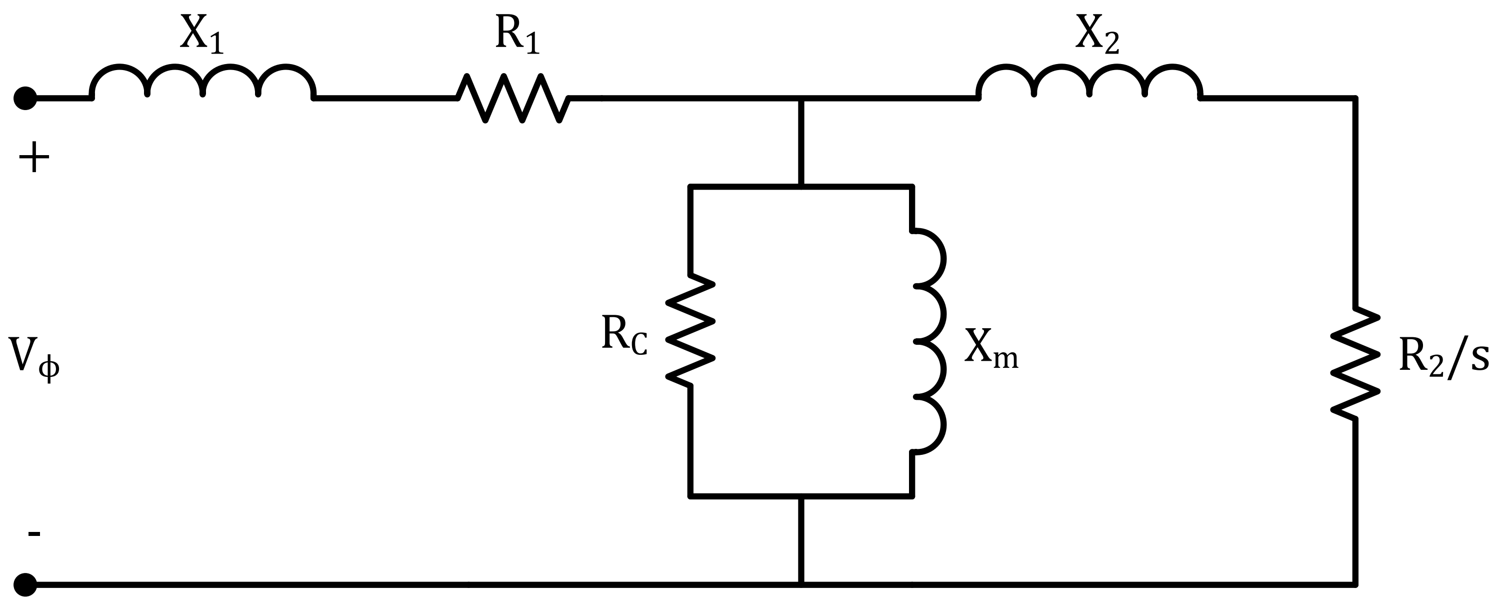
Mathematical Modeling and Algorithm Development

Solution

- Estimation of model parameters
  - Estimate the parameters using easily obtained data
  - Develop tuning procedure
- Iterative Newton-Raphson solution
  - Solve for parameters using iteration of several non-linear equations.
- Example:
  - Induction Motor

Mathematical Modeling and Algorithm Development

- Induction motor:



Mathematical Modeling and Algorithm Development

- Data available
  - Rated speed
  - Rated power
  - Rated voltage
  - Rated and half load power factor
  - Rated and half load efficiency
  - Starting and full load torque
  - NEMA class

Mathematical Modeling and Algorithm Development

- Solve in order for:
  1. Rotor resistance
  2. Stator resistance
  3. Constant power loss
  4. Sum of stator and rotor reactances
  5. Stator reactance
  6. Rotor reactance
  7. Core resistance
  8. Magnetizing reactance

Mathematical Modeling and Algorithm Development

- Then solve auxiliary equations:
  1. Rotor voltage at half load
  2. Rotor voltage at full load
  3. Rotor current at half load
  4. Rotor current at half load
  5. Rotor current at full load
  6. Rotational losses

Mathematical Modeling and Algorithm Development

- The process repeats until all resistance and reactance values have a maximum difference of 0.01 Ω per iteration
- Example of equations:

Rotor resistance

$$R_2 = \frac{\left(P_{\text{rated}} + P_{rot}\right)s_{FL}}{3I_{2F}^2\left(1 - s_{FL}\right)}$$

Constant power loss

$$P_{const} = P_{\text{rated}}\left(\frac{1}{\eta_{FL}} - 1\right) - 3I_{1F}^2 R_1 - 3I_{2F}^2 R_2$$

Rotor voltage at half load

$$\mathbf{E}_{\mathbf{H}} = V - \mathbf{I}_{\mathbf{1H}}\left(R_1 + jX_1\right)$$

Questions?