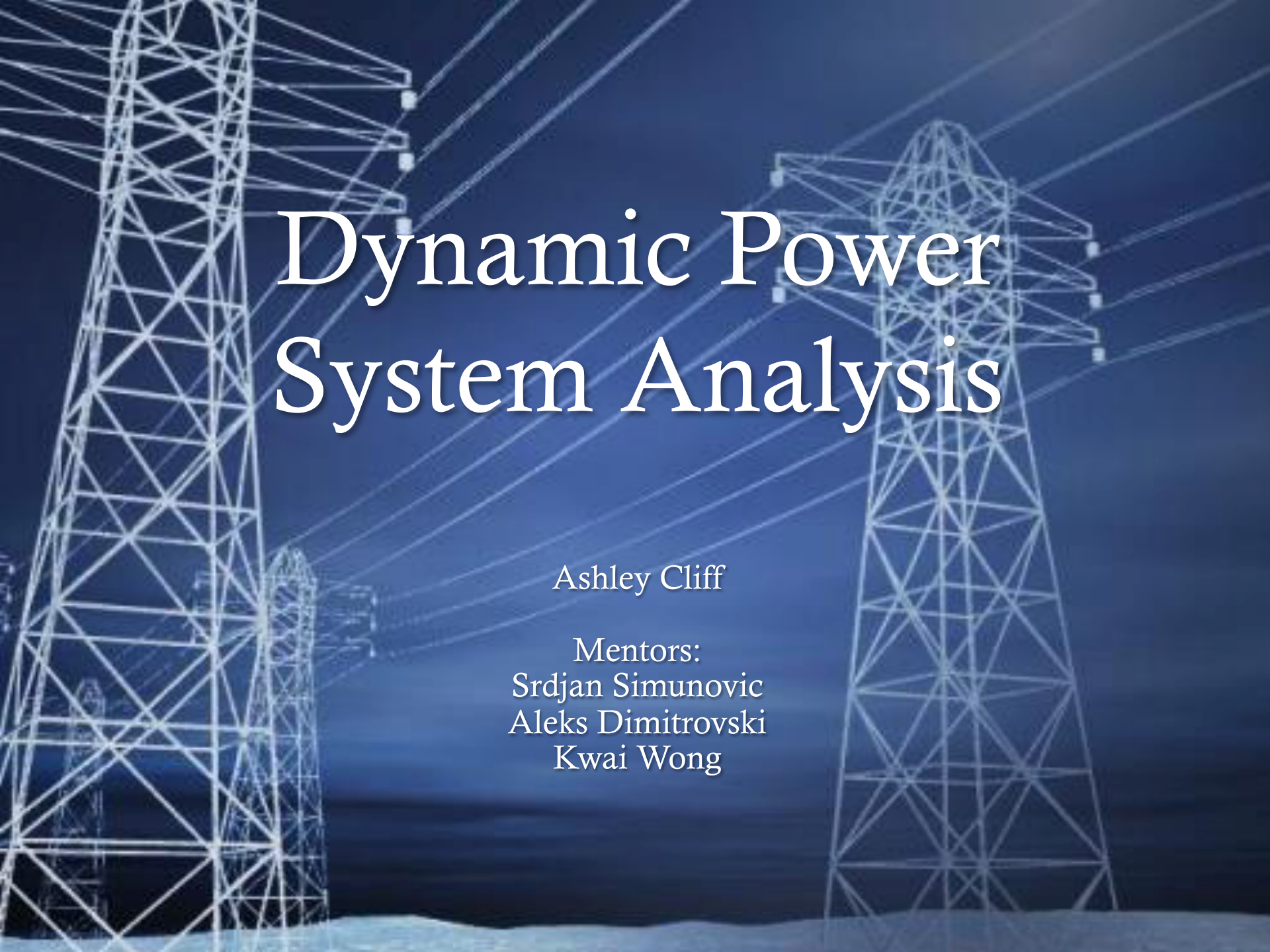

Dynamic Power System Analysis

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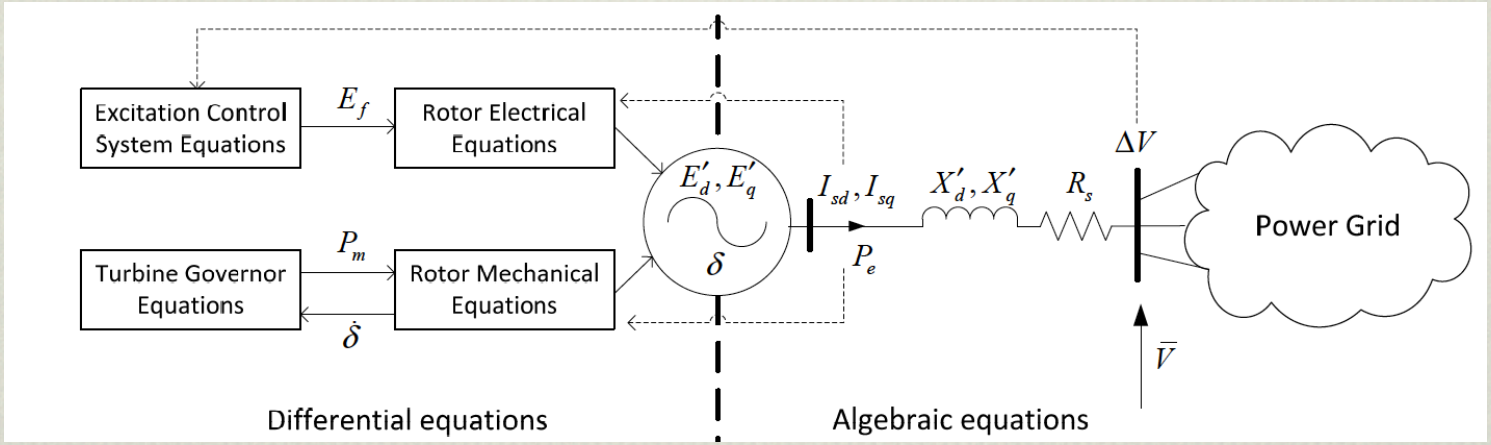
Background

- Power System: Power grid with transformers, buses, generators, loads, etc.
- Steady State system vs. Dynamic system



❖ Algebraic Equations: power distribution

$$P_i = \sum_{k=1}^{n} |V_i||V_k|[g_{ik}\cos(\theta_i - \theta_k) + b_{ik}\sin(\theta_i - \theta_k)]$$

$$Q_i = \sum_{k=1}^{n} |V_i||V_k|[g_{ik}\sin(\theta_i - \theta_k) - b_{ik}\cos(\theta_i - \theta_k)]$$

❖ Differential Equations: power generation

$$\frac{d\delta}{dt} = w_B S_m$$

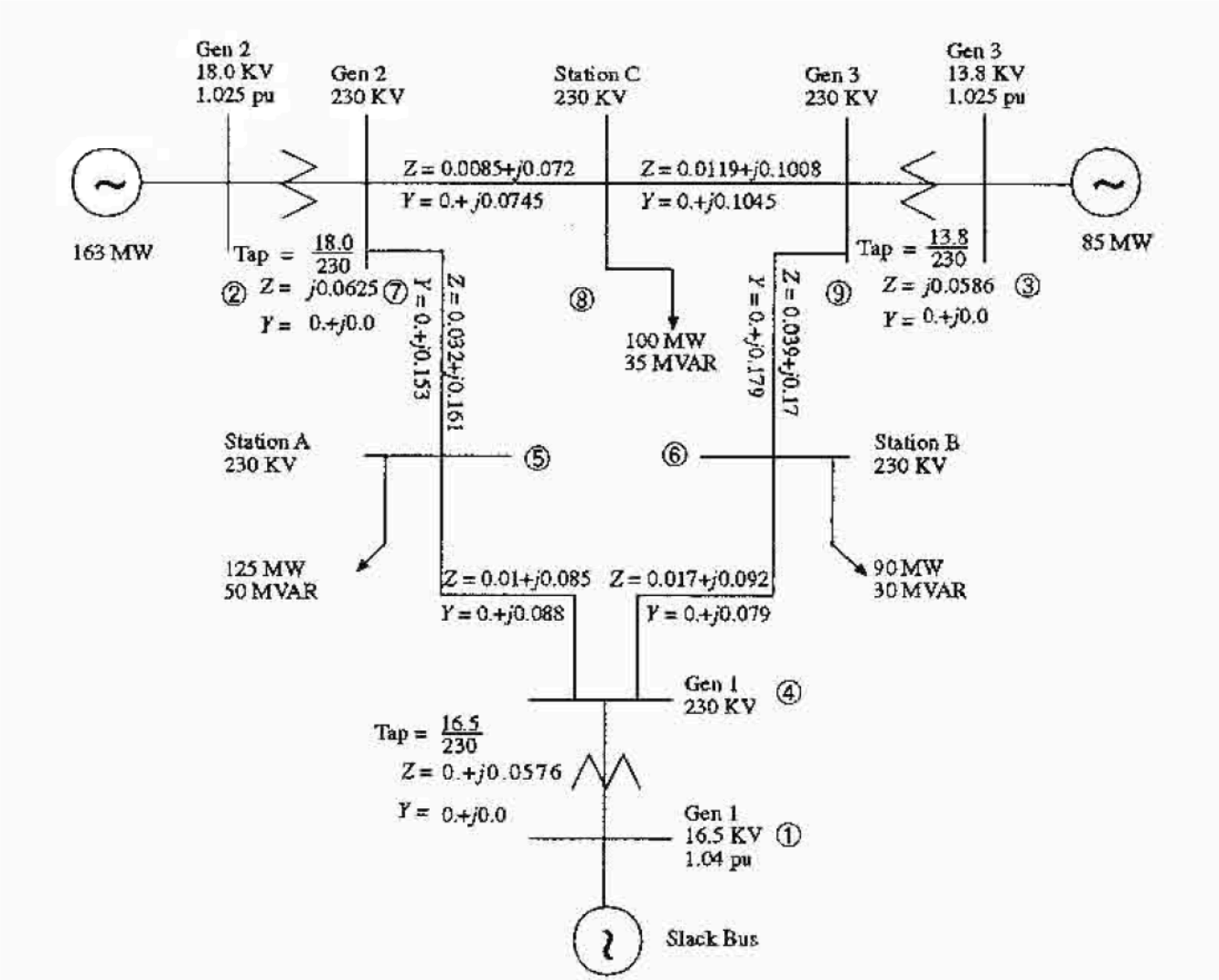
$$\frac{dS_m}{dt} = \frac{1}{2H}[-DS_m + T_m - T_e]$$

$$\frac{dE'_q}{dt} = \frac{1}{T'_{do}}\left[-E'_q + (X_d - X'_d)I_d + E_{fd}\right]$$

$$\frac{dE'_d}{dt} = \frac{1}{T'_{qo}}\left[-E'_d - (X_q - X'_q)I_q\right]$$

$$\frac{dE_{dc}}{dt} = \frac{1}{T_c}\left[-E_{dc} - (X'_q - X'_d)I_q\right]$$

Power Diagram

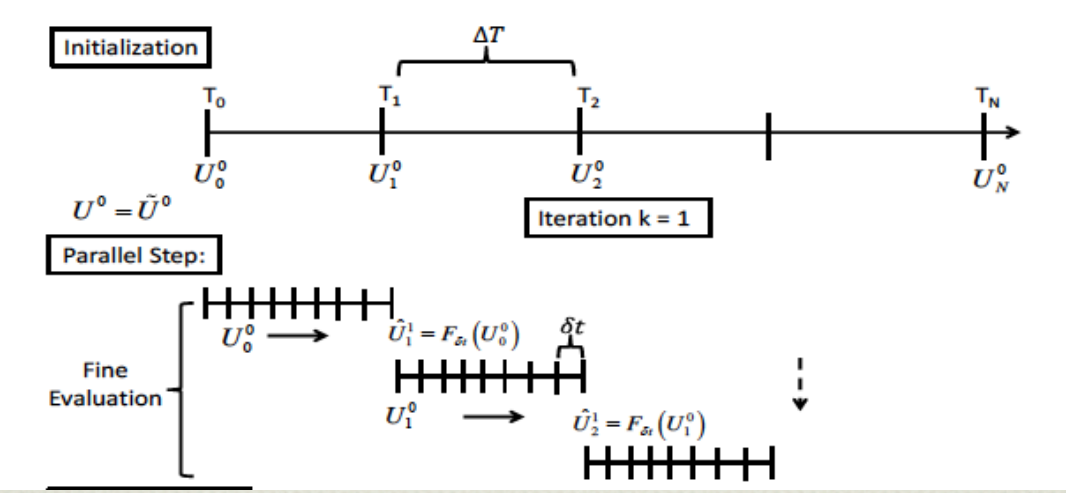


Purpose

- Simulate power outages faster than real time
- Currently: PSS®E by Siemens requires 1 minute of computation for a 1 second of real-time simulation (Eastern Interconnect → more than 60,000 buses and 8,200 generators.)

Methodology

- Parareal – time decomposition



- Newton's Method –

  non-linear algebraic equations

- Runge-Kutta 4 –

  differential equations

$$J(\mathbf{x}) = -\left[\begin{array}{ccc|ccc} \frac{\partial P_1}{\partial \delta_1}(\mathbf{x}) & \cdots & \frac{\partial P_1}{\partial \delta_N}(\mathbf{x}) & \frac{\partial P_1}{\partial |V_1|}(\mathbf{x}) & \cdots & \frac{\partial P_1}{\partial |V_N|}(\mathbf{x}) \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_N}{\partial \delta_1}(\mathbf{x}) & \cdots & \frac{\partial P_N}{\partial \delta_N}(\mathbf{x}) & \frac{\partial P_N}{\partial |V_1|}(\mathbf{x}) & \cdots & \frac{\partial P_N}{\partial |V_N|}(\mathbf{x}) \\ \hline \frac{\partial Q_1}{\partial \delta_1}(\mathbf{x}) & \cdots & \frac{\partial Q_1}{\partial \delta_N}(\mathbf{x}) & \frac{\partial Q_1}{\partial |V_1|}(\mathbf{x}) & \cdots & \frac{\partial Q_1}{\partial |V_N|}(\mathbf{x}) \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Q_N}{\partial \delta_1}(\mathbf{x}) & \cdots & \frac{\partial Q_N}{\partial \delta_N}(\mathbf{x}) & \frac{\partial Q_N}{\partial |V_1|}(\mathbf{x}) & \cdots & \frac{\partial Q_N}{\partial |V_N|}(\mathbf{x}) \end{array}\right]$$

Goals & Future Work

- Overall Goal: Determine how to stabilize the system before it collapses by running simulations of initial causes faster than real time
- My Goal: Understand the process and successfully run an entire simulation
- Parallelize the Parareal code

Sources

- Gurrala, Gurunath. "Power System Parallel Dynamic Simulation Framework for Real-Time Wide-Area Protection and Control."

- Gurrala, Gurunath, Aleksandar Dimitrovski, Pannala Sreekanth, Srdjan Simunovic, and Michael Starke. "Parareal in Time for Fast Power System Dynamic Simulations."

- Meier, Alexandra Von. *Electric Power Systems a Conceptual Introduction*. Hoboken, N.J.: IEEE :, 2006. Print.

Questions?