Fault Simulation for Hardware Emulation

John Curtin
Faculty Advisor: Dr. Fred Wang
Graduate Mentor: Geoff Laughon

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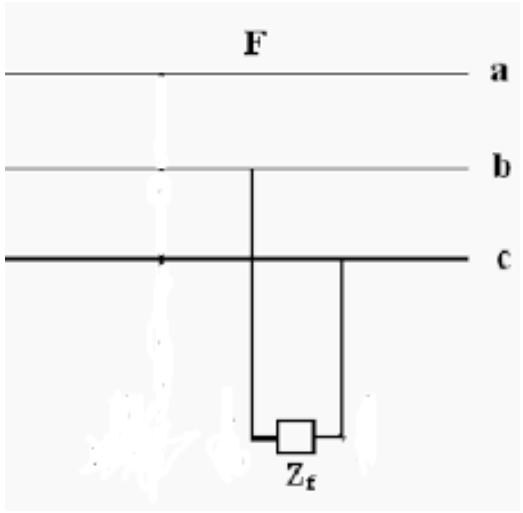
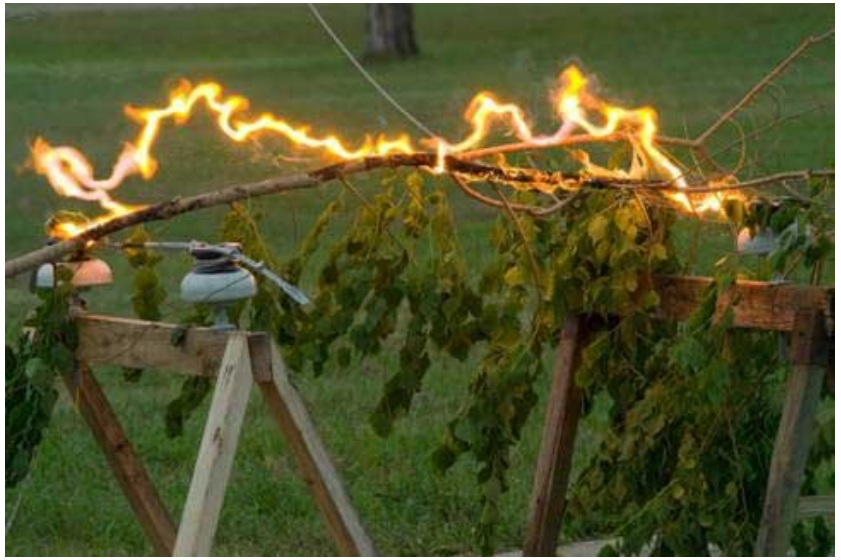
Faults

- Many different kinds
  - Example: Line-to-Line





- Large amounts of power dissipation
- Caused by fault current

Faults (Continued)

- Other kinds:
  - Line-to-Ground, Double-Line-to-Ground, Three-phase, open-circuit
- Cause massive disturbances in power systems
  - Can damage/destroy equipment
  - Causes power outages
- Fault current important parameter in protection systems

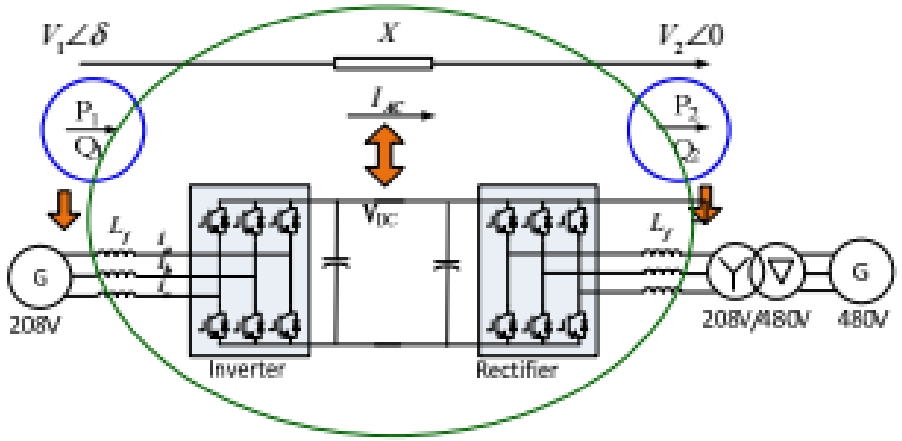
Hardware Test Bed (HTB)

- Hardware simulation of power grid
- Made up of several hardware racks

- More realistic than software

Hardware Test Bed (HTB) (Continued)

- Uses AC-to-DC power converters
  - Coupled for loads and generators



- Uses short line approximation
- Can simulate open-circuit faults

Hardware Construction/Design

- Worked extensively building cabinets
- Involved metalwork, soldering, crimping, wiring, and so on
- Important skills for engineers

Problem Statement

- To help the HTB accurately simulate faults
  - Includes pre-fault, transient, and post-fault current waveforms
- Create Simulink Simulation
- Use to make C code to control power converters
- Known values
  - Sending voltage
  - Receiving voltage
  - Line impedance
  - Fault impedance
  - Fault location
  - Start and End time
- Calculate Line and Fault Currents

Background Research

- Traditional fault analysis
  - Uses phasor-domain analysis
  - Not adequate for research project
  - Does not incorporate transient

- Researched several topics, including:
  - Z-bus method
  - Generator Stability
  - d-q coordinates

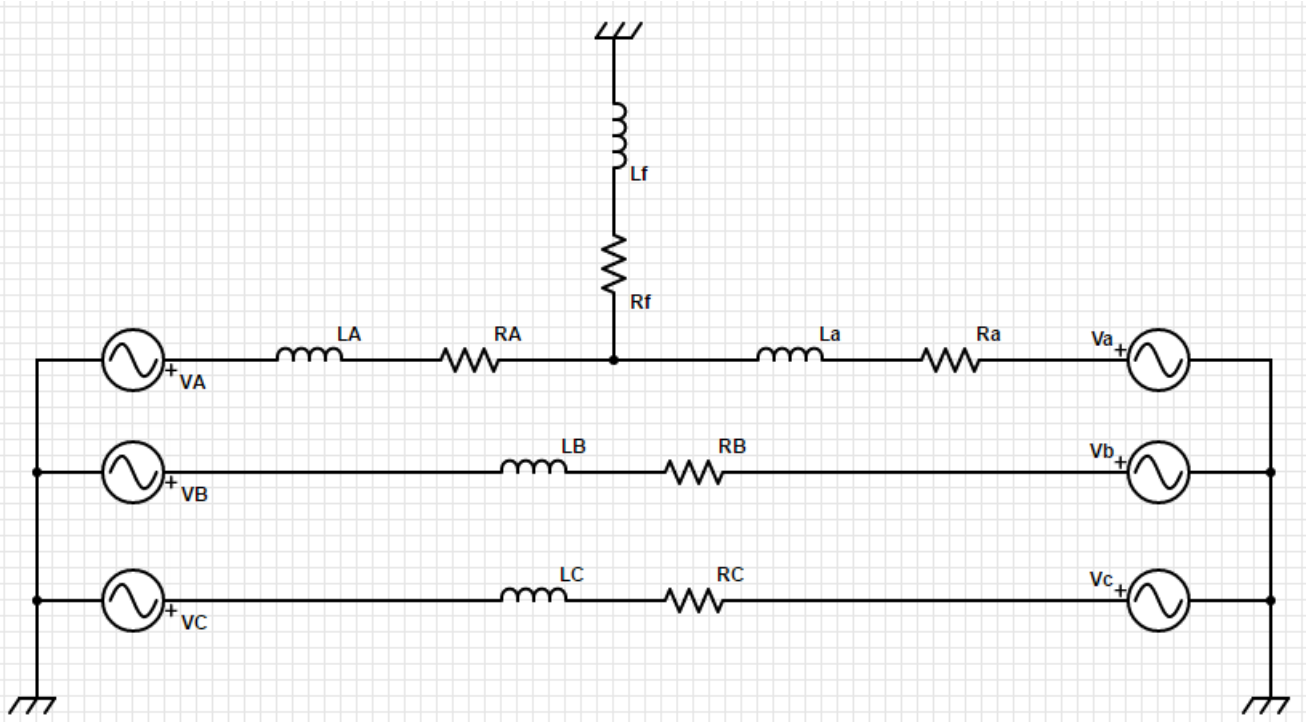
Background Research (Continued)

- Decided method
  - s-domain transfer function
  - $s=\sigma+j\omega$
  - Continuous, all-inclusive variable
  - Constraints of s-domain do not conflict with project constraints

- Use circuit analysis with $Z=R+sL$

Implementation

- Model circuits
  - Example: L-to-G



- Before Fault

$$iA = \frac{VA - Va}{ZA + Za}$$

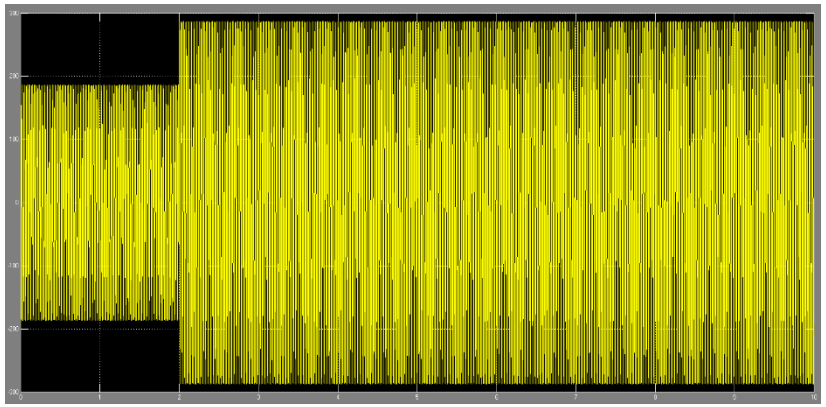
- After Fault
  - iF=iA-ia

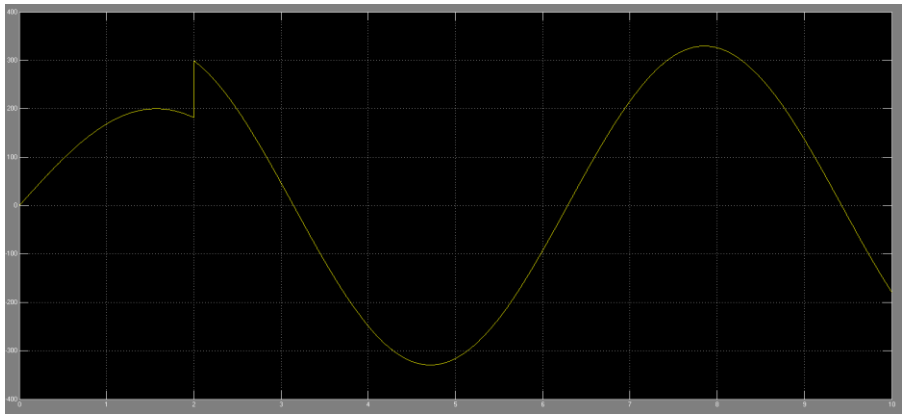
$$\left\{\left\{iA \to \frac{-Va\ Zf + VA\ (Za + Zf)}{ZA\ Zf + Za\ (ZA + Zf)},\ ia \to \frac{VA\ Zf - Va\ (ZA + Zf)}{ZA\ Zf + Za\ (ZA + Zf)}\right\}\right\}$$

Simulation

- Put mathematical models into Simulink
  - Note: not using circuit simulation tools
  - Make model as close to C code as possible

- Static Transfer Function
  - Does not give transient effect





Simulation (Continued)

- Dynamic Transfer Function
  - Variable coefficients
  - Switch with step functions
  - Attempted several methods
    - Ran out of time

Conclusion

- Wrong research topics
  - Consumed time
- Learned interesting topics
- Create Dynamic transfer function in future

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Questions and Answers