Fault Simulation for Hardware Emulation

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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
• 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
  \[ i_A = \frac{V_A - V_a}{Z_A + Z_a} \]

• After Fault
  • \( i_F = i_A - i_a \)

\[
\begin{align*}
\{ i_A &\rightarrow \frac{-V_a Z_f + V_A (Z_a + Z_f)}{Z_A Z_f + Z_a (Z_A + Z_f)} , i_a &\rightarrow \frac{V_A Z_f - V_a (Z_A + Z_f)}{Z_A Z_f + Z_a (Z_A + Z_f)} \}
\end{align*}
\]
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