ECE 529
Utility Applications of Power Electronics

Session 6
Switch models in transients programs (ATP, PSCAD/EMTDC, EMTP-RV)

- Diode
  - Start conducting when forward biased & positive current
  - Turn off at current zero - no reverse current

→ Ideal Diode
  → on-state voltage drop is 0
- Thyristor model
  - Turn on with gate pulse (device forward biassed) (models for control circuits)
  - Turn off when current tries to reverse
  - Again ideal device (Swich)
    - no on state voltage drop

- GTO/IGBT (etc) model - self commutating switch
  - Gate circuit controls turn on and turn off
    (device & thyristor depend on external circuit for turn off)
→ Switch model for IGBT/GTO

→ Gate pulse has to

be continuous for

on period you want

switch on

→ Will turn off at next time

step.

→ Ideal switch → can current

in either direction

\[ \text{external diode} \]
- If want unidirectional current
  \[ \text{gate} \]
  \[ \text{limits current to one direction} \]

- Turn on/tum off times are one simulation time step
Circuit Simulation Results

- Output often as time domain waveforms
- Often want instantaneous peak values of $v(t)$ and $i(t)$
  - Or in some cases power or energy
  - Peaks missed with RMS or harmonic solutions

Simulation Tools: Transient Network Analyzer (TNA)

- Predates use of digital computers
  - Analog computer model
  - Hybrid: digital controls
  - Real-time digital simulators
- Cost limits to small class of problems
  - Closed loop testing of control hardware
Off-Line Time Domain Simulation

- Digital computer simulation of transients
- General purpose equation solvers: MATLAB, MathCAD
- Analog electronic and integrated circuits: SPICE, Saber
- Not really designed for power system transients

The Electromagnetic Transients Program-EMTP

- Hermann Dommel, Germany, then BPA
- Numerically solves difference equations
- Fixed versus variable time-step
- EMTP has become and industry standard (verified models)
- Modules in other power systems programs
- Matlab toolbox
EMTP Variants

- Original version mainly modeled RLC elements
- Many extensions and several versions
  - ATP: Alternate transients program (http://www.emtp.org)
  - EMTP-RV (http://www.emtp.com)
  - EMTDC: student version available free from their website (http://www.pscad.com/)
  - RTDS: Real time digital simulator
  - OPAL-RT: Real time digital simulator
  - Sim Power Systems block set for Matlab

EMTP-like Programs

- Designed to study transient phenomenon from a few hundred Hertz to hundreds of kHz
- Switching surges, faults studies, insulation coordination, power electronic interactions with power systems
- EMTP can also model dc systems and electromechanical interactions
- Trapezoidal integration scheme \(\rightarrow\) astable
  - Stable results if transient response modeled is stable
Capabilities and Outputs of EMT Programs

- Outputs are voltage, current, power, and energy versus time
- Control variables are available if controls are modeled
- Can model simple controls using EMTPs control models or can interface to FORTRAN (in some cases C or Matlab too)
  - Programs have internal control modeling
  - Graphical user interface

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Lecture 5

- This class will have assignments requiring use of an EMTP-like program
- Can use any of programs listed above, but best if use ATP, EMTP-RV, or PSCAD/EMTDC
  - ATP can be licensed through https://eueg.org/
  - EMTP-RV and PSCAD/EMTDC are available on campus and should be available in the UI remote access lab: https://uidaho.edu/remoteaccesslab
  - Student version of PSCAD/EMTDC could be a little small at times.
- If your employer has a preferred program, you can use that – let me know

Transient Power Converter Simulation  13  Spring 2023

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Zoom office hours
- Wednesdays 5pm
Pacific time
Simple Switching Configurations Underlying Power Electronics

Three pole switch: (ATPDraw implementation)
Simulation Results:

- Circuit 1: Transition from current in switch to ground (green) to switch to load (red). Note the 1 time step transition time.

- Circuit 2: Inductor current (green line - multiplied by -1), current in switch to ground (red line), and current through switch to the load (blue line). Note the R-L decay in the current to the load resistor.