

What Are Electromagnetic Transients?

- Power systems normally operate in steady-state
- Allows use of RMS phasors to determine fundamental frequency response.
- Transients result from switching operations, faults, lightning and other disturbances
- Response frequencies ranging from DC to MHz
- Response generally dies out rapidly
- Large voltage and currents are possible
- Basically RLC response to step change in voltage or current

Analyzing Power System Transients

- Require understanding of the transient you want to model and of the system
- Require good data to form detailed models
- Develop mathematical model of the system (equivalent RLC circuits)
- Solve differential equations—generally a set of cross-coupled equations with algebraic constraints
- Options:
 - Hand calculations in the LaPlace domain
 - Hand calculations in the time domain
 - Time domain numerical simulation (difference equations)
 - Time domain simulation generally results in data that is easily plotted as waveforms

Circuit Simulation Options

- Transient Network Analyzer (TNA)
 - Many are a scale model of the power system
 - Other common type was basically an analog computer
 - Long set up times, but very fast run times
- Hybrid TNA: scale model type TNA with digital controls and measurements
- Hybrid TNA's still used for modeling HVDC, FACTS, and other controls
- Now purely digital TNA for real time digital simulations
- Real time simulations faster to set up than TNA, still complex and too expensive for all but special circumstances

Digital Computer Simulations

- Digital computer allowed time domain simulation of circuit transients
- General purpose equation solvers: MATLAB, Mathematica, Maple, MathCAD
- Many time domain tools for analog electronic and integrated circuits: SPICE, Saber, Electronics Work Bench
- The electromagnetic transients program (EMTP) dates back to 1960's development by Hermann Dommel, first in Germany, then at BPA
- Numerical integration methods solving difference equations (Fixed versus variable time-step)
- EMTP has become an industry standard (verified models)
- MatTRAN, NETOMAC, SimPOW, DIgSILENT are other alternatives

EMTP and EMTP-like Programs

- Original EMTP modeled R,L,C, switches, sources and transmission lines
- Many extensions added to model more components and speed the simulation
- Initial source code has been built on by different groups:

ATP Alternate transients program, a free PC based alternative to EPRI-DCG version (ported to other operating systems)

DCG-EMTP Latest in the line of EPRI-DCG (now just DCG) version. Often referred to as “The EMTP”.

EMTDC The Manitoba HVDC Research Centre modified modeling of switching (and later controls) to do more accurate power electronic simulations. Recent versions can run with real time link to Matlab. Reduced size version available free from their web site.

EMTP-like programs in EE529

- There will be examples created using some of these programs
- Can any of the programs above if you already have one
- If you work for a utility that uses DCG-EPRI version need to work through company for a copy
- Can use EMTDC Personal Edition (15 node limit). Download from <http://www.pscad.com/>
- Class room demos will largely use ATP version of EMTP along with EMTDC

Getting A Copy of ATP

- Although ATP is essentially free, a license application needs to be filled out. License information available at:
<http://www.emtp.org/>
- The purpose is to limit access to parties that have participated in “EMTP-Commerce” mainly EPRI-DCG members
- Cost is limited mainly to cost of shipping materials
- Upon approval of license new users generally sent floppy disks with the program

ATP Versions

- ATP ported to several operating systems: DOS, various MS Windows, VMS, OS/2, Linux, Mac-OS, and several commercial Unix versions
- Several versions for the PC platform, all built from same source code, all run in DOS windows
- Different compilers will result in speed differences and possibly differences in cases using random number generators
- ATP options for PC (some available only by download):
 - **Salford** Historically the default version shipped, Salford DOS Extender, difficult to install, not Windows NT compatible
 - **Watcom** Watcom FORTRAN compiler used to build for NT (and Win95) and OS/2 Warp. Easy to run and install (simply unzip file)
 - **Ming32** WinNT, 95, 98 version. Again easy to install. Slower than Watcom version (simply unzip file). Can request when order now.

Plotting Programs

- Older versions of EMTP displayed plot on screen at end of the simulation run (difficult to print)
 - Better results with special purpose plotting programs
- TPPLOT** Distributed with Salford ATP, required Salford DOS extender. Problems with latest graphics cards. Limited output options for word processors. Supports COMTRADE output
- PCPLOT** Simple but more intuitive plotting program. Doesn't require Salford Extender. Only meant for small systems and does not export plots to word processors
- GTPPLOT** Build of TPPLOT using GNU Fortran Compiler. Doesn't require Salford Extender
- PlotXY** Simple Windows based plotting program. Easy to use and easy to export to word processors

Plotting Programs (Cont.)

- Other plotting options
- TOP** Based on EMTPout program Electrotek wrote for EPRI-DCG and extended for harmonics programs. Available free from <http://www.electrotek.com/TOP/>. Very good post processing capabilities. Somewhat counter-intuitive interface
- Matlab** Can use "PL42MAT" to convert output from ATP to data file for Matlab. Can then use Matlab for plotting and post-processing

Graphical User Interfaces

- EMTP is written in FORTRAN and uses FORTRAN read statements, leading to restrictions on input data file
- Several attempts at graphical user interfaces
- Most failed since tied to specific platforms or operating systems
- EMTDC probably has best interface at the moment
- ATPDraw is best of options available for ATP. Recent versions use Windows graphics directly
- Use mouse and icons to create circuit diagram and program creates the EMTP data file
- Can run ATP and a plotting program from ATPDRAW
- Available for free from <http://www.ee.mtu.edu/atp/> or the other ATP sites