EE 5220 - Lecture 1

Mon Jan 14, 2008

Topics for Today:

- Introductions - about 33 enrolled, an all-time high
  - ~14 students on campus
  - ~19 online students
- Startup
  - Web page: [http://www.ee.mtu.edu/faculty/bamork/ee5220/](http://www.ee.mtu.edu/faculty/bamork/ee5220/)
  - Book, references, syllabus, more are on web page.
  - Software - ATP/EMTP, Matlab
  - EE5220-L@mtu.edu (participation = half letter grade, 5%)
  - Lectures - new video streams, some archived videos also
  - Daily lecture notes scanned and .pdf file archived
  - Exercises posted as pdf on web page.
  - Grading: grad students must achieve B (80%) or higher.
  - Prereqs: - Circuit Analysis RLC Responses, EE5200
  - Do all exercises in Ch.1 (solutions are posted)
- Chapters 1 and 2, probs 1.2, 1.3, 2.2, 2.3, 2.4, 2.7 due Friday.
Graduate School – What to expect

♦ Smaller size classes. Everybody is an A student, high expectations. Top students to study with, collaborate with.
♦ Take an active role in your education. Anticipate what needs to be done. Ask questions during lecture.
♦ Open-ended problems and projects, larger scope, longer deadlines.
♦ Professor will create an environment for you (lecture, lab, research) to succeed in, you do the rest.
♦ Stress concept-based approaches (instead of procedural), abstract thinking, reward for developing creative innovative approaches.
♦ Communications – develop excellent speaking and writing skills.
♦ Research – scientific method, conceptually sound, make an advancement on existing state of the art.
Transient Analysis
An Overview

by
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EE 5220
January 14, 2007

Transient Studies
Why is there an increased need?

- Increase in compensation. Pushing system harder.
- Increase in system nonlinearities: magnetic + FACTS.
- Trend toward reduced system losses (= damping) can exacerbate transient problems.
- Nonlinear behaviors cannot be predicted by means of extrapolation or interpolation of observed behavior.
- System protection designed on assumption of a linearized system may misoperate. (Essential to perform transient simulation and test its operation).
- Economic pressure to design less conservatively requires closer scrutiny of equipment specification.

Time-Domain Modeling

- Nonlinear & Frequency-Dependent!
- Slow Transients
- Switching Transients
- Fast Front Transients
- Very Fast Front Transients
- Protection and Control
- Power Electronics

Slow Transients

- Ferroresonance
- Small-signal torsional oscillations
- Large-signal shaft transient stresses
- Turbine Blade Vibrations
- Fast Bus Transfer
- Controller Interactions
- Harmonics interaction

(See Task Force Presentation)

Switching Transients
(Energizing & Deenergizing)

- Capacitor, Reactor Switching
- Transformer Inrush, Black Start, etc.
- Line Energization
- Concerns:
  - TRV, Voltage Stresses, Insulation Coordination, arrester heating
  - Test: pre-insertion resistors, inductors, and synchronized closing devices.

Fast Front Transients

- Lightning Surges: 10 kHz to 1 MHz
- Determine line flashover rates (LFOR)
- Arrester Application Guidelines
  - Establish/verify surge arrester ratings
  - Determine optimum arrester location
  - Minimum L-L and L-G clearances
  - Optimum location of surge capacitances
  - Determine MTBF for a substation
Very Fast Transients
(100 kHz - 50 MHz)
- Gas-Insulated Substations
- Switching surges: 4-100 ns rise time
- Oscillations: 1.5 - 2.5 pu of V-peak
- Not a problem for lower voltage class equipment (BIL is plenty high)
- Problem for higher voltage classes
- Center conductor to enclosure flashover, sometimes enclosure-ground

System Protection
- Relay operation depends on VTs, CTs, CCVTs, MOCTs.
- Sometimes there's a need to model HV system, instrument transformers, and the relays themselves.
- Electromechanical, static, and microprocessor based relays can be modeled

Power Electronics
- Motor Drives
- FACTS, SVCs, static phase shifters...
- HVDC terminus
- Arc Furnace AC-DC converters
- Custom Power
- Concerns:
  - Verify application, predict system performance, identify possible problems, evaluate possible solutions

G4: IEC 61850
Overview - RL Circuits

\[ R = 0.25 \quad jX = 2.5 \]

\[ L (j\omega L) \]

\[ t = 0 \]

**BASIC:**

\[ L \]

\[ I_0 \]

\[ t = 0 \]

\[ R \]

1) Identify Initial & Final State

\[ i_L(0) = I_0 = i_L^- = i_L^+ \]

\[ i_L(\infty) = 0 \]

\[ i_L(t) = I_0 e^{-\frac{R}{L}t} - (I_0 - I_0)e^{-\frac{R}{L}t} \]

\[ = I_0 - (I_0 - I_0)e^{-\frac{R}{L}t} \]

\[ = 0 - (0 - I_0)e^{-\frac{R}{L}t} \]

\[ = +I_0 e^{-\frac{R}{L}t} \]
\[ \tau = \frac{L}{R} \text{ s} \]

Consider \( e^{-\frac{t}{\tau}} = e^{-\frac{R}{L}t} \)

Increase \( R \rightarrow \) Faster rate of change, less time to final state.

Increase \( L \rightarrow \) Slower rate of change, longer to final state.

Stored energy:

\[ = \frac{1}{2} Li^2 \text{ Joules} \]
\[ = \frac{1}{2} Cv^2 \]
\[ = \frac{1}{2} kx^2 \text{ (spring)} \]
\[ = \frac{1}{2} I_0 \omega^2 \text{ (flywheel)} \]

\[ \uparrow \]

"H"
RC Circuits - $\gamma = RC$  

Initially: $\bar{V}_c(0) = \bar{V}_c(0^+) = \bar{V}_c(0^-) = 0$  
Final State: $\bar{V}_c(\infty) = V$  

$\Delta V_c = V_0 - V_o = V - V_o$  

Note: $\Delta V_c$ drives response!  

$\bar{V}_c(t) = V - \Delta V e^{-\frac{t}{RC}}$  

$= \# \bar{V}_c(\infty) - \Delta V e^{-\frac{t}{RC}}$
\[ \frac{V_o}{25} = \frac{X}{R} \approx 10 \text{ for Transmission System} \]

\[ \zeta = \frac{L}{R} = \frac{X}{\omega R} = \frac{2.5}{377 \times 25} \approx 0.028 \text{ s} \]
At one time constant

\[ e^{-t/\tau} \]

\[ e' = 0.368 \]
1) Right click to menu of elements

\[ U_0 = (V^+) - (V^-) \]

2) Left-drag
   Right-rotate

3) Right-click - Parameters (Help Button)

4) Click on ATP | Make Names
   | Make File (creates ATP File)
   | Run ATP

\[ \rightarrow \text{Run PlotXY} \]
Homework

Due Fri: 5pm

1.2 3
1.3 3

2.2 - INV. Laplace
2.3
2.4
2.7

Due Wed:

1.4
1.5
1.6
1.7

Calc + ATP Sim.

Calc + ATP Sim.
ATP is installed in many/all of the computer labs in the department. The family of programs should be visible on the Windows desktop in a folder called ATP. If you’d like to install it on home or office computer, please apply for a personal license at www.emtp.org (Canadian/American Users Group), make sure you satisfy the licensing criteria, and then print and mail a signed copy to the users group. When you have received e-mail confirmation of your license, forward it to your instructor who will provide you with an installation CD. It is not legal to install it onto a non-MTU computer without an approved license agreement.

In the ATP Program group, there should be several options:

- ATPDraw: Graphical User Interface for building/editing/running ATP simulations.
- ATPDraw Manual in pdf format
- PlotXY: Basic very user-friendly plotting program (can paste Win Metafile from here).

In general, everything can be done from within the ATPDraw program. Start ATPDraw by double-clicking on its icon in the ATP program group. Then...

1) Click on the blank sheet symbol to create a new simulation, or click on the file symbol to open an existing simulation. Edit/Draw the circuit and specify parameters. Use Save-As to save this *.acp file (or just click on diskette symbol to save changes to existing simulation). The file that the circuit diagram and parameters are stored in is referred to as a “project” file. These are kept in c:\atp\atpdraw\project\*.acp (older project files *.adp can also be opened)

2) Select ATP | Settings. There are several tabs. The first tab is the most important. There is a HELP button for each tab. Click on it for an explanation of the required data.

   Simulation Tab - Choose reasonable values for Delta T (the integration timestep size) and Tmax (the length of the simulation). If Δt is smaller than needed, the simulation will take longer to run and you’ll create huge bloated output files. If Δt is too big, this could result in large integration errors and incorrect results. Make sure that Δt is at least an order of magnitude smaller than the smallest time constant τ and/or the period of the highest frequency. Xopt is zero if you want to specify inductances in units of mH, or 60 if you want to use Ohms at 60 Hz. Copt is zero if you want to specify capacitances in units of μF or 60 if you want to use M-Ohms at 60 Hz.

3) To run the simulation and see the results:
   a) Select ATP | Run ATP (upper one in the list) - This creates ASCII input data file c:\atp\atpdraw\atp\*.atp and then runs the simulation. Two output files will be created: c:\atp\atpdraw\atp\*.lis is a text file containing a log of the simulation (i.e. a record of how the input file was parsed and interpreted and a record of how the simulation proceeded - this file can be referred to in case of simulation input errors), and c:\atp\atpdraw\atp\*.pl4 which is a binary data file containing simulated waveforms.

4) When the simulation is done running, the PlotXY program will automatically come up and it should automatically load the *.pl4 file that was just created. You can click on “LOAD” to manually select the *.pl4 file that you desire to plot. Click on the Voltage or Current waveforms you wish to plot and the click on PLOT to display them. Experiment with turning the grid off and on, use the tracking cursor, zoom in by closing a window around the desired part of the waveform, etc. When you get the plot you want, clicking on “COPY” puts a Windows metafile into clipboard, allowing you to easily paste the waveform file into a Word or Word Perfect document.
Note! If working together, turn in ONE homework set, else the first one encountered will be graded! You and your homework partner shall in any case receive the same grade.

ASSIGNMENT GUIDELINES:

Assignments will be given out regularly - typically one larger one each week. You will typically have 2-7 days to complete an assignment, depending on how long it is. Late penalties may be assigned - typically 10% off for each day of inconvenience. If there is not already enough room on the assignment sheet, attach additional sheets of 8½ x 11 engineering grid paper (not notebook paper), stapled in upper left corner. Show all work, illustrate by schematic or a diagram, provide assumptions, give equations before substitution, show all units and underline or circle all answers. If attaching computer simulation results, highlight important results and provide complete annotations so that the significance of the results is clear - let's develop the documentation habits of a design engineer - could someone else reconstruct your work? Neatness and clarity of the documentation are important. You are strongly encouraged to discuss concepts and theory related to homework via the course e-mail forum, send e-mail to ee5220-L@mtu.edu to reach all of us and start a discussion.

In some cases you will work together in pairs. Remote students may have to work alone if they are the only one at their site. Although it's not recommended, each of you may work alone on your part of the exercise, meeting and tutoring each other on the details prior to handing in the homework. Partners are to sign off on each other's work. Your approval signifies that:

- you've checked your partner's calculations for correctness,
- you understand the theory, concepts, and solutions method of your partner's work, and
- your partner has done a proportionate share of the work.

Answers (but not necessarily the solutions) will be posted or marked on the graded homework.

Local Students: Put your homework in Drop Box #35 on the 7th Floor of EERC.  
[Remote Students: Scan and e-mail as .pdf attachment, or fax to 906.487.2949 (high-res mode).]

Graded homework may be claimed in the box outside of your instructor's office (EERC 614).  
[Remote students: your work will be returned via mail.] After claiming your returned homework, please follow up on any incorrect solutions.

Your professor is typically available for office hours help from 2:05-2:55pm Mon,Wed,Fri, plus other times by arrangement. E-mail: bamork@mtu.edu; Office: 487-2857; Home: 487-9552. A classroom office hour can be scheduled on demand, this works extremely well. Contact your professor.