EE 5220 - Lecture 1 Mon Jan 8, 2024

Topics for Today:

- Introductions - about 20 enrolled initially,
  - ~4 students on campus
  - ~16 online students (some industry engineers may be late add)
- Startup
  - Canvas URL: https://mtu.instructure.com/courses/1396044
  - Web page: http://www.ee.mtu.edu/faculty/bamork/ee5220/
  - Book, references, syllabus, more are on web page.
  - Software - ATP/EMTP, Matlab
  - EE5220-L@mtu.edu + Canvas discussion + .. (half letter grade, 5%)
  - Lectures - new videostreams, some archived videos also
  - Daily lecture notes scanned and .pdf file archived
  - Exercises posted as pdf on Canvas Assignments.
  - Grading: grad students usually must achieve BC (75%) or higher.
  - Prereqs: - Circuit Analysis RLC Responses, EE5200
  - Do all exercises in Ch.1 (solutions are posted)
- First homework includes:
  - Ch 1 & Ch 2, probs 1.2, 1.3, 2.2, 2.3, 2.4, 2.7, due 9am Tues Jan 16th.
  - Examine graded project report(s) from last semester, summarize feedback.

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.

MTU - EE5220 Home Page | Michigan Tech Single Sign On | New Tab

https://pages.mtu.edu/~bamork/ee5220/

EE 5220
Power System Transients

Spring Semester 2024
EERC 227 - M,W,F 2:05-2:55 pm

Dr. Bruce Mork | Office Hours

UPDATED WEEK-BY-WEEK

Course Syllabus | Pre-Req Material | Text & References | Useful Web Links | Homework Cover Sheet | Grades to Date

Term Project Guidelines S'22 | List of S'22 Term Projects | Past Term Project Examples: Outline , Final Report | ATP Quick-Start |

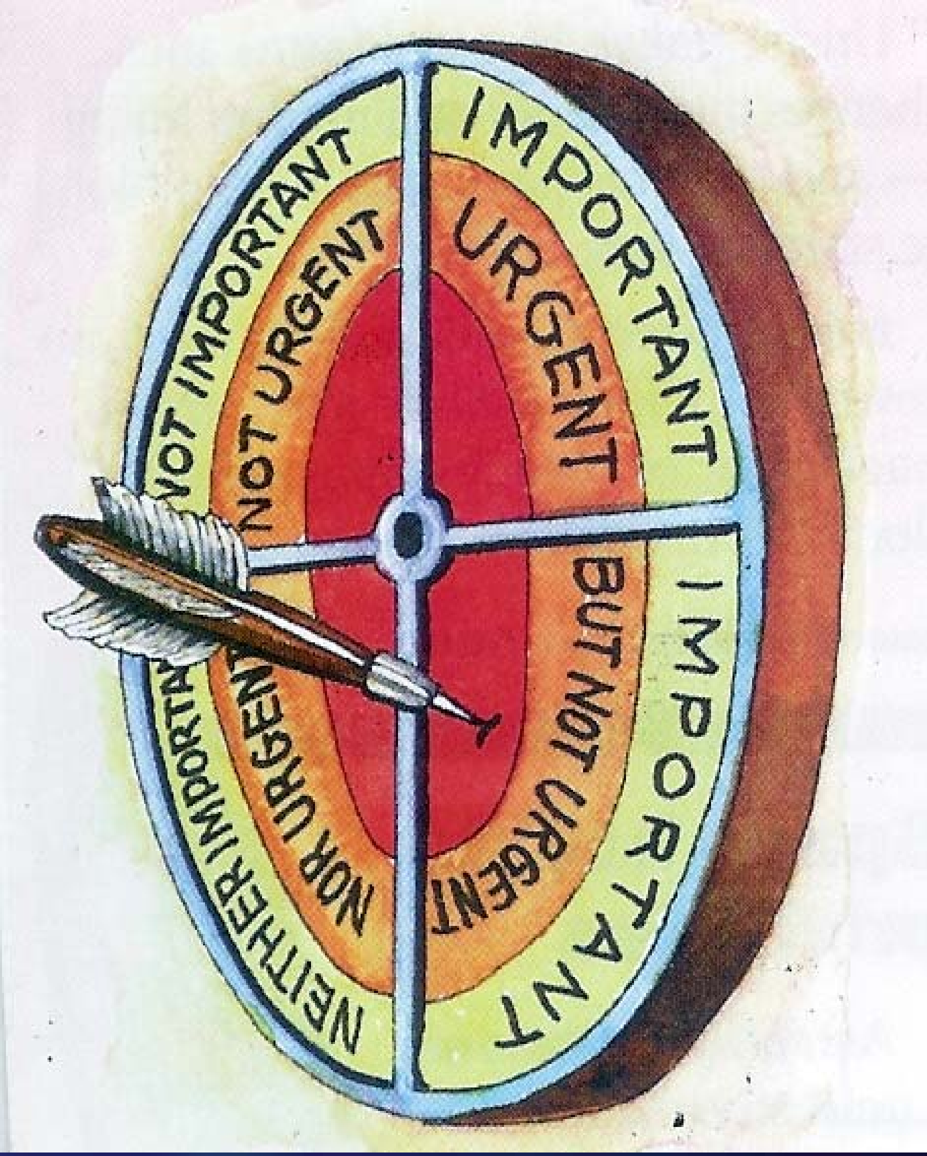
Updated thru: Week 1

Schedule and Coverage (Subject to Change Depending on Learning Needs of Students):

Weekly Coverage *(Read Material Before Class)*	**Lecture Date**	**Material Coverage:**
"Week 0" Startup/Prep	Review (Self Study & Discussion)	• Circuit Analysis RL, RC, RLC response; • EE4221, 4222, 5200 time domain coverage (short circuit, traveling waves on transmission lines) • Introductory usage of ATP in EE5200
1 - Ch. 1, 2 ATP Quickstart ATP Tutorial Video	L1 - Jan 8th L2 - Jan 10th L3 - Jan 12th	Course Intro, RL and RC Circuits. HW#1 -- 1.2, 1.3, 2.2, 2.3, 2.7 (Due Jan 16th 9am) | Answers RLC Circuits, Laplace, Initial Conditions. HW#2 -- 1.4, 1.5, 1.6, 1.7, 2.4 (Due Jan 23rd 9am) | Answers Forced Response of RL circuits: Short Circuits and CB Ratings | ATP Short Circuit Ex: SC.acp
2 - Ch. 2,3 Cap Bank Sw 115-kV Cap Photo	Jan 15th L5 - Jan 17th L6 - Jan 19th	MLK Day - no class (Note: Lecture 4 does not exist) Natural Response of Series and Parallel RLC. HW#3 -- 3.2, 3.3, 3.4, 3.6, 3.12 (Due Jan 30th 9am) | Answrs More on RLC natural response; Switching of Shunt Capacitor Banks (nat'l + forced response).
3 - Ch. 3, 4	L7 - Jan 22nd L8 - Jan 24th L9 - Jan 26th	Switching of Shunt Capacitor Banks - secondary effects and problems. Cap Switching: sk.acp Cap Bank Switching, cont'd HW#4 (Due Feb 13th 9am) | Answrs Switching of Shunt Capacitor Banks - secondary effects and problems.
4 - Ch.4,5,13	L10 - Jan 29th L11 - Jan 31st L12 - Feb 2nd	Parameter considerations for Capacitor Bank switching simulations Simulation pointers, topology, singularity; Parameters; CB ratings for capacitive switching Homework 4 overview. Inner Workings of ATP.
5 - Ch. 5,12	L13 - Feb 5th L14 - Feb 7th Feb 9th	Cap Bank switching wrapup; Inner workings of ATP, Inductance Implementation. HW#5 -- Cap (Section 12.4); Prob 5.3; Prob 5.6 (due 9am Feb 20th) | Answrs Winter Carnival - No Class (Note: Lecture 15 does not exist) Term Project Guidelines - Send short e-mail with Term Project idea by end of Week 6.
6 - Ch.5,9 Notes	L16 - Feb 12th L17 - Feb 14th L18 - Feb 16th	Grounding - Guest Lecturer Circuit Breaker interruption issues for shunt caps, reactors - Restrike, Reignition. Derivation of the Transmission Line Equations, ABCD parameters Incident and reflected components of V and I as function of line length. HW#6 (Due Mar 5th) | Answrs By end of week 7: Submit formal outline of project with key references.
7 - Ch. 9,11.4,13.7	ATP Video L19 - Feb 19th L20 - Feb 21st L21 - Feb 23rd	Long line behaviors, Zc, propagation constants, Traveling waves - Notes | Sample Case in ATP Restrike and Reignition - notes for guest lecture | video Transmission line models, considerations, applications of line constants. Transposition, Line Constants output log file, parameters, Line Chg Current. HW#7 (Mar 19th 9am) | Ansrs
Spring Break	Feb 26th - Mar 1st	Enjoy. Come back refreshed and ready.

Time Management

- Which mode of operation is best?
- Most of us spend way too much time on important-urgent category, i.e. in CRISIS MODE.
- Better – start early, spend most time on "Important but not yet Urgent."



From "Seven Habits of Highly Effective People"

TIME MANAGEMENT

- Plan on min 10 hrs/wk of focused productive time.
- Grad courses draw on pre-req concepts from undergraduate courses, so some weeks may be more.
- Online students:
  - View lectures at time convenient to work schedule.
  - Must keep to the same week-by-week schedule as on-campus students.
- Online students may have field assignments or need to travel. Flexible, but you need to follow weekly deadlines.
- Homeworks:
  - Look it over early on, start discussions on e-mail forum
  - Take advantage of e-mail discussions: combine practical knowledge of online students with applied math and theoretical knowledge of on-campus folks.
  - Grad courses – can't wait 'til the night before to get started – there is no way you can complete it.

Transient Analysis
An Overview

by
Bruce Mork
Michigan Technological University

EE 5220
January 11, 2010

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 scruitiny of equipment specification.

6210 - Stability - Angle
- Voltage

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)

"SELF-HEALING"

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 resisistors, 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 GIS
- 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 micro-processor based relays can be modeled

- IEC 61850
WAM/WAC/WAMPAC

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

control

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Getting Started with ATP

EE 5220 - Fall Semester 2024

ATP is installed on the software server remote.mtu.edu and is accessible via Remote Desktop. VPN may be required from off-campus. It may also be installed in computer labs in the department. The family of programs is within the Windows Start tab in a folder called ATP. Run ATPDraw - V7.x If you'd like to install it on home or office computer, you must apply for a personal license https://eeug.org/index.php/how-to/be-licenced (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 you 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 V7: Graphical User Interface for building/editing/running ATP simulations.
ATPDraw Manual in pdf format
PlotXY: Basic very user-friendly plotting program (can paste Win Metafiles 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 version project files *.adp can also be opened)

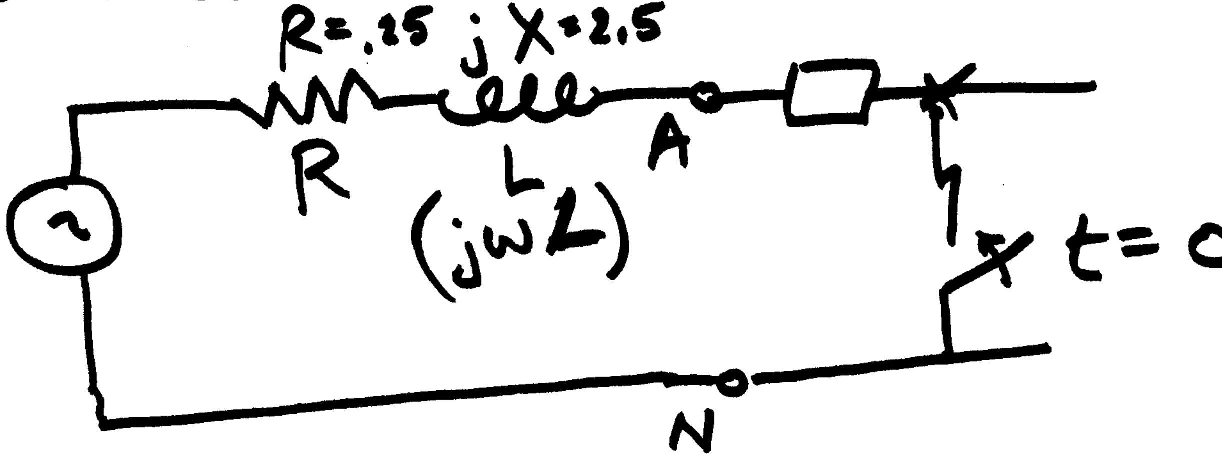
2) Select ATP | Settings. There are several tabs. The first tab is the most important. There is a HELP button for each tab. Click on it for an explanation of the required data.

   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.

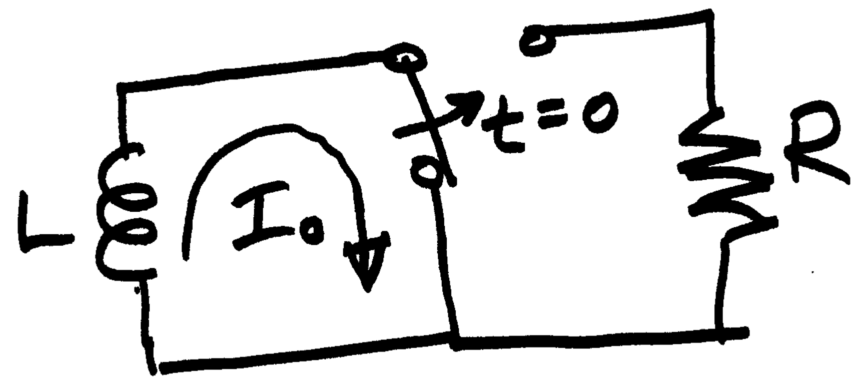
3) To run the simulation and see the results:
   a) Select ATP | Run ATP (upper one in the list) - This creates ASCII/text input data file h:\atp\atpdraw\atp*.atp and then runs the simulation. Two output files will be created: h:\atp\atpdraw\atp*.lis is a text file containing a log of the simulation (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. (Note: local installations use c: instead of h:)

4) When the simulation is done running, go to ATP | Plot to run the **PlotXY** program. PlotXY will automatically load the *.pl4 file that was just created. You can click on "LOAD" to manually select a *.pl4 file or add'l *.pl4 files that you desire to plot or overplot. 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 document.

Overview – RL Circuits



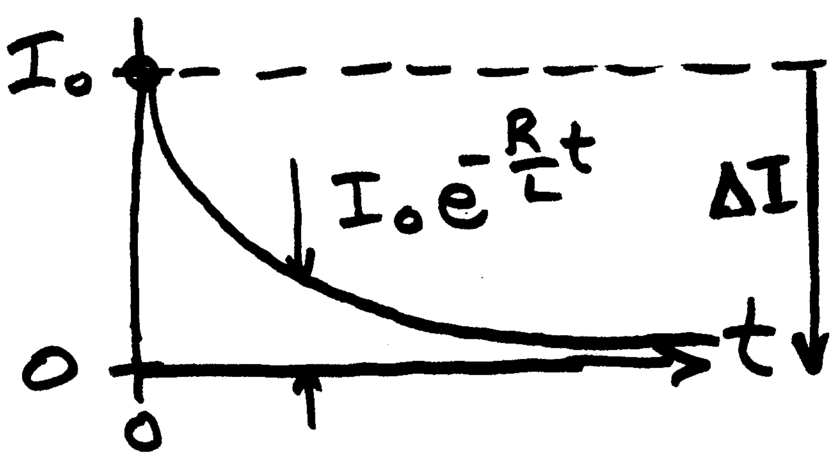
BASIC:



1) Identify Initial & Final State

$$i_L(0) = I_0 = i_L^- = i_L^+$$

$$i_L(\infty) = 0$$



$$i_L(t) = I_\infty - \underline{\underline{\Delta I}}\, e^{-\frac{R}{L}t}$$

$$= I_\infty - \underbrace{(I_\infty - I_0)}\, e^{-\frac{R}{L}t}$$

$$= 0 - (0 - I_0)\, e^{-\frac{R}{L}t}$$

$$= +I_0 e^{-\frac{R}{L}t}$$

~~0~~ms ⟺ $1/60$ s = <u>16.67 ms</u>
28 ms

$$e^{-\frac{t}{\tau}}$$

At one time constant

$$e^{-1} = 0.368$$