EE 582
Day 1 - Introduction
Monday, March 6, 2000

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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

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Homework:

Mar 10th
1.2
1.3
2.2
2.3
2.4
2.7

Hand in as

Mar 13th
1.4
1.5
1.6
1.7

typical homework

sets.
25% - Midterm
25% - Homework
25% - Term Proj
25% - FINAL
Homework:

Due Fri:  
(Mar 10th)

1.2} CALC + ATP
1.3}  
2.2 - INV LAPLACE
2.3} CALC
2.4} + ATP
2.7}  

Due Mon:  
(Mar 13th)

1.4} CALC + ATP
1.5}  
1.6}  
1.7}  
Overview - RL Circuits

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

Basic:

1) Identify Initial & Final State
   \[ i_L(0) = I_0 = i_L^- = i_L^+ \]
   \[ i_L(\infty) = 0 \]

\[ i_L(t) = I_0 - \left( I_0 - I_0 \right) e^{-\frac{R}{L}t} = I_0 - (0 - I_0) e^{-\frac{R}{L}t} = I_0 e^{-\frac{R}{L}t} \]
RL time constant

\[ \tau = \frac{L}{R} \text{ s} \]

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:

\[ = \frac{1}{2} Li^2 \text{ Joules} \]
\[ = \frac{1}{2} C v^2 \]
\[ = \frac{1}{2} kx^2 \text{ (spring)} \]
\[ = \frac{1}{2} I_0 \omega^2 \text{ (fly-wheel)} \]
RC Circuits -

\[ \tau = RC \]

Initially: \[ V_c(0) = V_c(0^+) = V_c(0^-) = 0 \]

Final State: \[ V_c(\infty) = V \]

\[ AV_c = V_0 - V_0 = V - V_0 \]

**Note:** \( AV_c \) drives response!

\[ V_c(t) = V - AV e^{-\frac{t}{RC}} \]

\[ = \boxed{V_c(\infty) - AV e^{-\frac{t}{RC}}} \]

\[ t \]

\[ V \]

\[ V_0 \]

\[ V_0 \]

\[ V \]

\[ \Delta V \]
\[ V_c(0) = V_o \]
\[ V_c(\infty) = 0 \]
\[ \Delta V = V_o - V_o \]

\[ V_c(0) = V_c(\infty) + \frac{\Delta V}{e^{\frac{t}{RC}}} \]
\[ = V_c(0) e^{-\frac{t}{RC}} \]

**Time constants**

Compare \( \tau \) to 60-Hz period

\[ \frac{2.5}{25} = \frac{X}{R} \leq 10 \text{ for Transmission System} \]

\[ \tau = \frac{L}{R} = \frac{X}{\omega R} = \frac{2.5}{377 \times 25} \approx 0.028 \text{ s} \]
28 ms \Rightarrow \frac{1}{60} s = 16.67 ms

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

At one time constant

e^t = 0.368
ATP BASICS:

1) Right click to menu of elements

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

2) Left-drag
   Right-rotate

3) Right click - Parameters (Help Button)

4) Click on ATP | Make Names
   | Make File (creates ATP file)
   | Run ATP
   \[ \rightarrow \] Run PLOT XY