B.A. Mork **EE 5220 - HW #4** Spring 2024

Partnered Homework - Capacitor Bank Switching Problems Due Feb 13th

The file sk.acp, the in-class demo, is available on our class web page. Save it into your H:\ATP\Projects\ folder. This case may be a good starting point for this study. Attached find a hand-drawn sketch of a capacitor bank addition project. Note: change the system voltage to 115-kV and the size the cap banks to 30 MVar each! Values given on the sketch are total 3-phase MVA/MW/MVAR and L-L voltages. The sketch is a L-N per phase equivalent of this 3-phase system. E-mail forum requirement: each team shall 1) initiate a question or discussion on at least one pertinent technical or simulation question related to this assignment; and 2) contribute (help answer) at least one other discussion not your own.

The aim of this exercise is to develop a simplistic per-phase simulation and investigate:

- Inrush and bus voltage recovery involving a single 115-kV Cap bank.
- Back-to-back energization (energize 2nd bank with first already energized).
- Recovery voltage following clearing a fault at point "R." (Include CB bushing cap, see Table 13.4 in textbook).
- Outrush problems involving the old oil-filled CBs for fault at point "O."
- Voltage magnification at point "V."

I suggest the following approach:

1) Determine system parameters and create system model in ATPDraw GUI.
2) Predict the expected behaviors with simple hand calculations. Using a spreadsheet, develop a straight-forward way of entering the key system parameters (neglect resistance) that directly calculates the values of a) the back-to-back current limiting reactors, if needed, and b) the outrush current limiting reactor, if needed. Input parameters should be CB max Ip x fo rating, bus inductances, voltage levels, Cap bank MVA sizes, etc.
3) Run ATP simulations for cases with and without the current liming reactors. Confirm the peak currents, frequencies, and Ip x fo products that the CBs are subjected to. (Refer to the CB ratings tables from lecture notes). Document the severity of the peak voltages observed for voltage recovery and voltage magnification.

Report format: Write a formal report. Present key waveforms. Give and explain the key equations you used. Attach your detailed hand calcs, and spread sheet. For this assignment, the content is what's important!

In your report:

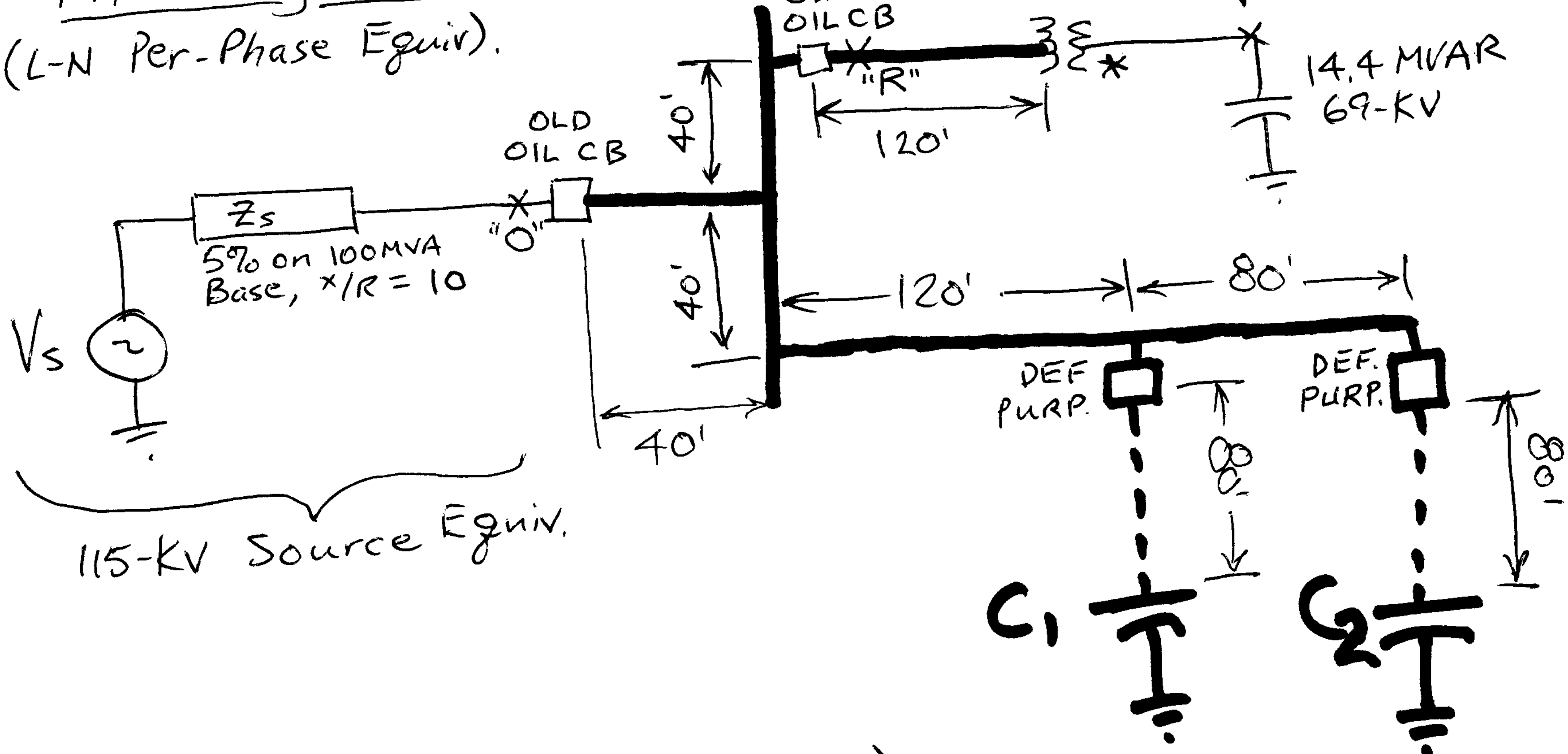
- Describe the system. Explain why the cap banks are used. Are they sized properly? Explain.
- Describe the system operating events leading up to each problem.
- Use ATP to demonstrate operating events, with simulated waveforms to illustrate problems.
- Recommend corrective actions
  - Current limiting L or R, synchronous switching, operating constraints, etc.
  - Show ATP output proving that problems have been mitigated.
- Make overall recommendations – what should the design and operations engineers do?
- Include references to useful literature. Refer to the last page of the Cap Bank Switching Tutorial for some key references.

Note - it's expected that you may have many questions as you step through the spreadsheet and ATP implementation details. Ask away and I will respond with e-mails and copy the whole class. We'll work our way through this together and learn some good transient simulation skills.

Homework 4 - Cap Bank Switching

The System:

(L-N Per-Phase Equiv).



KEY FOR BUSWORK: (Lecture 7, p. 3) (Table is for 115KV)

- (heavy solid line) 5" AL Sched 40 Tube
- (heavy dashed line) 1590 MCM
- (thin line) Not important (negligible since out of zone of high-freq oscillations).

$C_1 = C_2 = 40$ MVAR BANKS
0.08 W/KVAR

* Transformer:

5% impedance, $\frac{X}{R} = 30$
on 125 MVA Base

Basic Series Impedances (Ohm/mi):

	Xo/Ro	Ro	Xo	R1	X1	X1/R1	X1 (uH/ft)
4/0 Cu	4.721323	0.5867	2.77	0.303	0.8008	2.64	0.402
556.5 Al	5.76318	0.4704	2.711	0.1871	0.7421	3.97	0.373
1590 Al	7.415919	0.3568	2.646	0.07313	0.677	9.26	0.340
5" Al	8.11904	0.3041	2.469	0.0209	0.5005	23.95	0.251

Note: Greenwood says 0.2 - 0.4 uH/f is typical. 0.4 for smal conductor and 0.2 for large-size bus tubing.

Note: Zo values seem to be typically 3x bigger than Z1. This compares to T-Line sections that have no shield/ground wire.

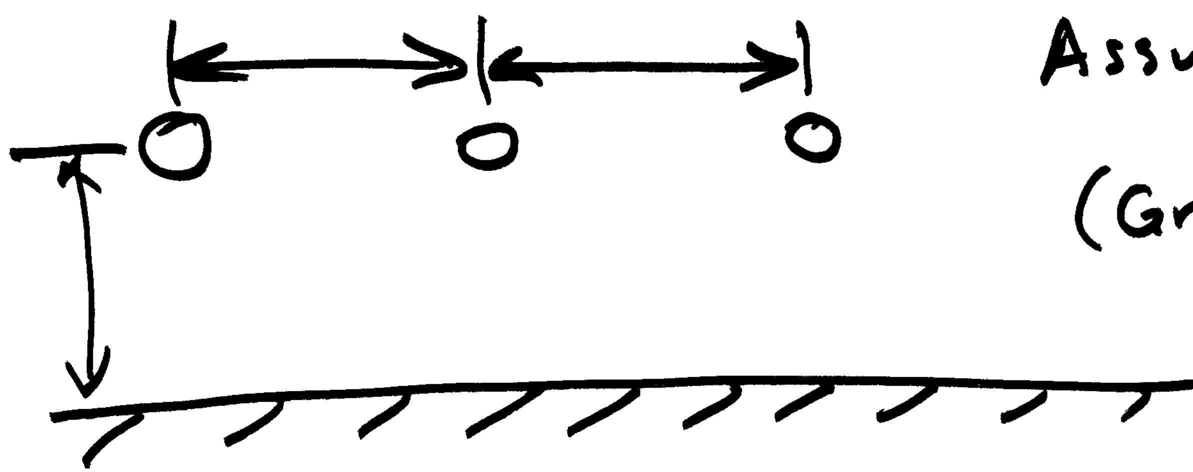
Damping:

$E = \frac{1}{2} C V^2$

Strain Bus - Overhead Conductor for bus conductor.

Tube/Pipe Bus - Al tube or channel

Focus on X/R ratio and L/ft.



Assume $Z_0 = Z_1 = Z_2$

(Ground Grid!)