Ongoing List of Topics:

- URL: http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm
- Term Project - last few proj/teams being firmed up and getting moving.
  - Follow timeline, see posting on web page
- Problem 10.1 - completed Tues 5pm.
- Will post next homework later today or Thurs
- Protection of Shunt Capacitor Banks (print out “Cap Bank Prot” at Week 12)
  - Basic application, reason for using shunt cap banks
  - Characteristics of individual “cans”
  - Cap bank configurations - delta, wye, sectionalized (or “double”) wye
- Basic Methods of protection
  - Neutral overcurrent
  - Voltage differential
  - Voltage balance (double wye)
  - Current balance (ungrounded double wye)
\[ |Z_{\text{in}}| \]

\[ R_{\text{dc}} - F \]

high-order R.L.C.
$0.10 \text{ W/KVAR} \left(200 \text{ KVAR}\right) = 20\text{ W}$

$\frac{V^2}{R_{cond}} = 20\text{ W}$
\[ \frac{87V}{(E_B - K E_C)} = 0 \]
Fuseless

C increases when elements fail.
Typical: 900V
Design: Operates at 400-800V Steady-state.

IEEE: \( \leq 50 \text{ Volts} \) (\( V_{ln} \)) within 5 mins.

\( P = \frac{V_{in}^2}{R_{diss}} \)

\( R_{diss} \Rightarrow 0.1 \text{ W/KVar} \)

\( \eta = RC \)
Capacitor Bank Design and Protection
Externally Fused Configuration Only

Bruce Mork
Michigan Tech University - Teaching Example

Bank Specification:
Grounded-Wye Bank
L-L System Voltage: 138 kV
Size of Bank: 80 MVAR

Can Specs:
Voltage: 13.28 kV
Rating: 200 kVAR
Loss: 0.1 WkVAR
Capacitance: 3,008 uFarads
Impedance: 881.79 Ohms
Current: 15.06 Amps
Diss Ohms: 8.818 MOhms

Configuration:

| Total No. Cans: | 400.00 | 414 | Cans |
| No. Cans/Phase: | 133.33 | 138 | Cans/Ph |
| Series Groups/Phase: | 6.00 | 6 |
| Parallel Cans/Group: | 22.22 | 23 |
| Impedance/Group: | 36.34 Ohms |
| Impedance/Phase: | 230.03 Ohms |
| Diss Ohms/Phase: | 2.300 MOhms |
| Discharge RC Time Constant: | 26.53 Secs |

Performance:

| System Voltage, pu: | 0.95 | 1.00 | 1.05 |
| Total MVAR | 74.72 | 82.79 | 91.27 |
| Line Current, Amps: | 329.04 | 346.36 | 363.68 |
| Voltage/Group, kV: | 12.515 | 13.279 | 13.943 |
| Voltage/Group, pu: | 0.950 | 1.000 | 1.050 |
| Losses, kW: | 7.472 | 8.279 | 9.127 kW |
| Dischg Time to 50%: | 203.43 | 204.79 | 206.08 Seconds |

Group Voltages:

| VT Ratio: | kV | V |
| 1 Blown Fuses | 13.279 | 120 |
| This Group: | 13.089 | 13.778 | 14.467 kV |
| 0.986 | 1.038 | 1.089 Per Unit |
| 118.29 | 124.51 | 130.74 VT Sec Volts |
| Other Groups: | 12.520 | 13.179 | 13.838 kV |
| 0.943 | 0.992 | 1.042 Per Unit |
| 113.14 | 119.10 | 125.05 VT Sec Volts |

| 3 Blown Fuses | 14.154 | 14.898 | 15.543 kV |
| This Group: | 1.066 | 1.122 | 1.178 Per Unit |
| 127.90 | 134.63 | 141.37 VT Sec Volts |
| Other Groups: | 12.307 | 12.955 | 13.603 kV |
| 0.927 | 0.976 | 1.024 Per Unit |
| 111.22 | 117.07 | 122.93 VT Sec Volts |

| 4 Blown Fuses | 14.753 | 15.530 | 16.306 kV |
| This Group: | 1.111 | 1.169 | 1.228 Per Unit |
| 133.32 | 140.34 | 147.36 VT Sec Volts |
| Other Groups: | 12.187 | 12.829 | 13.470 kV |
| 0.918 | 0.966 | 1.014 Per Unit |
| 110.14 | 115.93 | 121.73 VT Sec Volts |