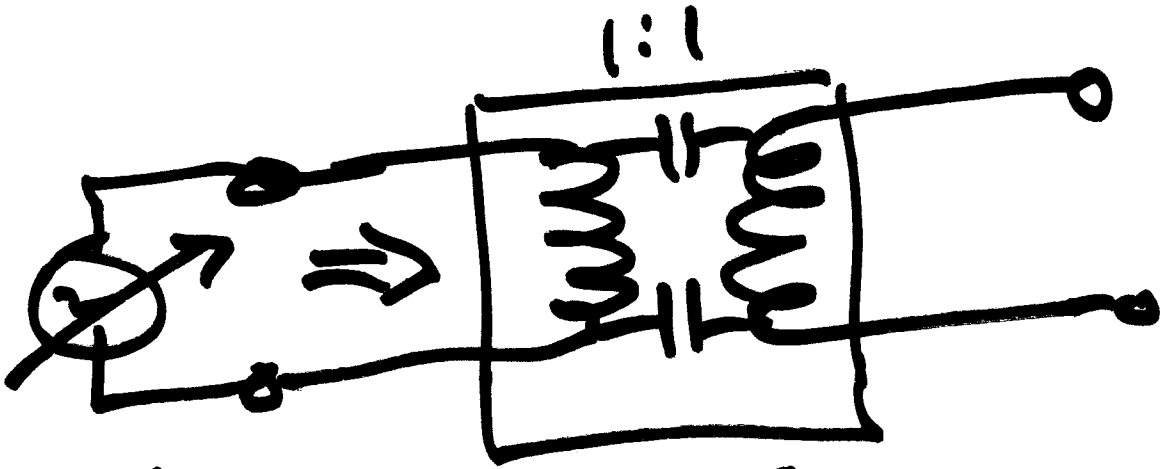
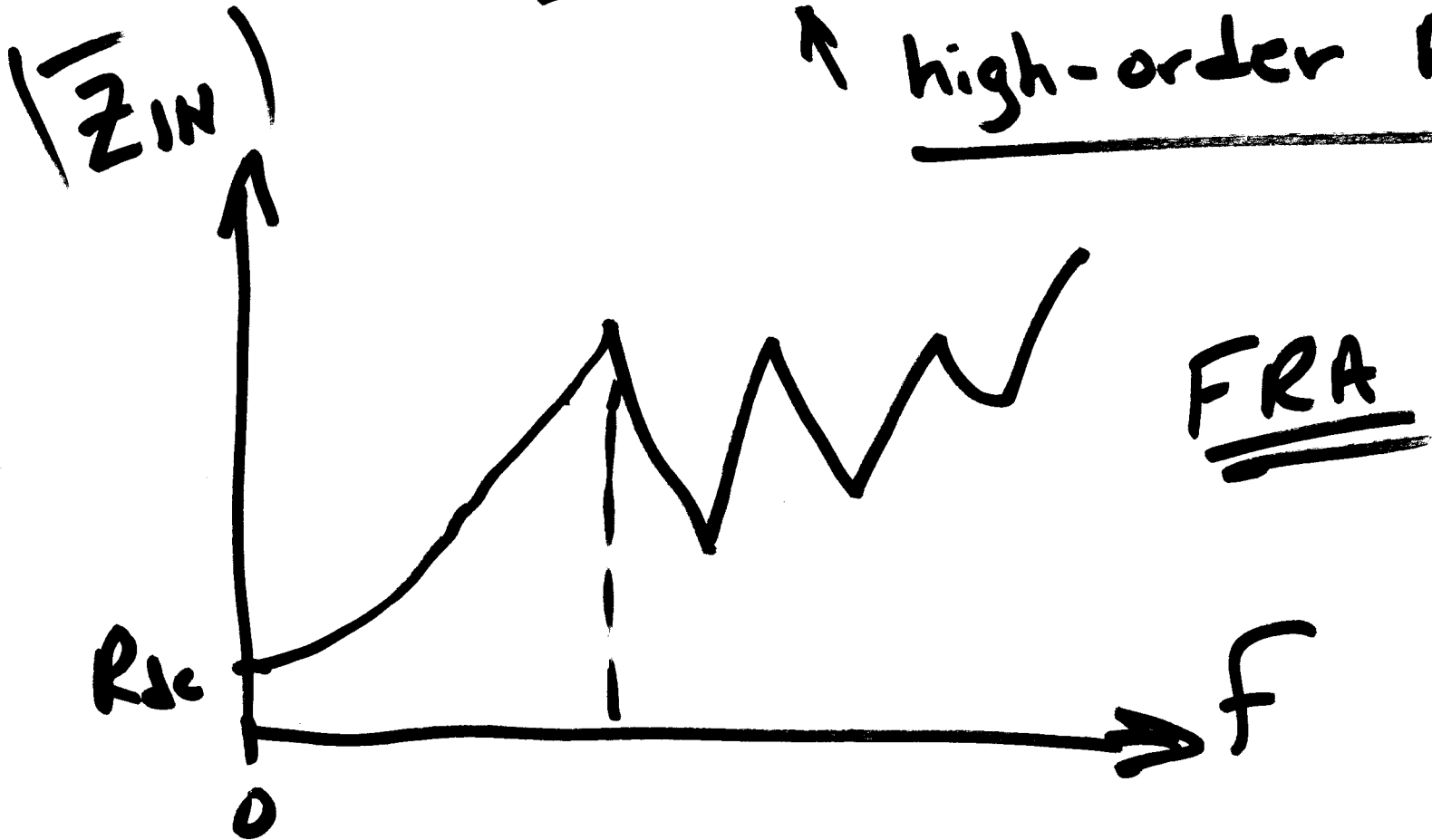


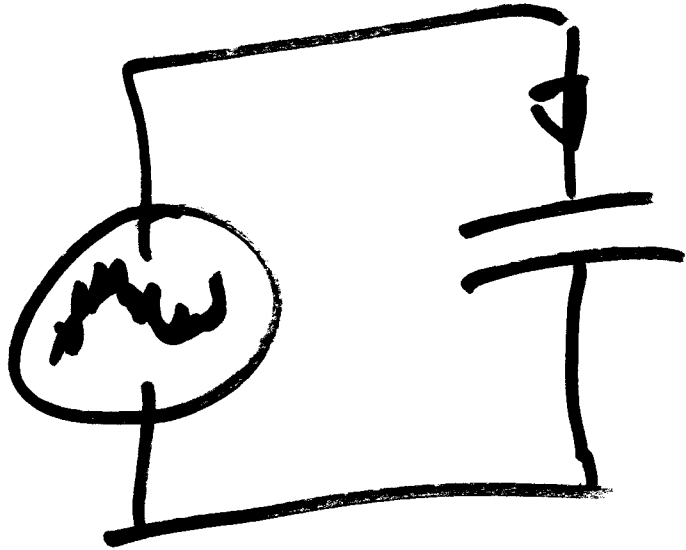
Ongoing List of Topics:

- URL: <https://pages.mtu.edu/~bamork/EE5223/index.htm>
- Term Project
 - Follow timeline, see posting on web page
- Problem 10.1 - very short problem, due Tues April 11th. 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)

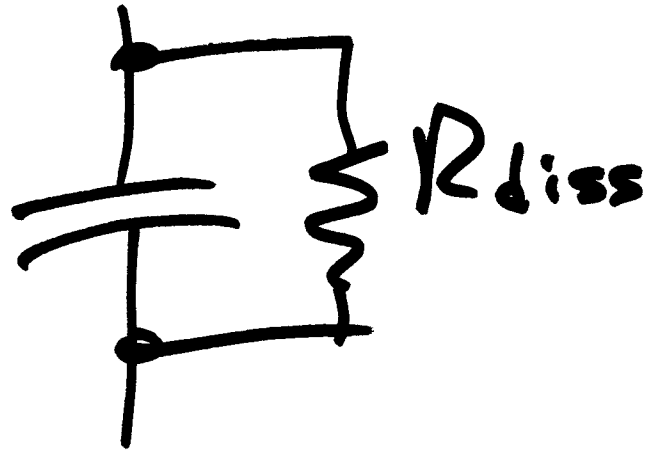


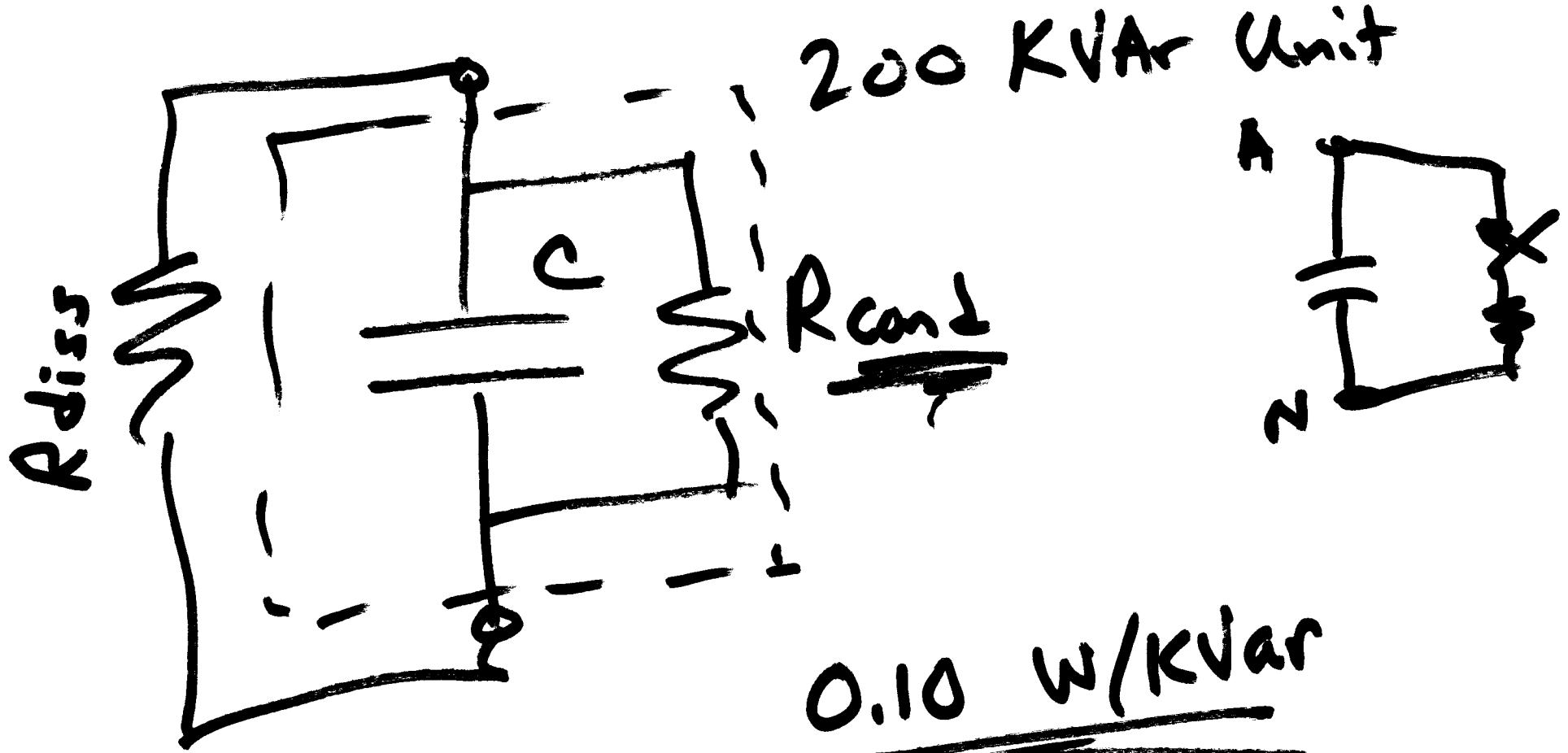
↑ high-order R-L-C.





$\frac{1}{\omega C}$



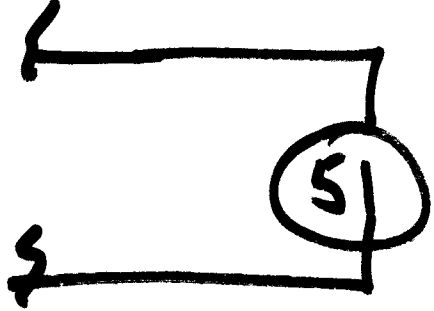
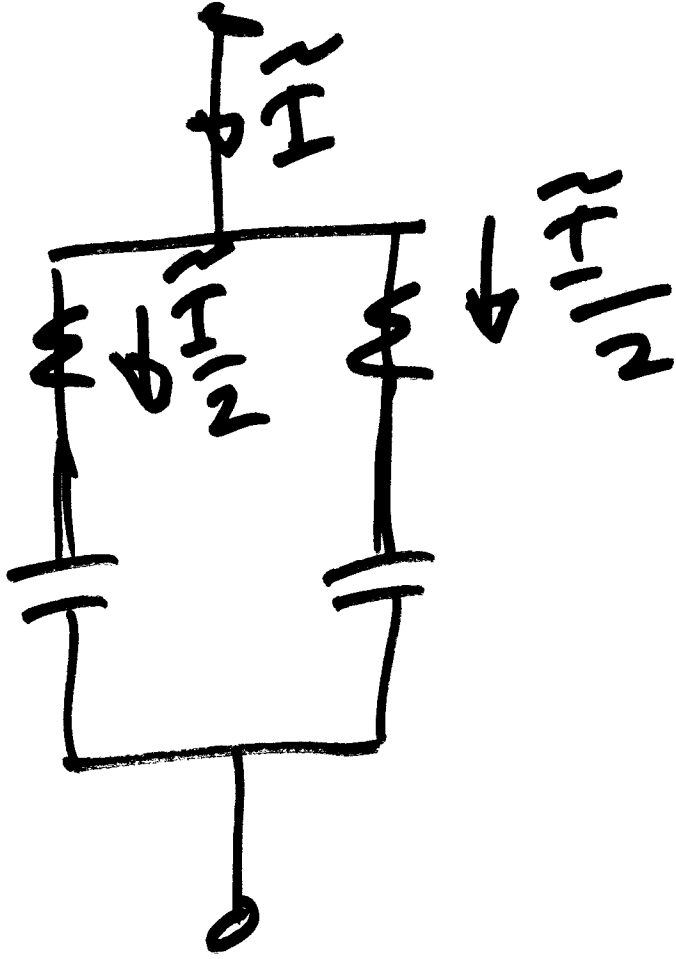


$$\underline{\underline{0.10 \text{ W/KVAR}}}$$

$$(200 \text{ KVAR}) (\underline{\underline{0.1 \text{ W/KVAR}}}) = \underline{\underline{20 \text{ W}}}$$

$$\frac{V_{can}^2}{R_{cond}} = 20 \text{ W}$$

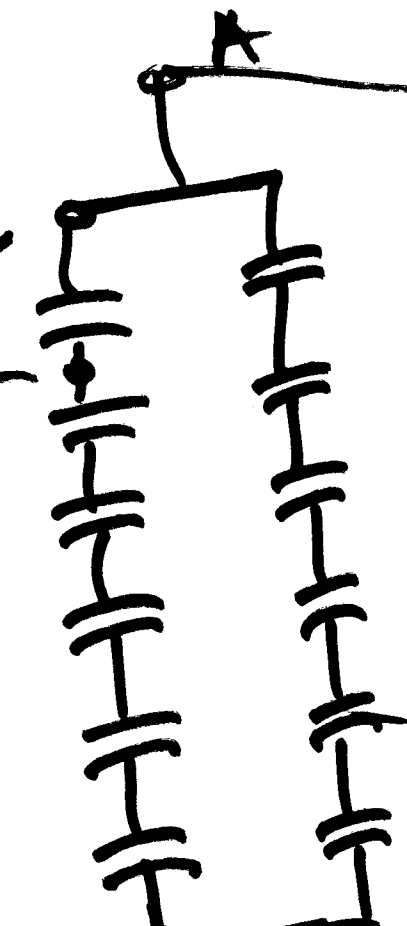
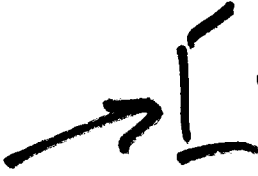
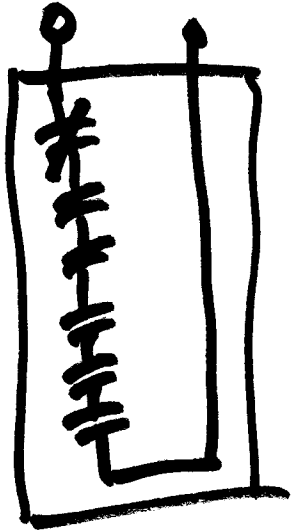
$\angle 2$ + -



87V

$$(E_B - \underset{\uparrow}{K} E_C) \approx 0$$

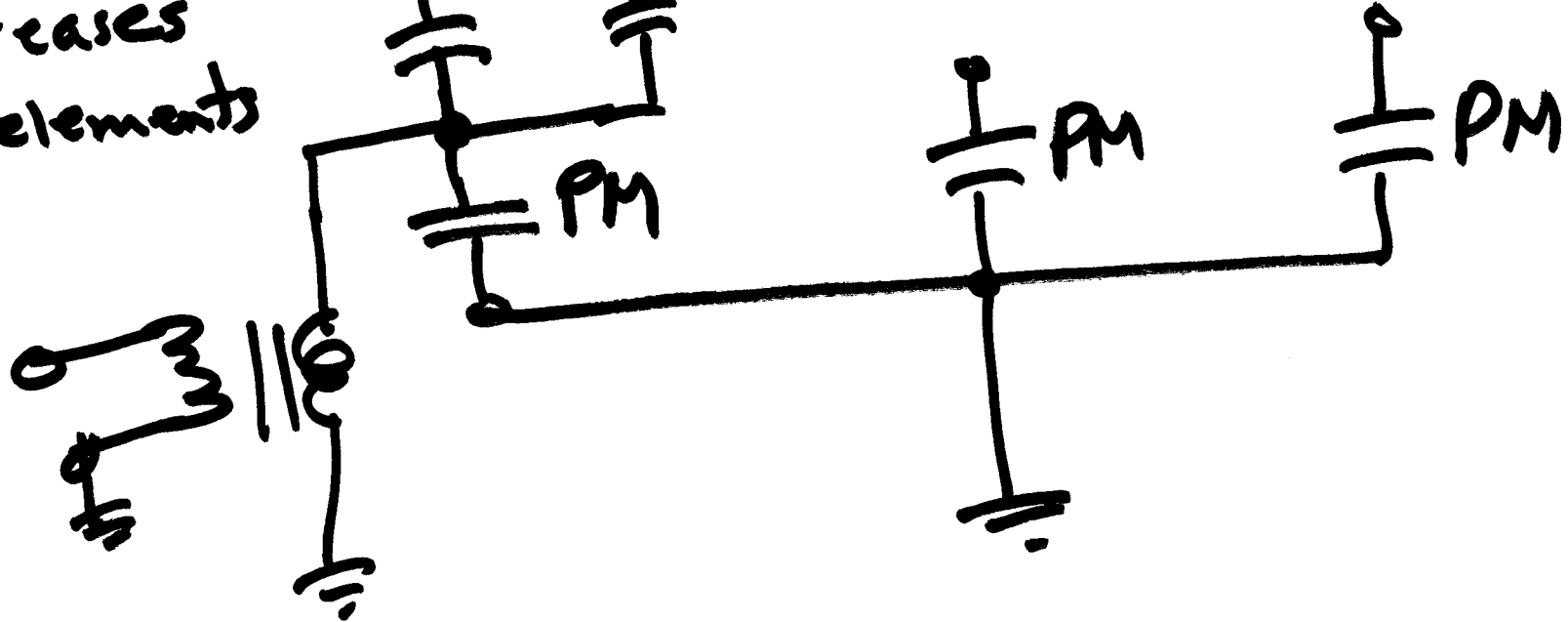
Fuseless

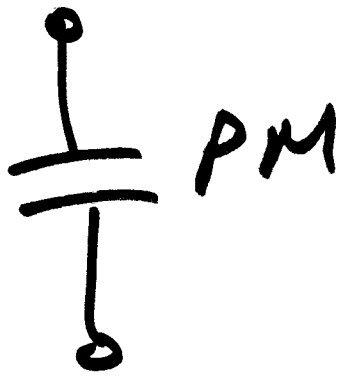


B

C

C increases when elements fail.



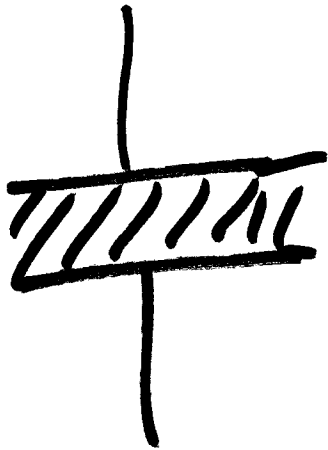


Typical: 900V

Design: Operates at 400-800V Steady-state.

W/KVar

IEEE: ≤ 50 Volts
(V_{LN}) within 5 mins.



$\Rightarrow 0.1 \frac{W}{KVar}$

$$\tau = RC$$

$$P = \frac{V_{LN}^2}{R_{diss}}$$

Capacitor Bank Design and Protection
Externally Fused Configuration Only!

Bruce Mork 8-Apr-09
 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 | W/kVAR |
| Capacitance: | 3.008 | uFarads |
| Impedance: | 881.79 | Ohms |
| Current: | 15.06 | Amps |
| Diss Ohms: | 8.818 | MOhms |

Configuration:

| | Calc | Chosen | |
|-----------------------------|--------|--------|---------|
| 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: | | 38.34 | Ohms |
| Impedance/Phase: | | 230.03 | Ohms |
| Diss Ohms/Phase: | | 2.300 | MOhms |
| Discharge RC Time Constant: | | 26.53 | Secs |

Performance:

| | 0.95 | 1.00 | 1.05 | |
|---------------------|--------|--------|--------|---------|
| System Voltage, pu: | | | | |
| Total MVAR | 74.72 | 82.79 | 91.27 | |
| Line Current, Amps: | 329.04 | 346.36 | 363.68 | |
| Voltage/Group, kV: | 12.615 | 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 50V: | 203.43 | 204.79 | 206.08 | Seconds |

Group Voltages:

VT Ratio:

| | |
|--------|-----|
| kV | V |
| 13.279 | 120 |

1 Blown Fuses

| | | | |
|---------------|--------|--------|---------------------|
| 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

| | | | |
|---------------|--------|--------|---------------------|
| This Group: | 14.154 | 14.898 | 15.643 kV |
| | 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

| | | | |
|---------------|--------|--------|---------------------|
| This Group: | 14.753 | 15.530 | 16.306 kV |
| | 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 |