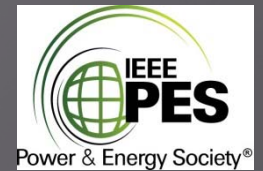




IEEE Jackson PES Meeting



SUBSTATION CAPACITOR BANK SWITCHING & PROTECTION DESIGN CONSIDERATIONS

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Ernst H. Camm

S&C Electric Company



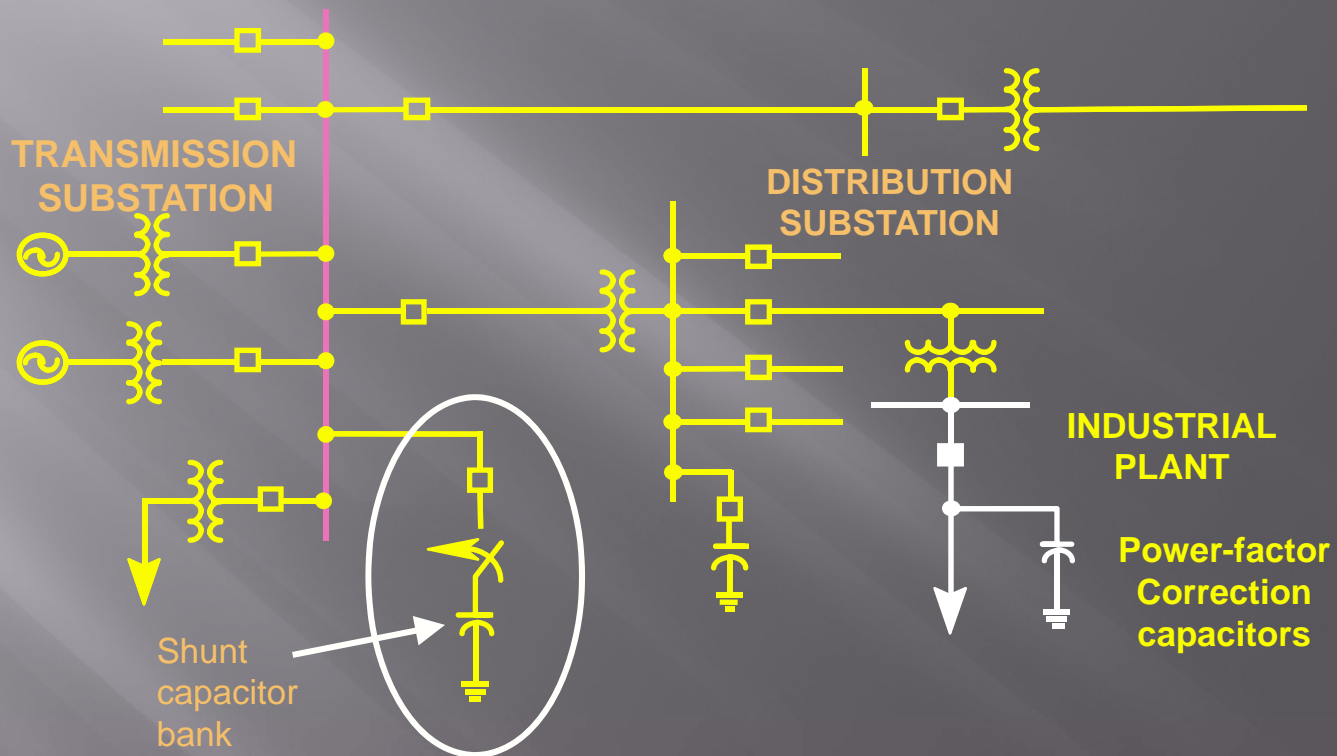
Outline of Presentation

- ▣ Introduction
- ▣ Types of capacitor banks
- ▣ Capacitor bank switching devices
- ▣ Capacitor bank protection
- ▣ Transient considerations
- ▣ Capacitor bank configurations

Introduction

- ▣ Capacitors widely used for:
 - Transmission system voltage support
 - Distribution system feeder voltage control
 - Increased system capacity
 - Reduced system power losses
 - Reduced end-user billing charges

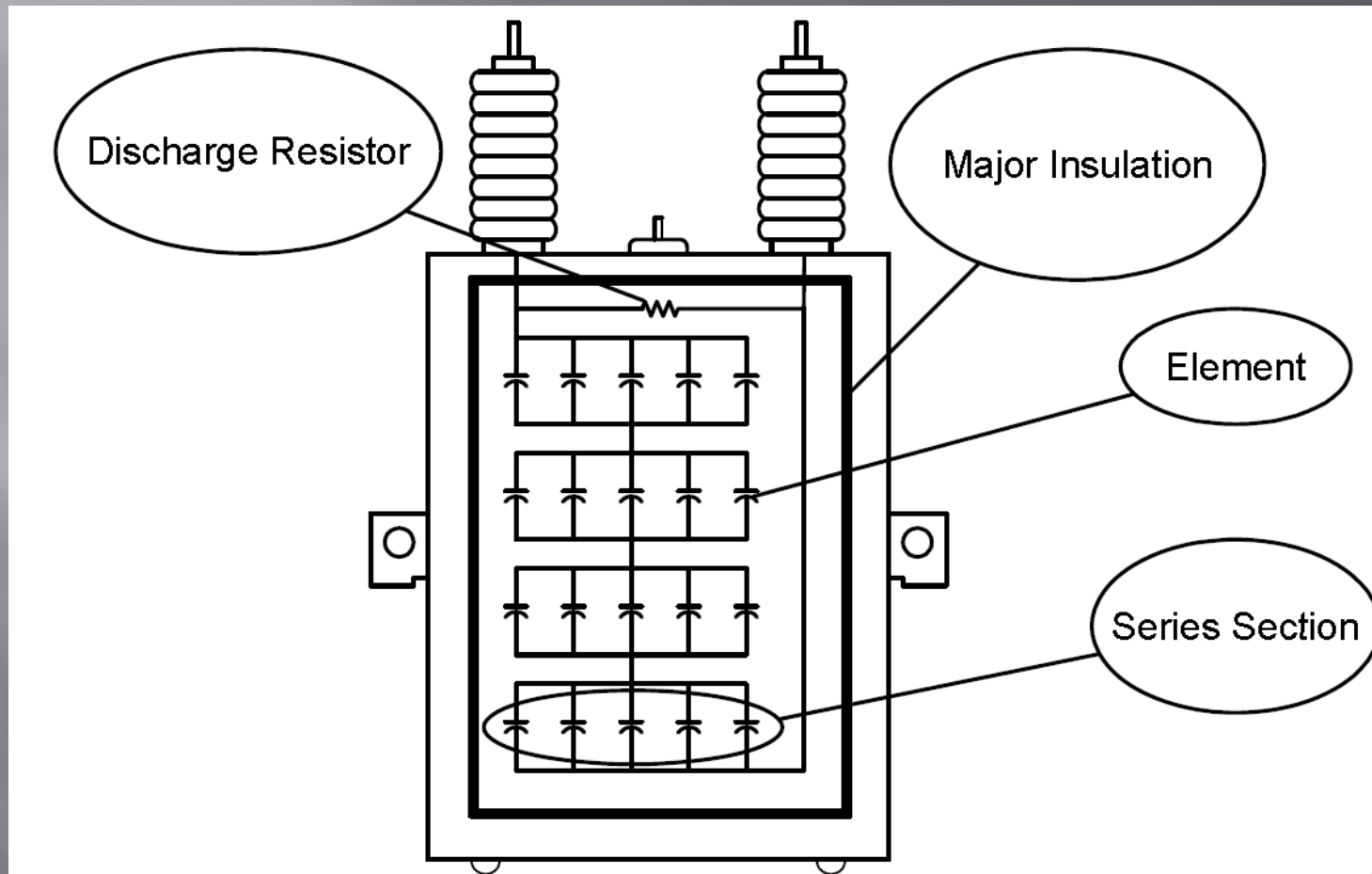
Introduction



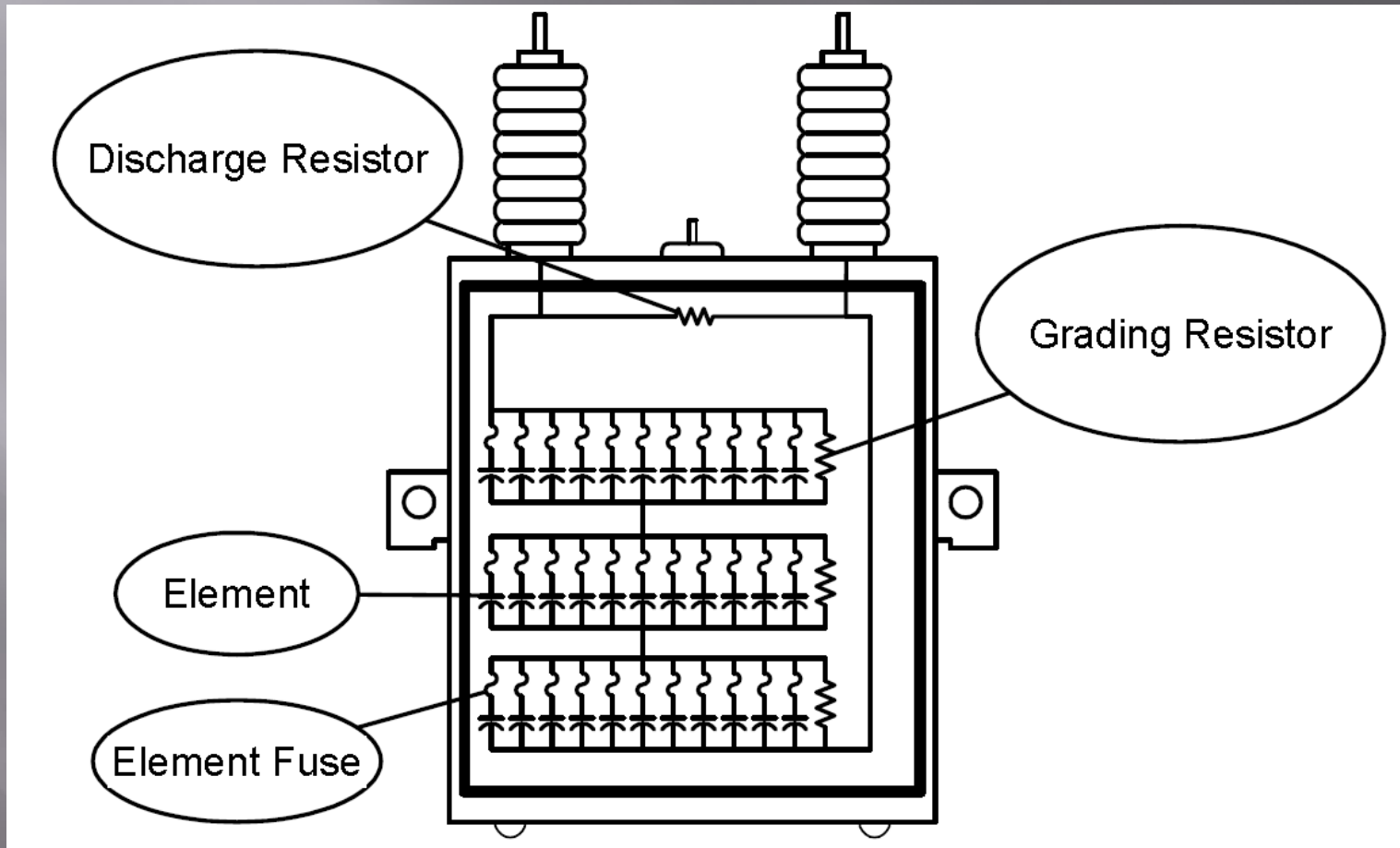
Types of Capacitor Banks

- ▣ Externally-fused
- ▣ Internally-fused
- ▣ Fuseless

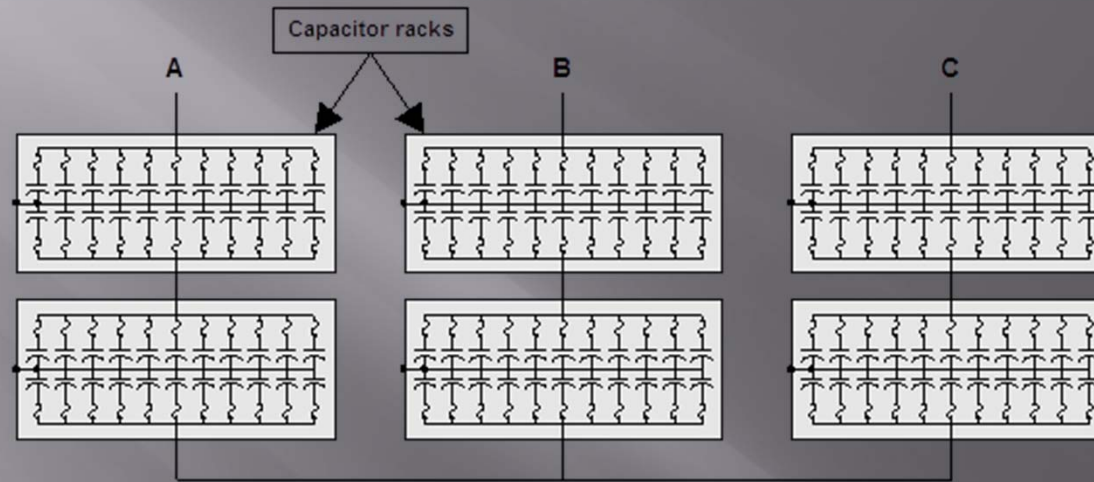
Unfused Capacitor Unit



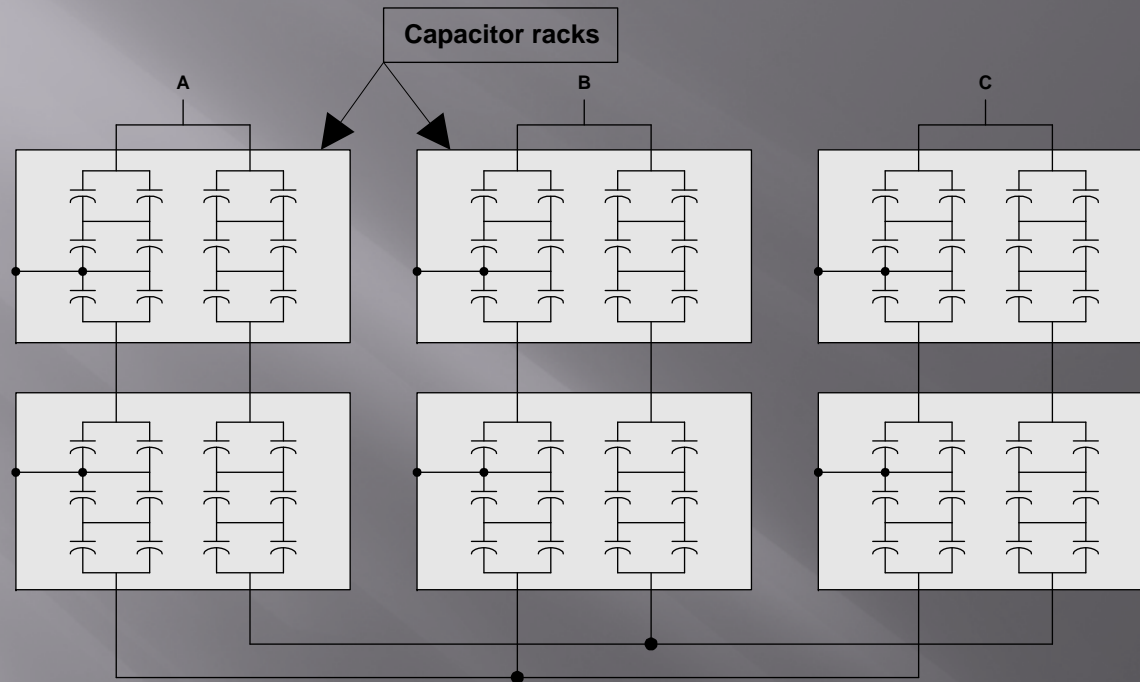
Internally-Fused Capacitor Unit



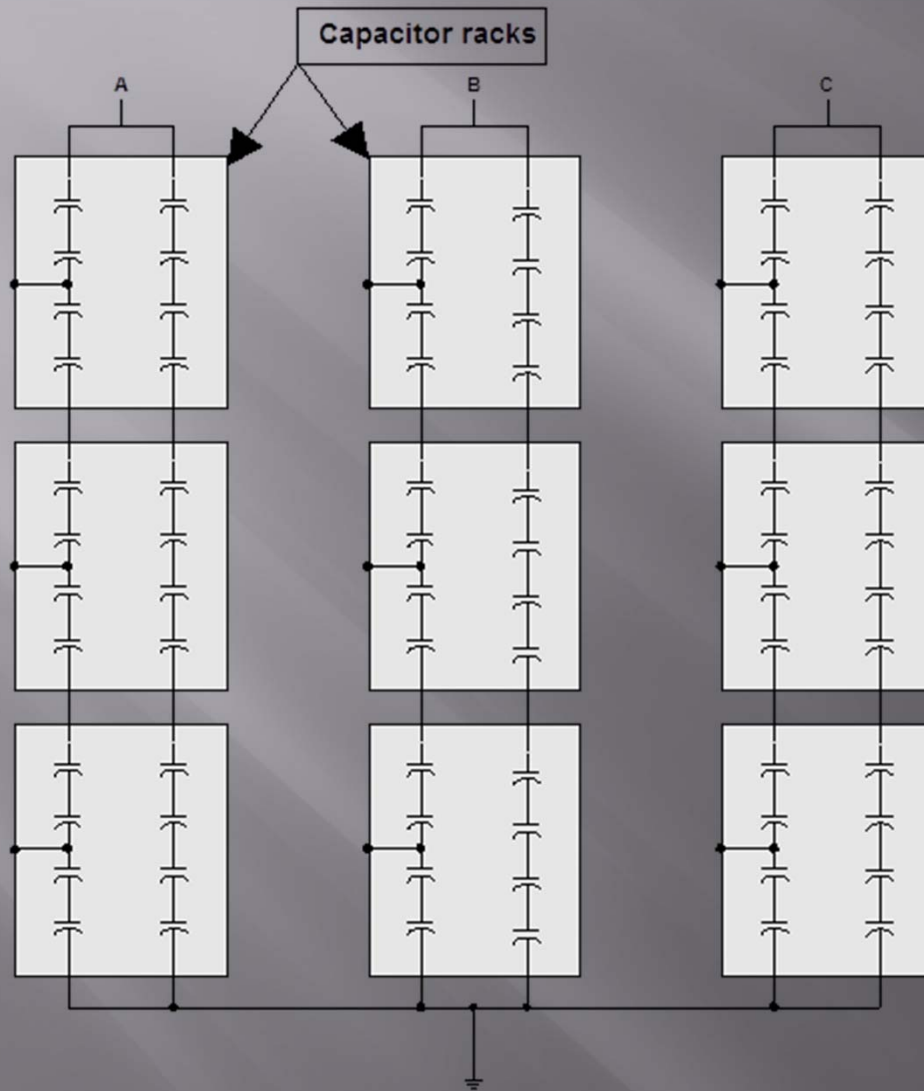
Externally-Fused Capacitor Bank



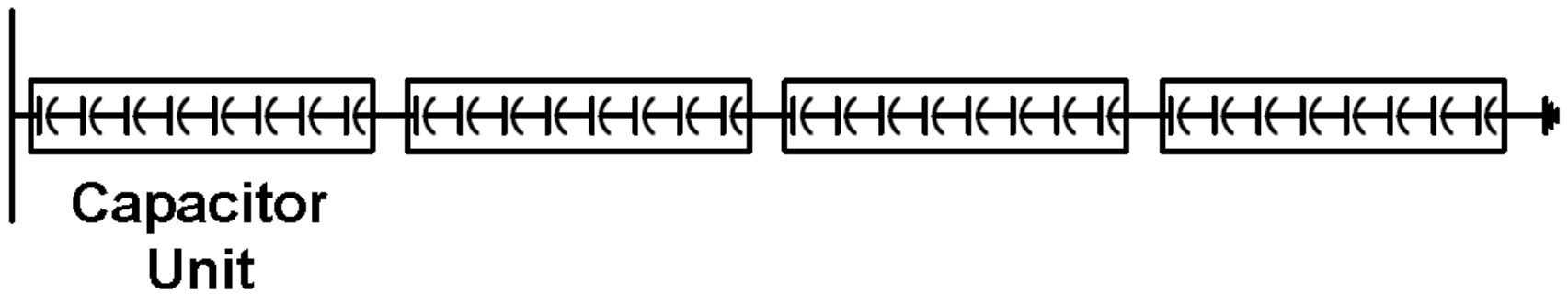
Internally-Fused Capacitor Bank



Fuseless Capacitor Bank



Fuseless Capacitor Bank



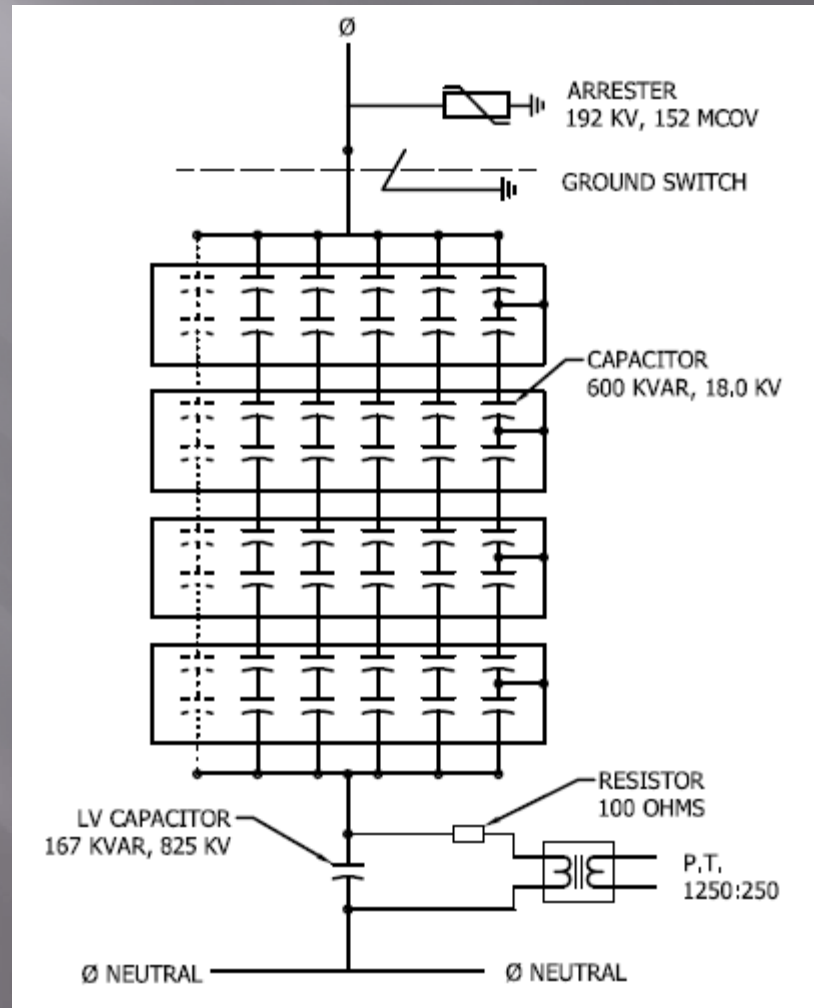
Advantages and Disadvantages of Capacitor Bank Types

	Externally-Fused	Internally-Fused	Fuseless
Total Losses	Low	Higher	Lowest
Capacitor unit temperature rise	Low	Higher	Low
Unbalance Protection Sensitivity	Low	Highest	Higher
Required Substation Space	Most	Least	More
Difficulty in locating faulted units	Least	Most	More
Equipment cost	More	Most	Least
Installation cost	Most	Least	Least

Advantages and Disadvantages of Capacitor Bank Types

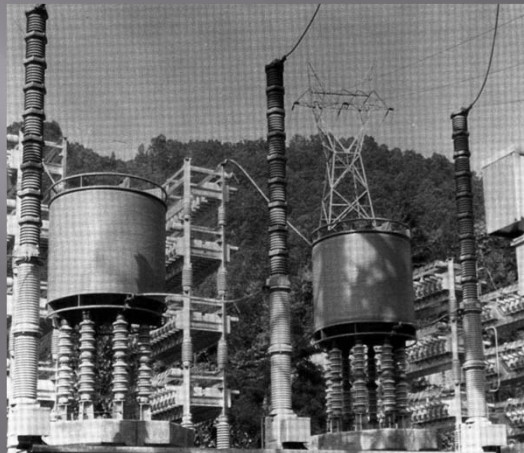
	Externally-Fused	Internally-Fused	Fuseless
Protection against animals	Worst	Better	Best
Capacitance change with failures	Highest	Lowest	Higher

Fuseless Capacitor Bank: Typical Connection Diagram



Capacitor Bank Switching Devices

- ▣ Vacuum switches (with optional controlled closing)
- ▣ Circuit-Switchers (with optional pre-insertion inductors)
 - Mark V
 - Mark VI
 - Series 2000
- ▣ Circuit breakers (with optional controlled closing)



Capacitor Bank Switching Devices

- ▣ IEEE Std C37.06-2009, IEEE Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities for Voltages Above 1000 V
 - Preferred capacitance current switching ratings for Class S1 cable systems circuit breakers rated below 100 kV
 - Preferred capacitance current switching ratings for Class S2 line systems circuit breakers rated below 100 kV
 - Preferred capacitance current switching ratings for circuit breakers rated 100 kV and above, including circuit breakers applied in gas-insulated substations

Capacitor Bank Switching Devices

▣ Rated capacitor bank current

Table 14—Preferred capacitance current switching ratings for circuit breakers rated 100 kV and above, including circuit breakers applied in gas-insulated substations^{a, b, c}

Line No.	Rated maximum voltage U_r kV, rms	Rated continuous current A, rms	Class C0 circuit breakers (1) (2)		Class C1 or Class C2 (2) (4)	
			Rated overhead line current A, rms	Rated Isolated capacitor bank or cable current A, rms	Rated isolated capacitor bank current (6) A, rms	Rated overhead line current A, rms
			Col 1	Col 2	Col 3	Col 4
1	123	(9)	50	50	1200	160
2	145	(9)	80	80	1200	160
3	170	(9)	100	100	1200	160
4	245	(9)	160	160	1200	200

Capacitor Bank Switching Devices

- Back-to-back capacitor bank switching
 - Rated inrush current
 - Peak value (kA, peak)
 - Frequency (kHz)

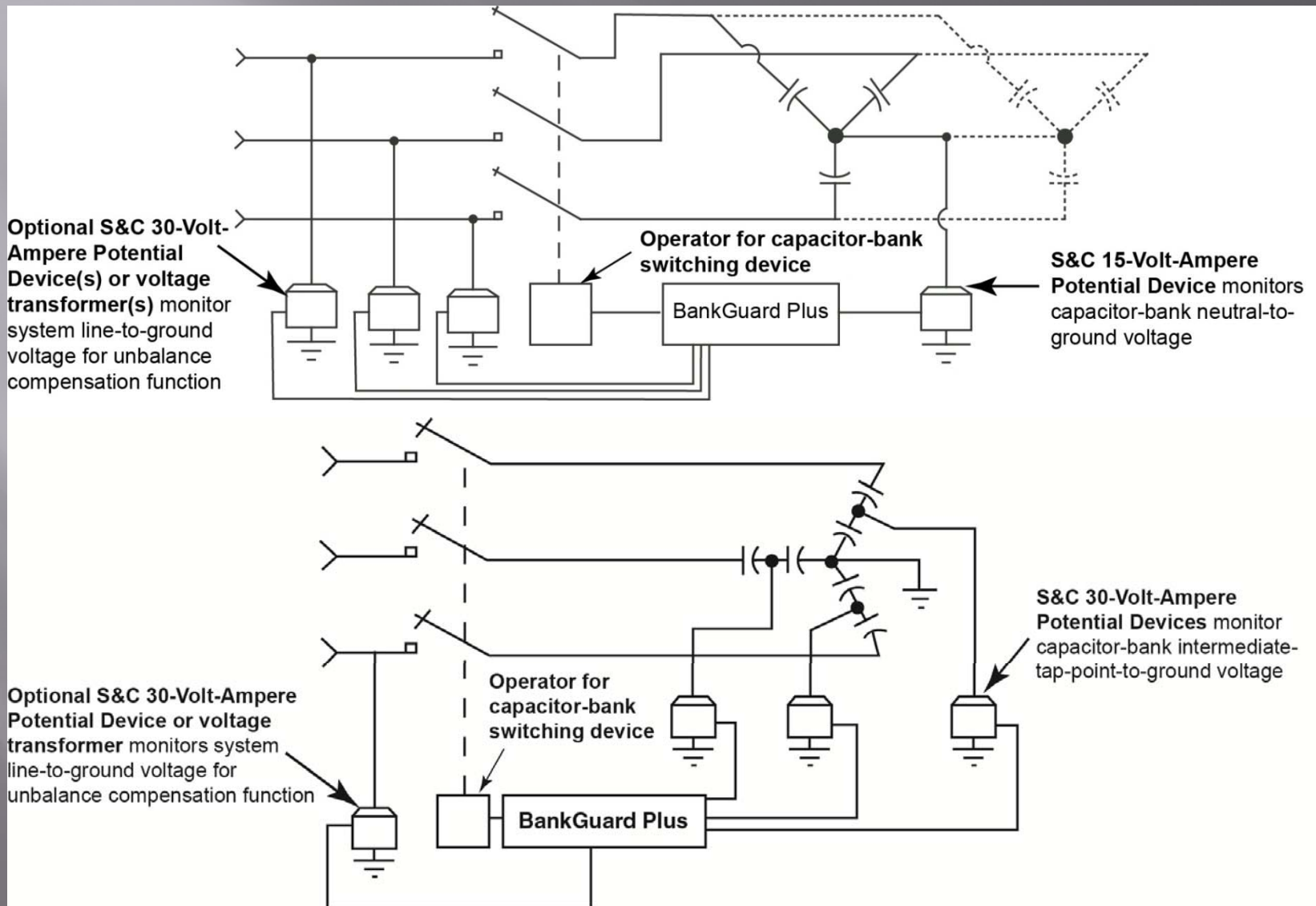
Table 14—Preferred capacitance current switching ratings for circuit breakers rated 100 kV and above, including circuit breakers applied in gas-insulated substations ^{a, b, c} (continued)

Line No.	Rated maximum voltage U_r kV, rms	Class C1 or Class C2 circuit breakers (2) (4)								
		Back-to-back capacitor bank switching								
		Rated back-to-back capacitor bank current (6) A, rms	Rated inrush current (3) (5)							
			Preferred rating (7)		Alternate 1 rating (7)		Alternate 2 rating (7)		Alternate 3 rating (7)	
			Peak value kA, peak	Frequency kHz	Peak value kA, peak	Frequency kHz	Peak value kA, peak	Frequency kHz	Peak value kA, peak	Frequency kHz
Col 1	Col 7	Col 8	Col 9	Col 10	Col 11	Col 12	Col 13	Col 14	Col 15	
1	123	700	16	4.3	6	2	25	13	60	8.5
2	145	700	16	4.3	6	2	25	13	60	8.5
3	170	700	20	4.3	6	2	25	13	60	8.5
4	245	700	20	4.3	6	2	25	13	60	8.5

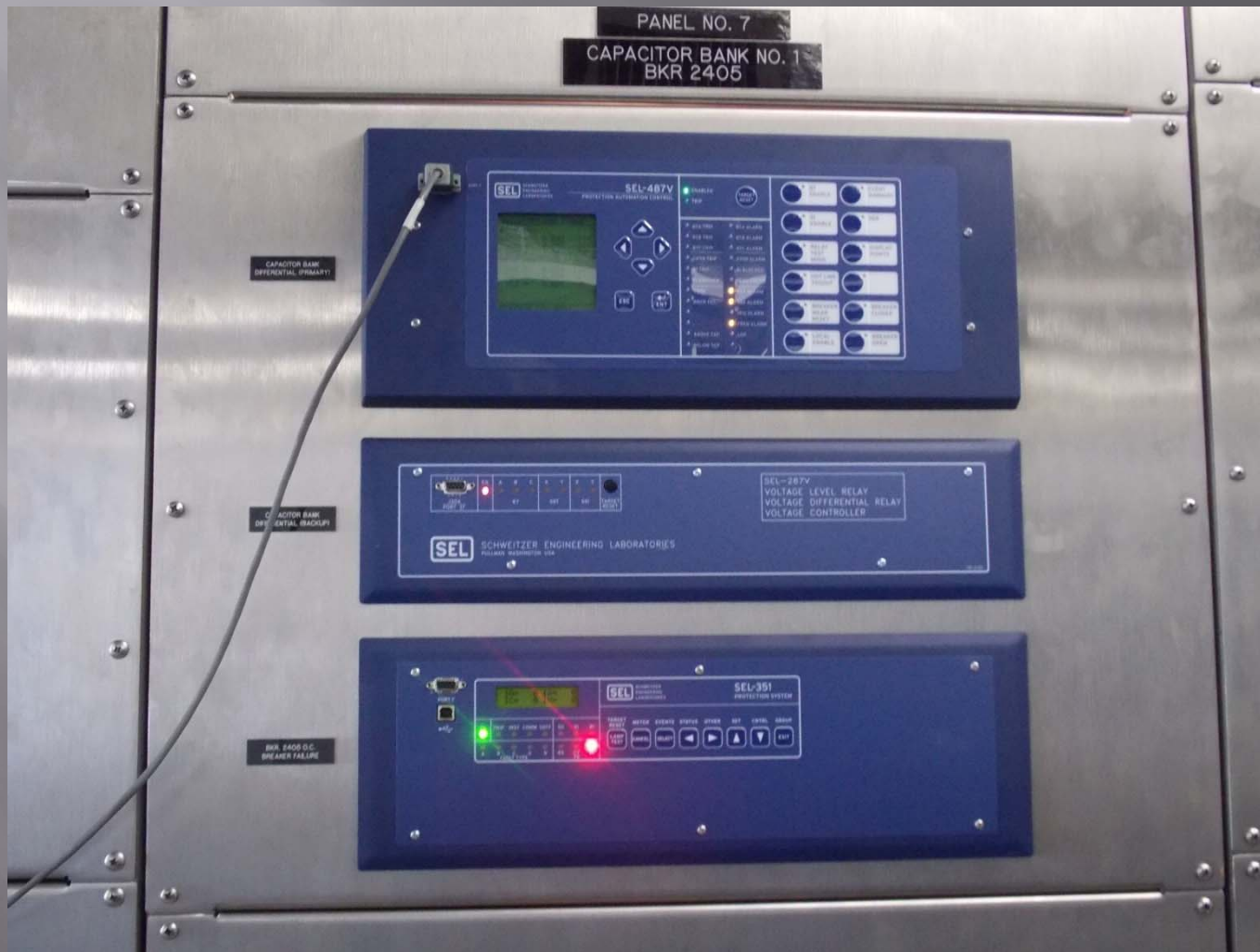
Capacitor Bank Protection

- ▣ Capacitor fusing (fuse links)
- ▣ Unbalance relaying
- ▣ Overcurrent relaying

Capacitor Bank Protection Unbalance Relaying



Capacitor Bank Protection Unbalance & Overcurrent Relaying

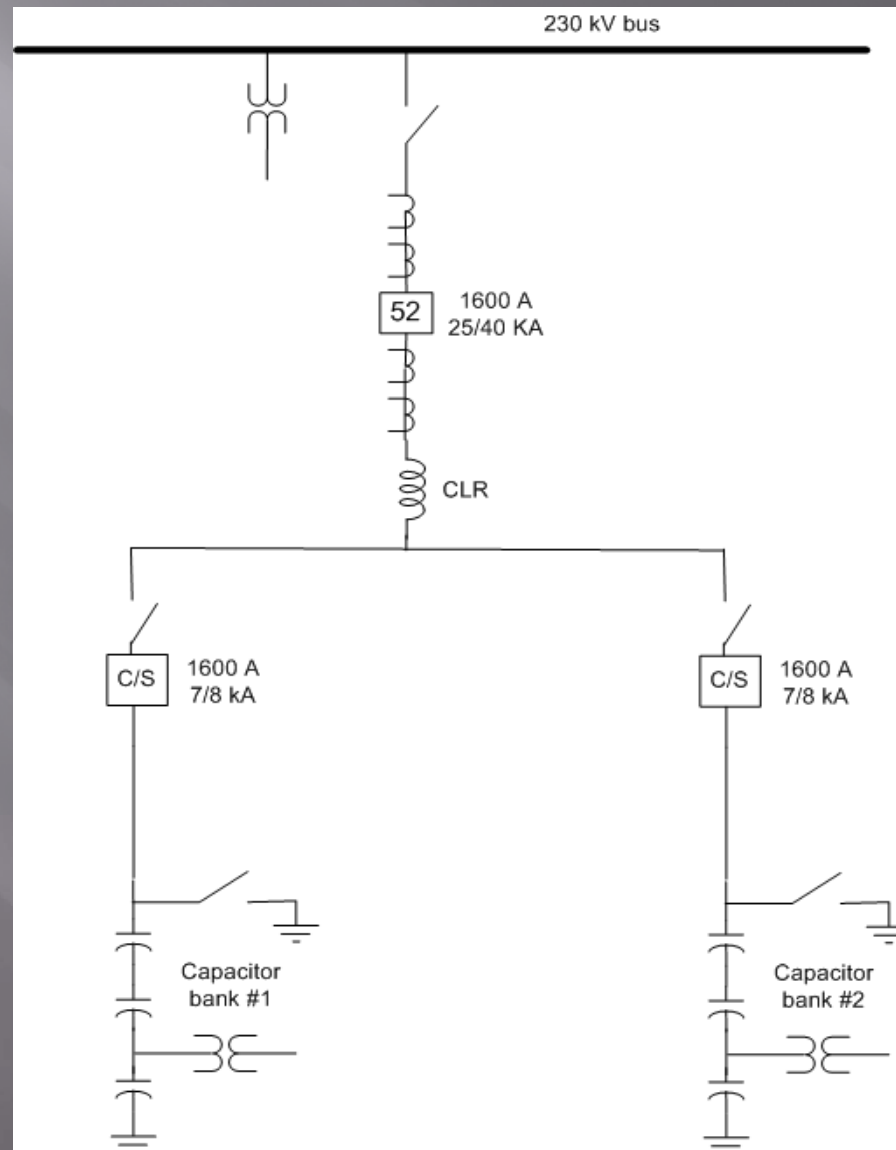


Transient Considerations

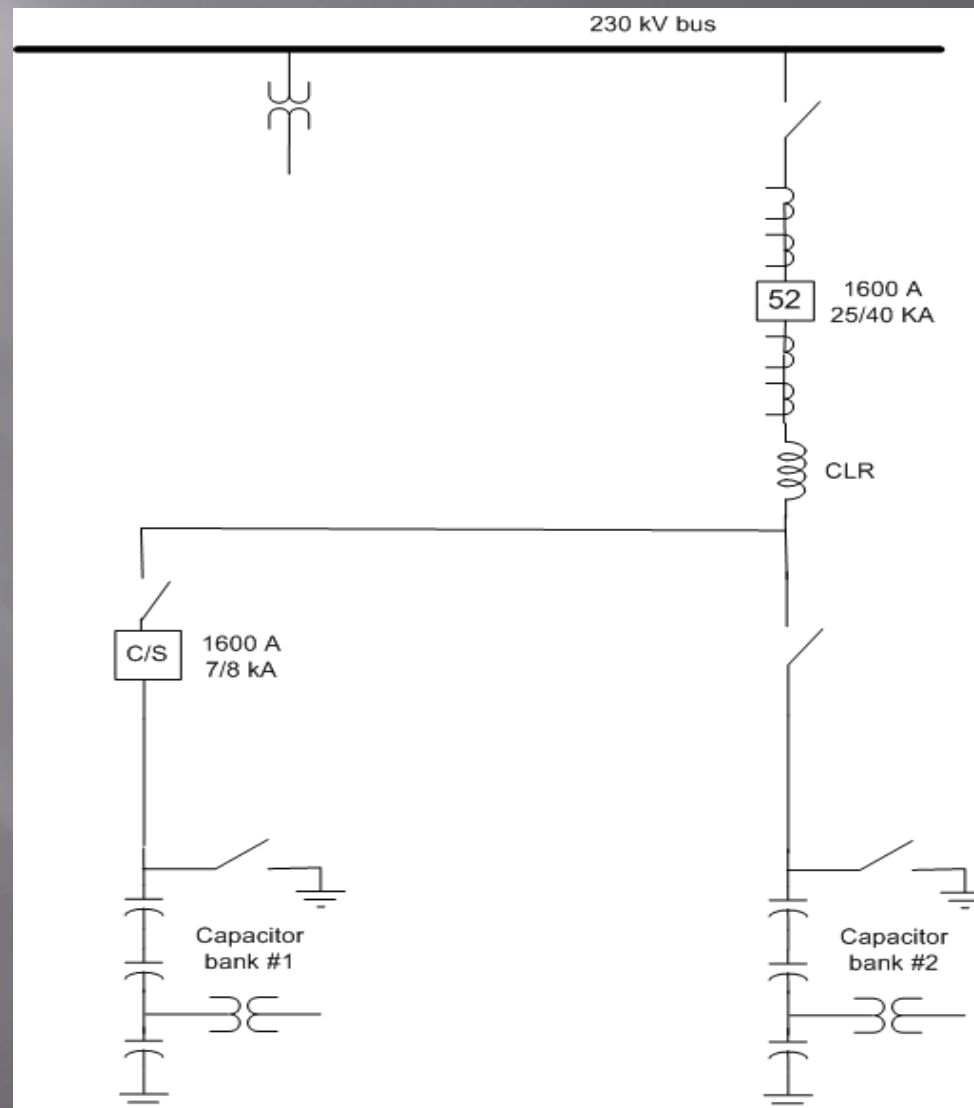
- ▣ Transient overvoltages & mitigation
- ▣ Back-to-back inrush currents & mitigation
- ▣ Outrush currents into close-in faults & mitigation
- ▣ Current-limiting reactor effect on CB TRV
 - TRV taming capacitance



Capacitor Bank Configurations



Capacitor Bank Configurations



QUESTIONS ???

