

# 21C Cap Bank Protection

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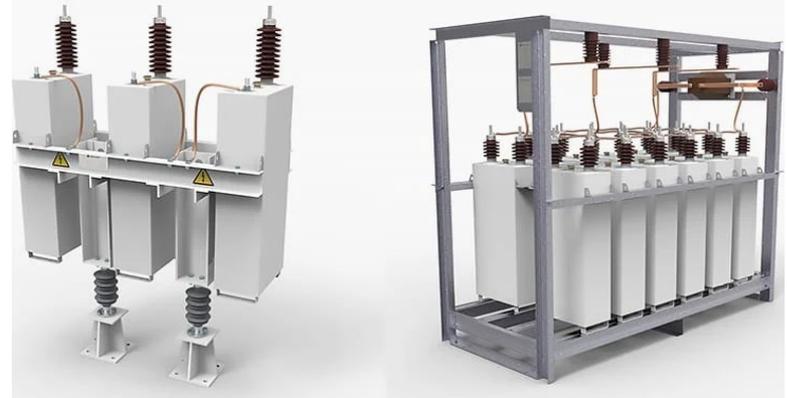


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The use of shunt capacitor units has gained popularity because they are quite affordable, simple to install and commission and can be placed anywhere in the electrical distribution system.

The major topics are:

- Power Factor Correction
- Feeder-Loss Reduction
- Release of system capacity
- Power Harmonic Filtering
- Power Quality Enhancement
- Efficient Power Utilization
- Voltage stabilization & Regulation



# Shunt Capacitor Bank Configuration

## Externally Fused SCB:

An individual fuse, externally mounted between the capacitor unit and bus, typically protects each capacitor unit.

## Internally Fused SCB:

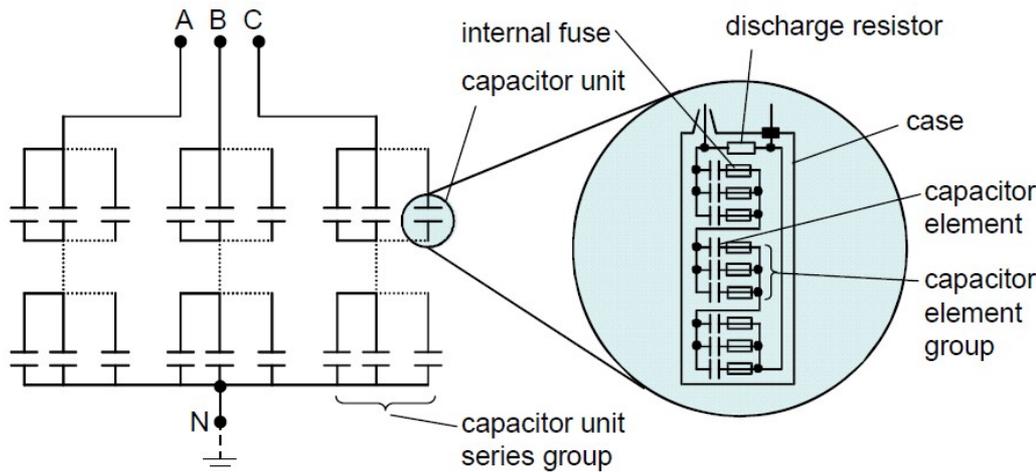
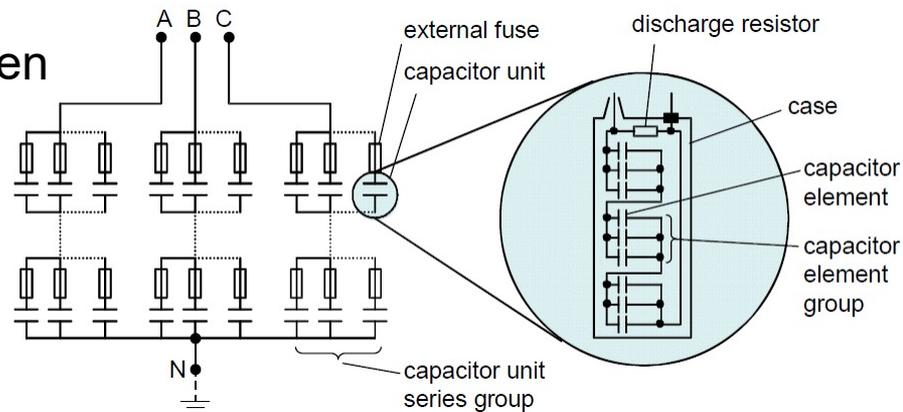
Each capacitor element is fused inside the capacitor unit.

## Fuseless SCB:

capacitor units are connected in series strings between phase and neutral

## Unfused SCB:

uses a series/parallel connection of the capacitor units



# Shunt Capacitor Bank Design

## Grounded Wye-Connected Banks:

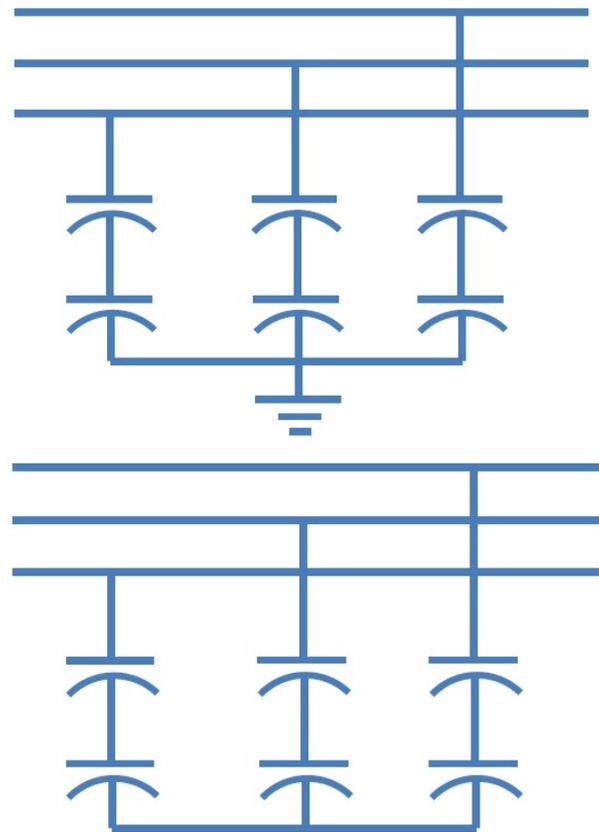
composed of series and parallel-connected capacitor units per phase and provide a low impedance path to ground

## Ungrounded Wye-Connected Banks:

Ungrounded wye units do not allow zero sequence currents, third harmonic currents, or big capacitor discharge currents during system ground failures to flow.

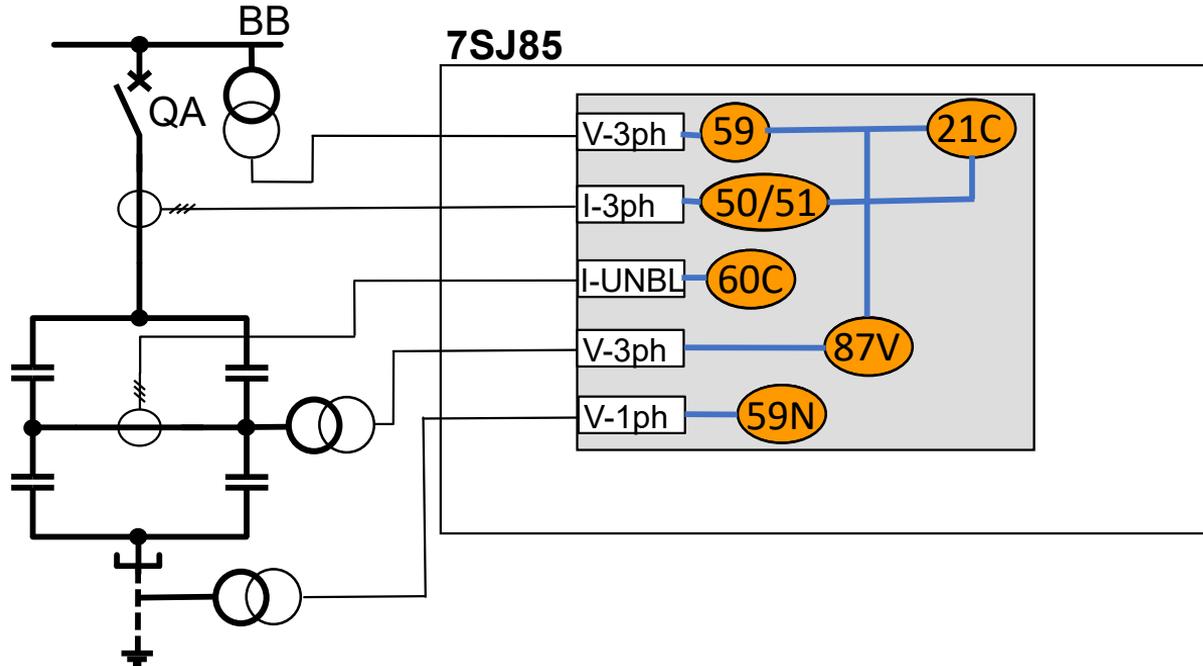
## Delta-Connected Banks:

single series group of capacitors rated at line-to-line volt



# Shunt Capacitor Bank protection

Shunt capacitor banks are protected against faults that are due to imposed external or internal conditions



## Why 21C protection?

- Voltage Differential Protection (87V) limitations
- sensitive monitor of the capacitor bank conditions
- Keep energized while the bank is still safe to operate
- Immune to temperature variations and temperature gradients
- Applicable to different configuration fuse less, fused, grounded and ungrounded system
- Human readable way to monitor the Capacitor bank
- Prevent transient response during energization or external faults

## Impedance based protection

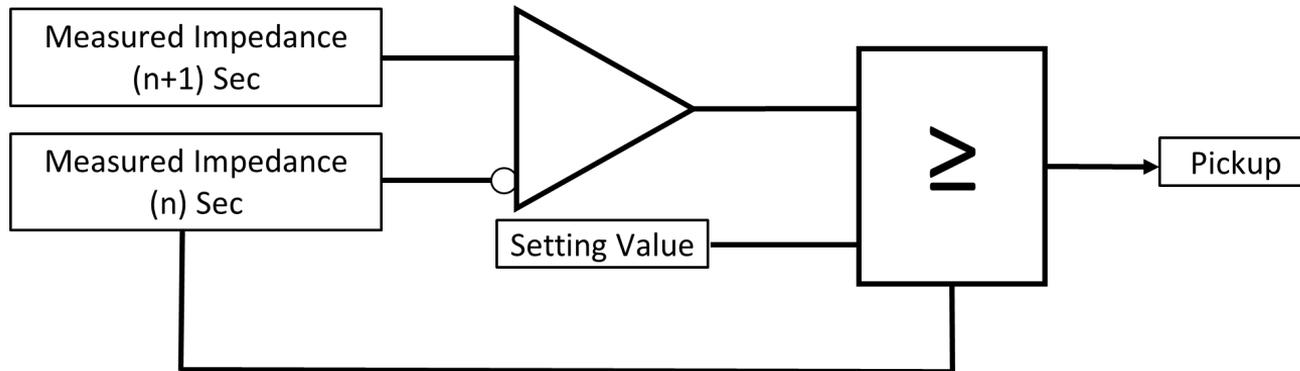
The 21C protection element calculates the impedance of the string using the bus voltage and the current flowing through the string using Ohm's law. This impedance is compared to the expected impedance of the capacitor string

Depending on the configuration of the capacitors and fuses, impedance of the cap bank will change when a fuse operates (open circuits an element).

$$\underline{Z_{phase}} = \frac{V_{ph}}{I_{ph}} \quad \Rightarrow \quad \begin{aligned} |Z_{phase}| &= \frac{|V_{ph}|}{|I_{ph}|} \\ \angle(Z_{phase}) &= \angle(V_{ph}) - \angle(I_{ph}) \end{aligned}$$

## Temperature effect

- The capacitance variation due to temperature can easily reach  $\pm 2\%$  for a temperature range of 0 to 140 F
- When the number of capacitors elements per string is high, for example more than 30, the impedance variation of  $\pm 2\%$  is in the same order as a single capacitor element failure.
- In order to mitigate the temperature-induced impedance variation, the blow temperature compensation algorithm is used .

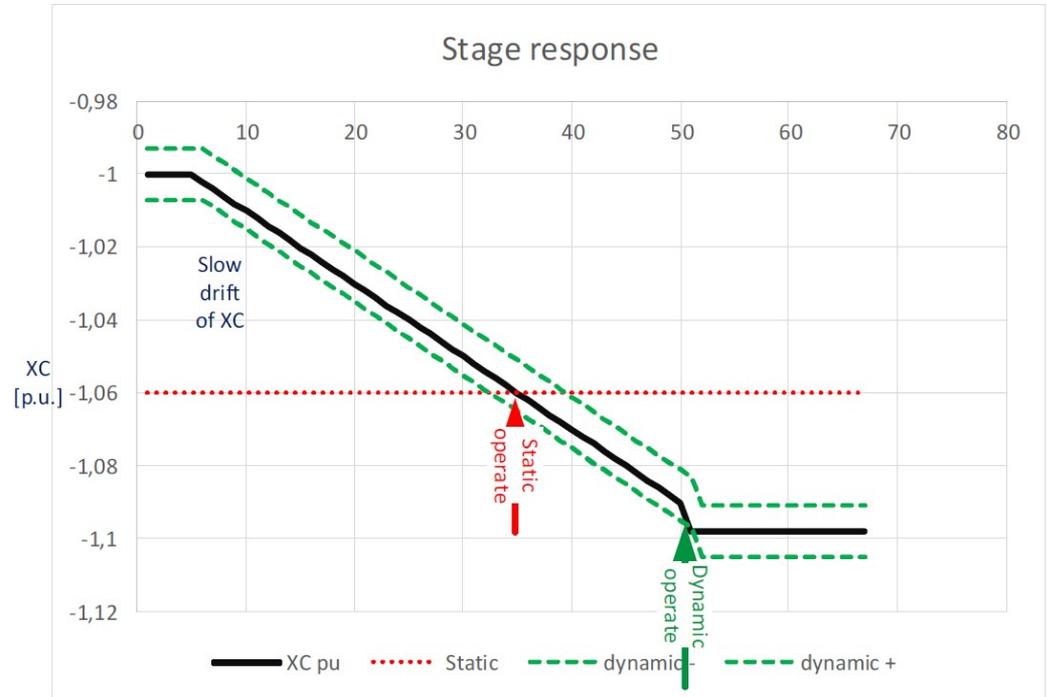


## Static Delta:

The static delta stage monitors the value of the measured capacitive reactance and the rated per unit reactance.

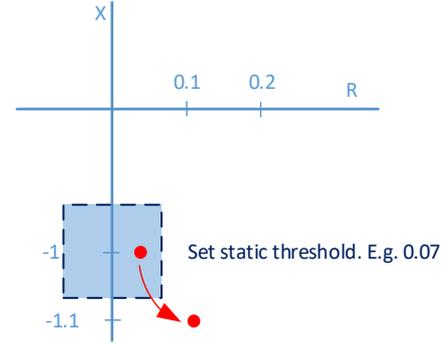
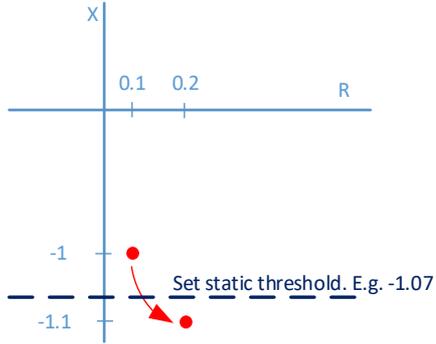
## Dynamic Delta:

The dynamic delta stage monitors the change of the measured capacitive reactance relative to the value that was measured 1 second earlier

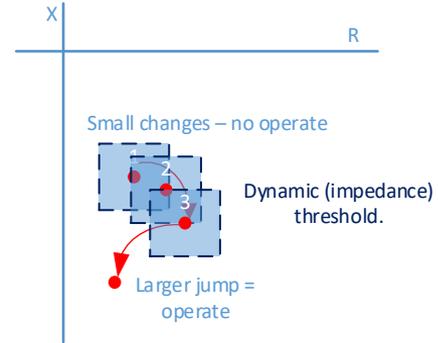
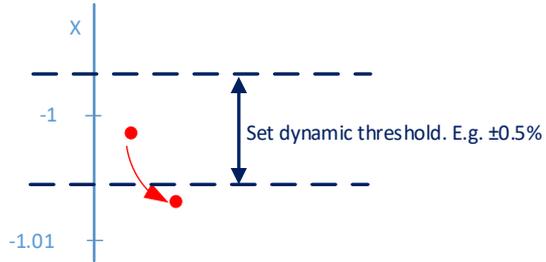


# Impedance protection stages

## Static Delta:



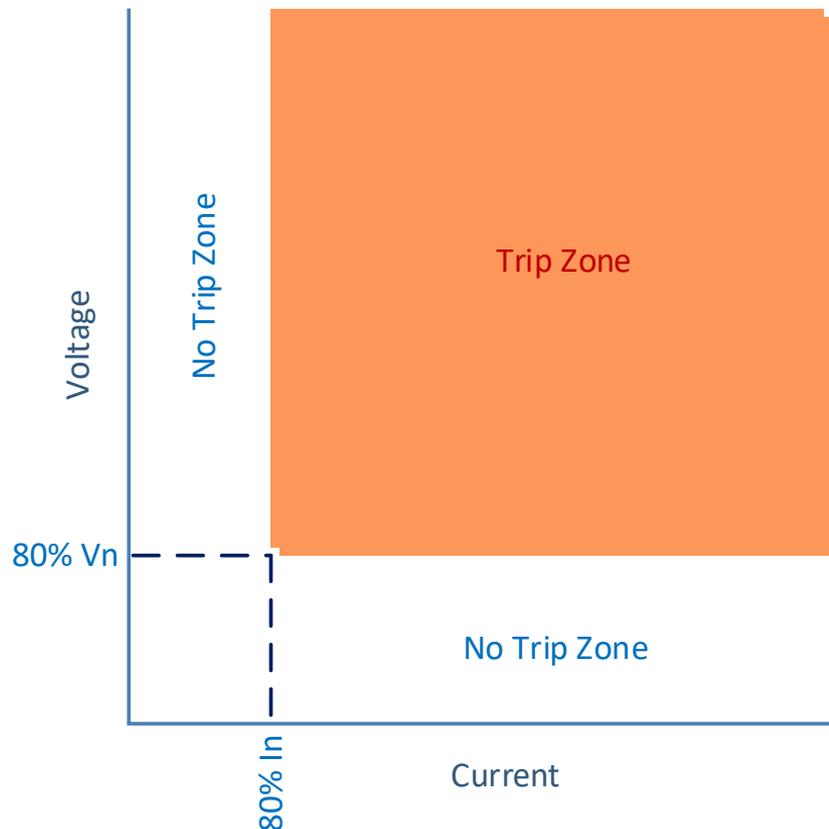
## Dynamic Delta:



## Current & Voltage Supervision

To prevent transient response of the 21C during energization or external faults, a current and voltage plausibility check is included. The settings for these are applied as follows:

- The setting for this supervision should ensure pickup at approx. 80% of the rated capacitor bank Current & Voltage



- Better localization of the shorted section, reducing maintenance time
- Better availability of the bank by reducing nuisance tripping
- Not affected by bus voltage variations
- Immune to temperature variations and temperature gradients
- Unaffected by the self-canceling effect of capacitor element going out on either side of the LV potential transformer
- Applicable to fuse less, fused, grounded and ungrounded system
- Human readable way to monitor the Capacitor bank

## Conclusion

- The 21C function can be applied as a sensitive monitor of the capacitor bank condition.
- Sensitive dynamic delta stages can detect fuse operations in the capacitor bank.
- Static delta stages can be set to alarm or trip the cap bank when internal asymmetry causes harmful voltage levels on the capacitors.
- Impedance-based protection for capacitor banks (21C) was proposed to overcome some drawbacks of voltage differential protection (87V). More specifically, it was shown to be more secure in fuseless capacitor banks
- The 21C protection is not a replacement, but a complementary protection scheme

Thank you for your attention

