Substation Arresters

Overview of ongoing research

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Objectives

Acquire	Operate	Maintain	Dispose
How to specify Surge Arresters?	How to best monitor arrester performance?	What is the technical basis for implementing, or timing maintenance actions to prevent arrester failures?	How to determine when arresters have reached the end of their useful life?
Selection procedures	Arrester Accelerated Aging Test		
Requirements & tests	Remote Monitoring	Condition testing	Inspection Guide
Specifications		Failure Database	Guide for Removal
		User experiences	

Progress

Acquire

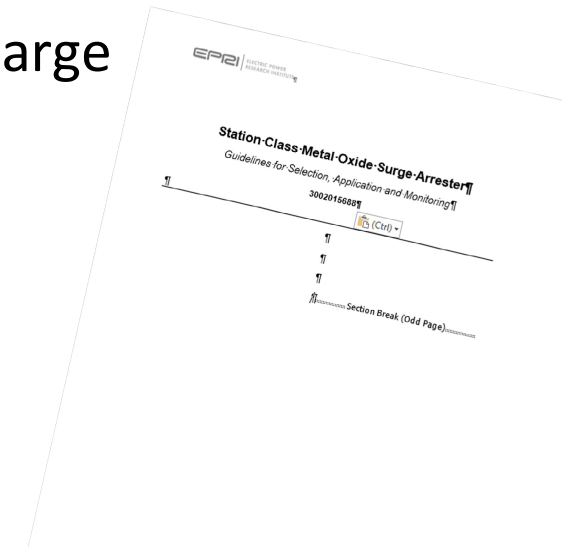
How to specify Surge Arresters?

Selection procedures

Requirements & tests

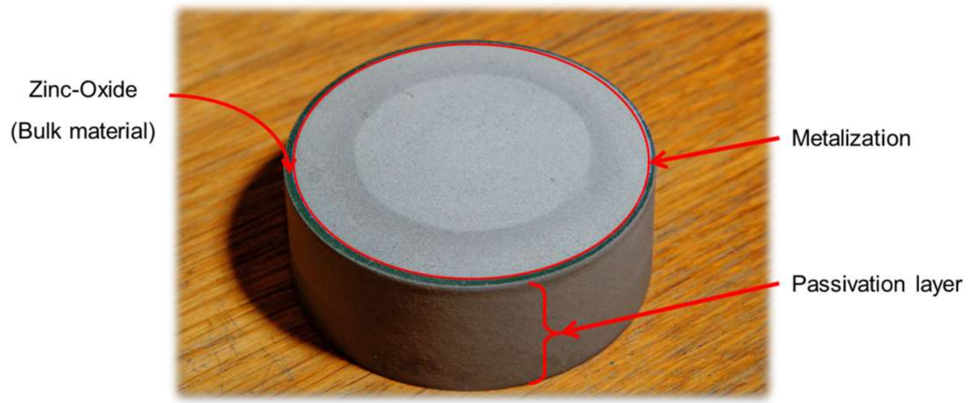
Specifications

- Review of New Arrester Standards
  - ANSI and IEC
  - Identify Strengths and weaknesses
  - Explain new way of specifying discharge energy requirement
  - Guidelines on how to select arrester characteristics
  - Report PID 3002015688
    - Updated Selection guidelines



Updated Selection guidelines

- Introduction to Metal Oxide Arresters
  - Functioning
  - Construction
  - Long term performance



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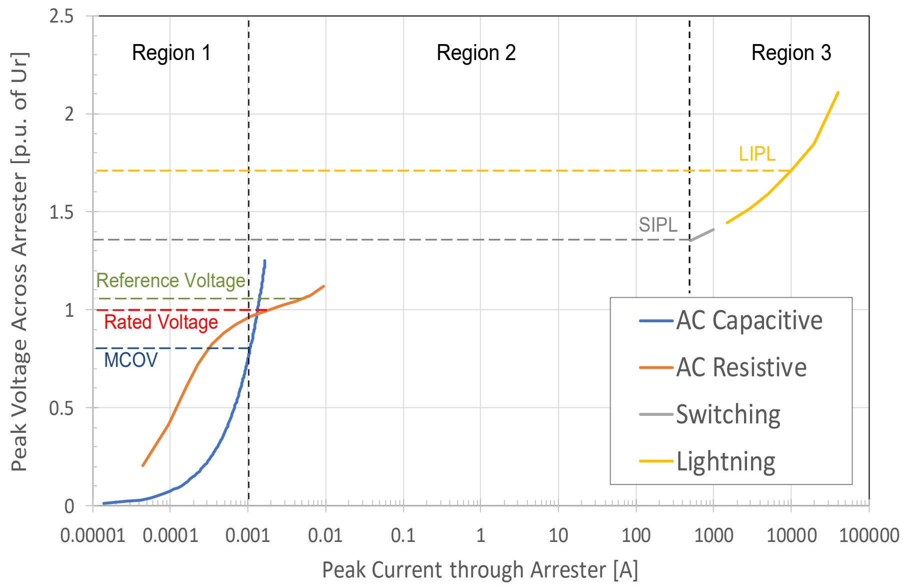
Updated Selection guidelines

- Characterization of Arresters
  - Review of IEC 60099-4 and IEEE C62
  - Characterization
    - for Power Frequency Voltages
    - of Protective Characteristics
    - of Energy Handling Characteristics

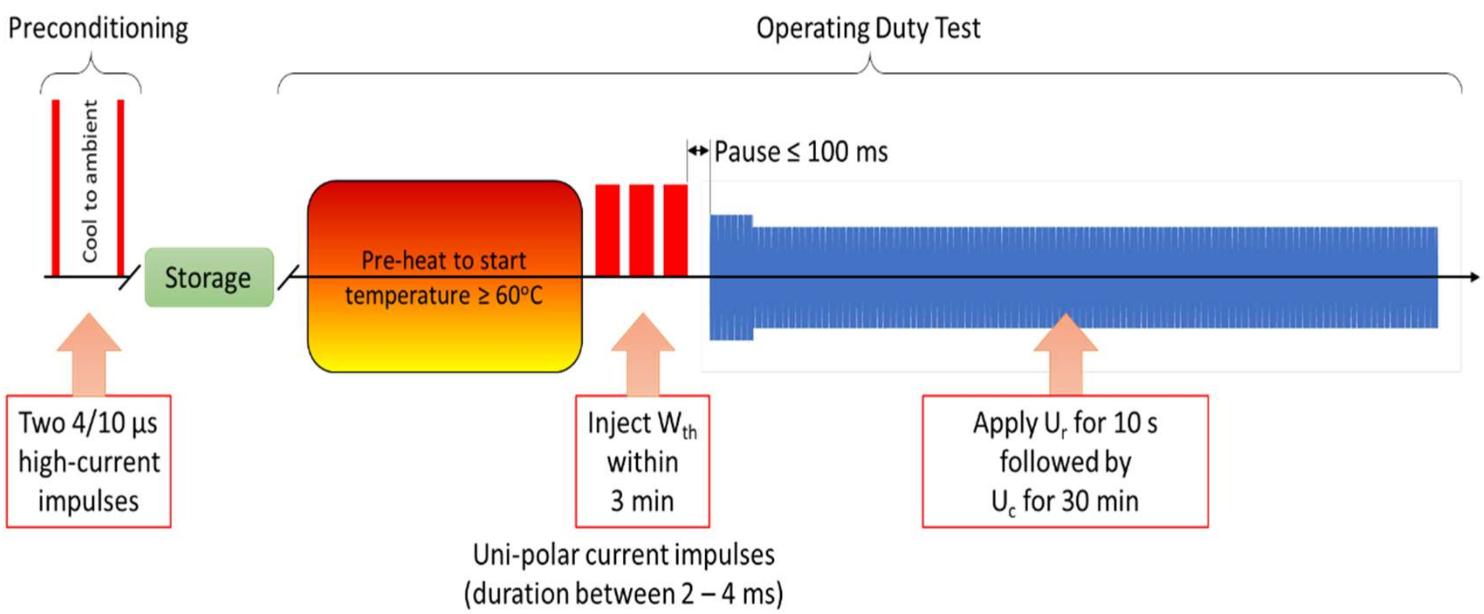


Energy Handling Capability

- The ability of the arrester to conduct surges without being overloaded.
  - Thermal energy absorption refers to the ability of the complete arrester to cool down under normal operating conditions after it has conducted a surge and so avoid thermal runaway.
  - Impulse energy handling refers to the ability of the blocks, by themselves, to withstand the thermal and mechanical stresses the block is subjected to by single-shot energy injection.

Determining Thermal Energy Rating (W_{th})

- IEC 60099-4



Determining Impulse Energy Rating

- Impulse handling capability

$$I = Kt^{-\delta}$$

  - For 400 Joules/cm^3 for a low current ac test
  - to 1200 to 1700 Joules/cm^3 for very fast high-current impulses.

$$\delta \approx 1$$

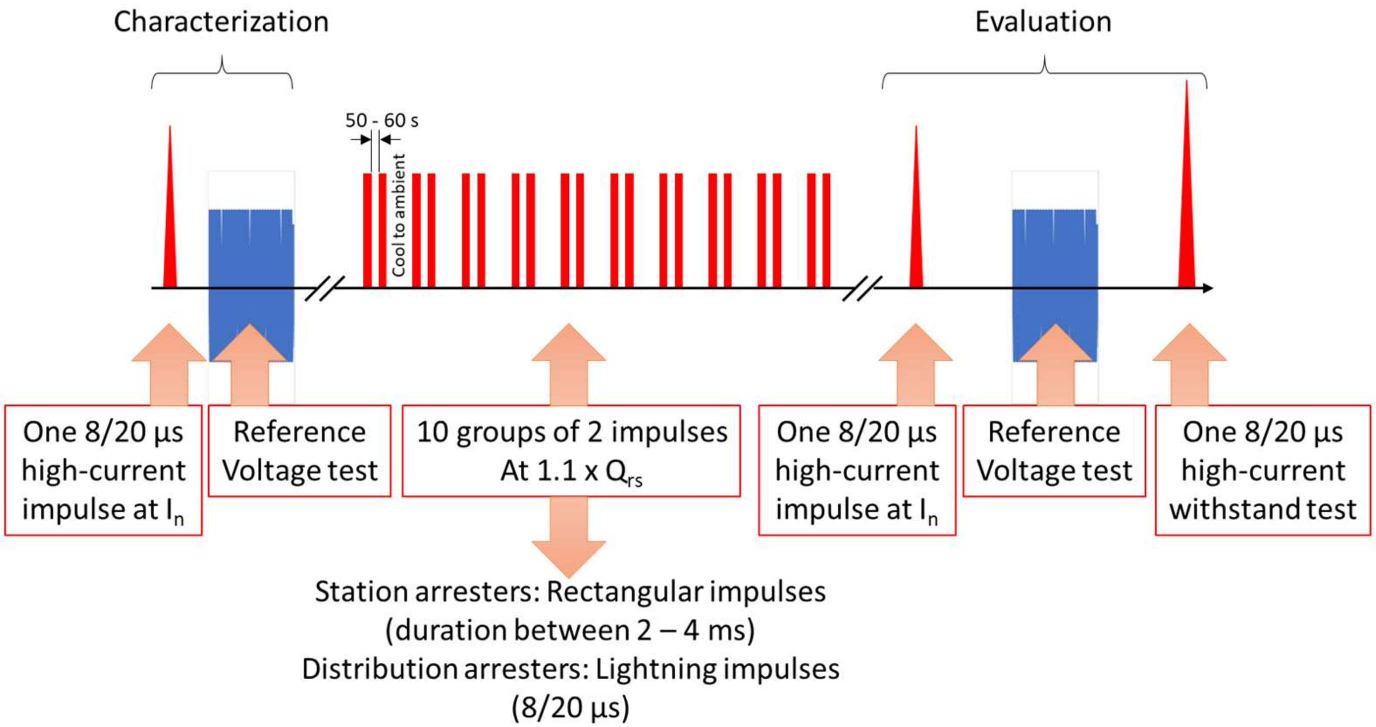
- Therefore:

$$K = I\ t$$

Charge transferred is a constant

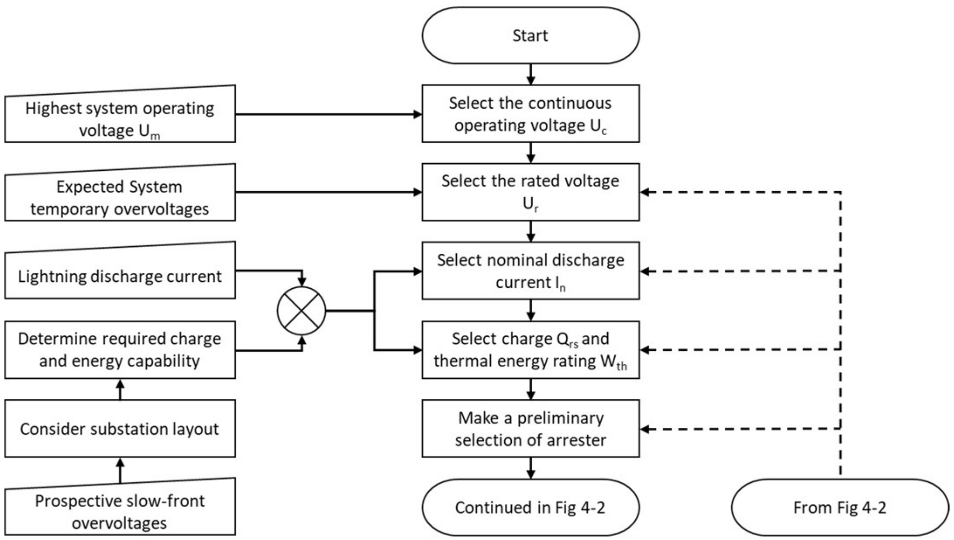
Determining Impulse Energy Rating (Q_{th})

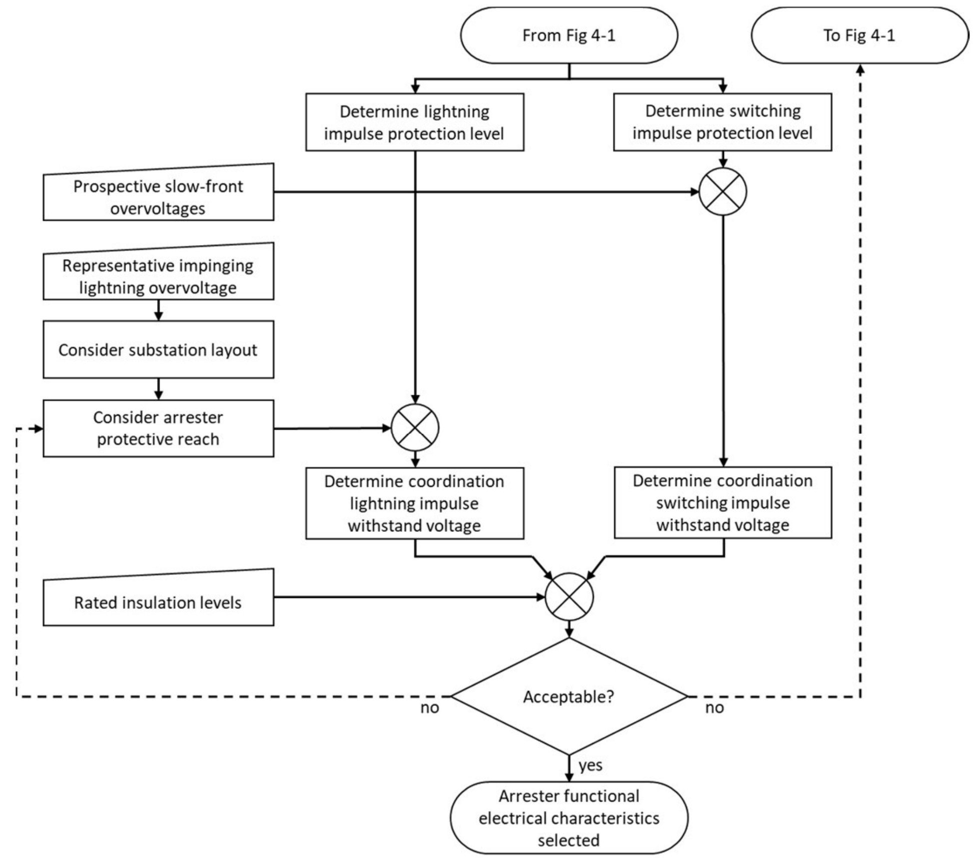
- IEC 60099-4



Selection of Arresters

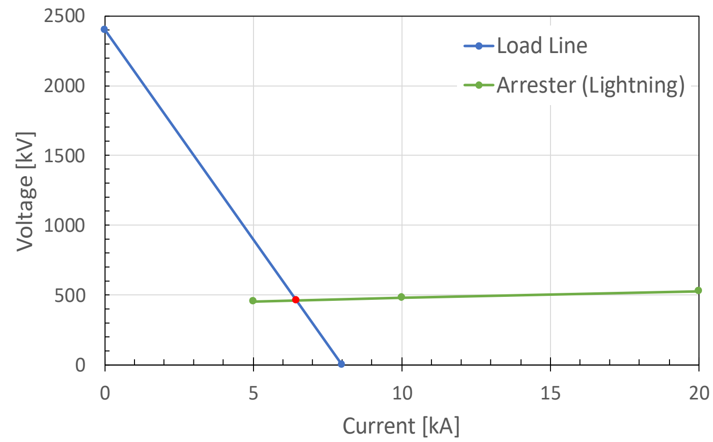
- Follow IEC Approach

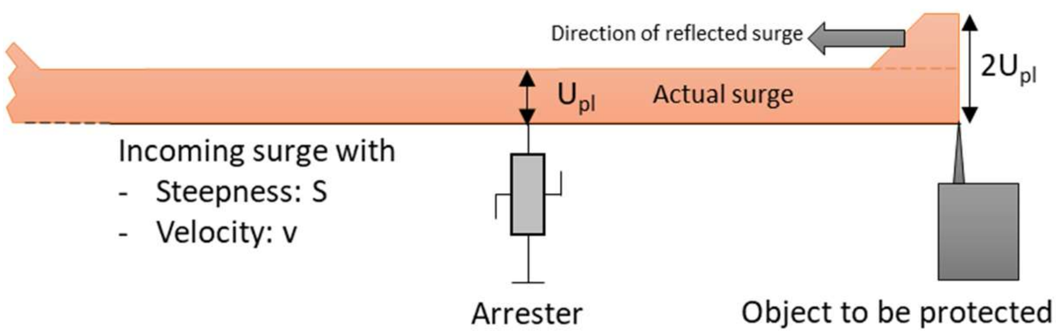


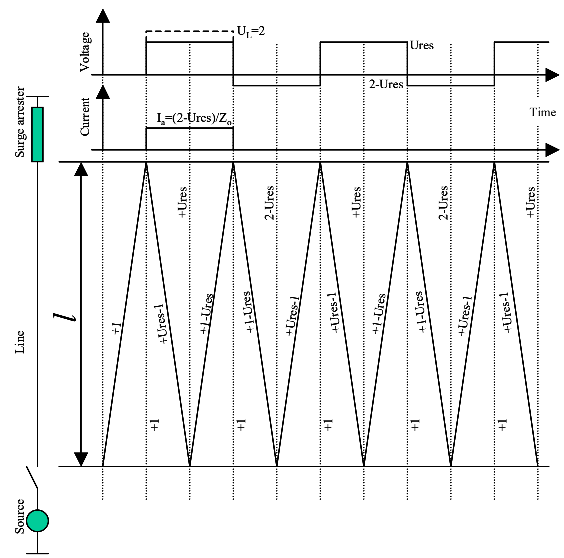


Selection of Arresters

- Detailed explanation
  - Determining Rated Current
  - Energy handling capability
  - Verification of protective characteristics







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Monitoring Surge Arrester Condition

- Introduce Monitoring Techniques
- Available Devices
- Introduce EPRI Arrester Sensor

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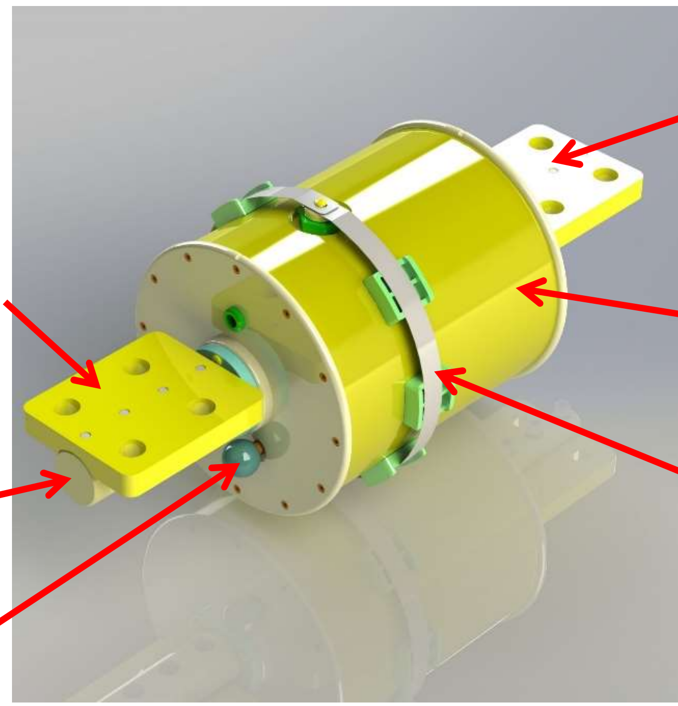
EPRI Arrester Sensor

Operate

How to best monitor arrester performance?

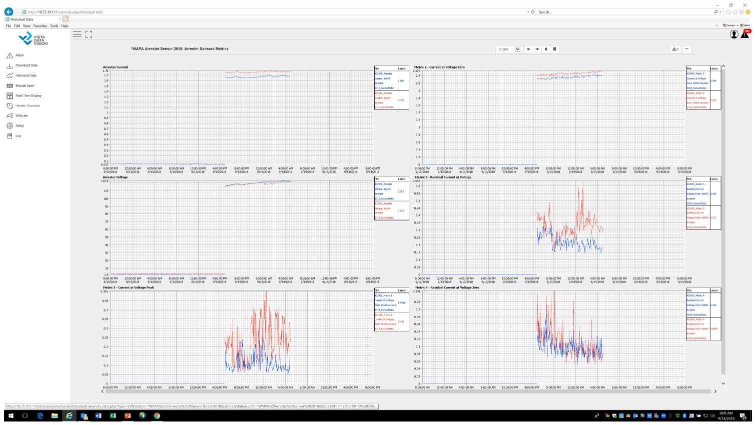
Remote Monitoring

- EPRI Arrester Monitor
  - Report “Surge Arrester RF Sensor - Development, Laboratory Testing and Field Demonstration”



Arrester Monitor

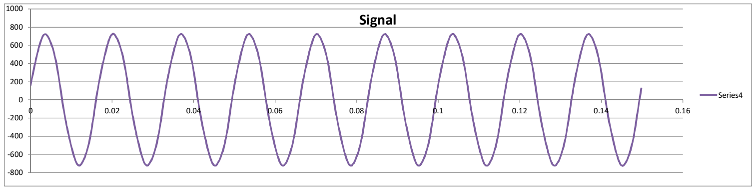
- Metrics
  - Arrester Voltage (kVolts)
  - Voltage F3 Component % (%)
  - Voltage F5 Component % (%)
  - Voltage F7 Component % (%)
  - Arrester Current (uAmps)
  - Current F3 Component % (%)
  - Current F5 Component % (%)
  - Current F7 Component % (%)
  - Residual Current Peak (uAmps)
  - Residual Current F3 Component (%)
  - Metric 1 - Current at Voltage Peak (uAmps)
  - Metric 2 - Current at Voltage Zero (uAmps)
  - Metric 3 - Resid. Curr at V. Peak (uAmps)
  - Metric 4 – Resid. Curr at V. Zero (uAmps)



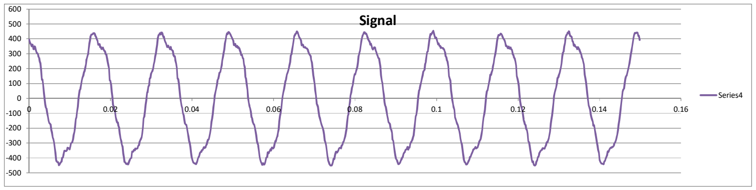
Arrester Monitor

- Methodology
  - Measures current and "voltage"
  - Derives estimate of "resistive" current

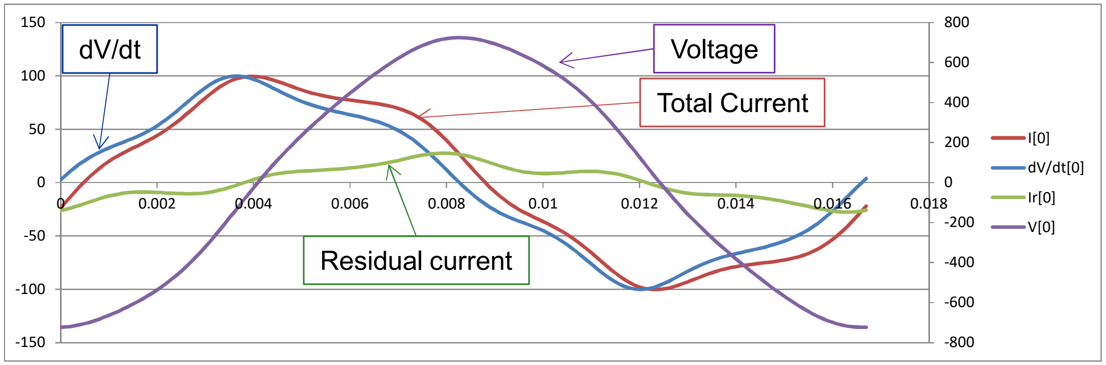
Sampled Voltage Signal



Sampled Current Signal

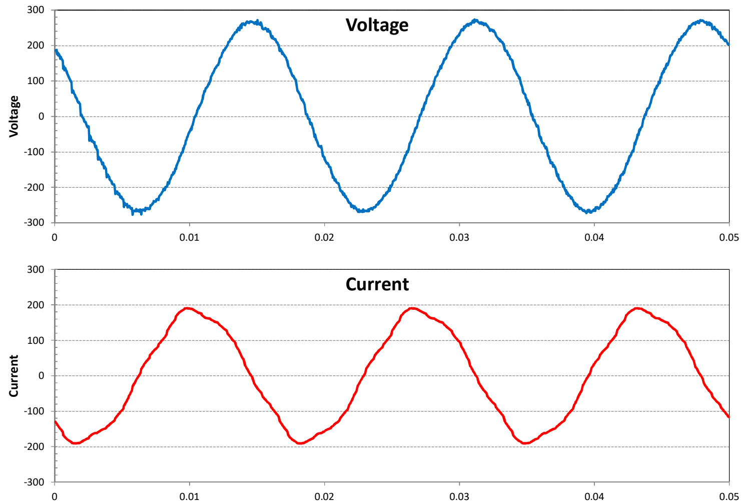


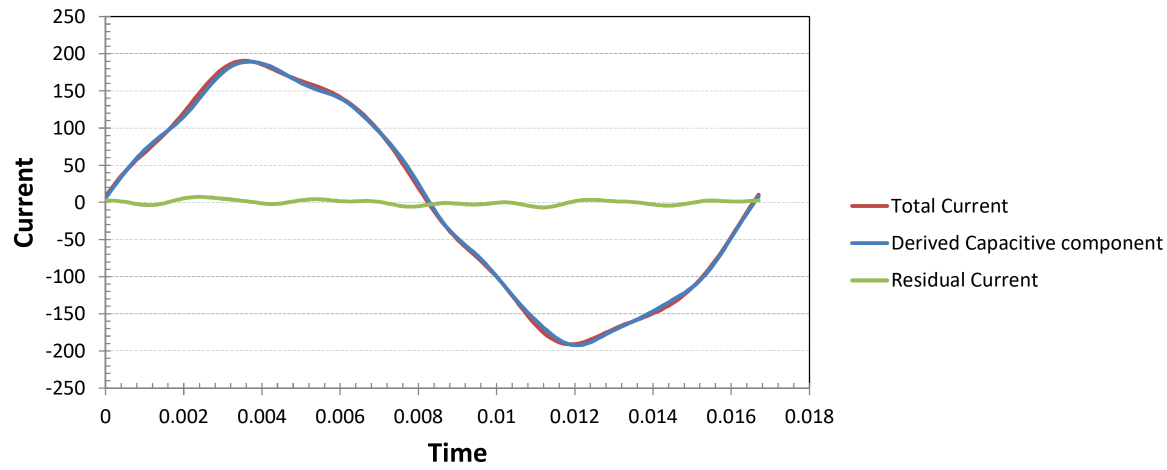
Reconstructed signals from Fourier analysis



Functional Test (I)

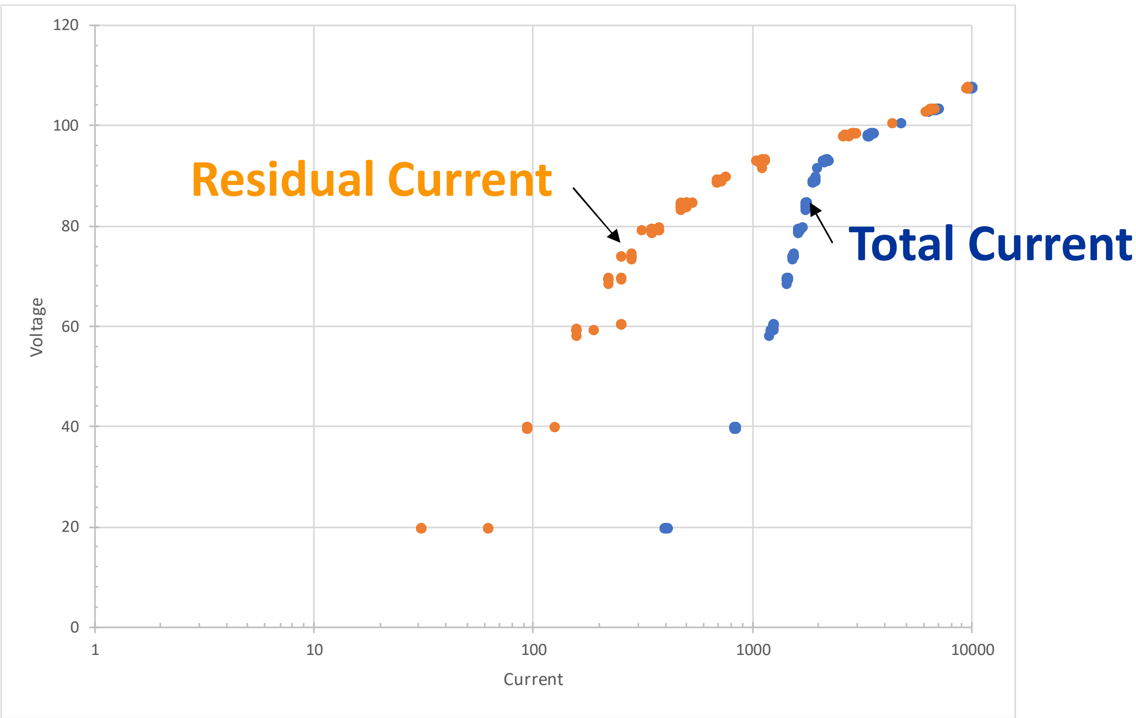
- Reconstruction of Capacitive Current
  - Bushing test
  - Source rich in harmonics

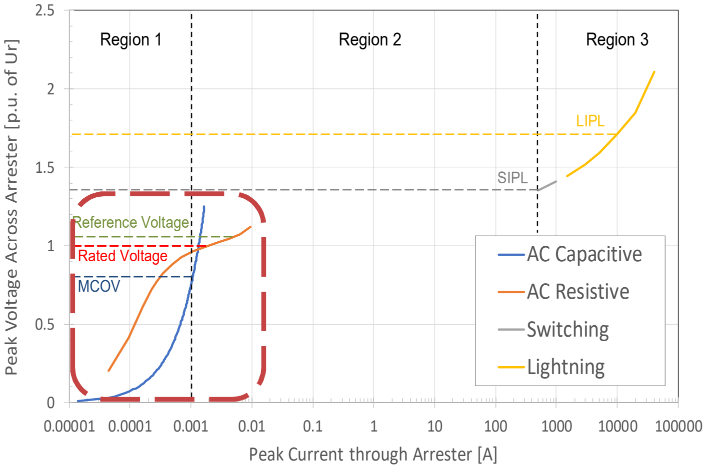




Functional Test (II)

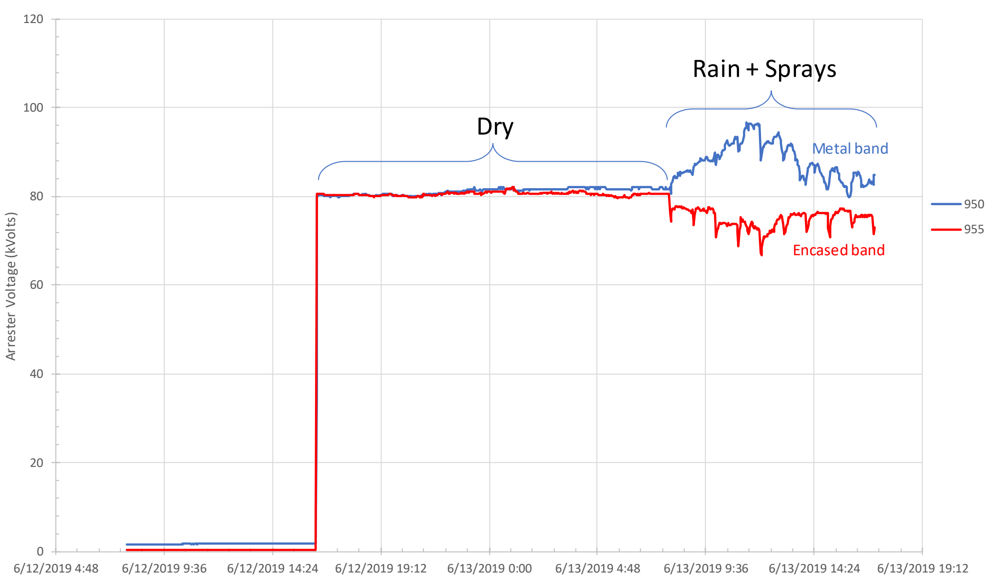
- Measurement of arrester V-I Characteristic



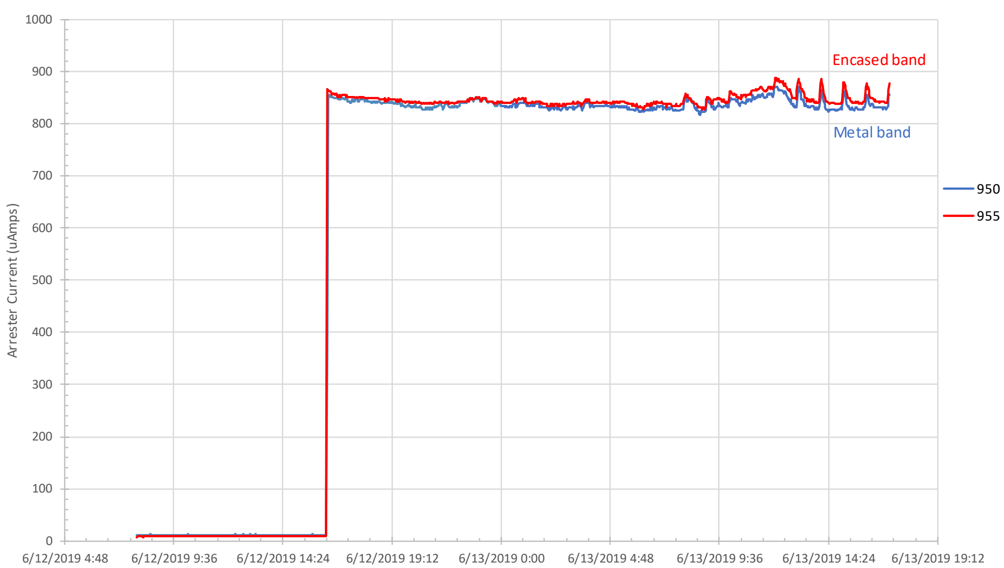


Simulated Substation Test

- 138 kV Substation Mockup
  - “True” service conditions
  - Hourly rain showers
  - Quick access if modifications are required

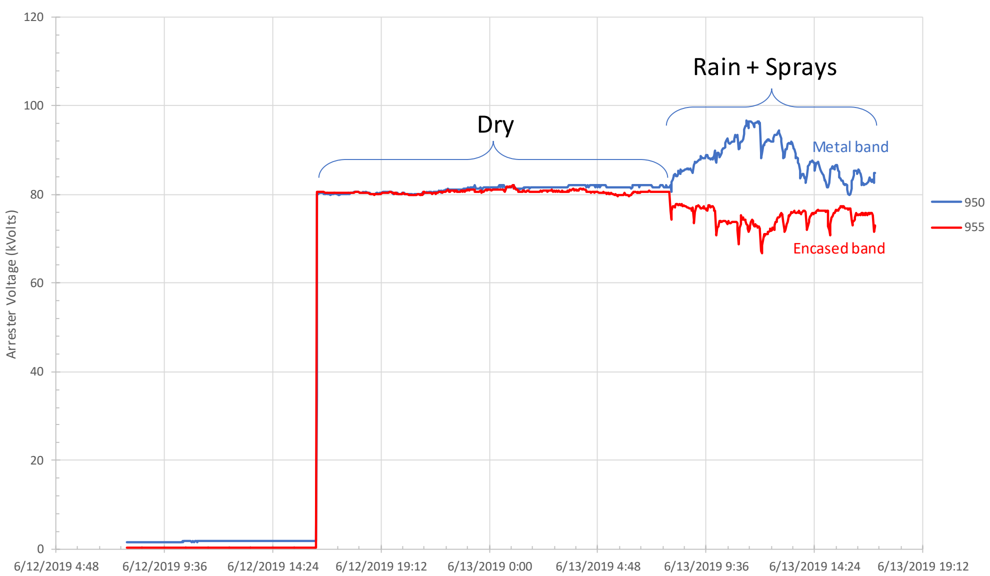


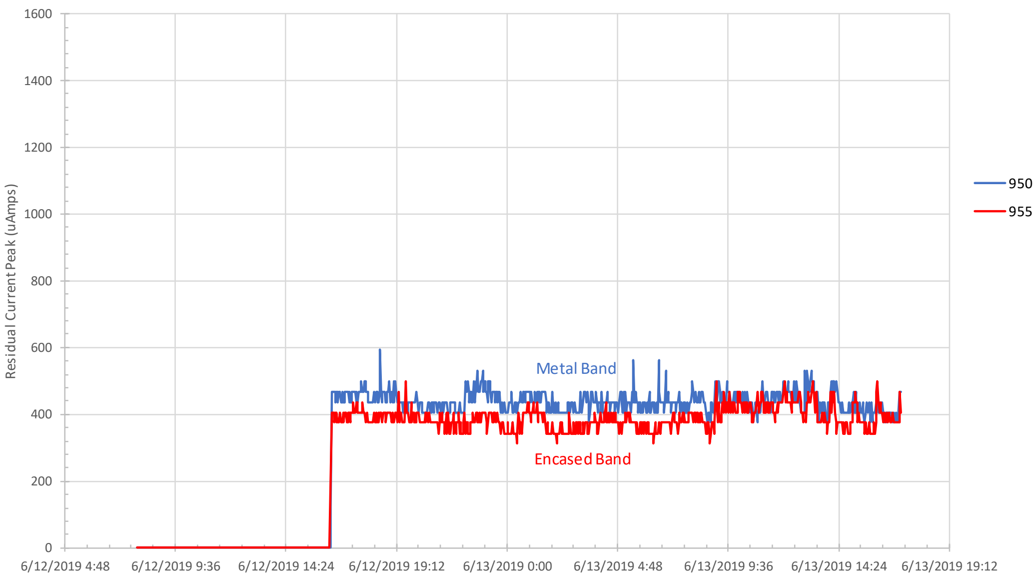
Voltage



Current

Arrester Metrics





EPRI Sensor Project: Next Steps

- RF Arrester Sensor
  - Field Demonstration to Collect Data
  - Lenox "substation"
  - Continual Development of Algorithms
    - Temperature Compensation
    - Phase Comparison
    - Trending
  - Thermal runaway test
    - Test and refine Algorithms

Progress

Operate	Maintain	Dispose
How to best monitor arrester performance?	What is the technical basis for implementing, or timing maintenance actions to prevent arrester failures?	How to determine when arresters have reached the end of their useful life?

Arrester Accelerated Aging Test

- Development of an accelerated aging test
  - The improve understanding of aging of MOV block material and passivation

Research Questions

Rating	Delta T (°C)
	Recommendation
A	No action required
B	Monitor or assess for further damage, or degradation
C	**Replace at earliest convenience (if polymer insulation)**
D	**Replace as soon as possible (if porcelain insulation)**

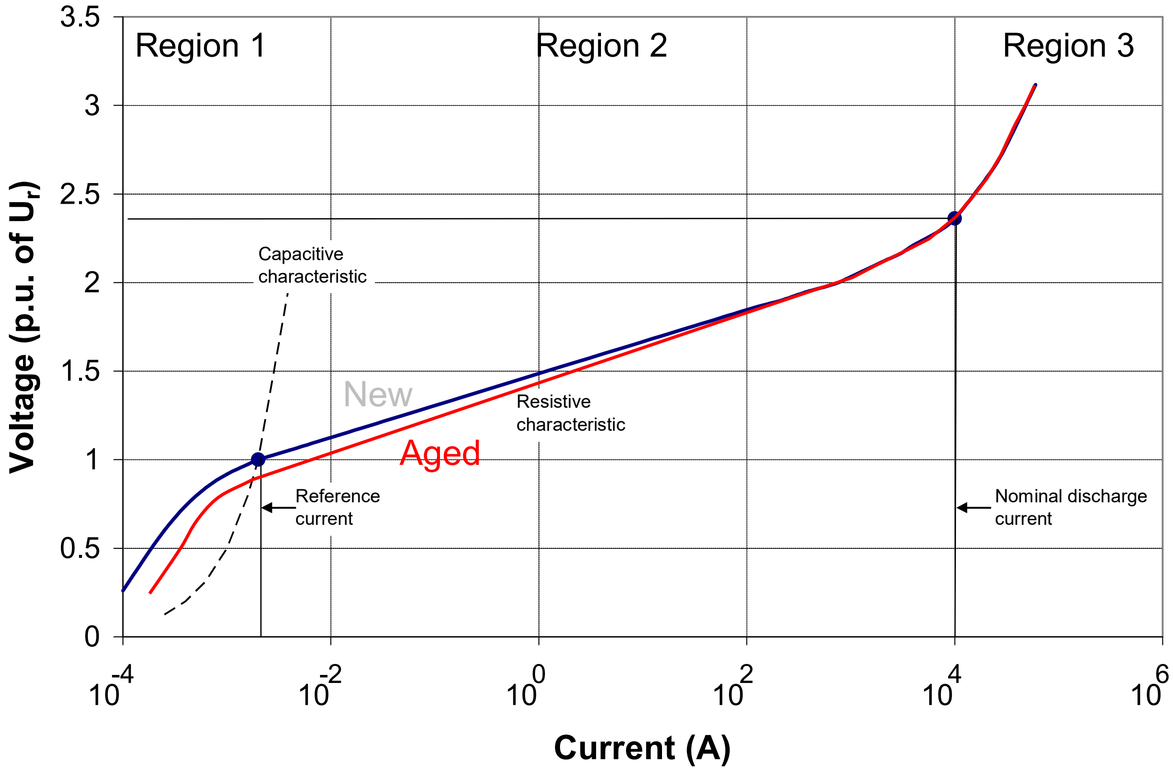
Why are these arresters heating?

What criteria should I use to determine arrester condition?

How can I improve my arrester specification to avoid this in the future?

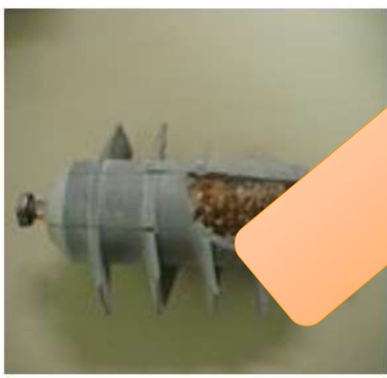
Development of electrical aging test

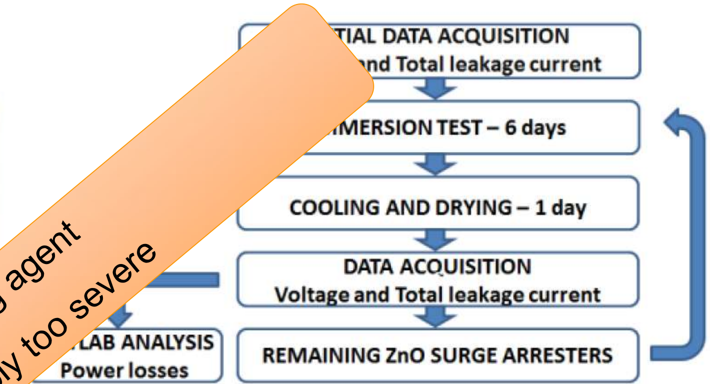
- Long Term Aging of Arresters

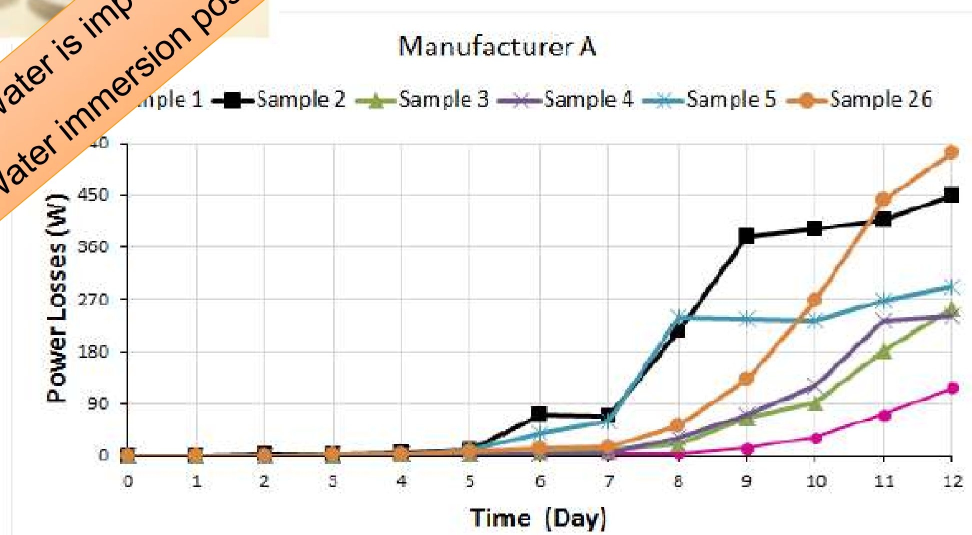


Electrical Aging tests in Brazil

- Water immersion test



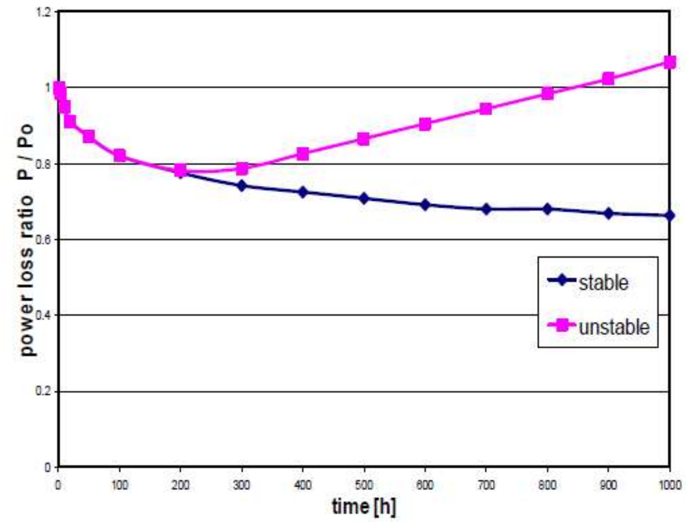




Water is important aging agent
Water immersion possibly too severe

Proposal for Electrical Aging Test

- Modified 1000 h stability test
  - 1000 h constant (elevated) voltage test at 115°C
    - ≈ 0.93 Ur (MCOV ≈ 0.8 Ur)
    - Monitor Power Loss
  - Test object
    - Complete distribution arrester
    - Sheds cut off to fit test chamber
  - Test chamber
    - Controlled environment
    - Steam injection



Test Setup for Electrical Aging Test

Steam Generator

Testing Chamber

HV Source

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Specifications		Failure Database	Guide for Removal
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