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Circuit Breaker Testing & Maintenance

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Agenda

- Why Test?
- Types of Testing
  - Timing
  - PF
  - Dielectric Quality
  - Inspections (V&O)
- Online Monitors
- Operational

Background Perspective

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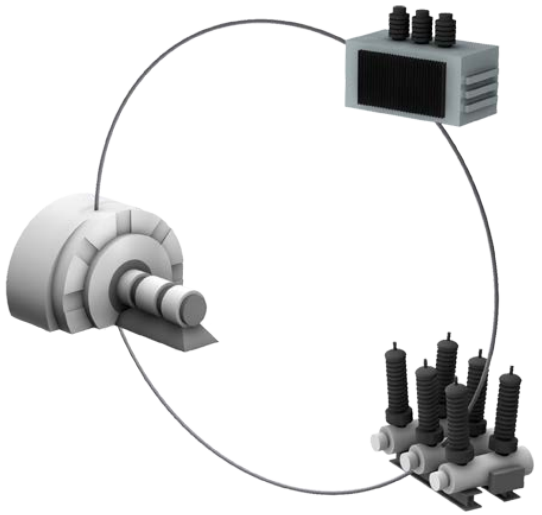
- Newly installed breakers operate for 30+ years

- Under ‘normal’ conditions most breakers are operational for: **less than 10 minutes in 30 years**

- Under ‘abnormal’ conditions most breakers are operational for **less than 1 minute in 30 years**

Reasons for Testing

- Part of a **comprehensive diagnostic maintenance** program
- Find **early indications** of possible problems
- **Prevent** problems rather than pick up pieces
- Build up a test record database for **trending**
- Pick out the **bad actors** – *Asset Management*



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Reasons for Testing (cont'd)

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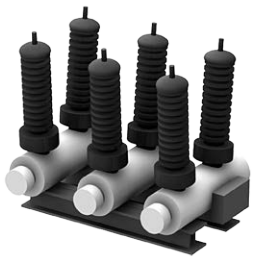
Performing Timing Tests is the best way to:

- *Verify* the **control circuit**
- *Check* motion of the **moving parts**
- *Validate* **time of operation** – verify manufacturer specs
- *Determine* **contact wear**
- *Demonstrate* results of **maintenance**
- *Assess* overall breaker **capability**



Before test start

We have to know how testing breaker works

- Circuit breaker design
- What is breaking medium?
- What is contact system design?
- What kind of mechanism operate the breaker?

Circuit breaker design

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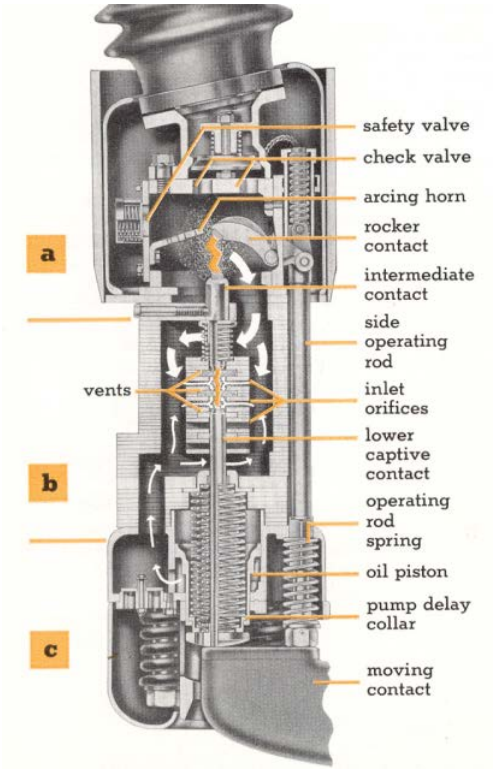
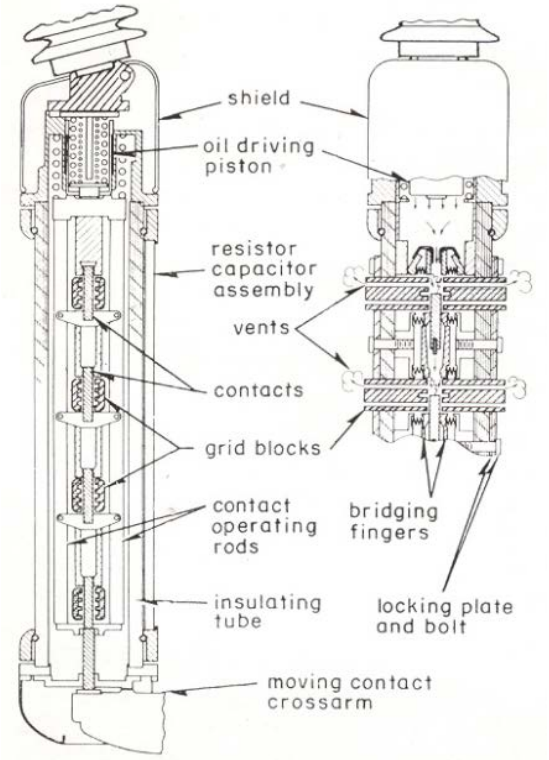
Dead tank breaker



Breaking element W MF-3A

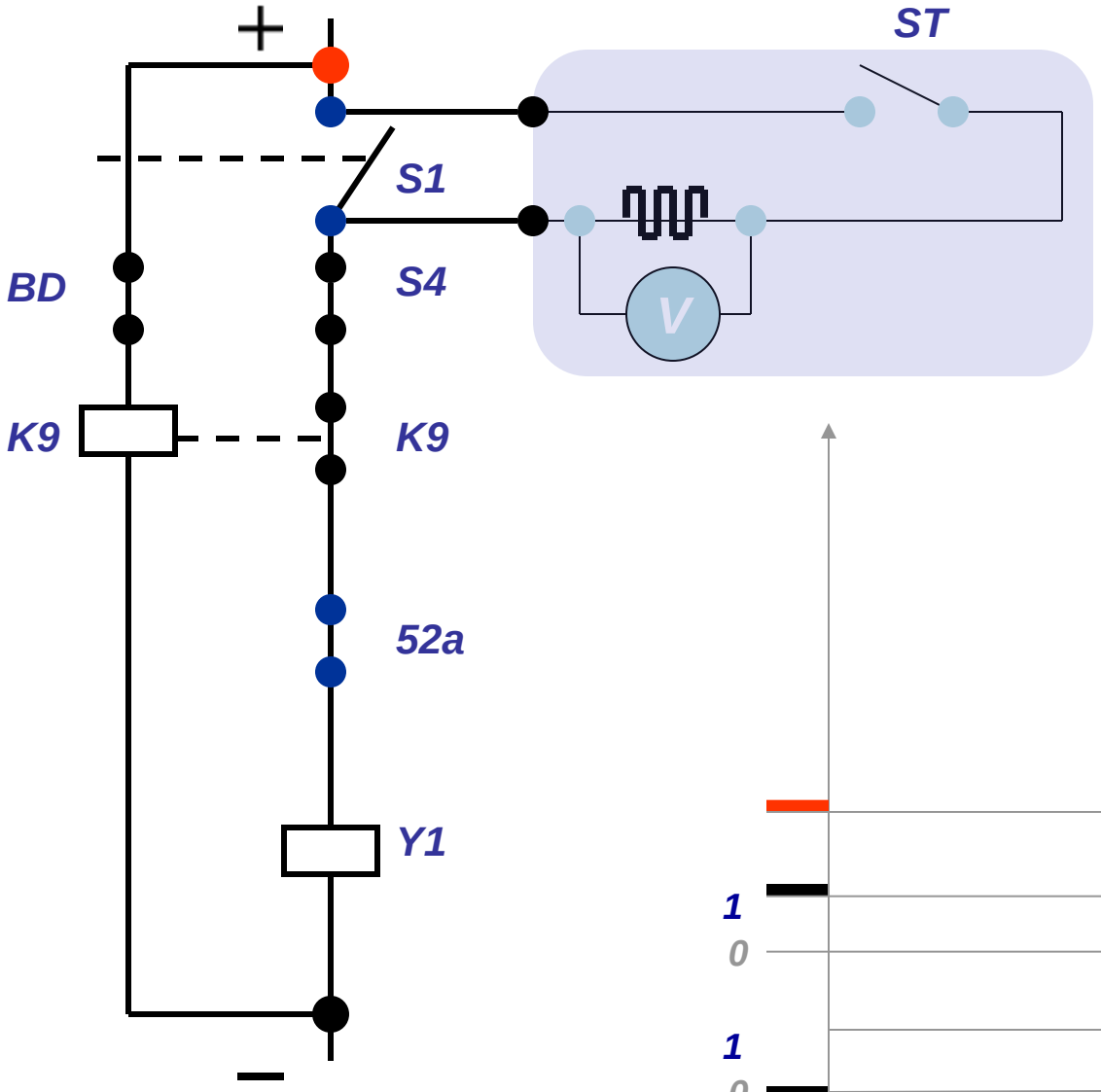


Cross section

Circuit Breaker Design

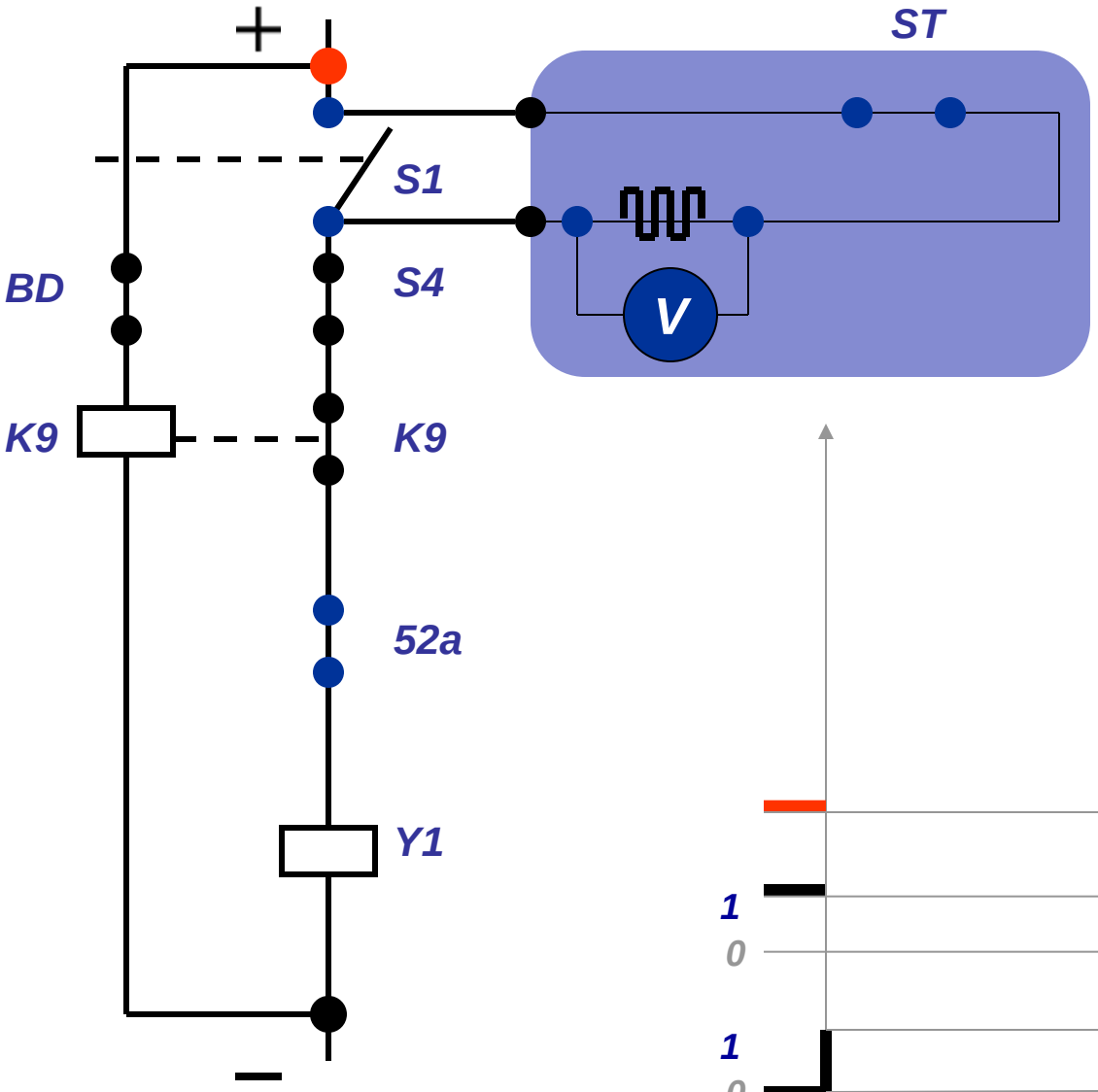
- Different breaker types will produce different data
  - SF6
  - OCB
  - Live Tank
  - Vacuum
  - Air

Trip Coil Current



TRIP/CLOSE leads connected

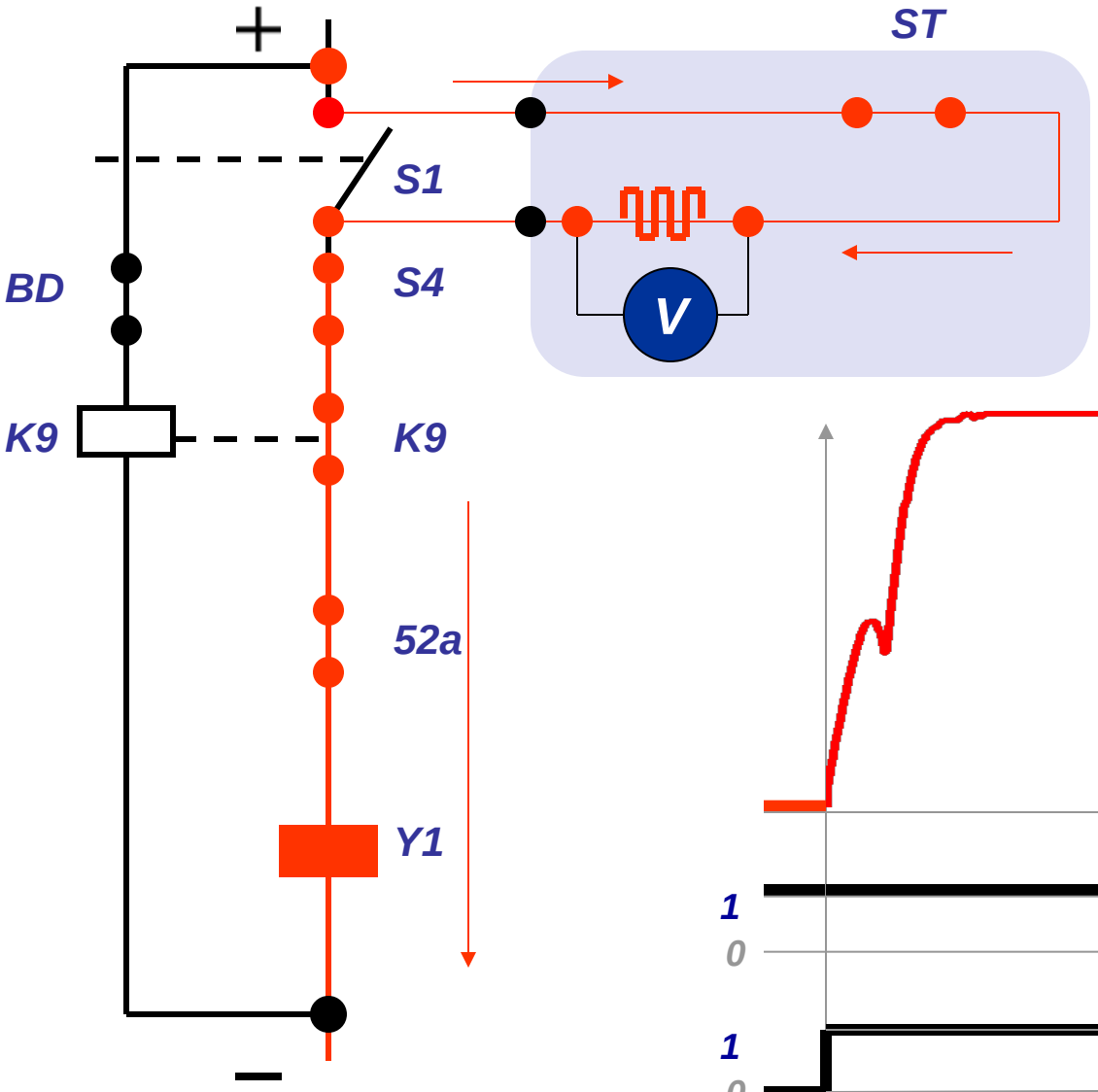
Trip Coil Current



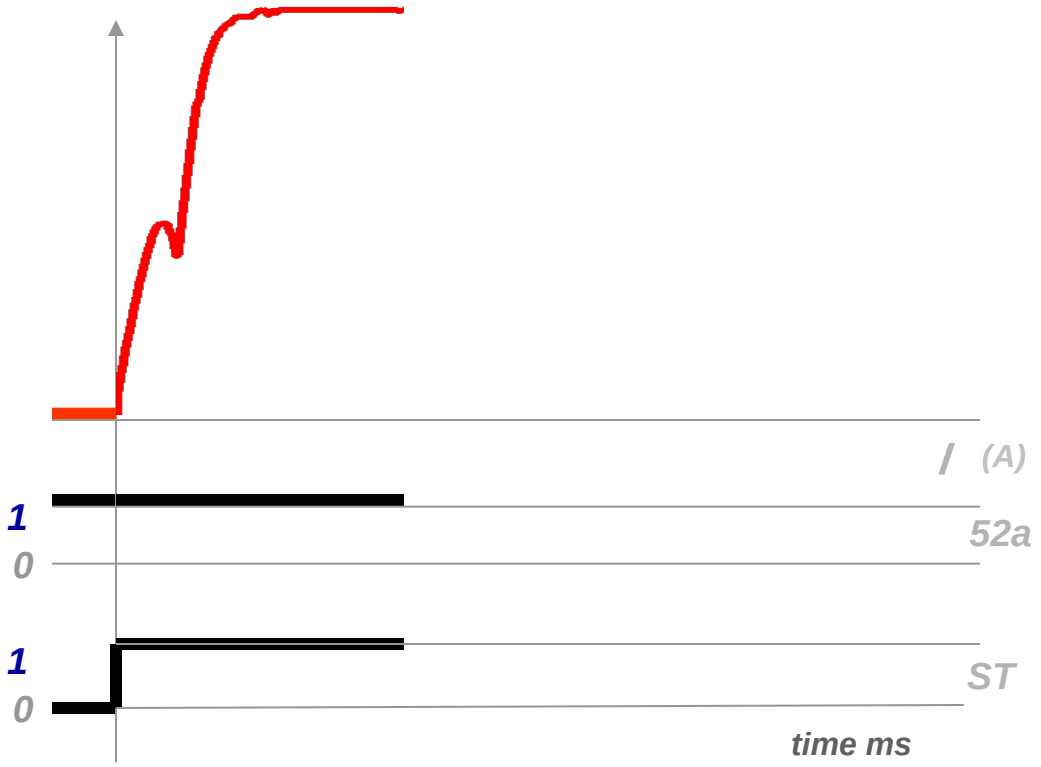
Safety switch closed

Test initiation

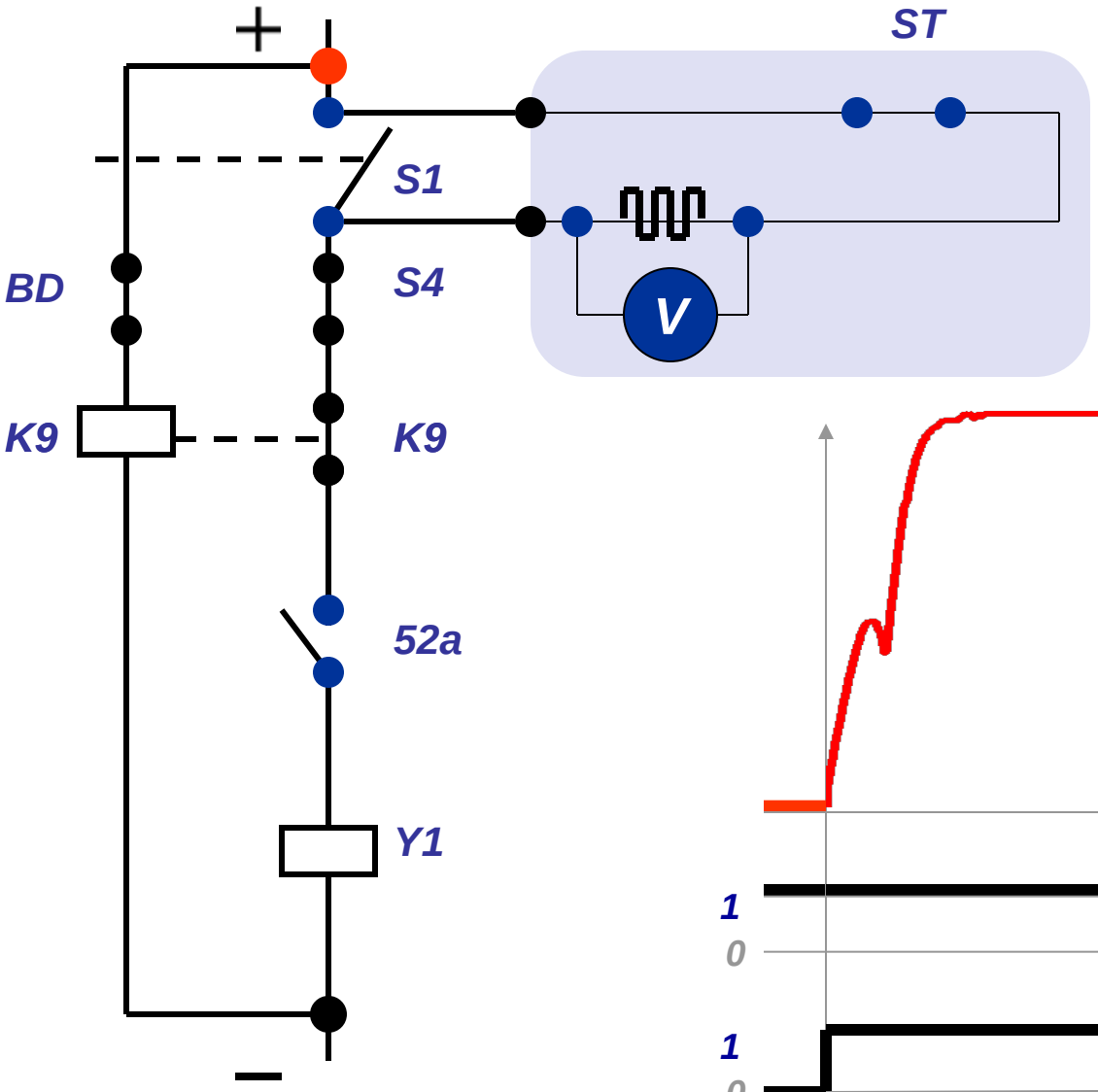
Trip Coil Current

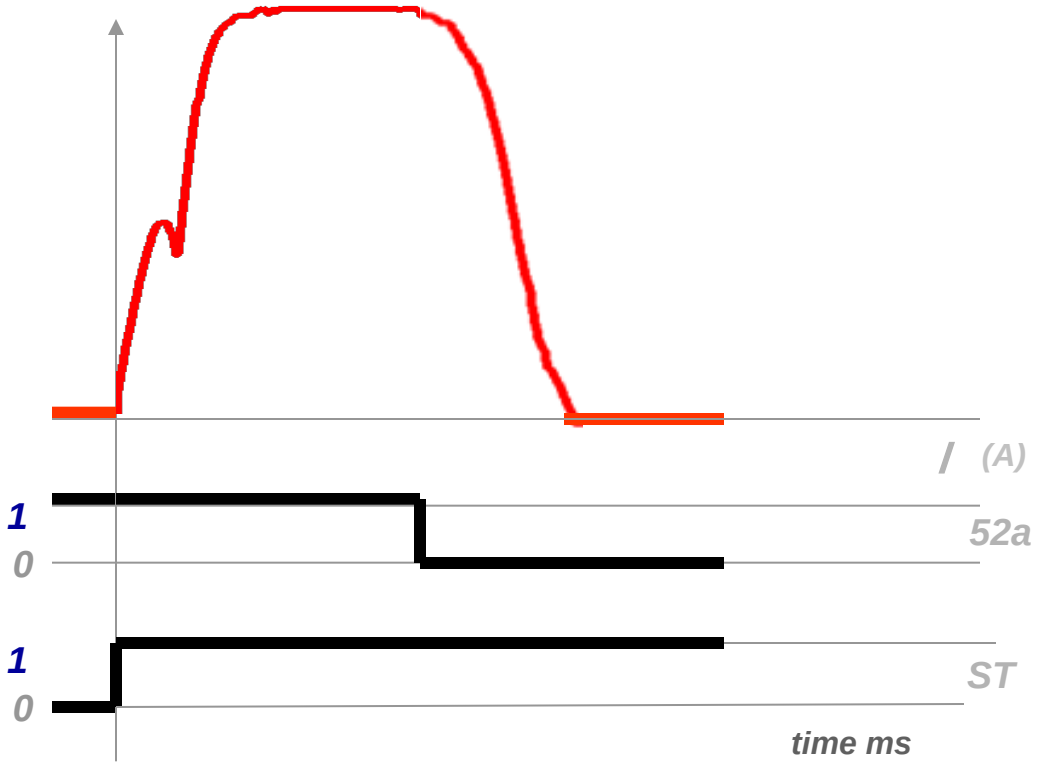


Current flows through trip coil

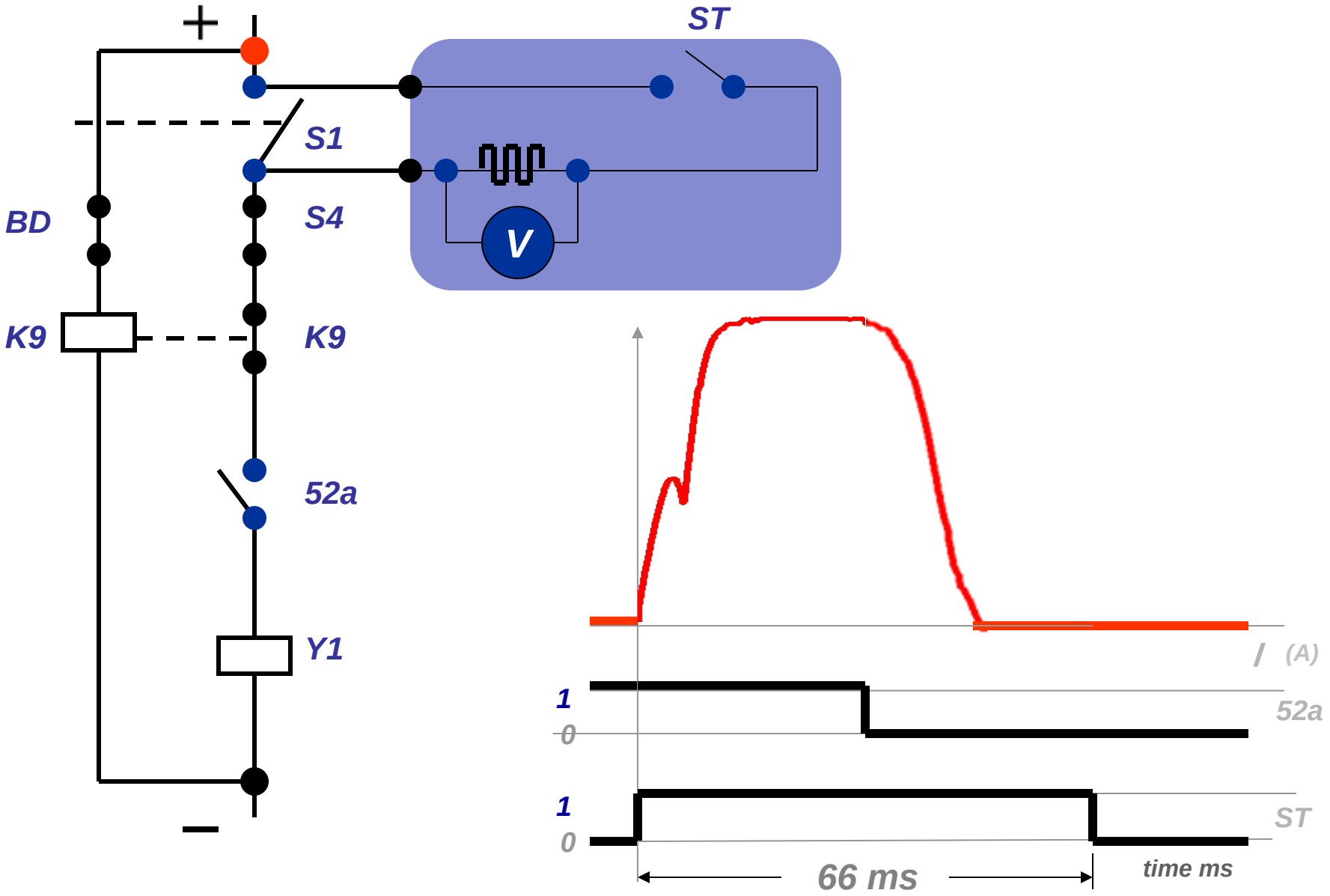


Trip Coil Current





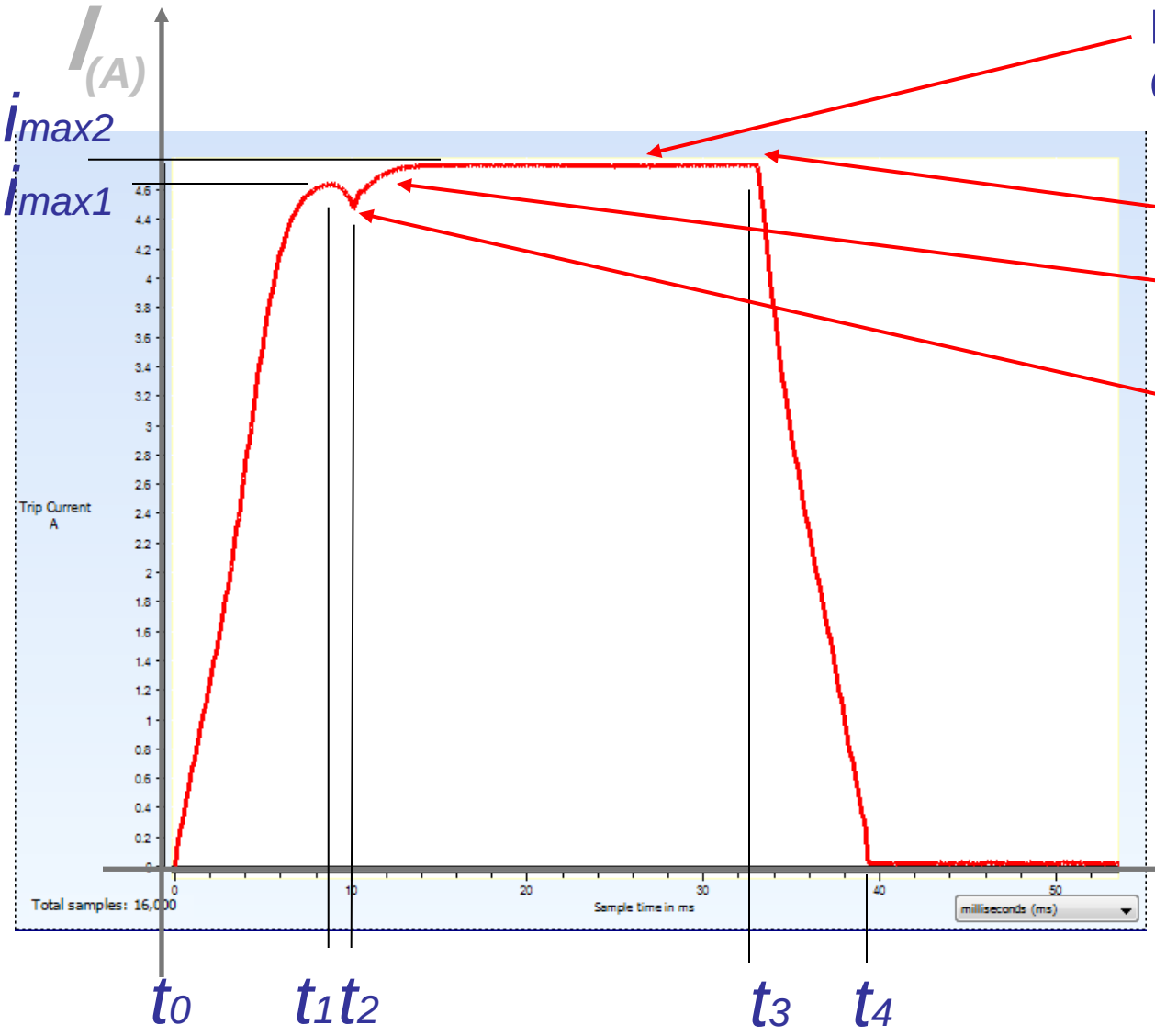
Trip Coil Current



Test results analyzing examples

- We must know the definition of what we are measuring and/or monitoring

Trip Coil Current



Maximum Current

Contact 52a Open

Change in impedance

Plunger stops

t_0-t_2 pick-up time

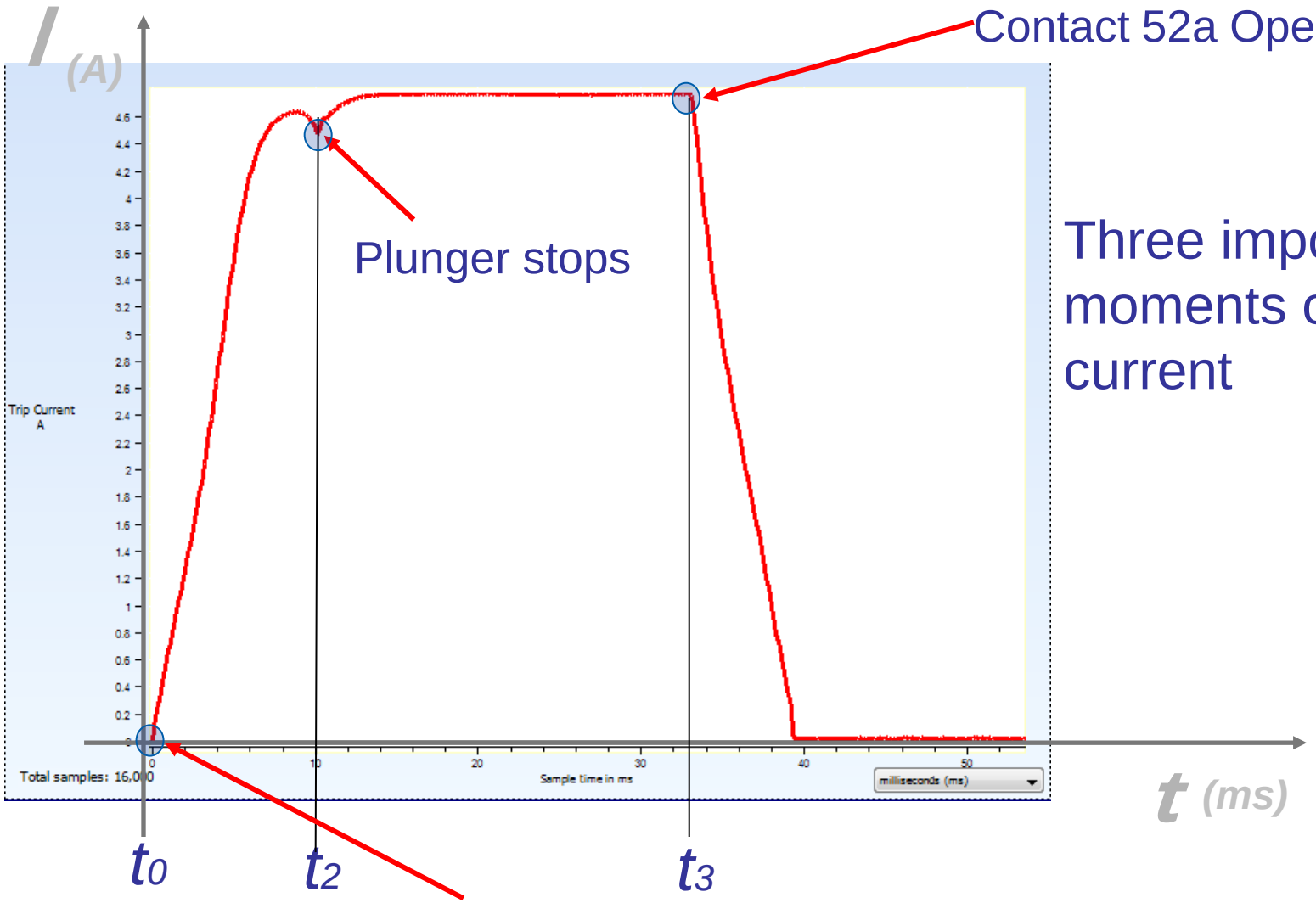
t_1-t_2 transient time

t_2 armature hit stop

t_0-t_3 ON period

t_3-t_4 fall time

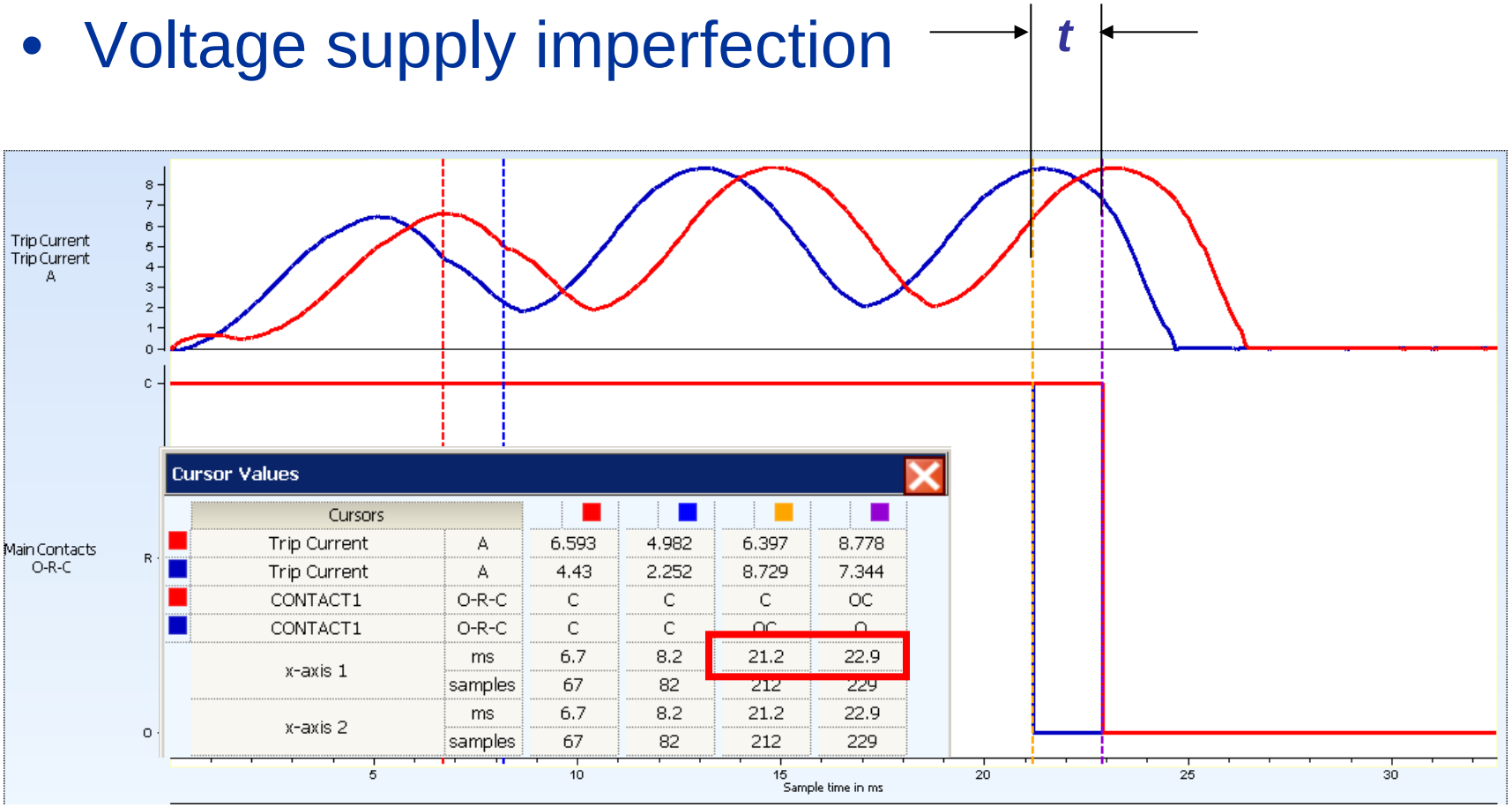
Trip Coil Current



Three important moments of trip coil current

Trip Coil Current

- Voltage supply imperfection

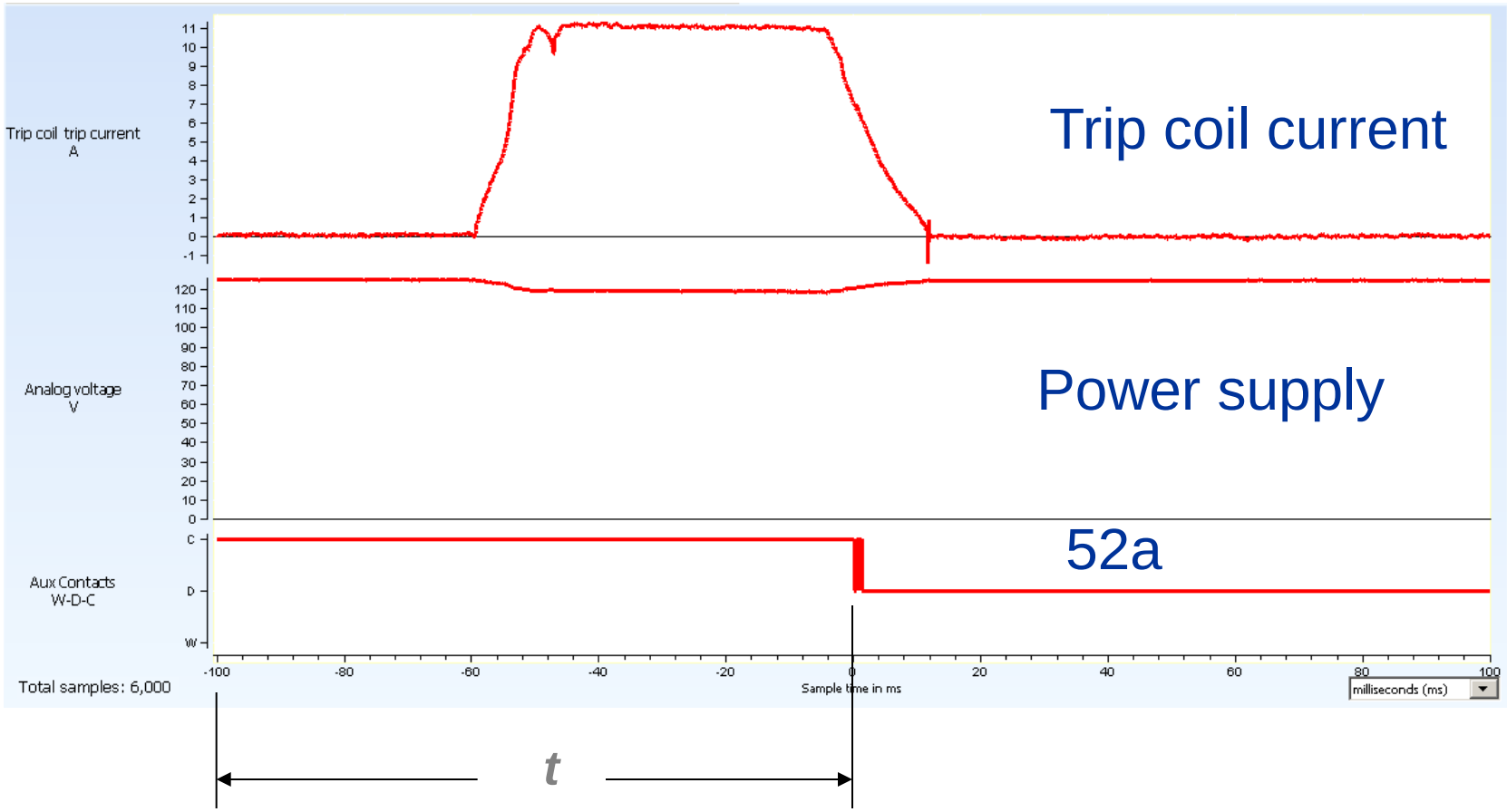


Cursors					
Trip Current	A	6.593	4.982	6.397	8.778
Trip Current	A	4.43	2.252	8.729	7.344
CONTACT1	O-R-C	C	C	C	OC
CONTACT1	O-R-C	C	C	OC	O
x-axis 1	ms	6.7	8.2	21.2	22.9
	samples	67	82	212	229
x-axis 2	ms	6.7	8.2	21.2	22.9
	samples	67	82	212	229

t – opening time difference 1.7 ms

Trip coil current – First Trip

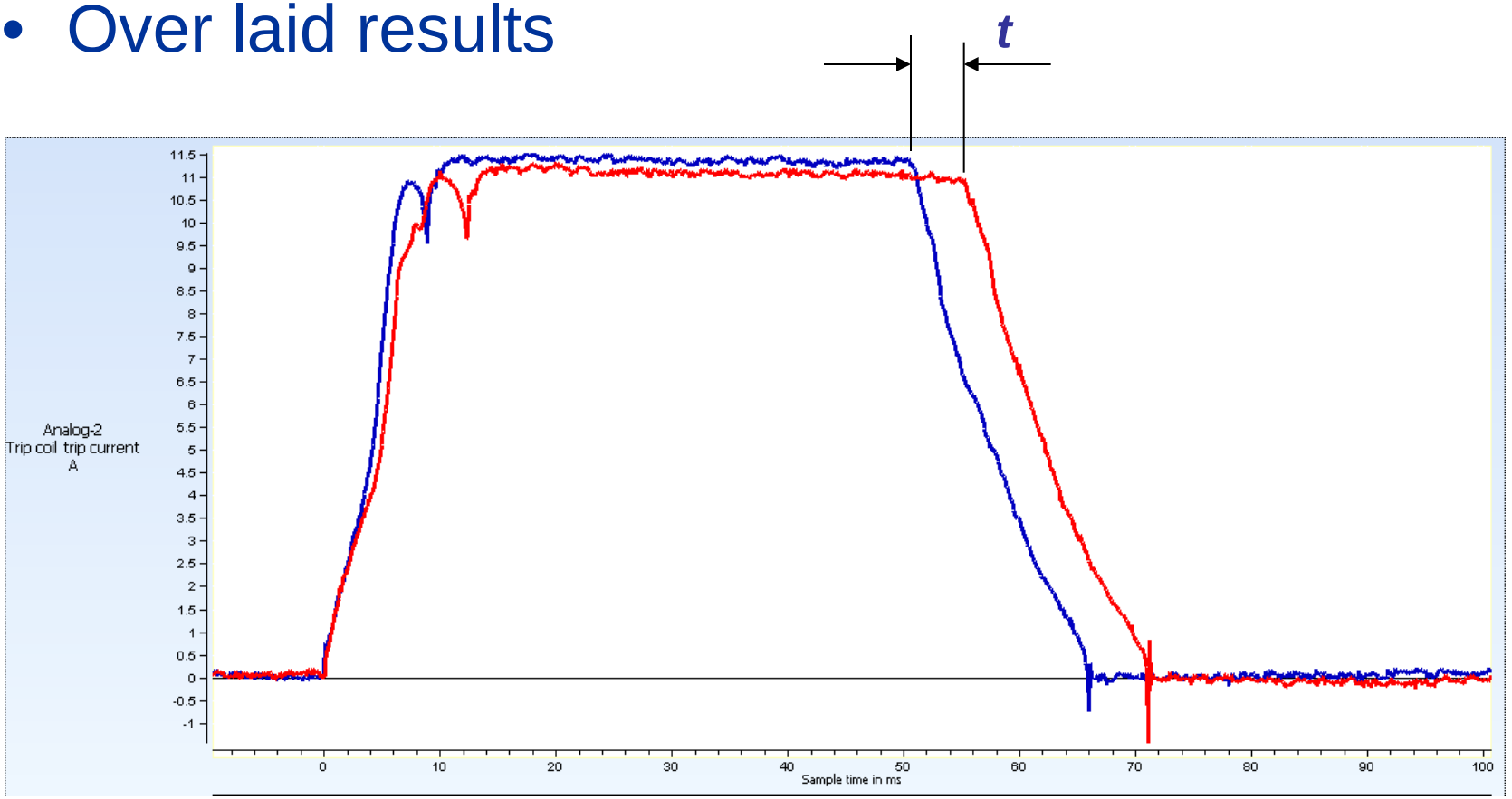
- Auxiliary contact 52a used as trigger



t = 100 ms pre recording time

Trip coil current – First Trip

- Over laid results



Trip coil current during first trip

Trip coil current after multiple operations

t = time difference 52a

Trip coil current – First Trip

- From the data captured in the First Trip test the following problems can be identified:
  - Mechanism lubrication deficiencies
  - Trip coil damage
  - Auxiliary contact problems (dirty, burned, etc…)
  - Loose connections in mechanism
  - Station battery and/or battery charger problems
  - Control cable sizing and contamination issue

T-Doble – Metrics (cont'd)

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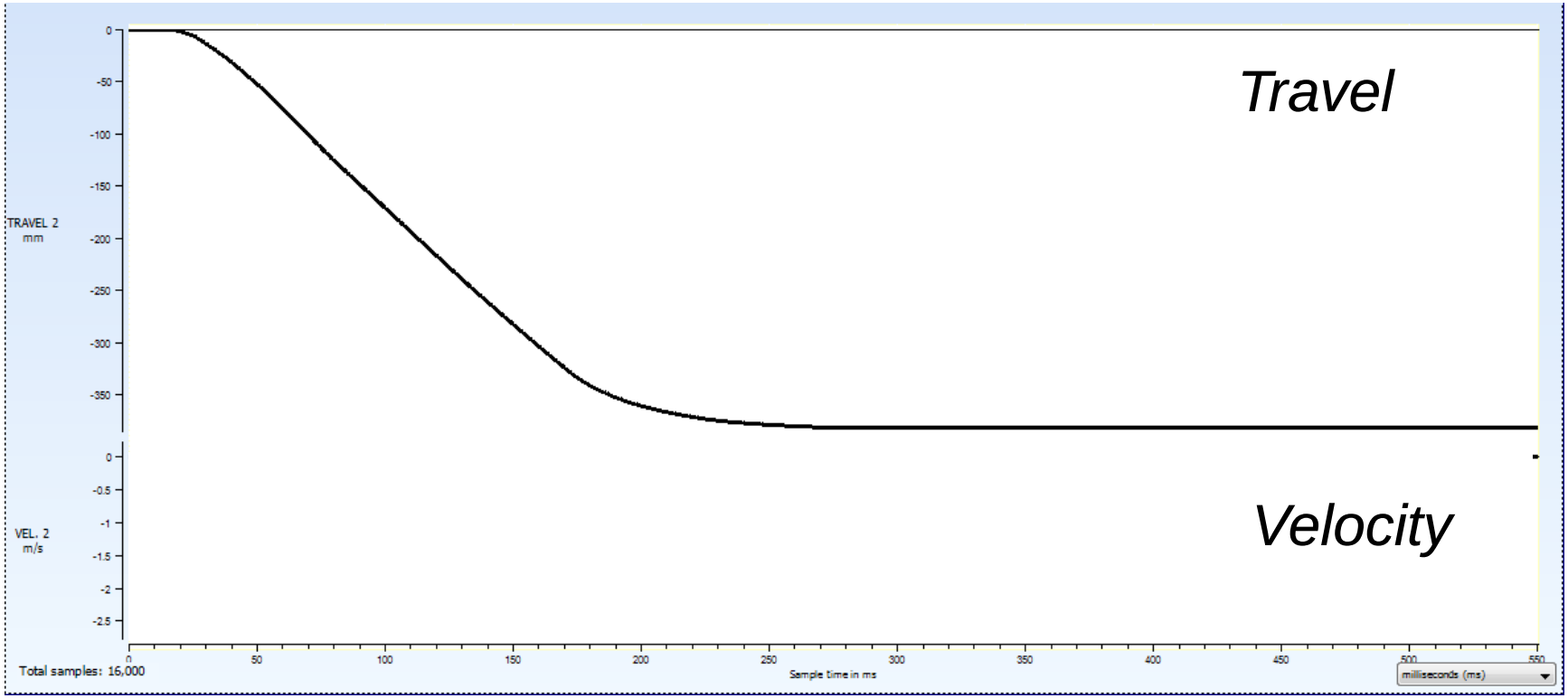
Comparing with test plan values: Pass/Investigate

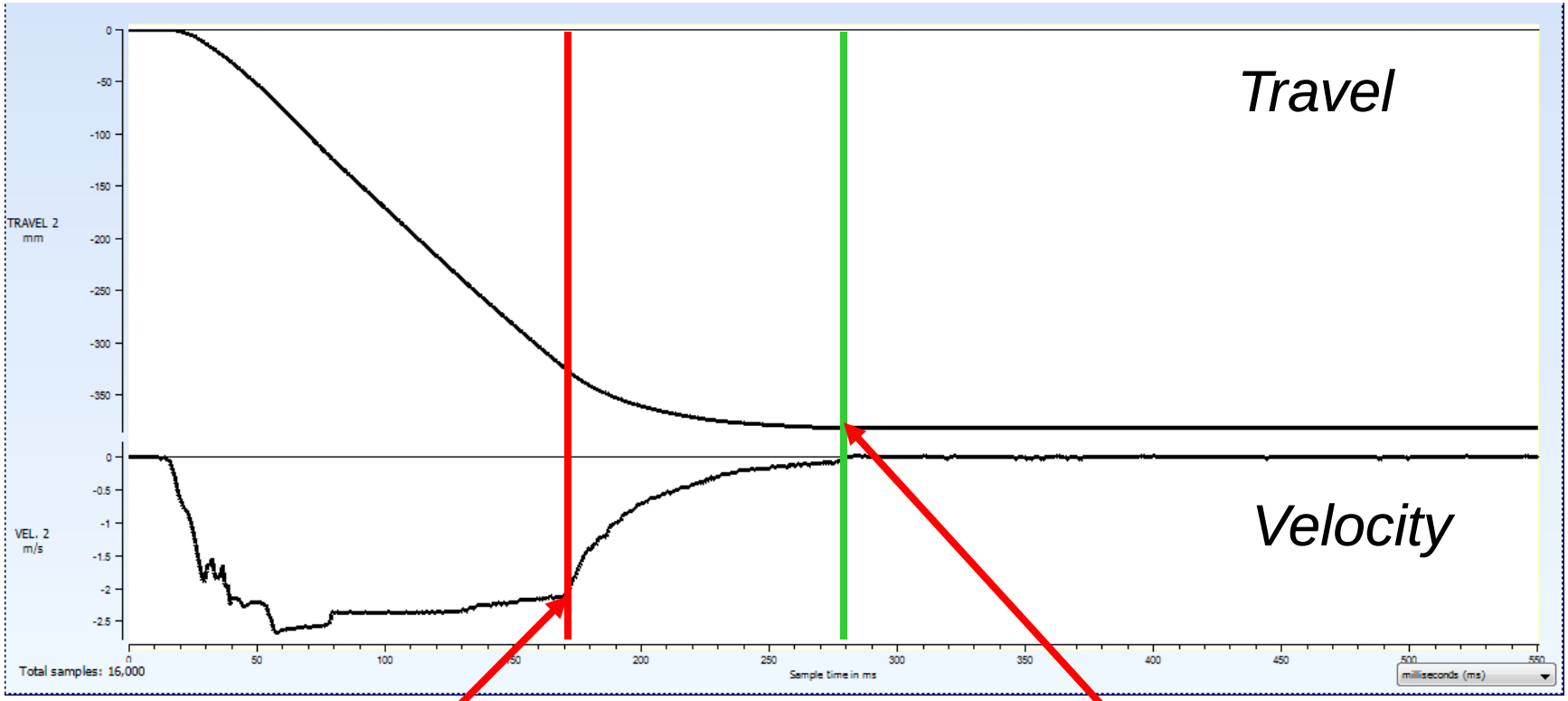
Main Contact Timing Measurements

Timing Reference: From Test Initiation			Main Contact Timing	
Channel ID	Label	Phase	Closing Time	Synchronization In Breaker
OCB-A	CONTACT1	Phase A	199.4 ms ✓	0.5 ms
OCB-B	CONTACT2	Phase B	199.9 ms ✓	
OCB-C	CONTACT3	Phase C	199.4 ms ✓	
			Close Limits	
		Maximum	300.0 ms	*
		Minimum	133.3 ms	

“Instant” Velocity Diagram



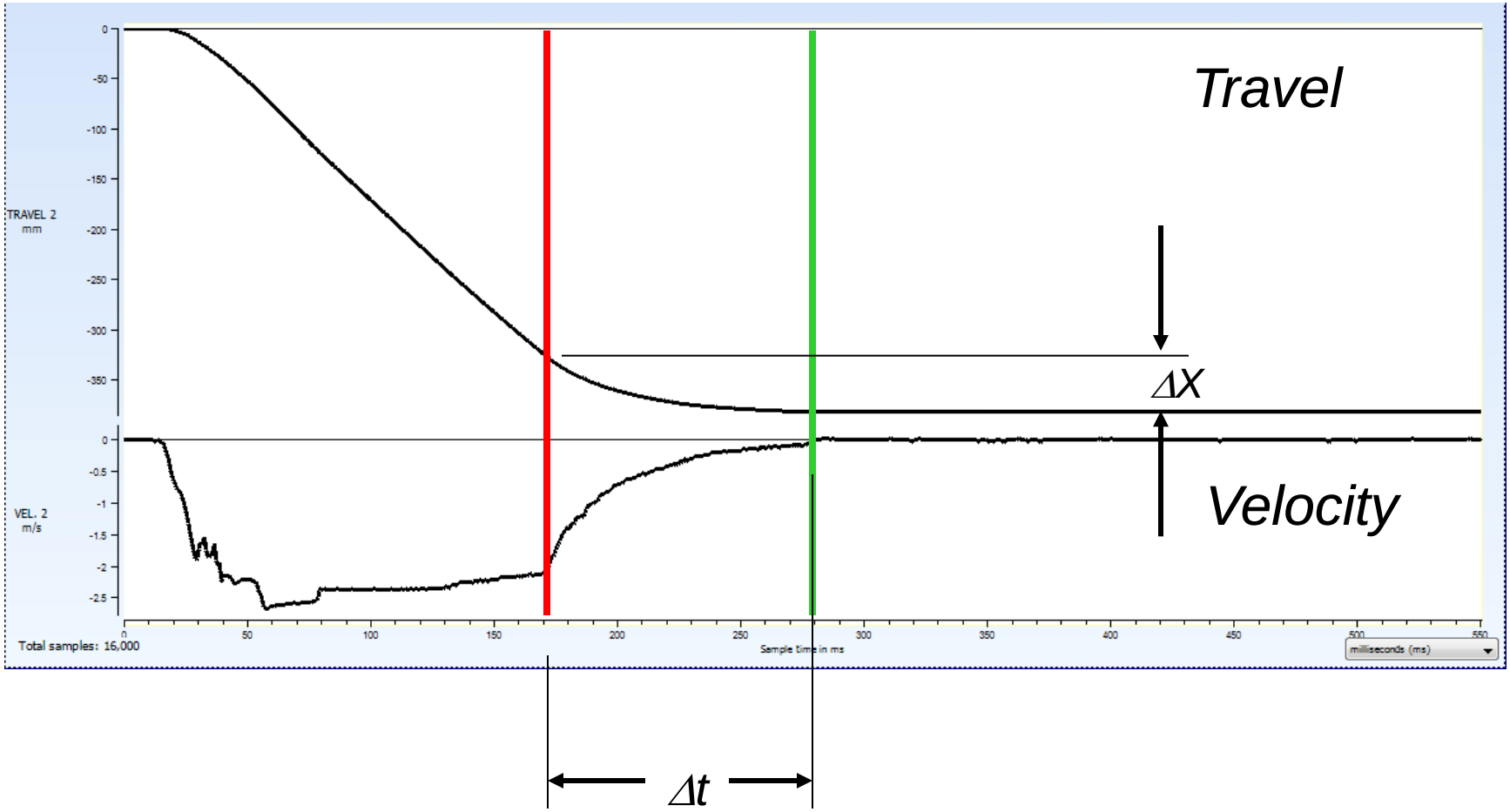
“Instant” Velocity Diagram



Sharp velocity change

Travel reach for first time open position

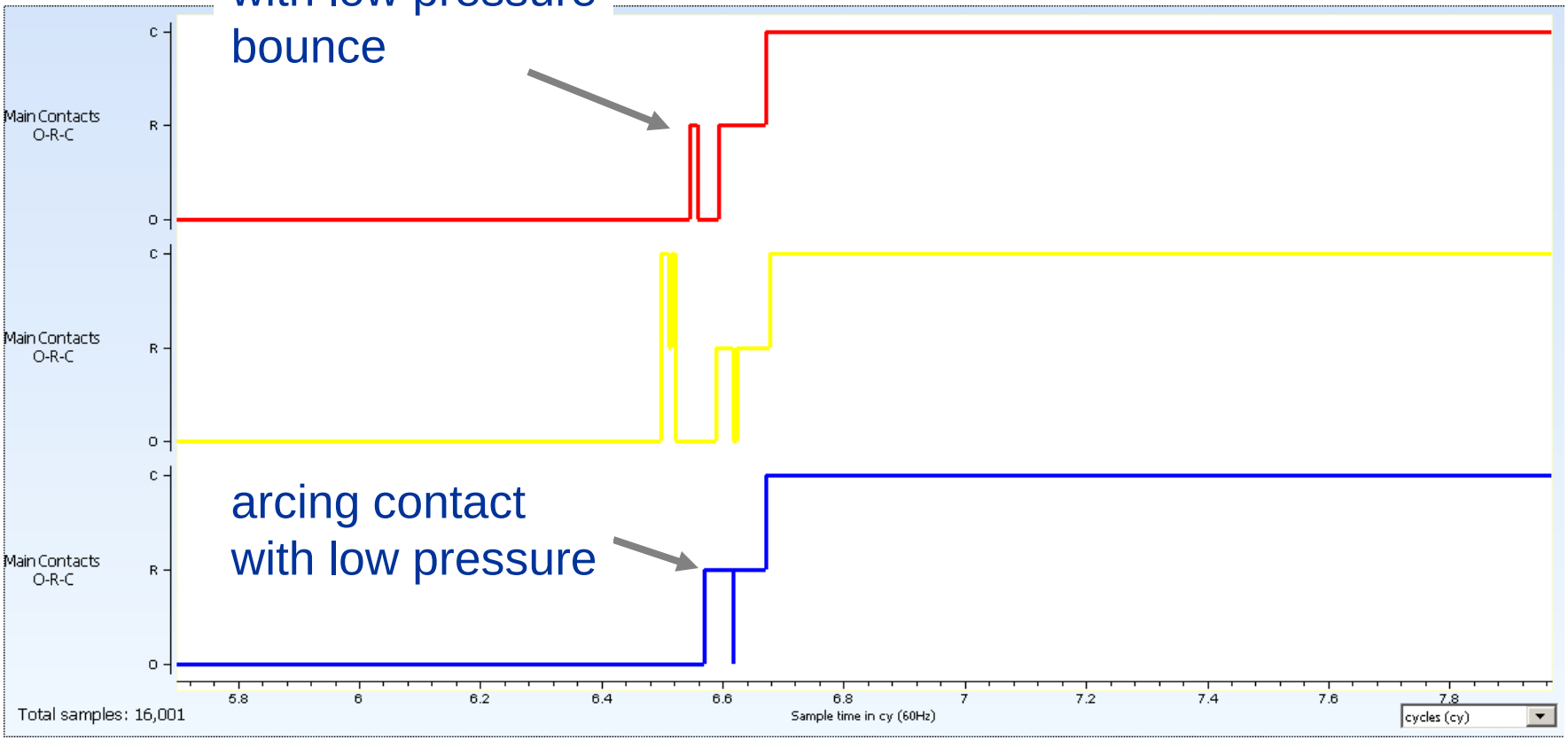
“Instant” Velocity Diagram



ΔX Shock absorber travel

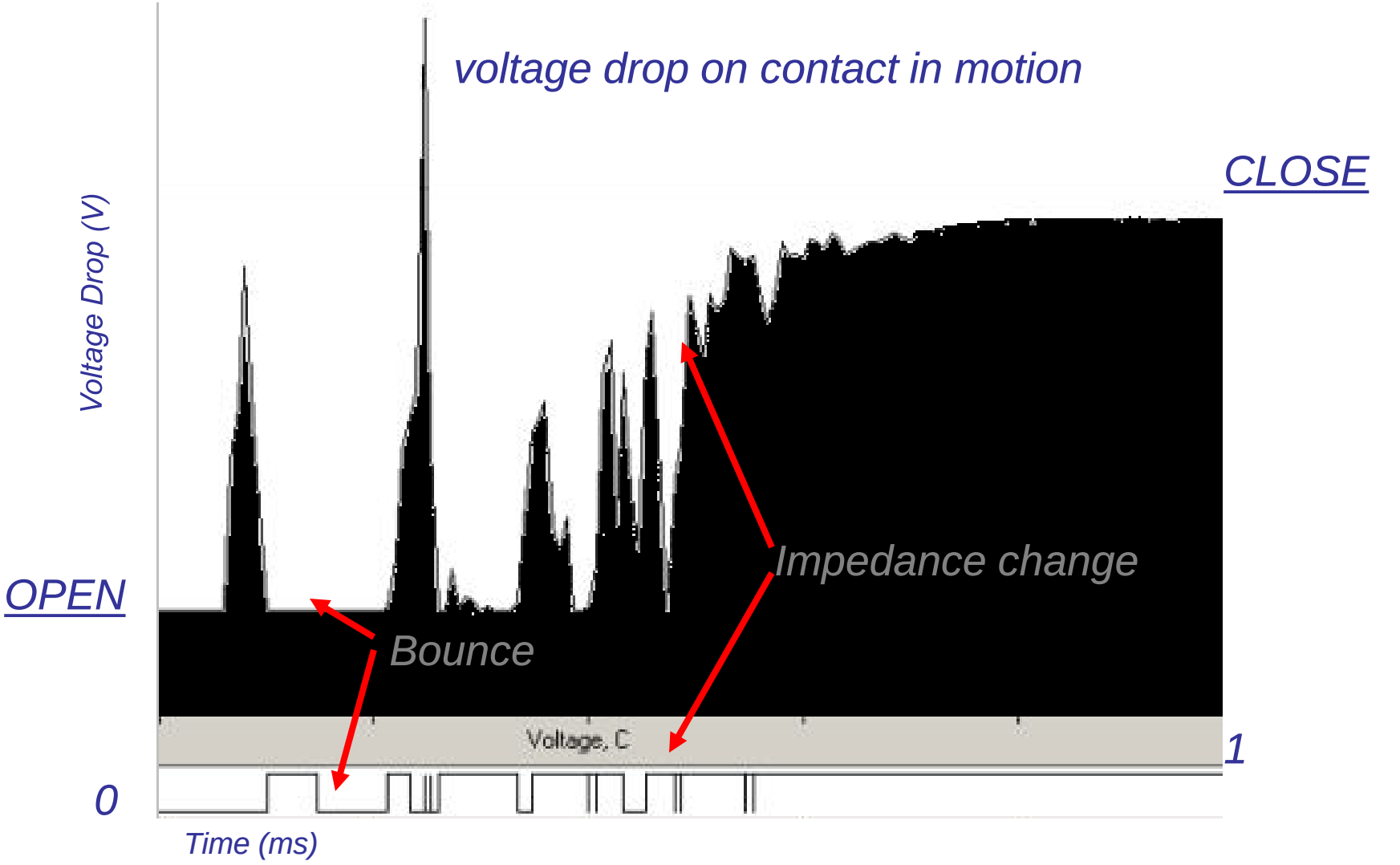
Δt Shock Absorber Time

Timing diagram



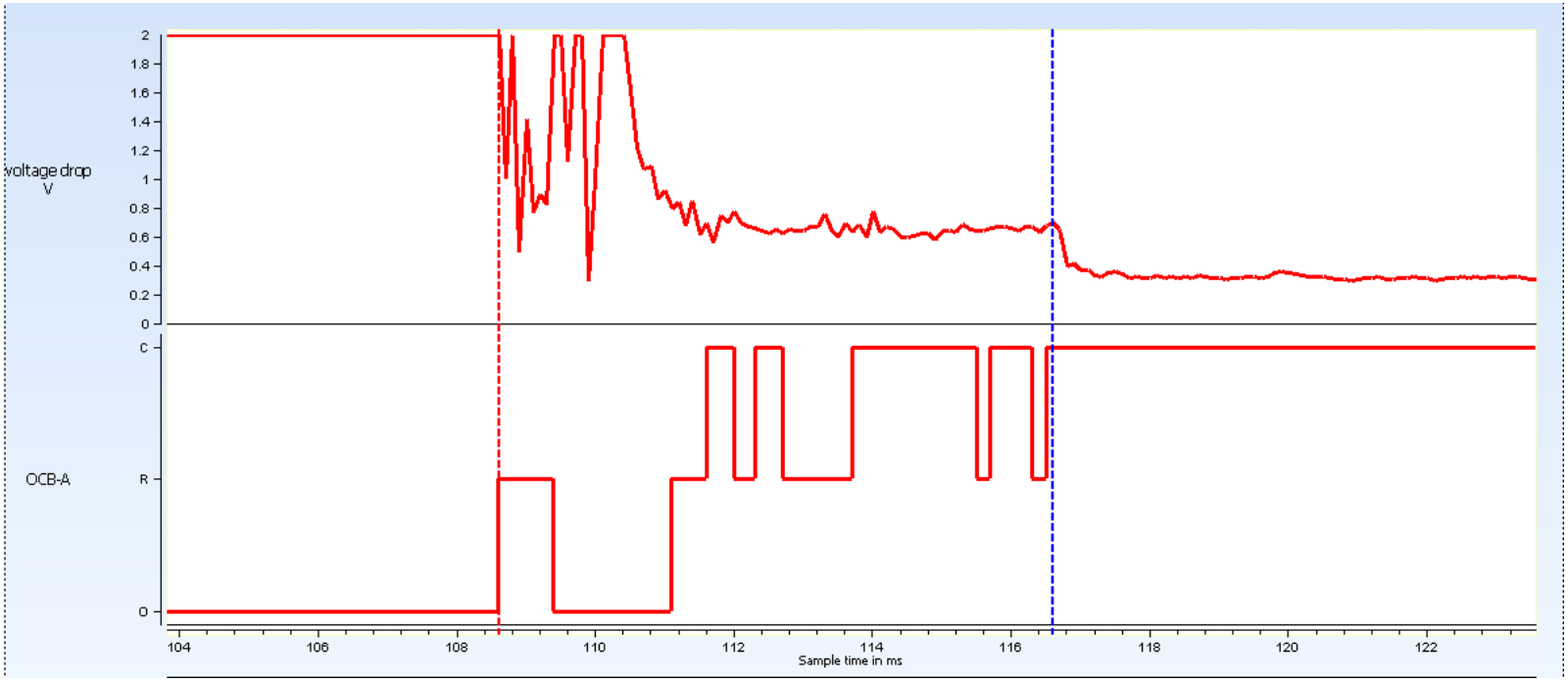
Timing Result Close Operation

Timing diagram



Timing main contacts

Timing diagram



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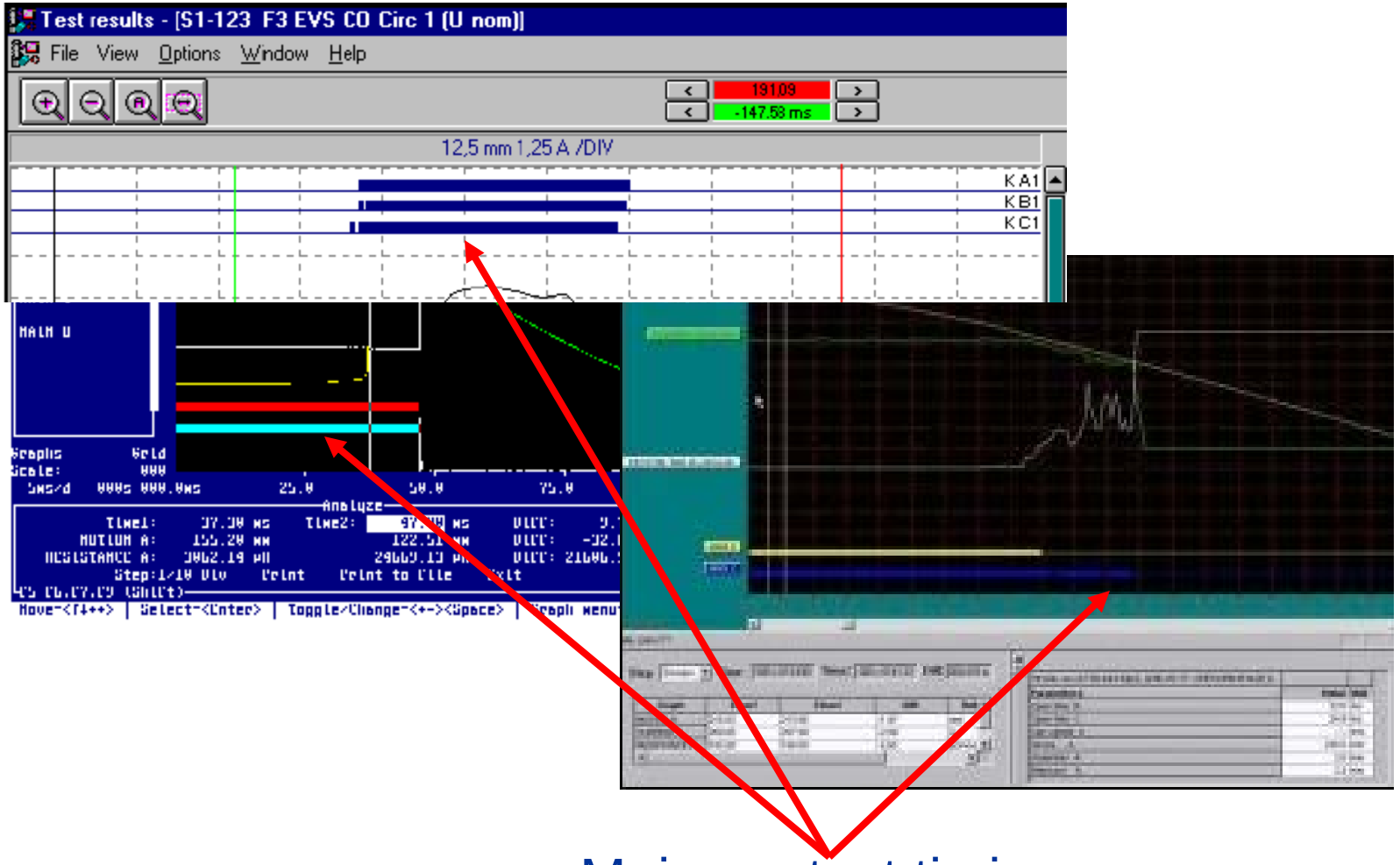
Timing diagram



Main contact timing

Power Factor Tests

- mA, W, % PF
- TLI (for oil breakers)
- Rating
- Bushing Tests

	N	Ener	Bus Ft.	Ins#	PH	Test kV	mA	Watts	% PF Meas.	% PF Corr.	Corr. Factor	TLI's	Rtg	Rtg
1	☐	1			C	10	1.804	0.103	0.57	0.57	1		G	
2	☐	2			C	10	1.808	0.091	0.5	0.5	1		G	
3	☐	3			B	10	1.803	0.129	0.72	0.72	1		G	
4	☐	4			B	10	1.813	0.12	0.66	0.66	1		G	
5	☐	5			A	10	1.591	0.225	1.41	1.41	1		I	
6	☐	6			A	10	1.823	0.162	0.89	0.89	1		G	
7	☐	1,2			C	10	3.575	0.174	0.49	0.49	1	-0.02	G	
8	☐	3,4			B	10	3.576	0.229	0.64	0.64	1	-0.02	G	
9	☐	5,6			A	10	3.372	0.366	1.09	1.09	1	-0.021	I	

Dielectric Quality

- Obviously will depend on the type of dielectric in breaker
  - SF6 breaker test for moisture, pressure, density
  - Oil breaker test for oil quality
  - Vacuum breakers will require vacuum bottle to be tested

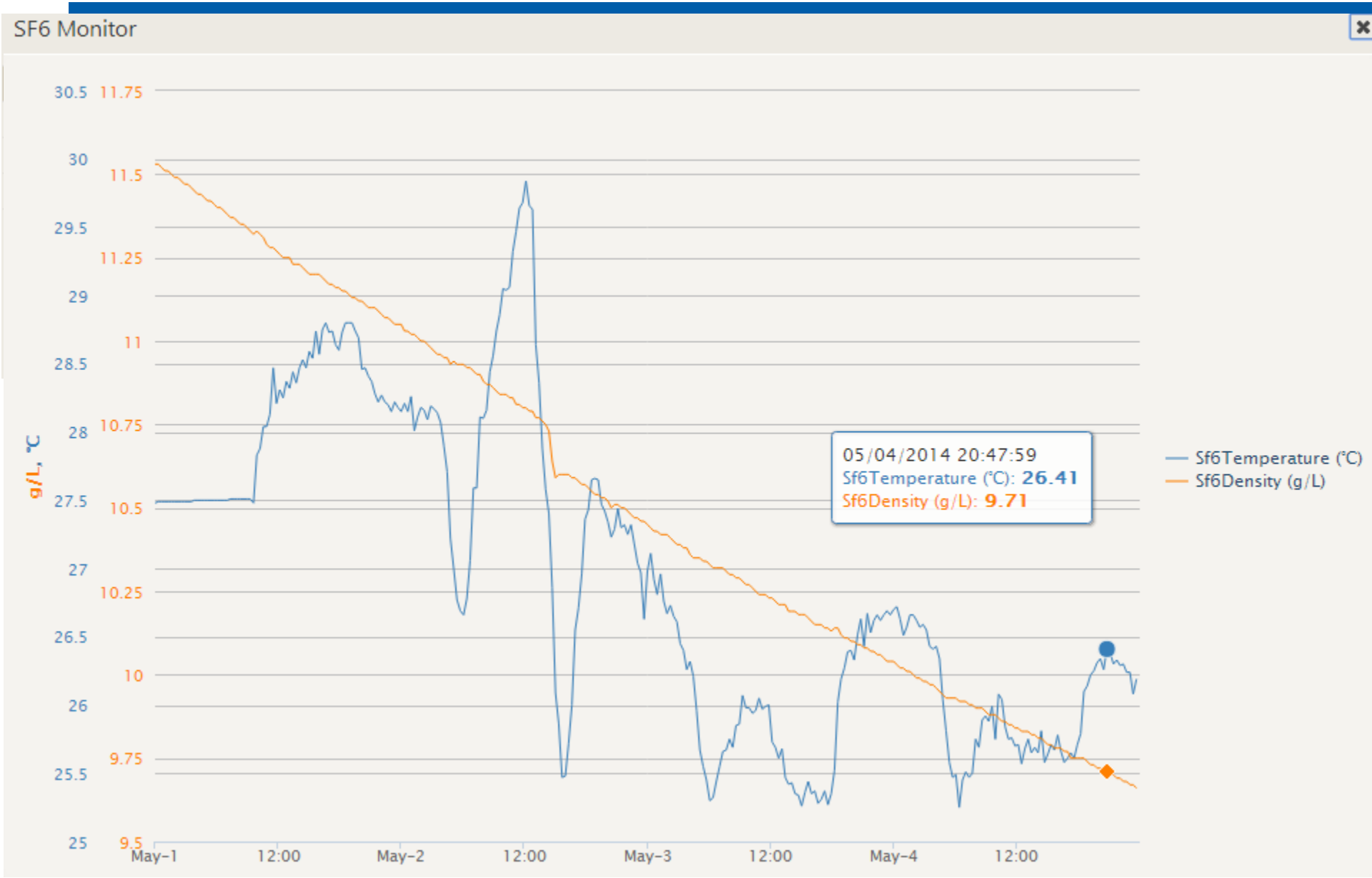
Dynamic Resistance Measurement

- Detecting overlapping arcing with main contacts
- Injecting DC current
- Using external power source (12 V car battery)
- Trip Free or C – delay – O
- Measuring voltage drop during breaker operation

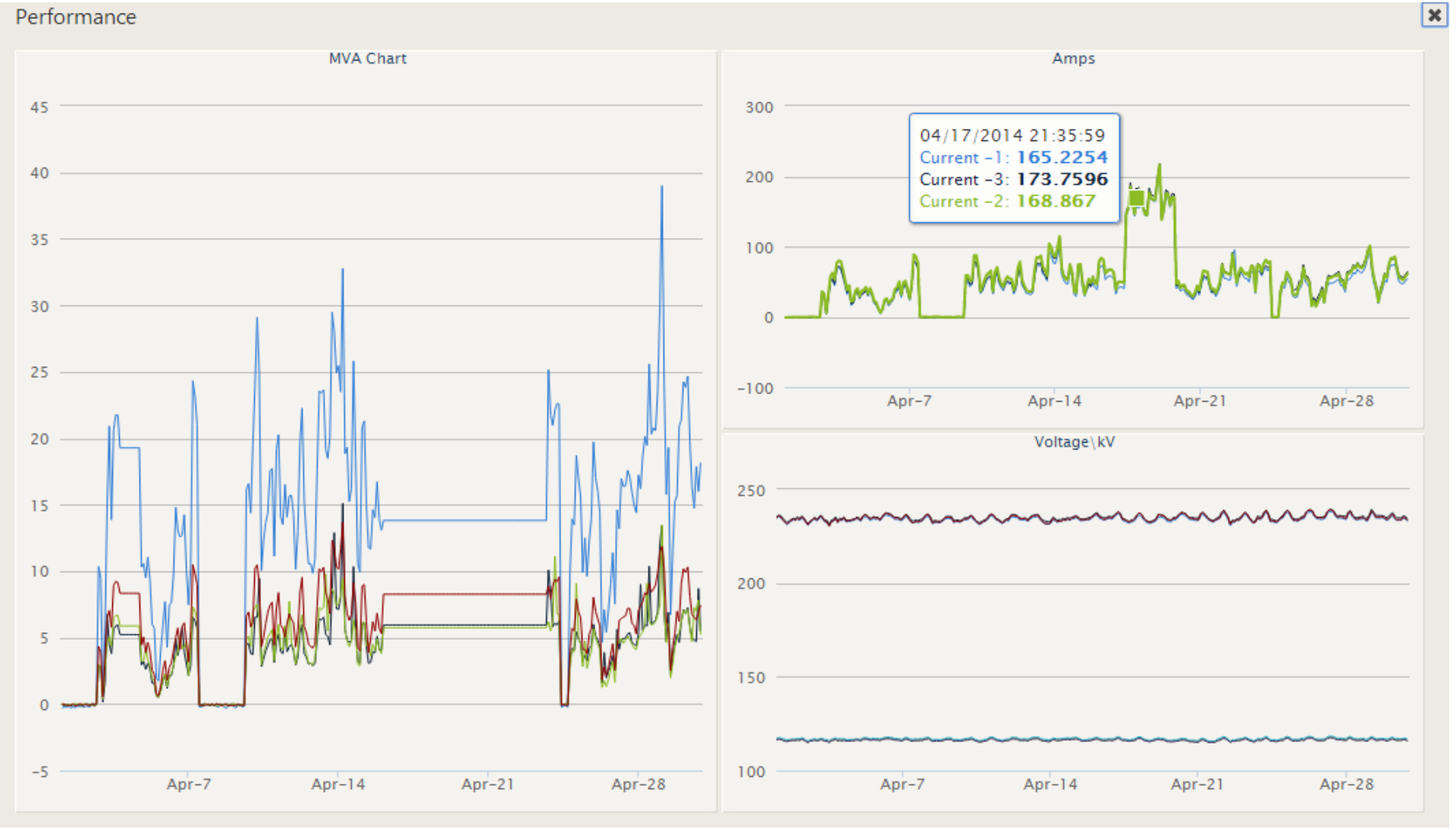
Online Monitors

- Measure Insulation Quality (SF6)
- Circuit Breaker Timing
  - Similar measurements to offline testing

Online Monitoring



Operational Data

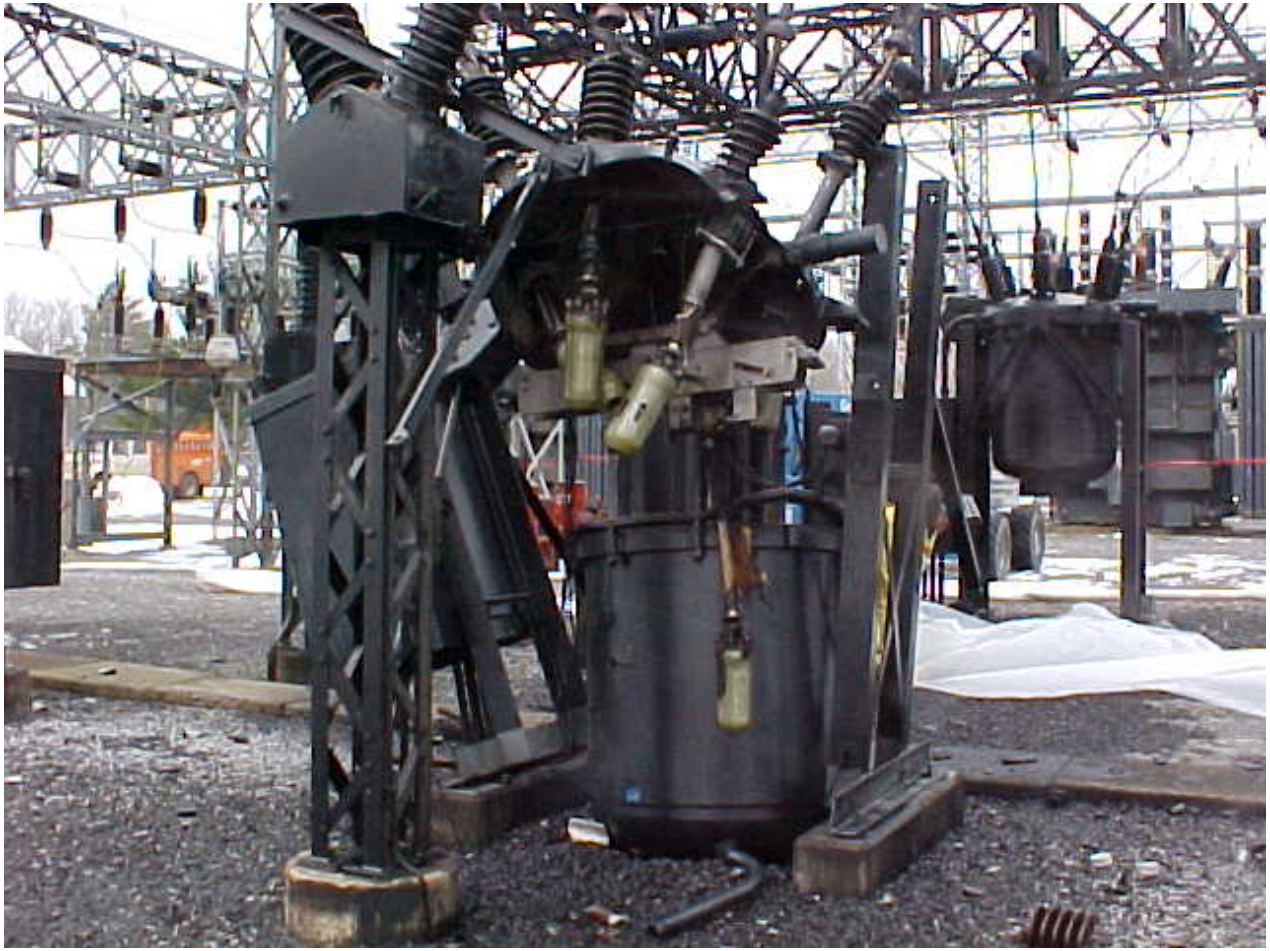


Operational Data

- Visual & Operational Inspections
  - Reading gauges
  - Maintenance records
  - Information on breaker operating mechanism
- Counters
  - Tracks number of breaker operations
  - Important to note not all operations on counter are due to faults, but the ones that are take a toll

Goal

- To avoid…



- Questions?

Thank You!

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