Extracting Valuable Information from HV Circuit Breaker Testing

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MIPSYCON 2014

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HYOSUNG

Agenda Topics

- SF6 and Oil Breaker Types (Info)
- Timing and Travel
- Power Factor
- Contact Resistance (Static and Dynamic)
- Minimum Pick-Up

Circuit Breaker Testing Protocol

- **Performance Characteristics**
  - **Timing and Travel**
  - **Command Coil Analysis**
  - **Motor Current Analysis**
- **Insulation Components**
  - **Gas, Oil, and Vacuum**
- **Contact Resistance**
- **Supplies and Battery System**
- **Bushings**
- **CTs**

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Performance Characteristics

- **Timing and Travel**
  - ✓ O, C, TripFree CO, ReClose O-C, O-CO
- **Command Coil Analysis**
  - ✓ Current Signature
  - ✓ Minimum Pick-Up
- **Motor Current Analysis**

Failure Modes

- **Major Problems May Include:**
  - ✓ Insulation Failure
  - ✓ Failure to Operate
  - ✓ Failure to Interrupt
  - ✓ Catastrophic Failure
- **Other Problems May Include:**
  - ✓ Slow Close
  - ✓ Slow Open

Types of Breakers

- ✓ Oil
- ✓ SF6 Gas
- ✓ Air: Blast or Magnetic
- ✓ Vacuum

Common Components

- ✓ Contacts
- ✓ Mechanism
- ✓ Insulation
- ✓ Arc Mitigation
- ✓ Control Cabinet

Circuit Breaker Types

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Live Tank vs Dead Tank


ABB
482

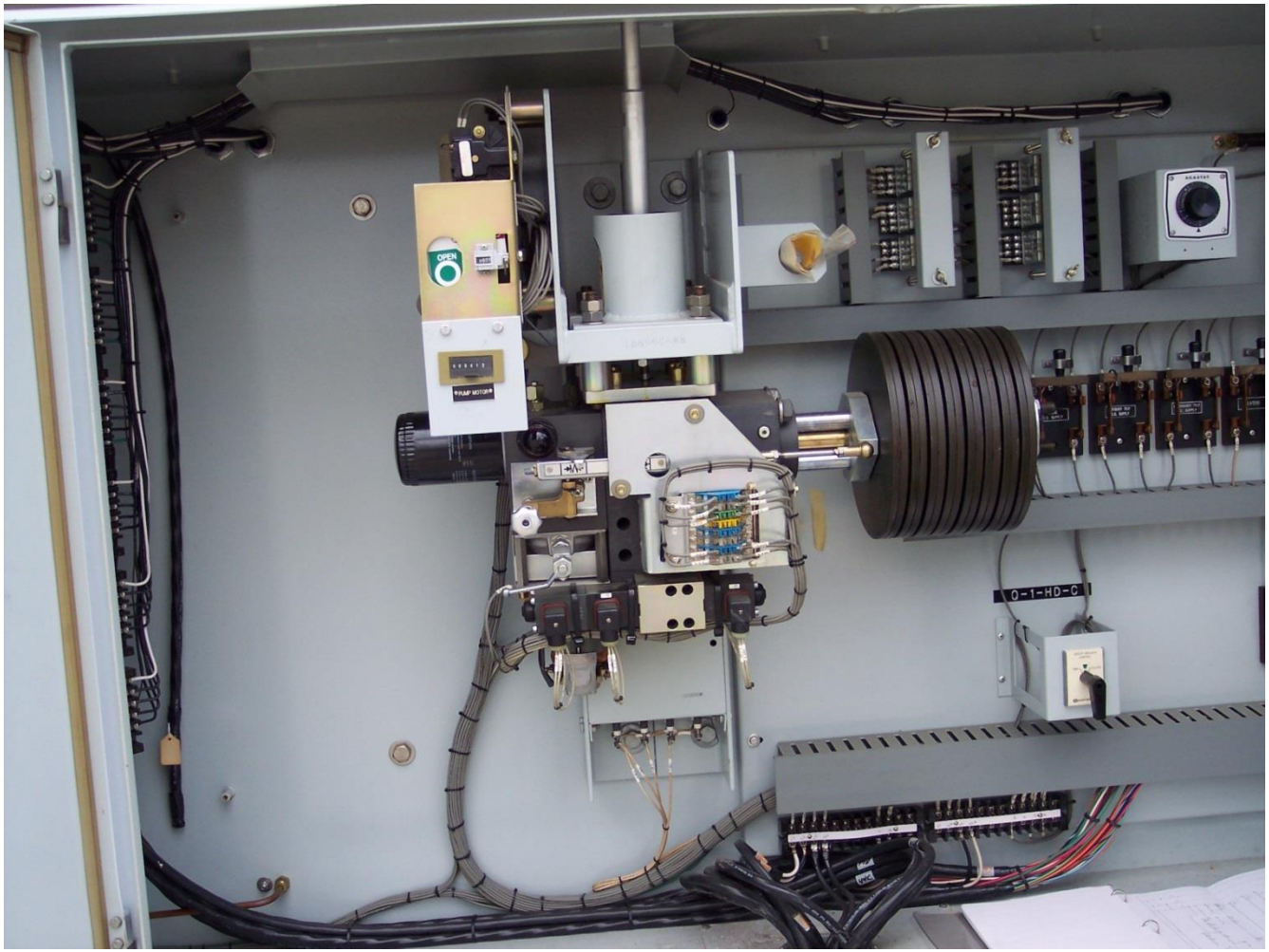

SIEMENS


01401

Typical Breaker Components

- **Mechanism**
  - ✓ Springs
  - ✓ Hydraulic
  - ✓ Pneumatic
  - ✓ Magnetic Actuator
- **Contacts**
  - ✓ Moving
  - ✓ Stationary

Principle of Operating Mechanisms



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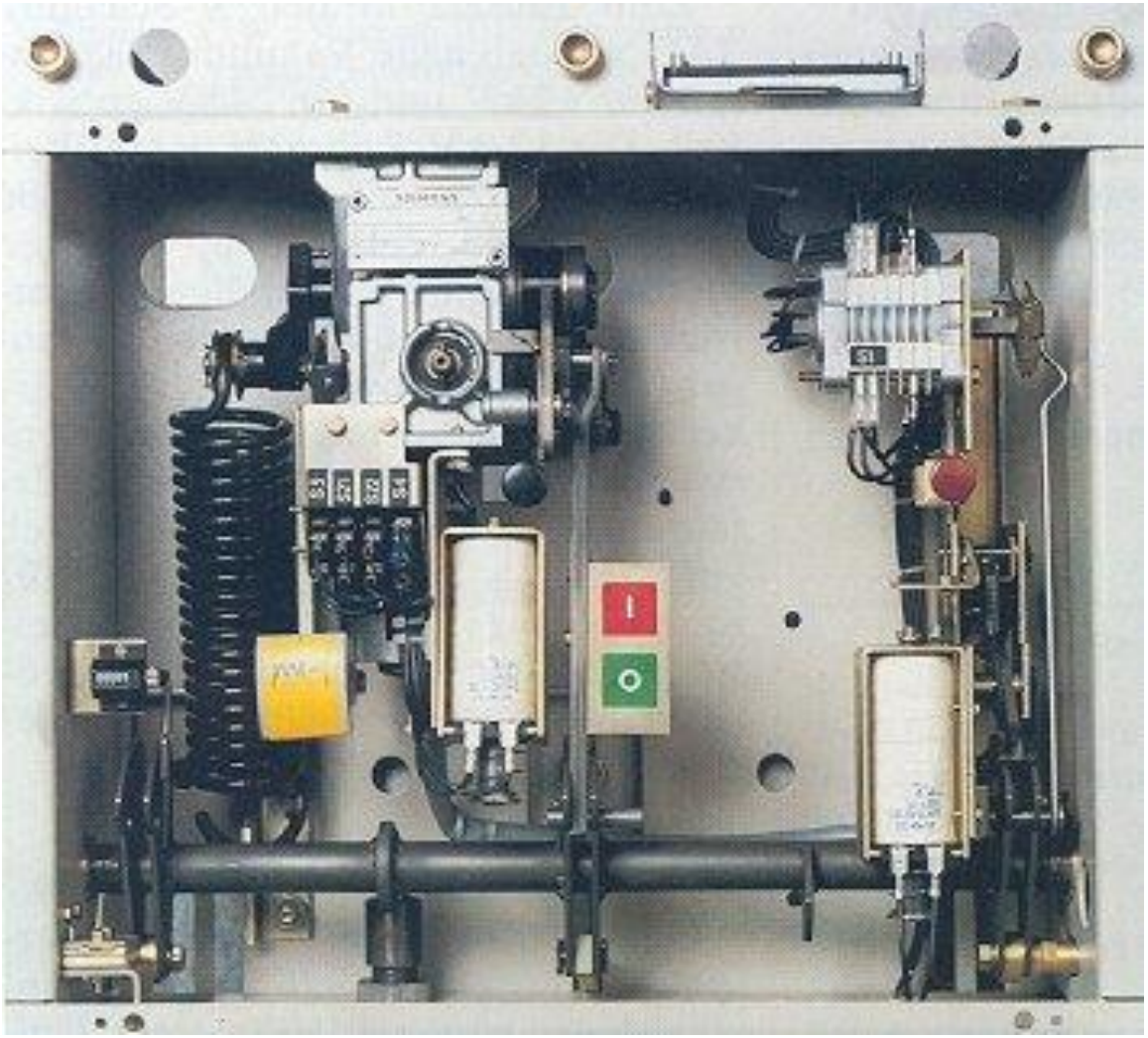
Principle of Operating Mechanisms



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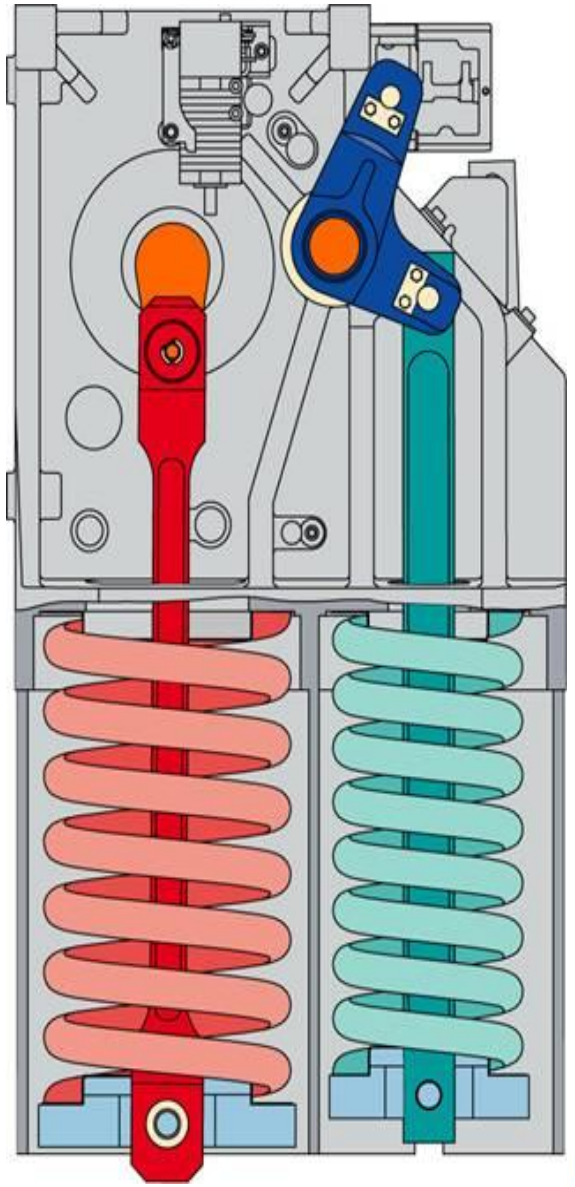
Spring Mechanism

- Close spring is bigger than Open spring
- While closing open spring must be fully charged



Spring Mechanism

- Close spring is bigger than Open spring

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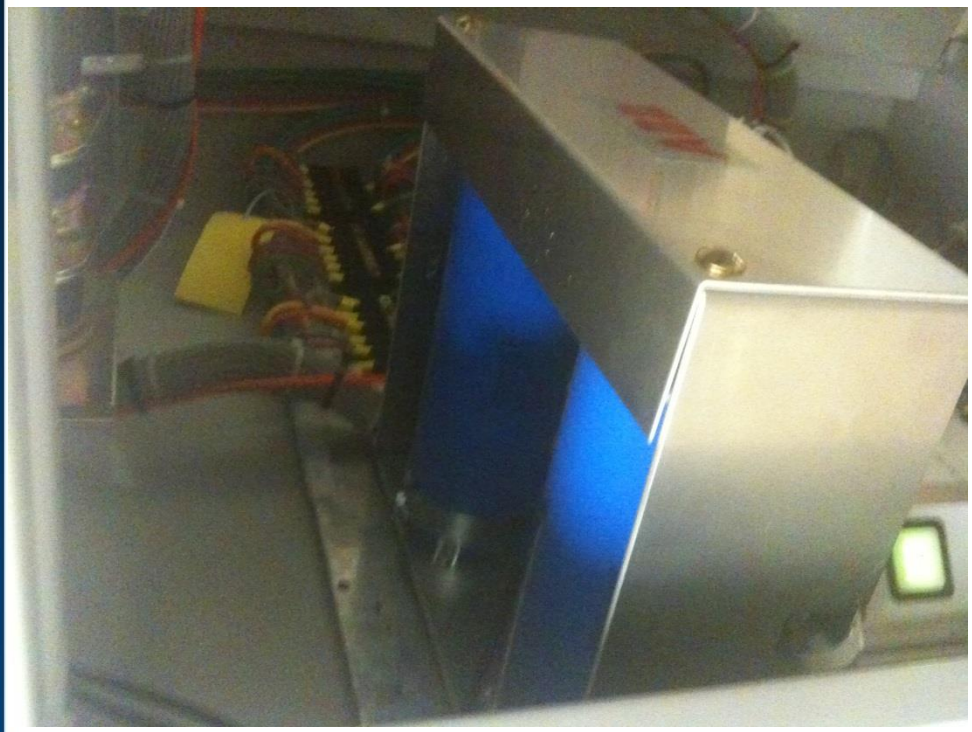
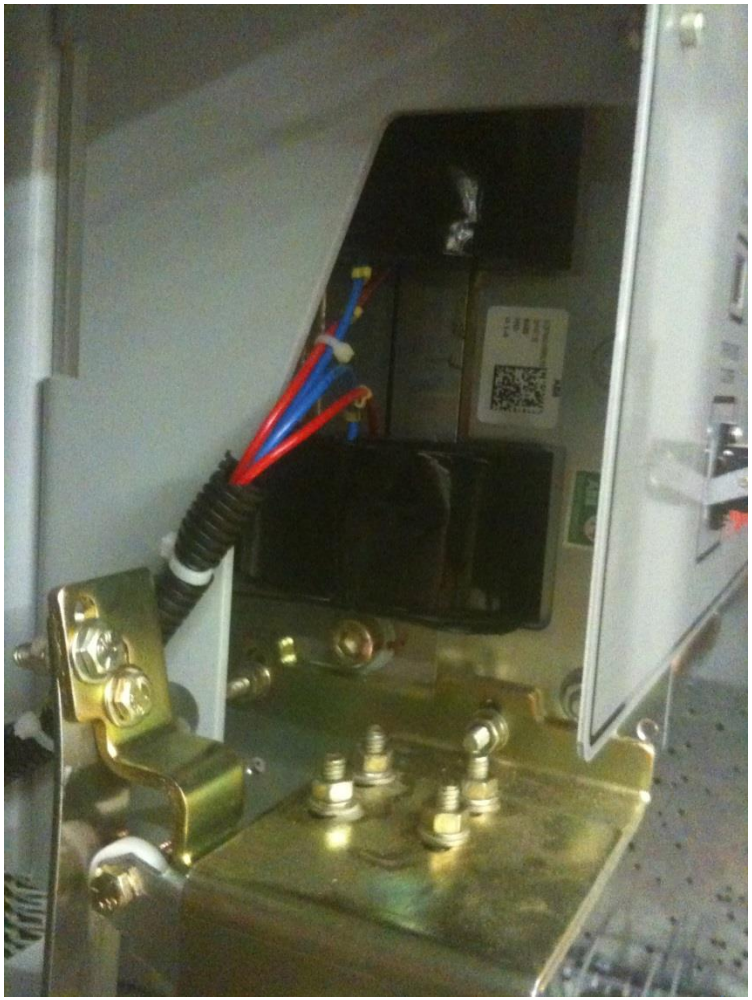
Hydraulic Mechanism

Magnetic Actuator





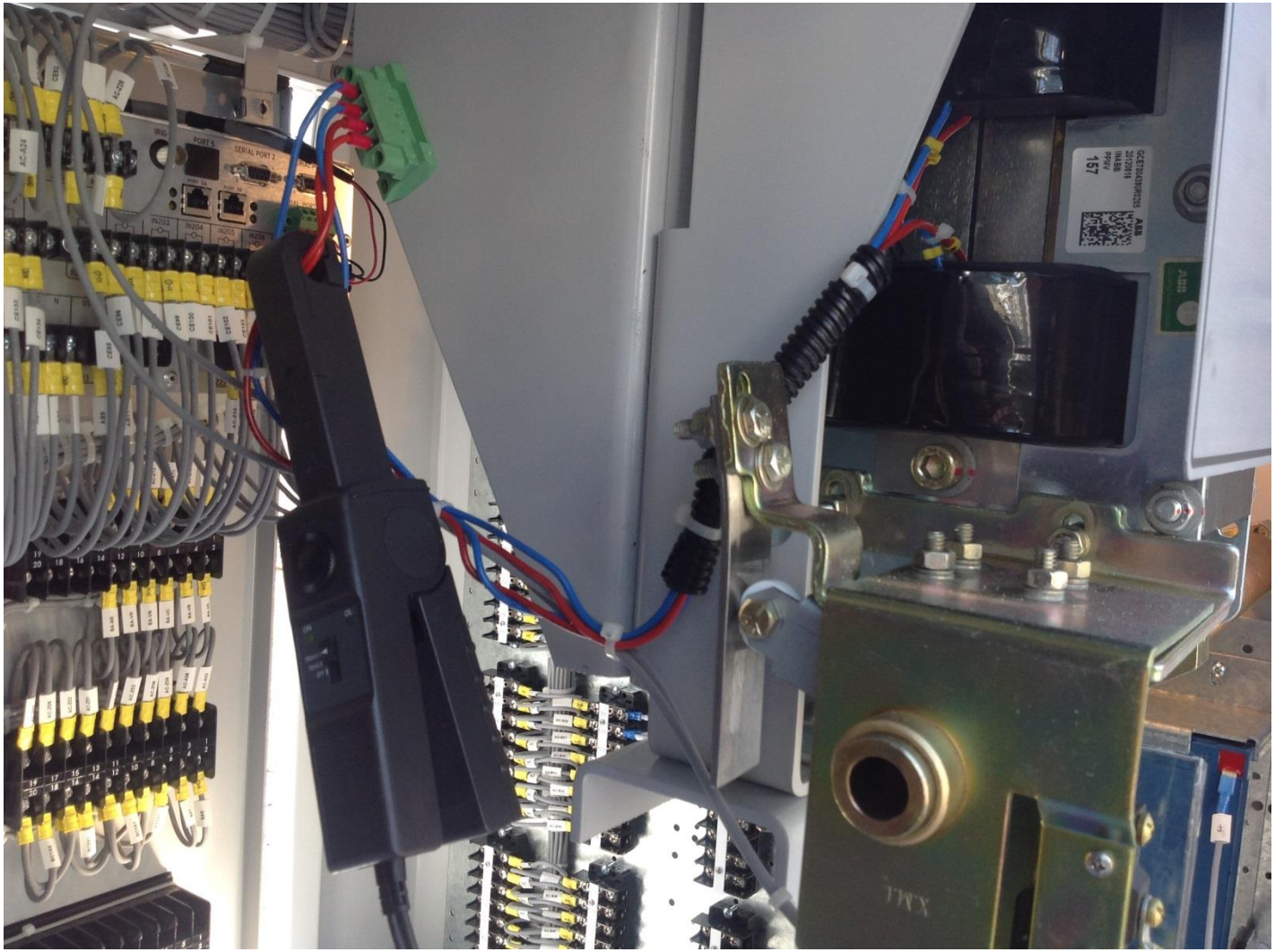
MA – Field Prep

MA Testing – Advanced Tests Recommended

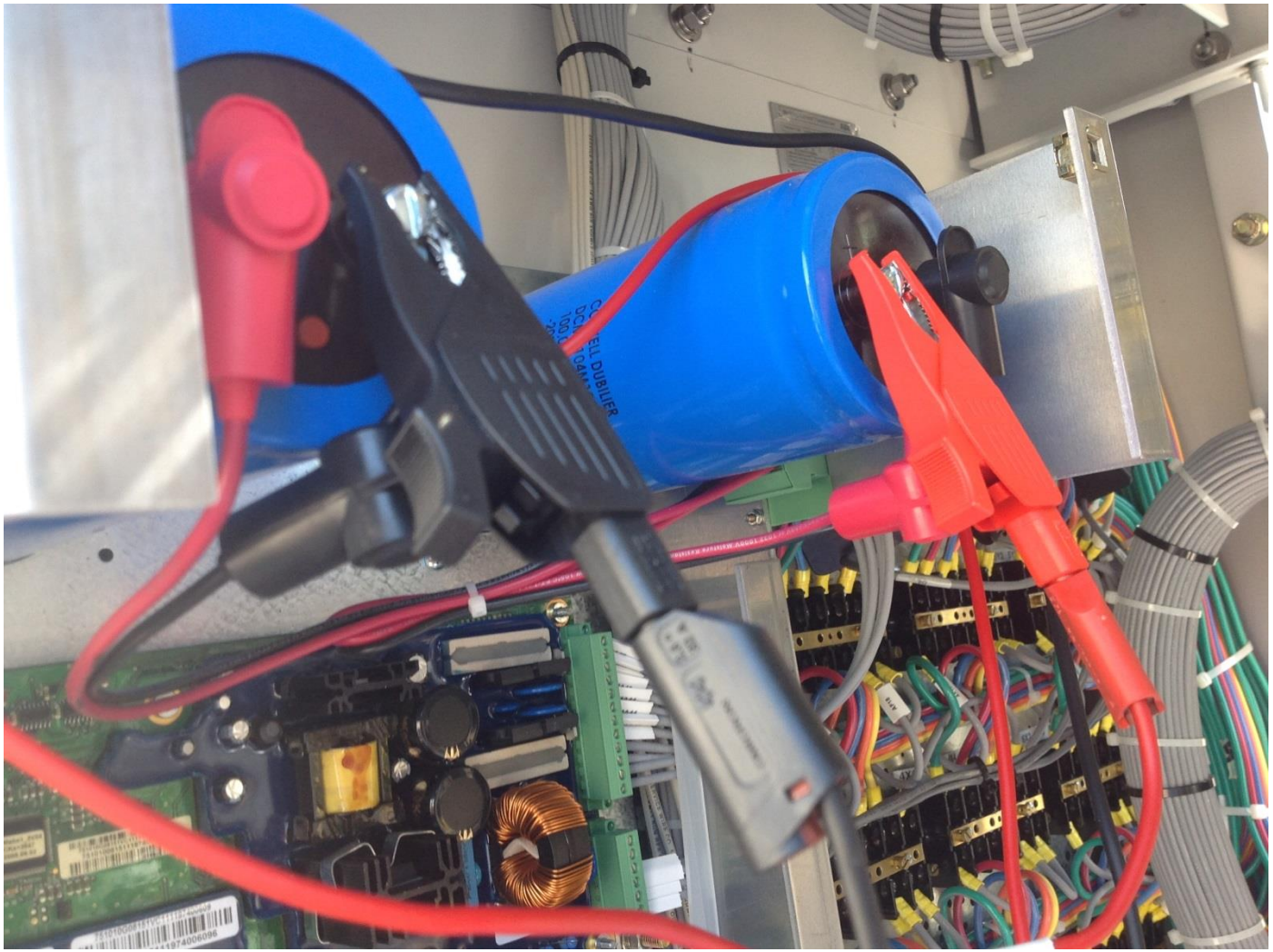
1. Main Contact Timing (O, C, CO, O-C)
2. Contact Resistance
3. Monitoring (USP)

   - Magnetic Actuator Function
   - Storage Capacitor Function
   - Capacitor Charger Function

Actuator Current via OMICRON Current Probe

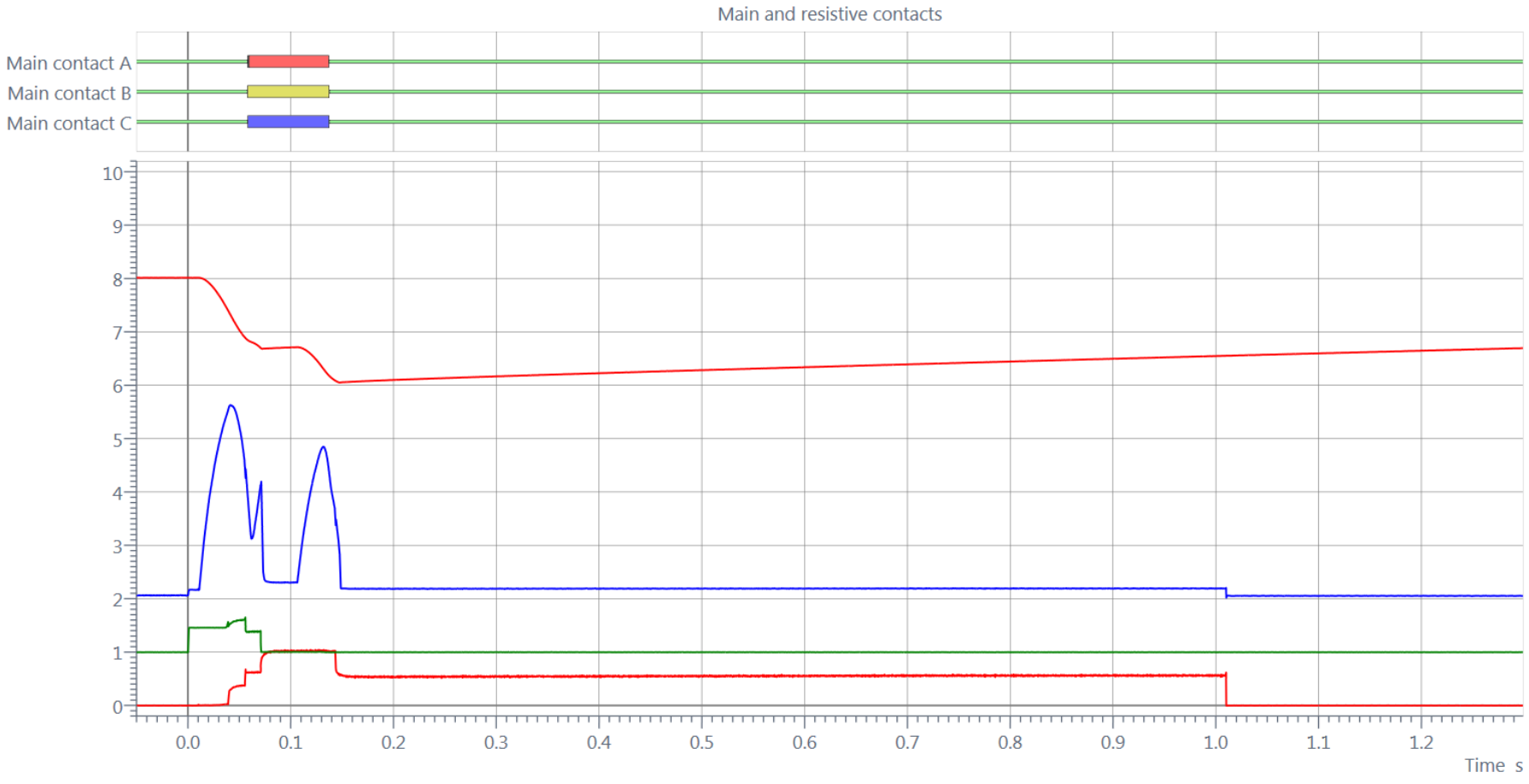


Capacitor Connections



Main Contact Connections

Analyzing the Measurement



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Circuit Breaker Summary

BREAKER TYPES	MECHANISM TYPES
Dead Tank Breaker (OCB)	Hydraulic
Dead Tank Breaker SF6	Pneumatic
Live Tank Air Blast	Spring
Live Tank SF6	Magnetic Actuator
Vacuum Breakers	**INSULATION SYSTEMS**
Air Magnetic	Oil
Low Voltage Air Blast	SF6
Reclosers	Air
Circuit Switchers	Vacuum
Sectionalizers	

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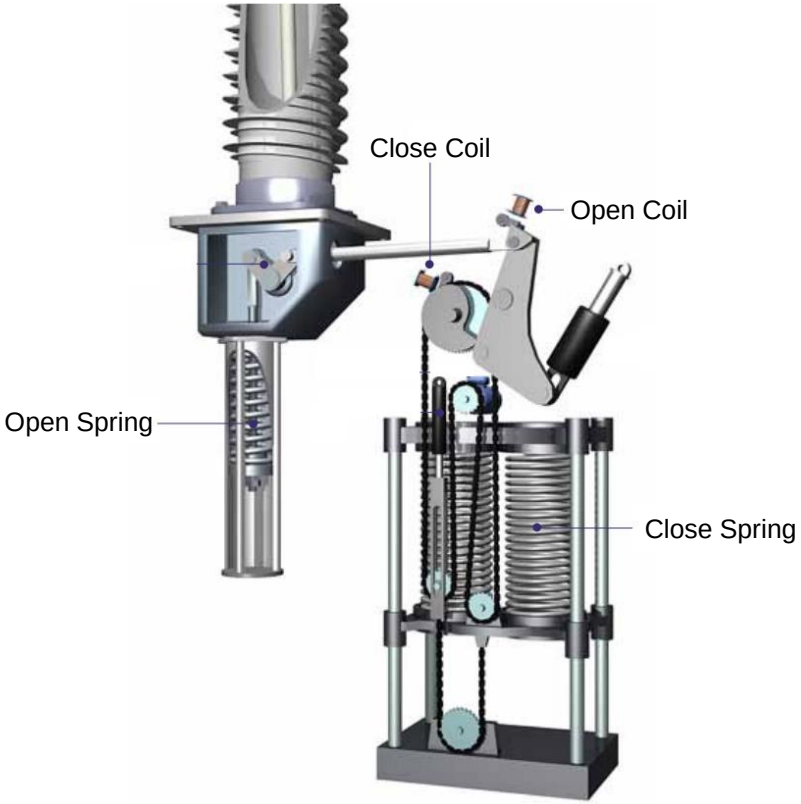
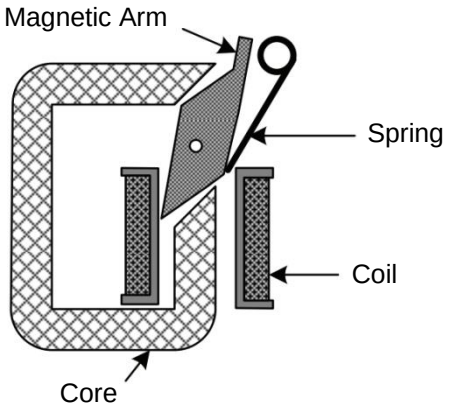
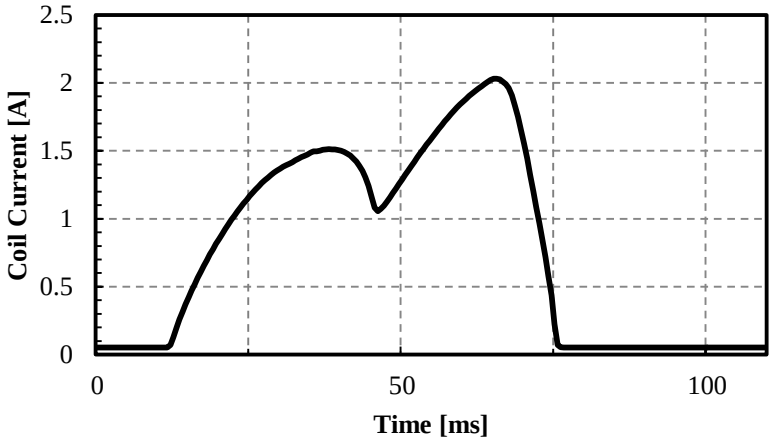
Spring Type Operating Mechanism



Source: ABB, [RUS07]

Open/Close Coil Principle





Trip Command – US Typical

Trip Command

Duration - 66.6 ms

	Trip Coil	Close Coil	Delay
OPEN (O)	66.6 ms (4 cycles)		
CLOSE (C)	133.3 ms (8 cycles)		
TRIPFREE (CO)	Standing	133.3 ms (8 cycles)	8.3 ms (1/2 cycle)
RECLOSE (OC)	66.6 ms (4 cycles)	Standing	300.0 ms

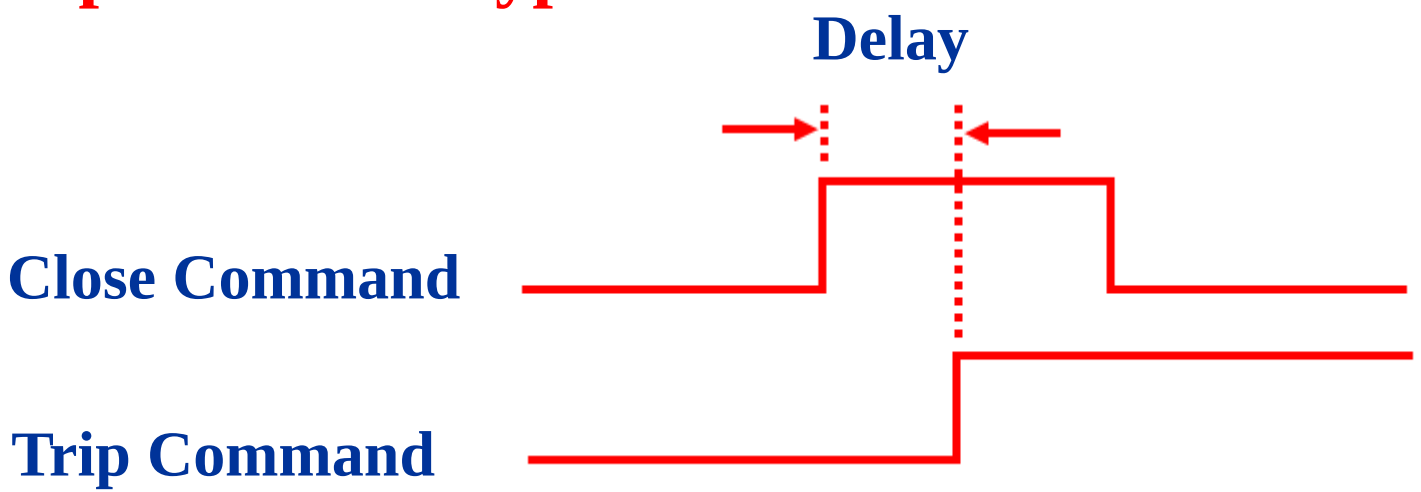
Close Command – US Typical

Close Command

Duration – 133.3 ms

	Trip Coil	Close Coil	Delay
OPEN (O)	66.6 ms (4 cycles)		
CLOSE (C)	133.3 ms (8 cycles)		
TRIPFREE (CO)	Standing	133.3 ms (8 cycles)	8.3 ms (1/2 cycle)
RECLOSE (OC)	66.6 ms (4 cycles)	Standing	300.0 ms

TripFree – US Typical

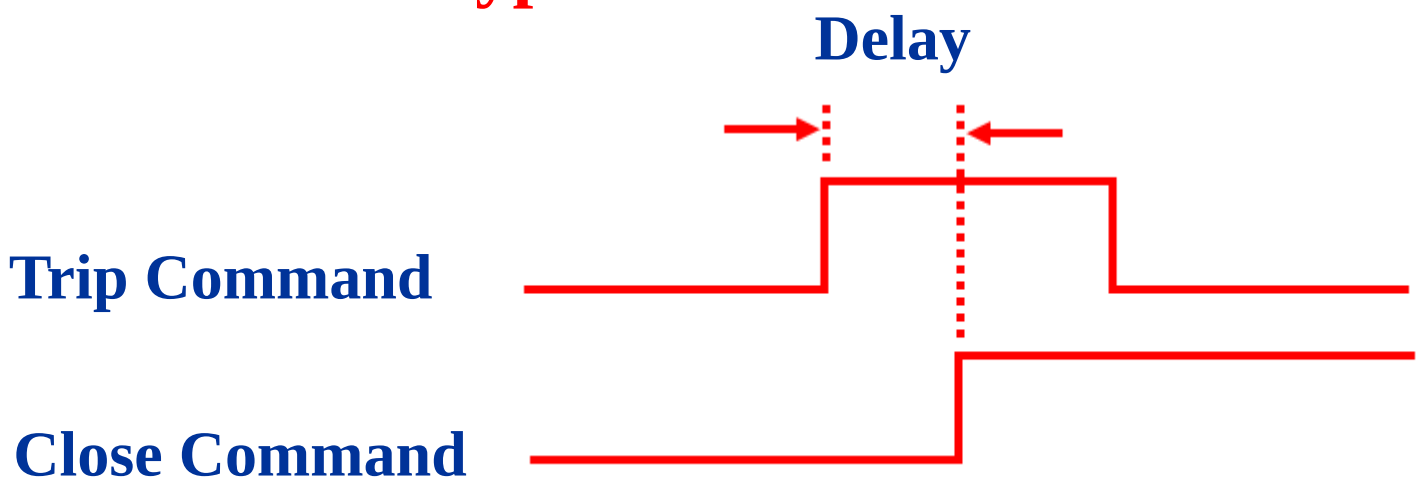


Close Duration – 133.3 ms

Trip Duration – Standing

Delay – ½ Cycle or 8.3 ms

ReClose – US Typical



Trip Duration – 66.6 ms

Close Duration – Standing

Sometimes > 300 ms

Circuit Breaker Timing and Travel

- **Perform a Measurement**

  -Contacts, Coils, Mechanism, Aux Switches

- **Interpret performance characteristics**

- **Consult manufacturers specifications (Pass or Fail) ,unlike power factor testing**

Timing and Travel

What Can be Measured ?

1. Displacement (Travel&Velocity)
2. Breaker State (O:R:C)
3. Coil Current
4. Battery Voltage Level
5. Auxiliary Contact State

Performance Characteristics

1. Main Contact Timing
2. Resistor Switch Timing
3. Delta Timing
4. Velocity
5. Total Travel
6. Over Travel
7. Rebound
8. Stroke
9. Contact Wipe
10. Dwell Time (TripFree CO)
11. Dead Time (ReClose OC)

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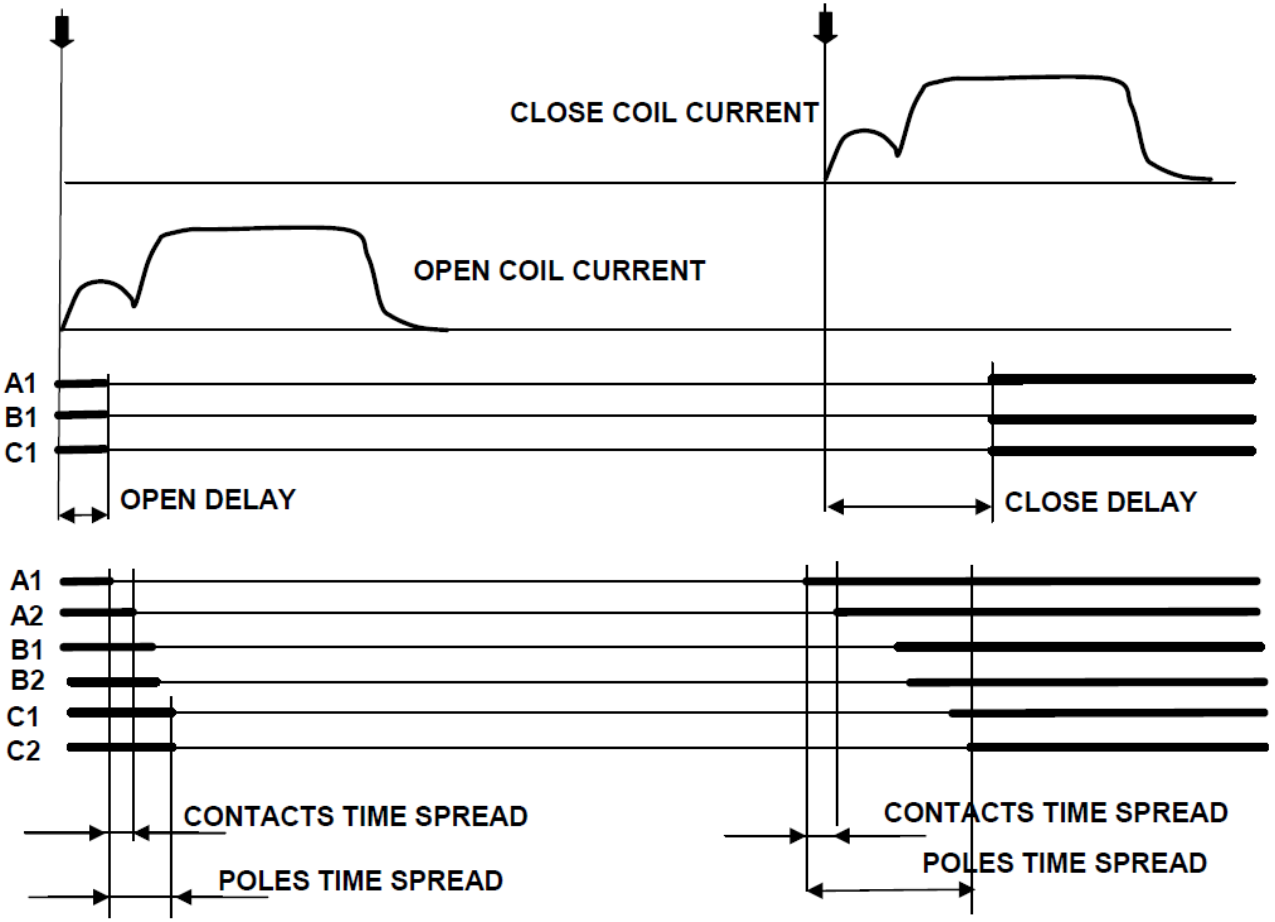
Specification Example

Identification	CB1
Control Circuit Open	70-140 VDC / 6.0 A
Control Circuit Close	90-140 VDC / 6.0 A
Opening Time	17-30 ms
Opening Velocity	3.8 m/s minimum
Pole Spread Open	2.7 ms
Closing Time	50-85 ms
Closing Velocity	1.7 to 2.3 m/s
Pole Spread Close	2.7 ms
Overtravel	4.0 mm maximum
Rebound	6.5 mm maximum
Stroke	113 mm maximum
Dwell Time	20-38 ms
Reclose Time (Dead Time)	300 ms minimum

Measured Values



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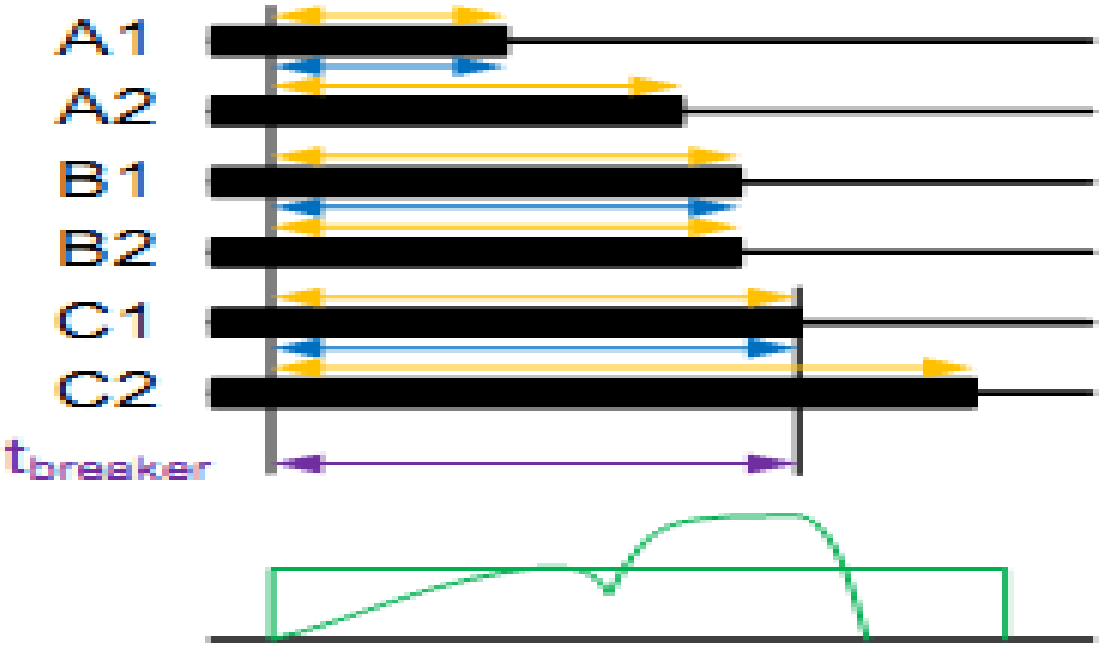
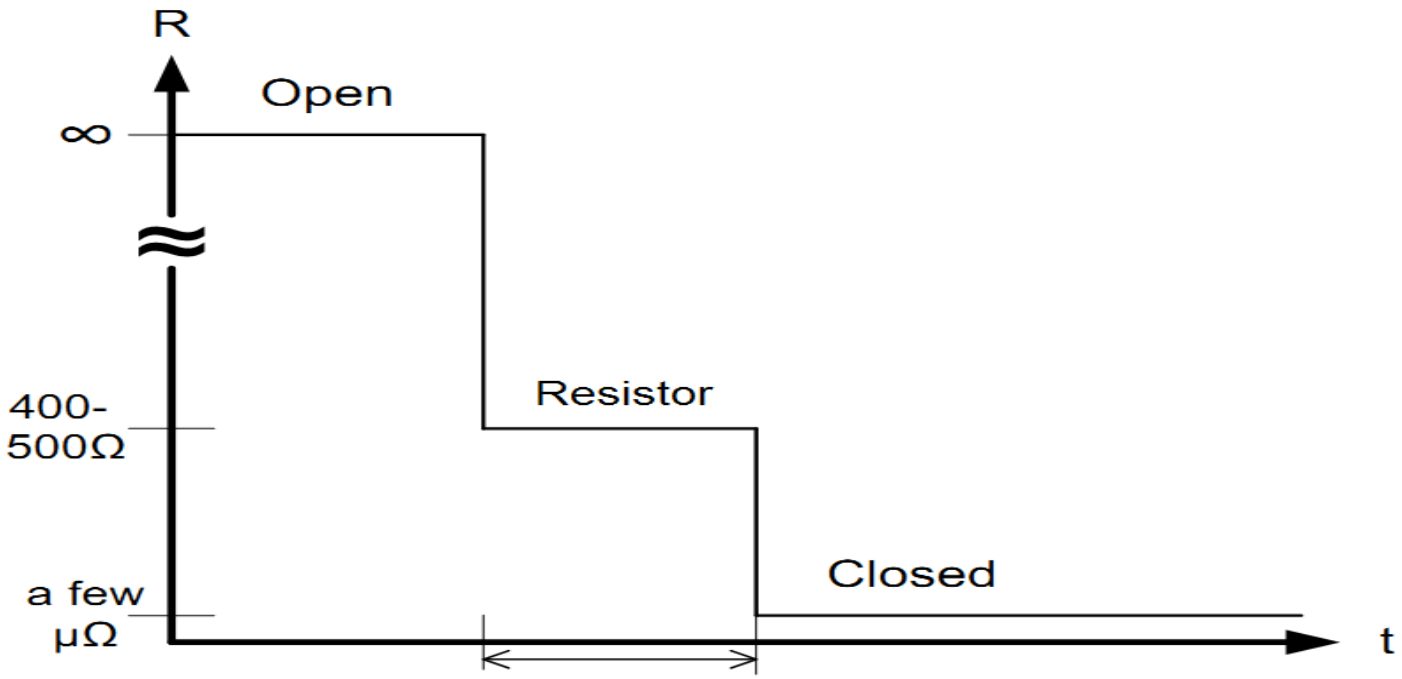
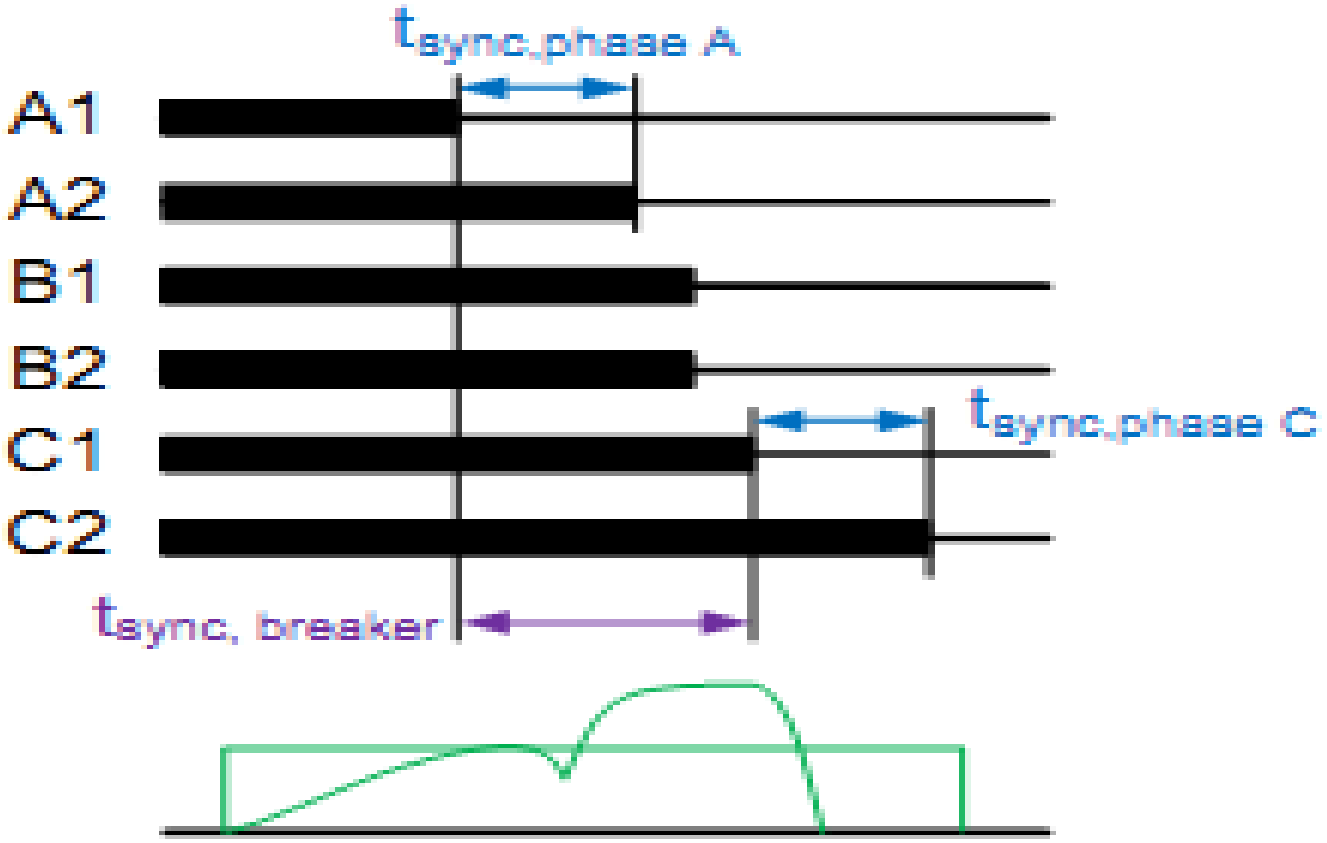
Main Contact Timing



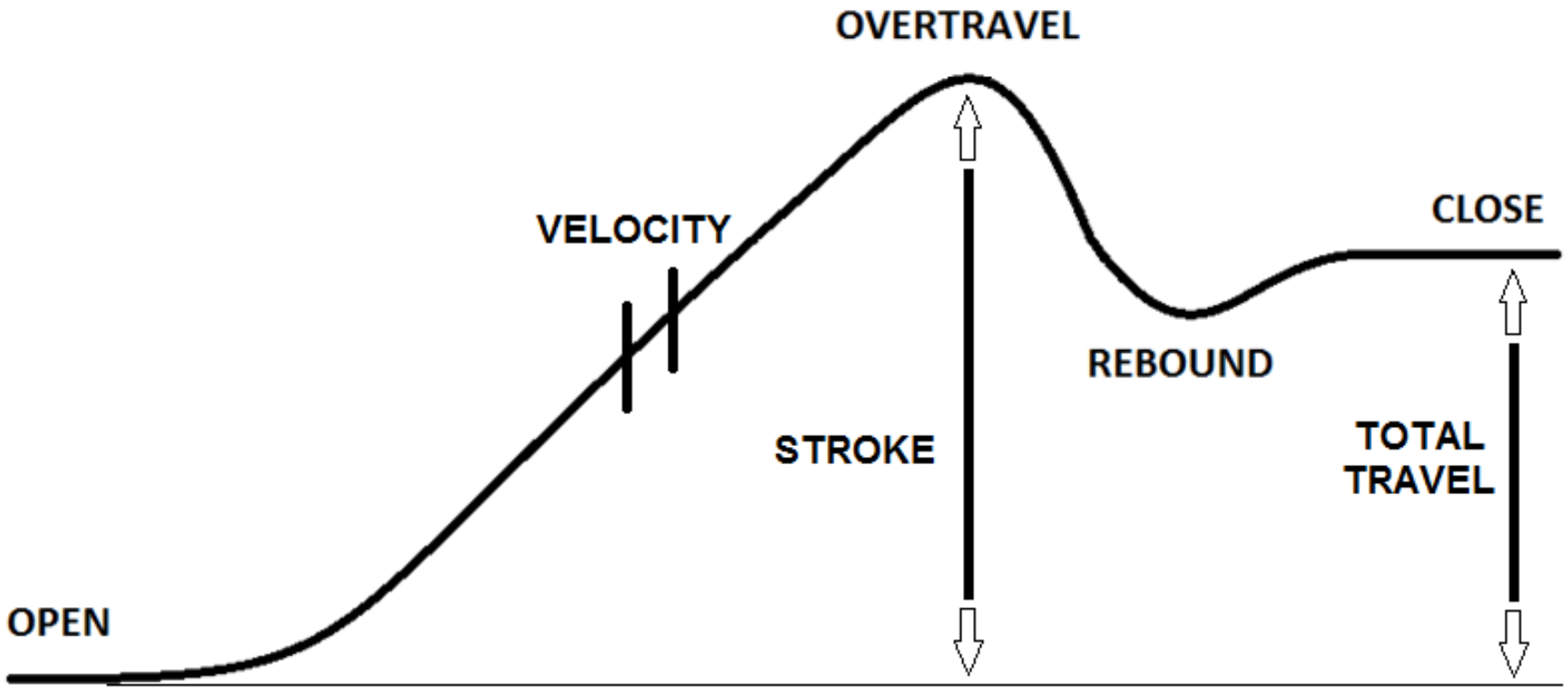
Resistor Switch Timing



Pole Spread (Delta)



Travel CLOSE



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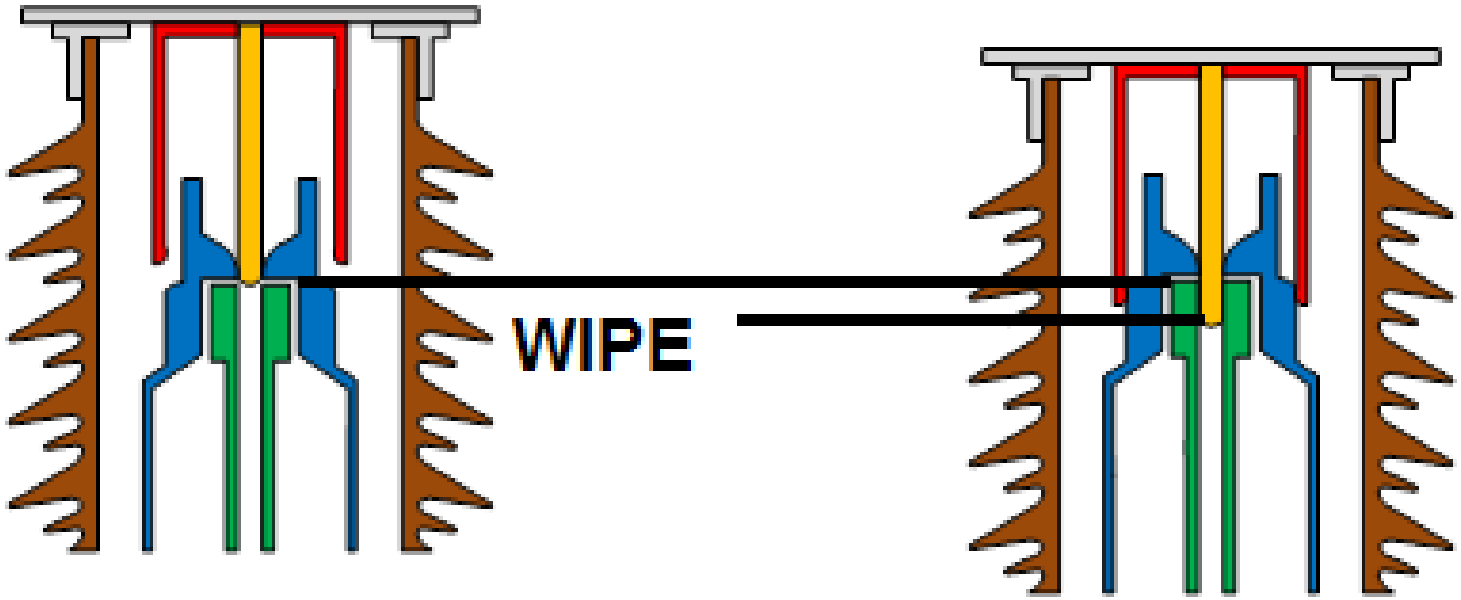
Contact Wipe

Contact Wipe: The distance the contacts move during a close operation from first make to the final resting position. This is an electrical measurement.



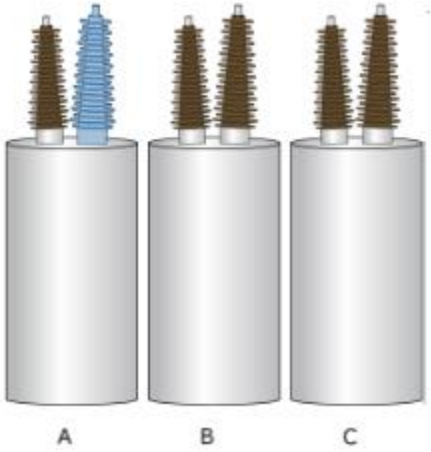
Insulation Components

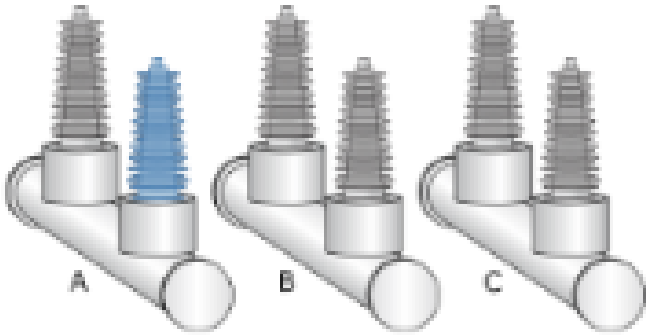
- **Overall Power Factor**

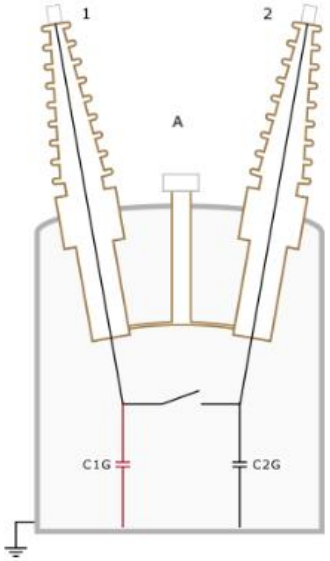
  -TLI Tank Loss Index (OCB)

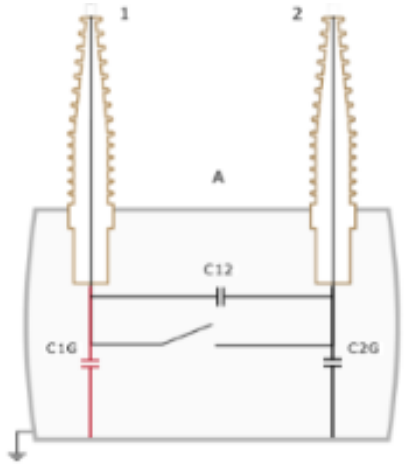
- **Insulation Resistance**
- **DGA and Oil Screen (OCB)**
- **SF6 – Moisture, Density, and SO2**

OCBs vs Dead Tank SF6









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OCB Test Procedure

Test	Insulation Tested	Breaker Position	HV	IN A	IN B	Test Mode
1	C_{1G}	Open	Bushing 1	-	-	GST
2	C_{2G}	Open	Bushing 2	-	-	GST
3	C_{3G}	Open	Bushing 3	-	-	GST
4	C_{4G}	Open	Bushing 4	-	-	GST
5	C_{5G}	Open	Bushing 5	-	-	GST
6	C_{6G}	Open	Bushing 6	-	-	GST
7	$C_{1G}+C_{2G}$	Closed	Bushing 1&2	-	-	GST
8	$C_{3G}+C_{4G}$	Closed	Bushing 3&4	-	-	GST
9	$C_{5G}+C_{6G}$	Closed	Bushing 5&6	-	-	GST

NOTE: All unused bushing should be left floating

Tank Loss Index (TLI)

TLI = (closed breaker test in watts) – (sum of open breaker losses in watts)

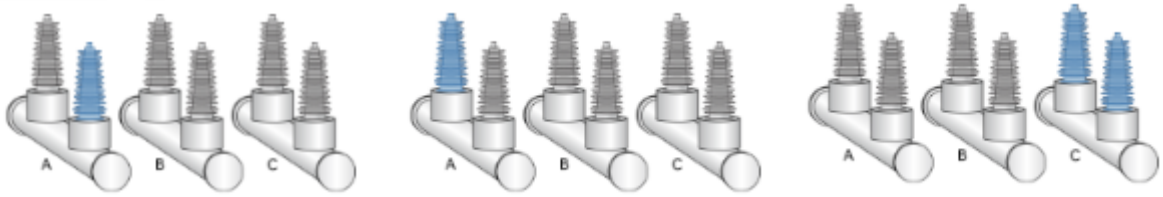
Negative TLI (-)	Positive TLI (+)
Lift Rod Guide	Lift rod
Interrupter Assembly	Oil
	Tank Liner

Dead Tank SF6 Test Procedure

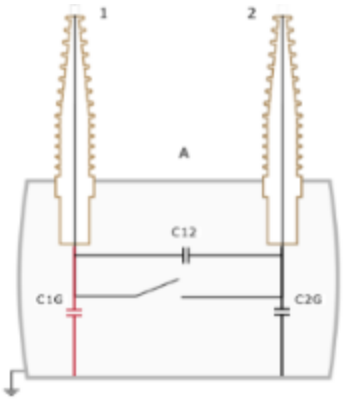
Test	Insulation Tested	Breaker Position	HV	IN A	IN B	Test Mode
1	C_{1G}	Open	Bushing 1	-	-	GST
2	C_{2G}	Open	Bushing 2	-	-	GST
3	C_{3G}	Open	Bushing 3	-	-	GST
4	C_{4G}	Open	Bushing 4	-	-	GST
5	C_{5G}	Open	Bushing 5	-	-	GST
6	C_{6G}	Open	Bushing 6	-	-	GST
7	C_{12}	Open	Bushing 1	Bushing 2	-	UST-A
8	C_{34}	Open	Bushing 3	Bushing 4	-	UST-A
9	C_{56}	Open	Bushing 5	Bushing 6	-	UST-A
10	$C_{1G}+C_{2G}$	Closed	Bushing 1&2	-	-	GST
11	$C_{3G}+C_{4G}$	Closed	Bushing 3&4	-	-	GST
12	$C_{5G}+C_{6G}$	Closed	Bushing 5&6	-	-	GST

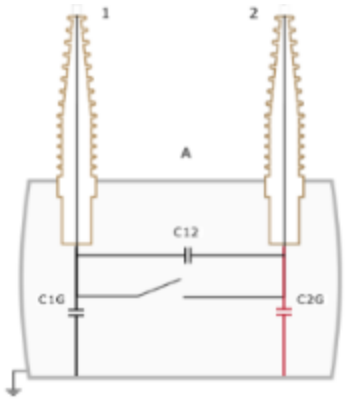
NOTE: All unused bushing should be left floating

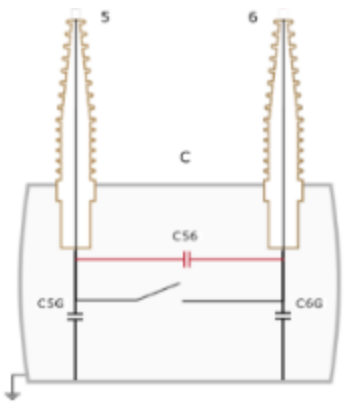
Power Factor



No.	Measurement	Breaker position	Test mode	Sweep	V test	Freq.	V out	I out	Watt losses	Cap. meas	PF meas
1	C1G	Open	GST	None	10.00 kV	60.00 Hz	10.00 kV	0.55 mA	1.68 mW	141.9 pF	0.0306 %
2	C2G	Open	GST	None	10.00 kV	60.00 Hz	10.00 kV	0.37 mA	1.40 mW	96.3 pF	0.0379 %
3	C3G	Open	GST	None	10.00 kV	60.00 Hz	10.01 kV	0.53 mA	1.67 mW	138.5 pF	0.0316 %
4	C4G	Open	GST	None	10.00 kV	60.00 Hz	10.00 kV	0.36 mA	1.41 mW	93.5 pF	0.0392 %
5	C5G	Open	GST	None	10.00 kV	60.00 Hz	10.01 kV	0.54 mA	1.64 mW	139.2 pF	0.0303 %
6	C6G	Open	GST	None	10.00 kV	60.00 Hz	10.01 kV	0.36 mA	1.37 mW	93.4 pF	0.0380 %
7	C12	Open	UST-A	None	10.00 kV	60.00 Hz	10.01 kV	0.01 mA	0.05 mW	3.4 pF	0.0459 %
8	C34	Open	UST-A	None	10.00 kV	60.00 Hz	10.01 kV	0.01 mA	0.06 mW	3.0 pF	0.0587 %
9	C56	Open	UST-A	None	10.00 kV	60.00 Hz	10.01 kV	0.01 mA	0.05 mW	3.0 pF	0.0519 %







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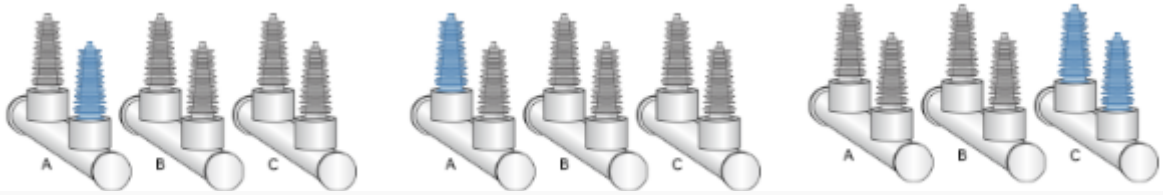
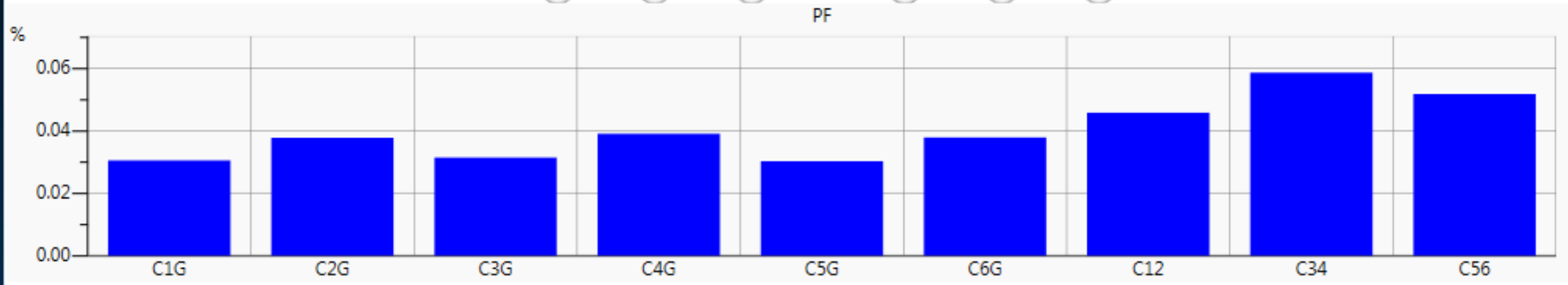
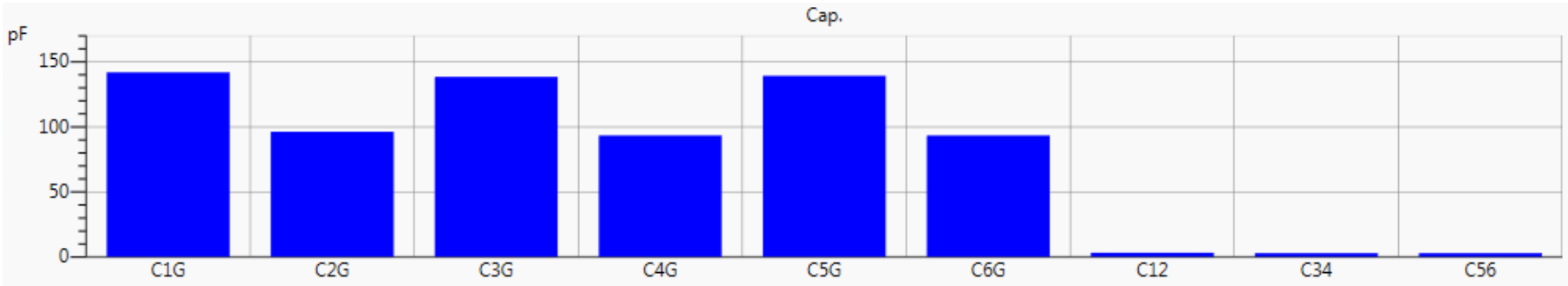
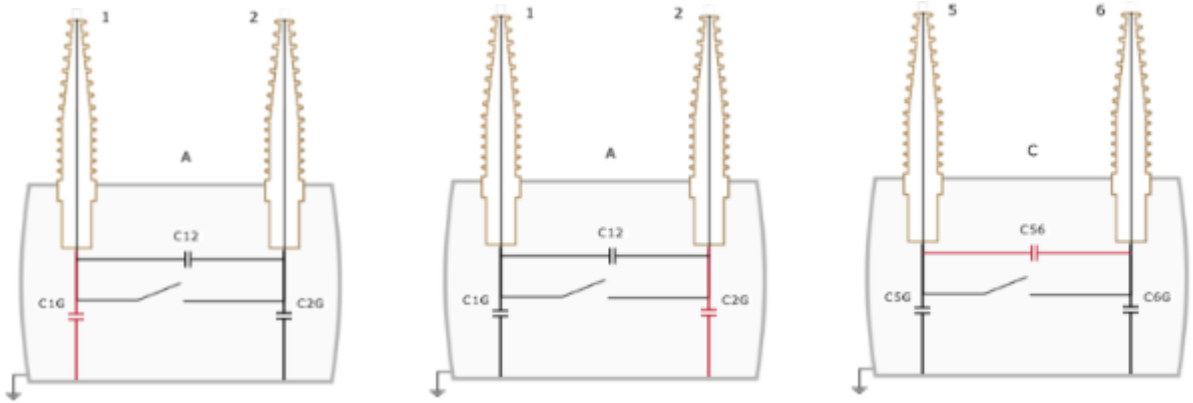
Power Factor









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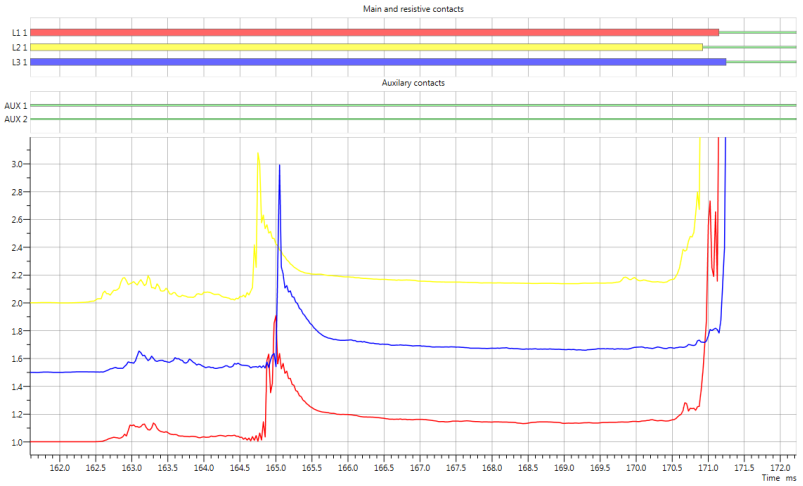
Contact Resistance

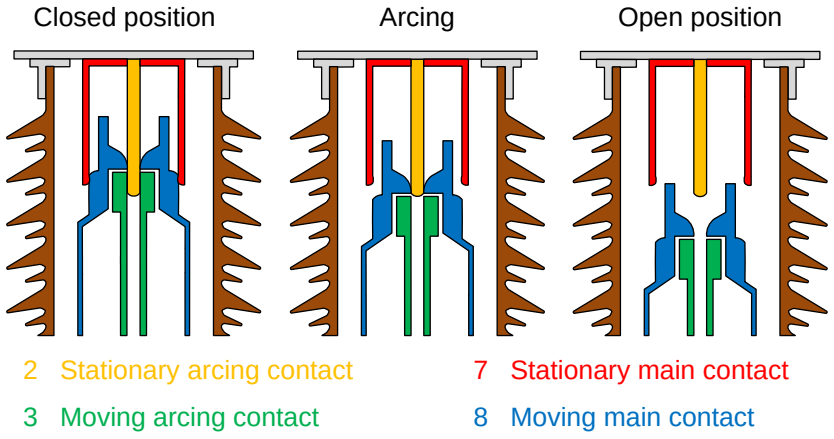
- **Static Contact Resistance**

Current Level	CB1		
	PHASE A	PHASE B	PHASE C
100 A	77.93 µΩ	78.39 µΩ	79.08 µΩ
200 A	77.93 µΩ	78.44 µΩ	79.15 µΩ
300 A	78.00 µΩ	78.43 µΩ	79.19 µΩ
400 A	78.00 µΩ	78.46 µΩ	79.19 µΩ

IEEE C37.09 - DC test current of 100 A minimum and not exceeding rated current

- **Dynamic Contact Resistance**





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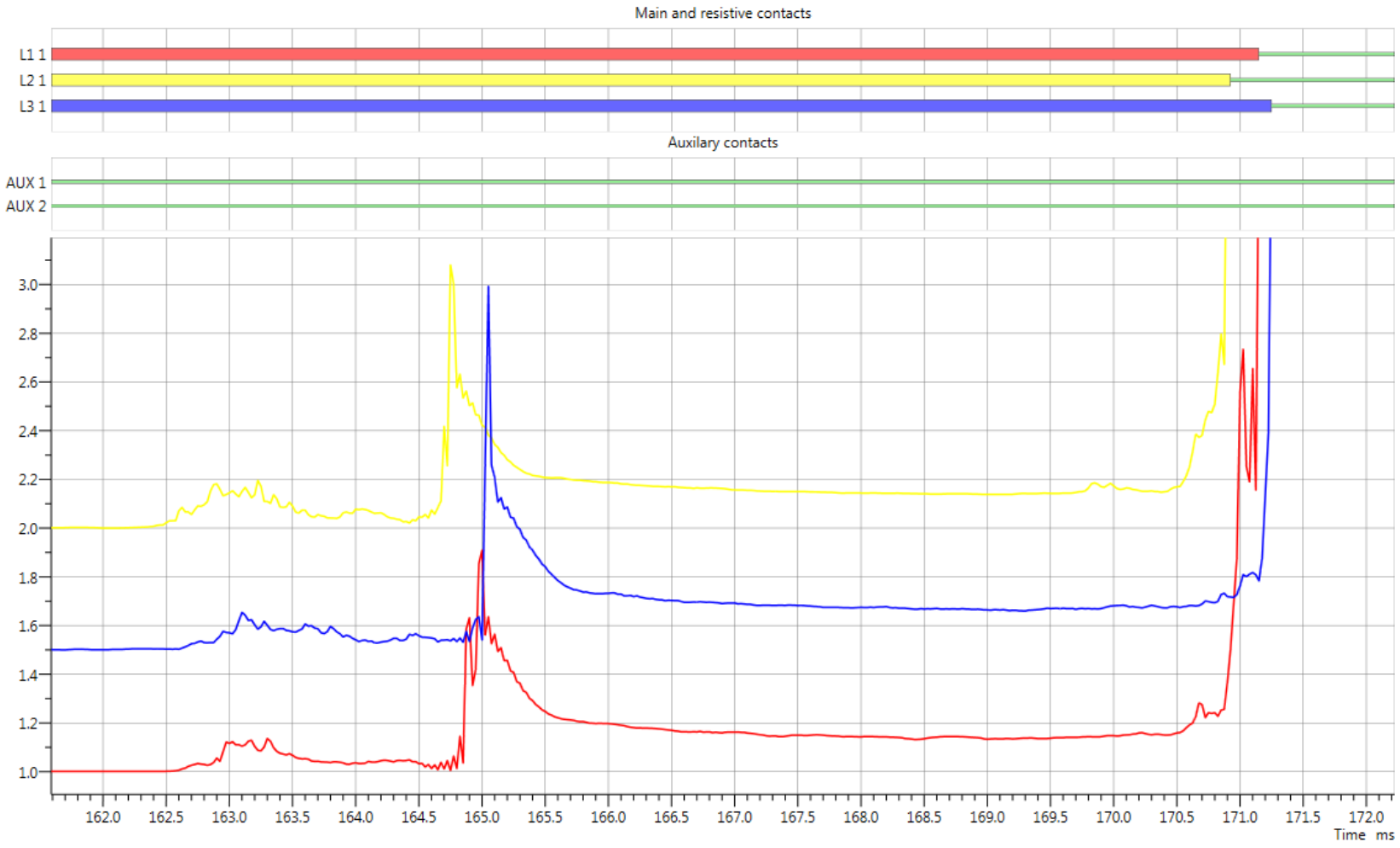
Dynamic Contact Resistance



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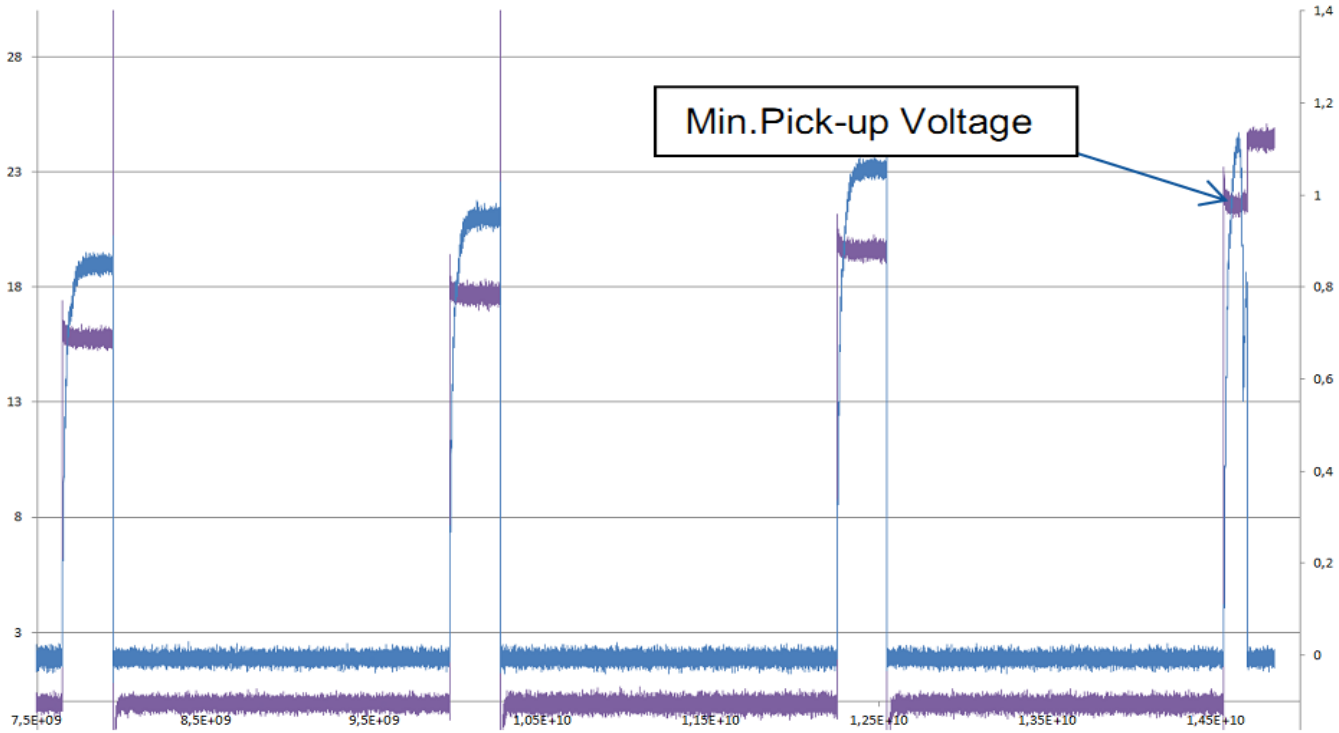
Minimum Pick-Up

- Determine the command coil parameters and ratings, AC or DC, and operating voltage.
- Determine a start and stop voltage for the command coil under test. Example, 125 VDC command coil, Start [10 VDC] – Stop [125 VDC]
- Determine pulse time: the pulse time should be limited so the command coil does not overheat, 300 ms is the default starting point.
- Determine dead time: this is the time that the command coil pauses between pulses. The dead time should be long enough to assist is cooling of the command coil. 2 seconds is a reasonable starting point.
- Determine the voltage step increment: This is the amount that the voltage is increased between command coil pulses: 5 VDC is a reasonable starting point.

Minimum Pick-Up



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Other Terminology and Applications

1. First Trip
2. Slow Close
3. Minimum Pick-Up
4. Minimum Voltage

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