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

• 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**
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

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

BD
K9
K9
52a
Y1

S1
S4

ST

V

I (A)
52a

ST

time ms
Trip Coil Current

Safety switch closed

Test initiation

Diagram showing electrical connections with labels such as BD, S1, S4, K9, 52a, Y1, ST, and a graph showing current (I) and time (t) in milliseconds (ms).
Current flows through trip coil
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

$t$ (ms)
Trip Coil Current

- Voltage applied
- Plunger stops
- Contact 52a Open

Three important moments of trip coil current:

- $t_0$
- $t_2$
- $t_3$
Trip Coil Current

- Voltage supply imperfection

$\text{t} - \text{opening time difference 1.7 ms}$
Trip coil current – First Trip

- Auxiliary contact 52a used as trigger

\[ t = 100 \text{ ms pre recording time} \]
Trip coil current – First Trip

- Over laid results

Graph showing trip coil current during first trip and after multiple operations. The time difference is indicated as $t = \text{time difference 52a}$.
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
Comparing with test plan values: Pass/Investigate
“Instant” Velocity Diagram

Travel

Velocity
“Instant” Velocity Diagram

Travel

Velocity

Sharp velocity change

Travel reach for first time open position
“Instant” Velocity Diagram

\[ \Delta X \] Shock absorber travel
\[ \Delta t \] Shock Absorber Time

Travel

Velocity

\[ \Delta X \] Shock absorber travel
\[ \Delta t \] Shock Absorber Time
Timing diagram

- Arcing contact with low pressure
- Bounce

Timing Result Close Operation
Timing diagram

voltage drop on contact in motion

CLOSE

Impedance change

OPEN

Bounce

Timing main contacts

Voltage Drop (V)

Time (ms)
Timing diagram
Main contact timing
## Power Factor Tests

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

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<th>Bus Ft.</th>
<th>Ins#</th>
<th>PH</th>
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<th>mA</th>
<th>Watts</th>
<th>% PF Meas.</th>
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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
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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