MHO TESTING TECHNIQUES AND MATH

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LECTURE GUIDE

- Why have a MHO unit testing techniques and math lecture?
- Simplified explanation of a MHO unit
- Ohms law & phase to phase (ph-ph) MHO unit flip chart.
- 3 phase (3PH) MHO unit flip chart
- Ph-ph voltages applied to the ph-ph MHO units flip chart. Demonstrate using Epochs, phase angle meter and volt meter.
- Zones 1, 2, & 3 MHO characteristic flip chart.
- Thales theorem flip chart.
- Testing techniques using 3ph fault, 3ph values & testing techniques flip charts. Using Epochs & relay prove correct.
- B-C ph fault values for a MHO unit set @ 60° MTA & 7.5Ω reach @ MTA.
- C-A ph fault values for a MHO unit set @ 75° MTA & 6.0Ω reach @ the MTA
- Questions?
**OHMS LAW: Z = E / I**

\[(A)PH - (B)PH MHO UNIT:\]
\[Z = E_{an} - E_{bn} / I_a - I_b\]

\[E_{ab} = E_{an} - E_{bn} = E_{an} \times \sqrt{3} \text{ & leading } E_{an} \text{ by } 30^\circ\]

\[I_a - I_b = 2 \times I \text{ for phase to phase faults. Currents are equal in magnitude & } 180^\circ \text{ apart.}\]

**Therefore: Phase to Phase MHO Units**
\[Z = \frac{E_{ph-ph}}{2I}\]
3 PH MHO UNIT: \[ Z = \frac{E_{I-n}}{I} \]

3 PHASE FAULT, E I-n VOLTAGES COLLAPSE IN ON THEMSELVES.

THE RESPECTIVE PHASE CURRENTS INCREASE IN MAGNITUDE & LAG THEIR E I-n VOLTAGE BY THE LINE ANGLE, OR THE ANGLE DEFINED BY THE FAULT IMPEDANCE WHICH IS MOSTLY LINE IMPEDANCE TO THE FAULT.
Vector Rotation Is Always CCW

Phase To Phase Voltage Vectors

From Phase To Neutral Voltage Vectors

The Phase-Phase Voltages Is The Difference Of Potential Or The Vector Difference Of The Ph-Neut Voltages

180° Lag

270° Lag

90° Lag

0° Reference
MHO CHARACTERISTIC'S 3 ZONES

ZONE 1 = 6.0 m @ 60° MTA
ZONE 2 = 7.5 m @ 60° MTA
ZONE 3 = 9.0 m @ 60° MTA

1 OHM = 2.25 INCHES
EXAMPLES OF THALES THEOREM

USING 1 MHO CHARACTERISTIC: 9.0Ω @ 60° MTA

1 OHM = 2.25 INCHES

CALCULATE REACH @ 15°
CALCULATE REACH @ 120°
22.25"
29.0"
PHASE A to B FAULT DIAGRAM
MHO UNIT
9.0 MVA @ 60° MTA

VECTOR ROTATION
CCW

1 INCH = 10 VOLTS
1 INCH = 5 AMPS

270° LAG

E_{C-N} 70.0 Volts
I_B 5.0 Amps
E_{A-N} 52.0 Volts
I_A 5.0 Amps
E_{A-B} 90.0 Volts
I_A-B 10.0 Amps

180° - -

90° LAG
Aph-Bph TEST VALUES FOR A MHO UNIT
SET AT 60° MTA & REACH AT THE MTA = 9.0Ω

WE WANT 5 AMPS/FAULTED PHASE OF TEST CURRENT FOR THE
REACH AT THE MTA. SO, CALCULATE FOR Ea-b THAT RESULTS IN 5
AMPS TEST CURRENT AT MTA:
Ea-b = Z X I X 2 = 9.0Ω x 5A X 2 = 90 VOLTS PH-PH
Ea-n & Eb-n = Ea-b / √3 = 90V / √3 = 52.0V PH-N

Ea-n=52V@0°, Eb-n=52V@120°, Ec-n=70V@240°, Ea-b=90V@330°

Z @ ±15° OFF OF MTA = 9.0Ω X COS 15° = 8.69Ω
Z @ ±30° OFF OF MTA = 9.0Ω X COS 30° = 7.79Ω
MTA +15° = 75° & MTA -15° = 45°
MTA +30° = 90° & MTA -30° = 30°

REACH @ MTA:  Ea-b=90V@330°
               Ia=5A @ 30°, Ib=5A @ 210°

REACH (RCH) @ 90° & 30°: Ia & Ib = Ea-b / Z@30° OFF OF MTA X 2
                           = 90V / (7.79Ω X 2) = 5.78A

Ia ⊥ = 60° & 0°                FOR REACH @ 90° & 30° RESPECTFULLY
Ib ⊥ = 240° & 180°

REACH (RCH) @ 75° & 45°: Ia & Ib = Ea-b / Z@15° OFF OF MTA X 2
                          = 90V / (8.69Ω X 2) = 5.18A

Ia ⊥ = 45° & 15°                FOR REACH @ 75° & 45° RESPECTFULLY
Ib ⊥ = 225° & 195°
3 PHASE FAULT DIAGRAM

9.0 Ω @ 60° MTA
MHO UNIT

270° LAG

IC-A, IC

-IA

180°

IB

-Ec-A

-Ec-N

IC

EA-N

55 Volts

EA-B

95.3 Volts

IEB 6.11 Amps

IAB 10.59 Amps

EB-C

90° LAG

1 inch = 10 volts
1.14 inches = 1 amp

VECTOR

ROTATION

CCW
3 PHASE TEST VALUES FOR A MHO UNIT SET AT 60° MTA & REACH AT THE MTA = 9.0Ω

WE WANT 5 AMPS/FAULTED PHASE OF TEST CURRENT FOR THE REACH AT THE MTA.
SO, CALCULATE FOR Ea-n, Eb-n, Ec-n THAT RESULTS IN 5 AMPS TEST CURRENT AT MTA:
Ea-n, Eb-n, & Ec-n = Z X I = 9.0Ω x 5A = 45 VOLTS!

Ea-n = 45V @ 0°, Eb-n = 45V @ 120°, Ec-n = 45V @ 240°

Z @ ±15° OFF OF MTA = 9.0Ω X COS 15° = 8.69Ω
Z @ ±30° OFF OF MTA = 9.0Ω X COS 30° = 7.79Ω
MTA +15° = 75° & MTA -15° = 45°
MTA +30° = 90° & MTA -30° = 30°

REACH @ MTA:  Ean=45V@0°, Ebn=45V@120°, Ecn=45V@240°
Ia=5A @ 60°, Ib=5A @ 180°, Ic=5A @ 300°

REACH (RCH) @ 90° & 30°: Ia = Ean / Z@30° OFF OF MTA = 45v/7.79Ω = 5.78A @ 90° & 30°
Ib & Ic = Ia
FOR RCH @ 90°: Ia⊥ = 90°, Ib⊥ = 210°, Ic⊥ = 330°
FOR RCH @ 30°: Ia⊥ = 30°, Ib⊥ = 150°, Ic⊥ = 270°

REACH (RCH) @ 75° & 45°: Ia = Ean / Z@15° OFF OF MTA = 45v/8.69Ω = 5.18A @ 75° & 45°
Ib & Ic = Ia
FOR RCH @ 75°: Ia⊥ = 75°, Ib⊥ = 195°, Ic⊥ = 315°
FOR RCH @ 45°: Ia⊥ = 45°, Ib⊥ = 165°, Ic⊥ = 285°
SOME USEFUL TESTING TECHNIQUES FOR PH-PH MHO UNITS USING 3PH MODERN TEST GEAR CONNECTIONS

- Keep voltage on the un-faulted phase @ nominal voltage and correct angle.
- Leave current at zero amps on the un-faulted phase.
- Use equal impedance test leads for current into the relay and back out to the test gear.
- Never test below an expected current of 5 amps. Do this by picking a test voltage that the expected current calculates out to 5 amps @ the MTA. Reach @ MTA is the highest impedance reach. Now for all other test angles leave test voltage the same.
- To prove the MHO unit characteristic, test 5 points on the circle. For accuracy DO NOT test points further than 30° off of the MTA. i.e. MTA is 60°, test the characteristic at 60°, 60° ± 15°, and 60° ± 30°. (60°, 75°, 45°, 90°, 30°)
- Before proving the MHO unit characteristic, make sure the MTA is within ± 2° of ideal and the reach at the MTA is within +5% of ideal. Make adjustments as necessary and re-check both MTA & reach at the MTA until both are in tolerance. Once both are within tolerance, characteristic checks are almost always within tolerance.
- Never test the MTA by swinging angles beyond 30° off of the MTA. i.e. calculate expected current for 20° off of MTA using the same test voltage calculated earlier. Apply this test voltage & test current to the MHO unit @ the MTA. Check MHO unit contact is closed (raise current until it is). Then swing the angle away from the MTA until contact just opens & record this angle. Then swing the angle back to the MTA & keep swinging the other direction away from MTA until the contact just opens again & record this angle. Add the two recorded angles and divide this sum by 2. This is the MTA of the MHO unit.
BØ – CØ TEST VALUES FOR A MHO UNIT
SET @ 60° MTA & 7.5Ω REACH (AT MTA)

WE WANT 5 AMPS/FAULTED PHASE OF TEST CURRENT FOR THE REACH AT
THE MTA.
SO, CALCULATE FOR Eb-c THAT RESULTS IN 5 AMPS TEST CURRENT AT MTA.

Eb-Ec = Z x 1 x 2 = 7.5Ω x 5A x 2 = 75 VOLTS Ø-Ø
Eb-n & Ec-n = E b-c / √3 = 75V / √3 = 43.3V Ø-N
Ea-n = 70.0V at 0°, Eb-n = 43.3V at 120°, Ec-n = 43.3V at 240°, Eb-c = 75V at 90°

Z at ±15° OFF OF MTA = 7.5Ω x COS 15° = 7.24Ω
Z at ±30° OFF OF MTA = 7.5Ω x COS 30° = 6.50Ω
MTA ±15° = 75° & 45°, MTA ±30° = 90° & 30°

WITH Eb-c = 75V @ 90°
FOR REACH AT MTA: Ib = 5a @ _____°, Ic = 5A @ _____°
FOR REACH AT 75°: Ib = ____ AMPS @ _____°, Ic = ____ AMPS @ _____°
FOR REACH AT 30°: Ib = ____ AMPS @ _____°, Ic = ____ AMPS @ _____°
FOR REACH AT 90°: Ib = ____ AMPS @ _____°, Ic = ____ AMPS @ _____°
FOR REACH AT 45°: Ib = ____ AMPS @ _____°, Ic = ____ AMPS @ _____°
CØ – AØ TEST VALUES FOR A MHO UNIT
SET @ 75°MTA & 6.0Ω REACH (AT MTA)

WE WANT 5 AMPS/FAULTED PHASE OF TEST CURRENT FOR THE REACH AT THE MTA.
SO, CALCULATE FOR Ec-a THAT RESULTS IN 5 AMPS TEST CURRENT AT MTA.
Ec-Ea = Z x I x 2 = 6.0Ω x 5 x 2 = 60 VOLTS Ø-Ø
Ec-n & Ea-n = E a-n / √3 = 34.6V Ø-N
Ea-n = 34.6V at 0°, Eb-n = 70V at 120°, Ec-n = 34.6V at 240°, Ec-a = 60V at 210°

Z at ±15° OFF OF MTA = 6.0Ω x COS 15° = 5.80Ω
Z at ±30° OFF OF MTA = 6.0Ω x COS 30° = 5.20Ω
MTA ±15° = 90° & 60°, MTA ±30° = 105° & 45°

WITH Ec-a = 60V @ 210°
FOR REACH AT MTA: Ic = 5a @ ___, la = 5A @ __?
FOR REACH AT 105°: Ic = ___ AMPS @ ___, la = ___ AMPS __?
FOR REACH AT 60°: Ic = ___ AMPS @ ___, la = ___ AMPS __?
FOR REACH AT 90°: Ic = ___ AMPS @ ___, la = ___ AMPS __?
FOR REACH AT 45°: Ic = ___ AMPS @ ___, la = ___ AMPS __?