LONGITUDINAL INDUCTION VOLTAGE MEASUREMENT

ON

COMMUNICATION CABLES RUNNING PARALLEL TO OVERHEAD LINES

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Introduction

- Electro-magnetic field is created as a result of current passing through the conductor.
- This field induces a voltage on adjacent conductors depending on:
  - Distance
  - Angle
  - Screening
  - Bonding.

Power Engineer's Considerations

- Safety
- Compliance with standards
- Commissioning Tests
- Collaboration of power and communication industries

Standards

- International Telecommunication Union
- Normal Conditions
  - Accessible by public, 60V r.m.s
  - Accessible by technicians, 150V r.m.s
- Fault Conditions
  - 430V r.m.s
  - Probability of faults
  - Protection clearance time

LFI Voltage Limits

LINE CATEGORY	Description	LFI Voltage Limit
A	High Reliability line with protective equipment that would clear an earth fault within *0.35 secs*	1500 V_{rms}
B	High Reliability line with protective equipment that would clear an earth fault in, *from 0.35 secs to 0.5 secs*	1000 V_{rms}
C	Line not classed as a High Reliability as protective equipment would not clear an earth fault within 0.5 secs	430 V_{rms}
All	Normal operating conditions where the cable can be accessed by technicians	150 V_{rms}
All	Normal operating conditions where the cable can be accessed by the public	60 V_{rms}

LFI Hazards

- Hazards to humans (Physiology and probabilistic Analysis)
- Voltage stress on Telecom Cables
- Damage to equipment

Human Effects

- Current Magnitude
- Current path, H-H, H-F
- Duration
- Instant of occurrence during heart cycle
- Body impedance
- Individual sensitivity
- Frequency

Fault Conditions

- Earth faults
  - Zero sequence current in earth-wires
- information needed during the design stage:
  - Phase conductor, earth-wire conductor and tower impedances,
  - Tower dimensions and spanning distances,
  - Fault currents at the substation,
  - Mutual impedances between
    - phase conductors and communication cables,
    - earth-wire conductor and communication cables

Induced Voltage

- Difference between voltage induced by faulted phase conductor and earth-wire.
- **V = CLiK**
  - where: **V** = induced longitudinal voltage [V]
  - **C** = mutual impedance per unit length [ohm/km]
  - **L** = length of exposure (between o/h line and communication cable) [km]
  - **i** = fault current [A]
  - **K** = shielding factor {K=1 for no shielding}

Mutual Impedance

- $C = 2\pi f \left| \log_e (1 + \frac{6 \times 10^5 \rho}{d^2 f}) \right| \times 10^{-4}$ ohm/km
- d = geometric separation between earth return circuits in meters
- ρ = earth resistivity in ohm-meter
- f = system frequency in Hz

Mitigation Measures

- Increasing shielding pairs in communication cables,
- Latent shielding for the communication cables via gas-filled protectors,
- Additional shielding conductor parallel to the power lines/cables,
- Fiber optic interface
- Reducing the fault level.

Commissioning Tests

- Injection in the overhead line and measuring the induced voltages.
- Not practical to inject high currents
- Scaled to maximum fault current assuming system linearity.
- At or close to system frequency (50 Hz in Australia),
- Existence of background noise “standing voltages”.

Test Difficulties

- Inject higher currents and varying the frequency as much away from system frequency as possible.
- Difficulty in adjusting generators to operate in a range, which they are not primarily designed for
  - Phase Angle Meters
  - Double Beam Oscilloscopes
  - Selective Voltmeters
  - Chart Recorders
  - Spike Transient Voltmeters

Test Difficulties

- Heavy equipment
- logistic difficulties
- Great amount of manpower
- Time required for performing tests
- Test in a large area

New Concept

- Primary test equipment capable of generating voltages and currents at various frequencies and connectable to GPS devices.
- Current injection is made with various frequencies, and induced voltage is measured simultaneously with the same applied frequency.
- The results are then extrapolated to show the response of the system for 50Hz frequency.

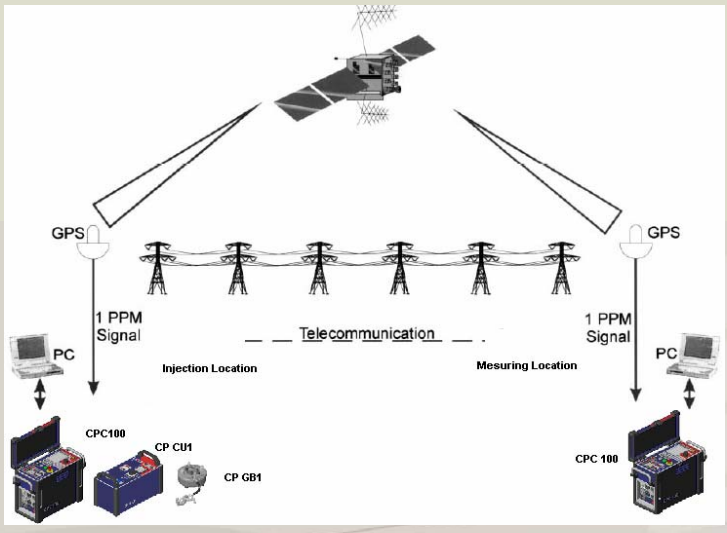
Test Difficulty

- Difficulty is that in some occasions the injection location is far away from the location where induced voltages have to be measured.

Solution

- Two primary test units,
- Global positioning system synchronising devices
- Simultaneous initiation of two sets located at different locations.

Test Set-up



Test Method

- Injection unit at injection location,
- Measuring unit measures the induced voltages at measuring point.
- Measurement with same injected frequency
- Two devices synchronised by GPS synchronising clocks.

Test Method

- Off system frequency injection
- Interpolation of values measured from 30 Hz and 70 Hz injection.
- Extrapolated to maximum fault current
- Checked against allowable limits.

Case Study

- On Friday July 15 2005, Western Power performed the measurement of longitudinal voltage induction for the new Thornlie Railway Line Extension on behalf of Public Transport Authority of Western Australia.

Design Assumptions

- A previous report had determined that induction depending on soil resistivity was:
  - 7.8V – 8.6V under normal train operation,
  - 166V – 204V under traction fault conditions.
  - Both values within allowable range

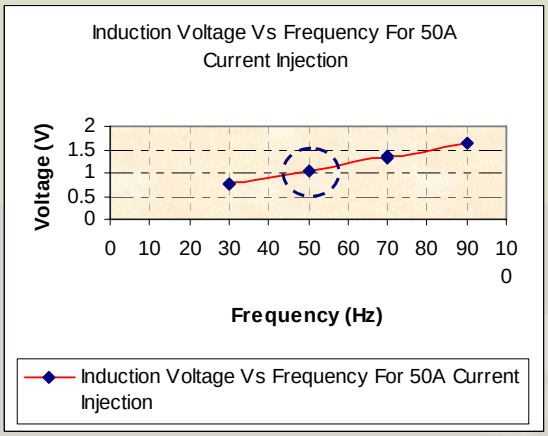
Test Results

- With injection current of 50A
- Voltage rise for two measurements were 1.02 and 1.05v
- Extrapolated to a calculated fault level of 4000A, which was 83V.

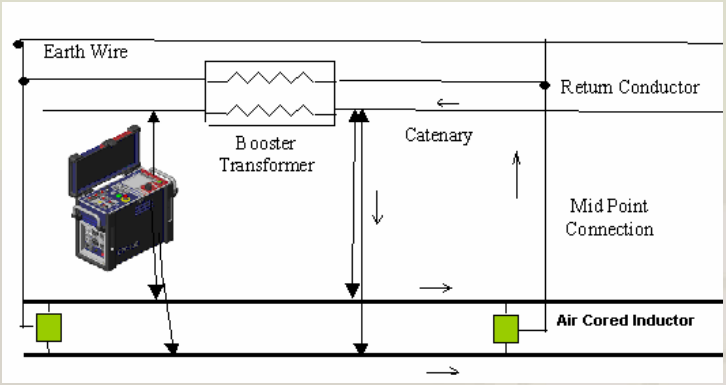
Test Benefits

- Eliminating need for heavy equipment.
- More accurate and meaningful results by filtering out system frequency noise.
- Answer to the problem of testing in a large area.

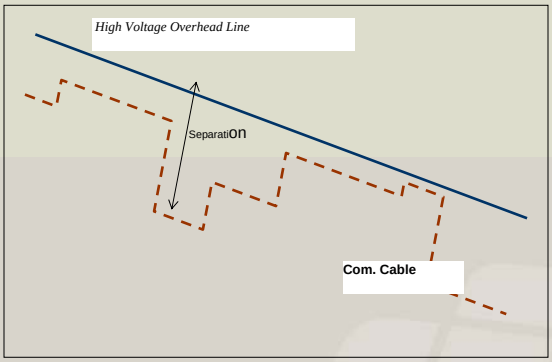
Noise Filtration



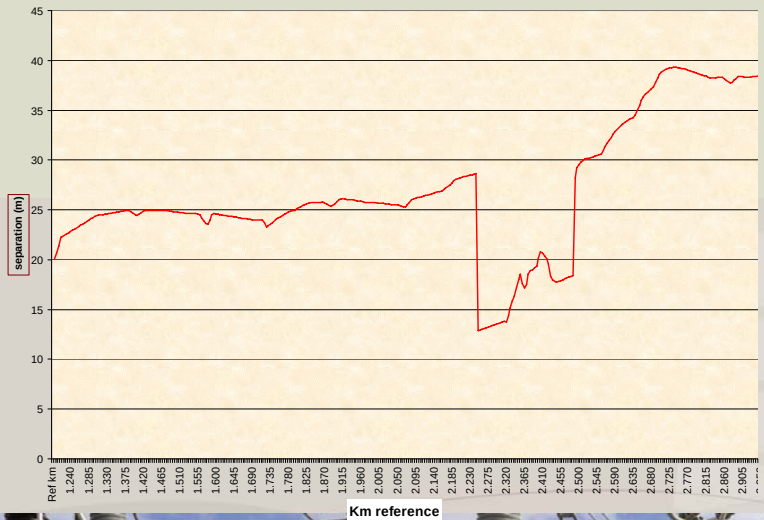
Test Configuration



Line Separation



Line Separation



Thank You for Your Attention!

Any Questions?