# Wind Power Plant Testing and Commissioning

## IEEE PES Wind Plant Collector System Design Working Group

## IEEE PES General Meeting

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# Collector System Commissioning

**Overview:**

- Testing and commissioning of MV systems
- Description & Methodology

**Purpose:**

- Assure all critical equipment installed to industry standards prior to energization
- Provide baseline data for future maintenance
- Collection system outages can be very costly -reportedly $50k to $90k average.

# Collector & Substation Equipment Testing

a. Ground Grid
b. Main Power Transformer
c. Breakers
d. Grounding Transformers/ Zig Zags
e. Arrestors
f. Instrument Transformers
g. Relaying
h. FO, UG, OH Cable Systems

# Main Power Transformer Testing

- Send someone to the factory to witness testing, especially important if this is the first transformer with this configuration and size
- Many owners opt to have the transformer vendor assemble/ fill/and test the transformer to limit transfer of risk to multiple parties
- Have representative on site to sign off tests and compare against factory results
- Use three axis impact recorder during shipping and handling

# Main Power Transformer Testing

When the transformer arrives on site.

1. Megger core ground to tank and compare against factory results
2. Check the three axis impact recorders on arrival and after setting on pad.
3. Verify Vacuum or Dry Nitrogen Pressure when unit arrived on site

# Wind Plant MPT Commissioning

- SFRA : benchmark field test required
- Compare SFRA curves from field and factory
- Owner or representative sign off on the field SFRA test.
- Standard definition: frequency response analysis (FRA)
  - ratio of a steady sinusoidal output from a test object subjected to a steady sinusoidal input.
  - Sweeping through the frequency range of interest gives rise to the S in SFRA.
- Transformer Turns Ratio Test
- Perform at all no load taps – Always test after moving a tap
- If LTC- Select a no Load tap and test at all LTC positions

# Main Power Transformer Typical Field Tests

- Insulation test (bushings and windings)
- Oil sample test after filling -24 hrs after energization
- CT Testing – Ratio, excitation, polarity, continuity
- Sudden Pressure – Verify testing into control house
- Controls – Cooling fans, LTC, etc.
- Check all remote alarms and analogs into SCADA or control house annunciators

# Main Power Transformer Typical Field Tests

## Insulation test (bushings and windings)

- Power Factor - 10 kV for ea. tfmr winding per spec..
  - HV/LV to TV and ground
  - HV/LV to ground, guard on TV
  - TV to HV/LV and ground
  - TV to ground, guard on HV/LV
- The results shall not exceed a 0.5% power factor when corrected to a 20° C reference temperature.

# Main Power Transformer Accessory Field Tests

## CT Testing

- Ratio verification on all taps
- Plot Excitation curves and compare against manufacturers curves
- Polarity checks to ensure correct orientation
- Check for a single ground on the CT circuit
- Continuity test (Loop check of CT circuit)

# Circuit Breaker Tests

- Power Factor Testing- Bushing and Tank
- Time travel tests
- Contact Resistance Test – Micro Ohm Meter

# Circuit Breaker Accessory Tests

1.Current Transformer Tests

2. SF-6 gas in bottle for purity and moisture

3. Trip coils tested at reduced voltage

3a. Ensure dual trip coils do not oppose

4. AC/DC transfer for close circuit

5. Trip and close circuit verification

6. Verify tightness of connections and all factory wiring

# Circuit Breaker Testing

Common Errors

a. Breaker orientation is reversed – Major issue with grounding breakers
b. Wrong Breaker installed – Main or Tie breaker in feeder position
c. DC Hi Pot vacuum breakers – Xray
d. Breaker operated without locking pins removed.

# Commissioning Arrestors

- Verify Nameplate Ratings against BOM
- Power Factor Testing  Similar test results between similar units
- Test for low impedance path to ground grid with no sharp turns

# Switch Commissioning

- Ensure Alignment of contacts
  - Simultaneity of closing
  - Contacts are seated correctly when closed
- Ductor/Micro Ohmmeter of closed contacts
- Check that the switch is oriented per the one line
- Verify switch handle is bonded to ground
- Verify allowable distances to grounded parts –construction may not = engineering
- Make sure the correct identification label gets installed on the correct switch

# Instrument Transformer Commissioning

- Power Factor Testing
- CT testing Same as Breakers
- Typically do not test oil on Instrument transformers but it can be done
- Turns ratio tests for all windings on PTs - Center tap and full taps
- Verify operation of Potential and carrier grounding switches on CCVTS
- Test for continuity on all PT and CT circuits
- Test for a single ground on CT circuits

# Instrument Transformer Commissioning

Common Errors made during commissioning

- Wrong CT or PT ratio connection
- Junction Box Cabinet not vented
- CT physically mounted backwards
- Unused CT circuit  or PT winding not grounded
- Incorrect phases connected to secondary wires

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# Wind Plant Relay Testing

- Important to test the various relay elements that have been set  i.e.: 51PU, 67, 27, 59, 81 O/U
- **More important to verify the logic setting in the relay**.
  - Modern microprocessor relays have few problems related to A/D and element pick up
  - Setting engineers will make more logic setting errors than element setting errors

# Relay Testing Results

All testing results may be subjected to NERC compliance audits. The following should be included in all testing documentation

1. Element testing results
2. Logic Testing results
3. Yellow lines of AC/DC circuit validation
4. Forms showing test results from apparatus testing
5. Relay and Metering Load Checks
6. Certificates of calibration of test equipment

# Wind Plant Energization Testing

- Rotation checks at turbines
- Follow up oil samples at MPT 24hr after energization
- Metering checks and Scada Readings
- Additional relay load checks
- Thermal scan of Substation at higher loads to establish a benchmark – evaluate hot spots

# Commissioning Turbine Transformer

## Similar Tests to Main Power Transformer

a. Turns ratio at all taps
b. Power Factor Testing (Not commonly performed on small)
c. Optional Oil Test
d. Verify ground connections
e. Ensure proper operation of disconnect
f. Check phase identification per engineering drawing
g. Megger the low voltage cables
h. Check rotation on low side after energization

# Overhead Collection Circuits

- Visual inspection
  - Pole top assembly,  plumb structures, rake and camper
  - Bird caging or bend conductor
  - Removal of temporary structures and guy wires in line with anchors
  - Insulators cleaned and correct phasing
- Installation per IEEE 524 or mfg. recommendations sag & tensions recorded
- Pole ground resistance testing –three point fall of potential with shield wires or neutrals removed
- Guy anchor pull test
  - Selective testing
  - Testing per mfg specifications

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# Fiber Optic Cables & Secondary Cables

- Fiber Optic Cables

  - Attenuation (dB) Loss Testing

**OR**

  - Optical Time Domain Reflectometer (OTDR) Testing

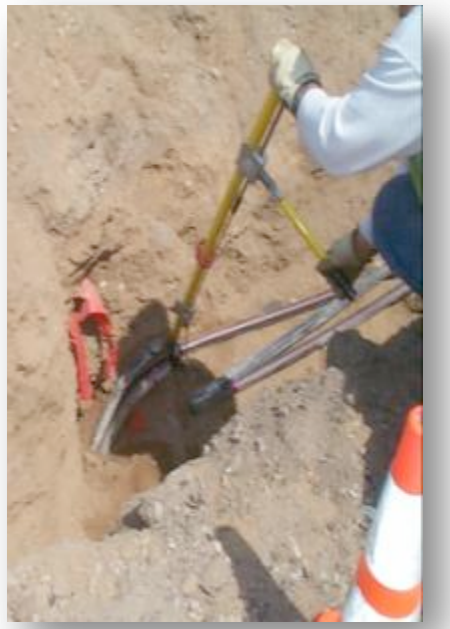
- Secondary Cable -600V or less
  - Ensure that the insulation was not shorted during the installation process. A low voltage insulation resistance measurement of less than 100MΩ may indicate a problem.

  - Verify the cable phasing from one end to the other.

# Medium Voltage Cable Systems

Combination of visual inspections & electrical tests

Visual inspection:

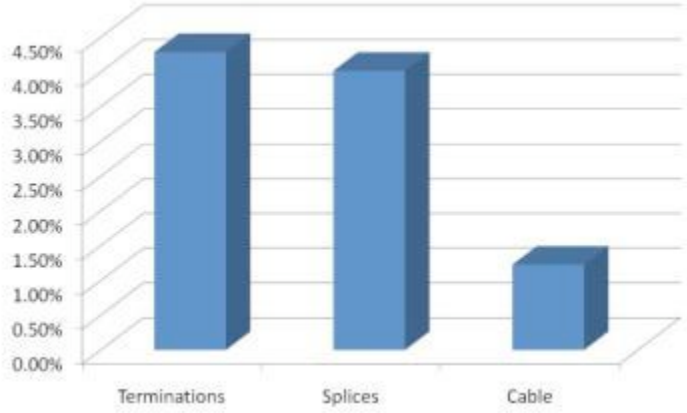


- Physical damage/Bending radius/cable supports
- Separation from instrument/control/ emergency circuits
- Phase identification
- Fireproofing (if required)
- Shield grounding
- Termination connections (clearance & torque value)
- Cable rating

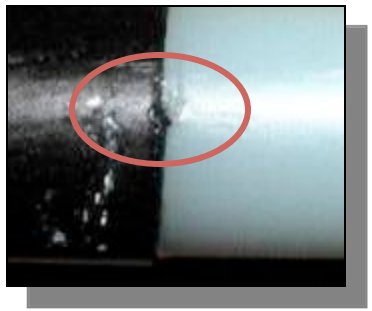
# Medium Voltage Cable Svstems

Electrical Testing:

- Conductor phasing
- Continuity of shield & conductors (opt.)
- Individual cable system test
- Common best practice
  - Off-line 60Hz PD test on individual cable segments per IEEE 48/386/404 and ICEA S-94-649* –locate defects
  - Limited voltage test complete circuit test (≤Uo)
    - DC insulation resistance or 0.1Hz ac withstand test
    - Can detect existing shorts before energization




>13,000 wind farm cable systems
% of components not meeting mfg. standards*



Detectable only with PD test

Knife cut 33% through insulation

Detectable w/PD test, DC insulation resistance, or AC withstand

Severe damage- (HV short)

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# Summary

- Collection system outages can be very costly –high potential of multi-turbine outages
- Assuring all critical equipment installed to industry standards prior to energization is a multistep process
- Provide baseline data for future maintenance
- Standardization of tests and documentation critical to successful implementation

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