

The Impact of Transmission Cable System Construction and Design on Commissioning Test Options & Results

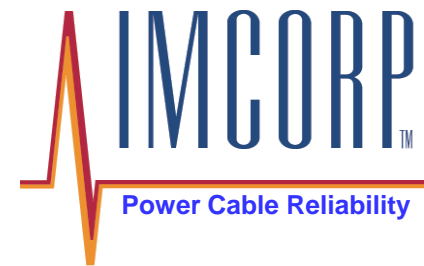
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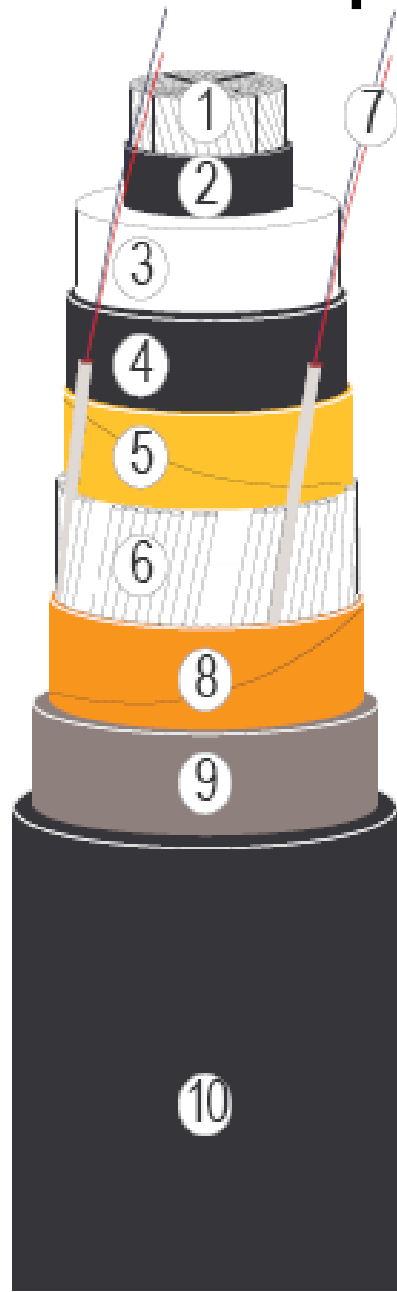


Overview



- 2 recently commissioned 230kV cable systems
- Commissioned using equipment & technologies stationed in the United States
 - 22MVA variable frequency voltage source
 - PD test technology
- Systems have similar component specs.
- Client required 1.7U_o withstand for 60 minutes
- Brief look at how system construction & design impact testing options & results

Cable Description



1 - CONDUCTOR

Cross-section : 3500 kcmil, segmental

Material : copper

Indicative diameter : 2.08 in

2 - INNER SEMI-CONDUCTIVE LAYER

Indicative thickness : 63 mils

Minimum point thickness : 24 mils

3 - INSULATION

Material : cross-linked polyethylene

Minimum average thickness : 920 mils *

4 - OUTER SEMI-CONDUCTIVE LAYER

Indicative thickness : 59 mils

Minimum point thickness : 40 mils

Maximum point thickness : 100 mils

5 - CONDUCTIVE SWELLING BEDDING TAPE

Indicative thickness : 13 mils

6 - ALUMINUM SHIELD WIRES

41 wires of 84.3 mils each

7 - OPTICAL FIBERS

3 FO cables of 2-50/125 μm multimode fibers embedded in a PE jacket

8 - SWELLING TAPE

Indicative thickness : 13 mils

9 - LONGITUDINALLY APPLIED SMOOTH ALUMINUM TAPE

Tape stuck onto the outer sheath

Minimum average thickness : 19.7 mils

10 - OUTER SHEATH AND EXTRUDED SEMICONDUCTING LAYER

Material : high density polyethylene

Minimum average thickness : 110 mils *

INDICATIVE EXTERNAL DIAMETER : 4.84 in

INDICATIVE WEIGHT : 16.6 lbs/ft

Cable System Comparison

Parameter	System A	System B
Length	30,745ft (9,371m)	3,784ft (1,153m)
Termination	Open air, Oil filled	Open air, Oil filled
Joint	16 pre-molded EPDM with shield interrupt	1 pre-molded EPDM no shield interrupt
Grounding Scheme	Single point bonding at each joint –no jumpers	Single point bonding at one termination
PD Test Recmnd'	Segment by segment	Single ended termination test

Comparison of PD Tests

Parameter	Segment	Single Ended
Sensitivity Assessment	Test one segment then assume typical	Entire cable system -no assumption
Location capability	No, detection within segment only	Yes, meter by meter profile
Visibility	2 segments per sensor	Entire cable system
Observation Time	Measurements at ea. accessory at 1 voltage	Measurements during withstand, ramp ↑, & ↓
PD Parameters	Detection, ApC mag. & Phase pattern	Detection, Location, APDIV/EV, ApC Mag. & Phase pattern

Preliminary Sensitivity Assessment for System A (5.8 miles)

- Shield interrupts reflect significant PD signal
- Interrupts cannot be readily jumpered
- Single or double terminal test is not possible
- Segment by segment test necessary
- 5-10pC sensitivity in both directions from one joint position: test at every other joint

Preliminary Sensitivity Assessment for System A (5.8 miles) con't

- 100pC observable through 4 joints thus HF signal blocker necessary at termination
- Probable test capabilities: detect PD from cable, joint, or termination in a +/- 2000ft segment with ~5-10pC sensitivity



System A Results

- Tests performed with multiple sensors in parallel to accelerate test process
- Voltage applied at nearly $1.7U_0$ for 60 minutes
- All cable systems passed the withstand test
- No PD was detected at any of the joint locations



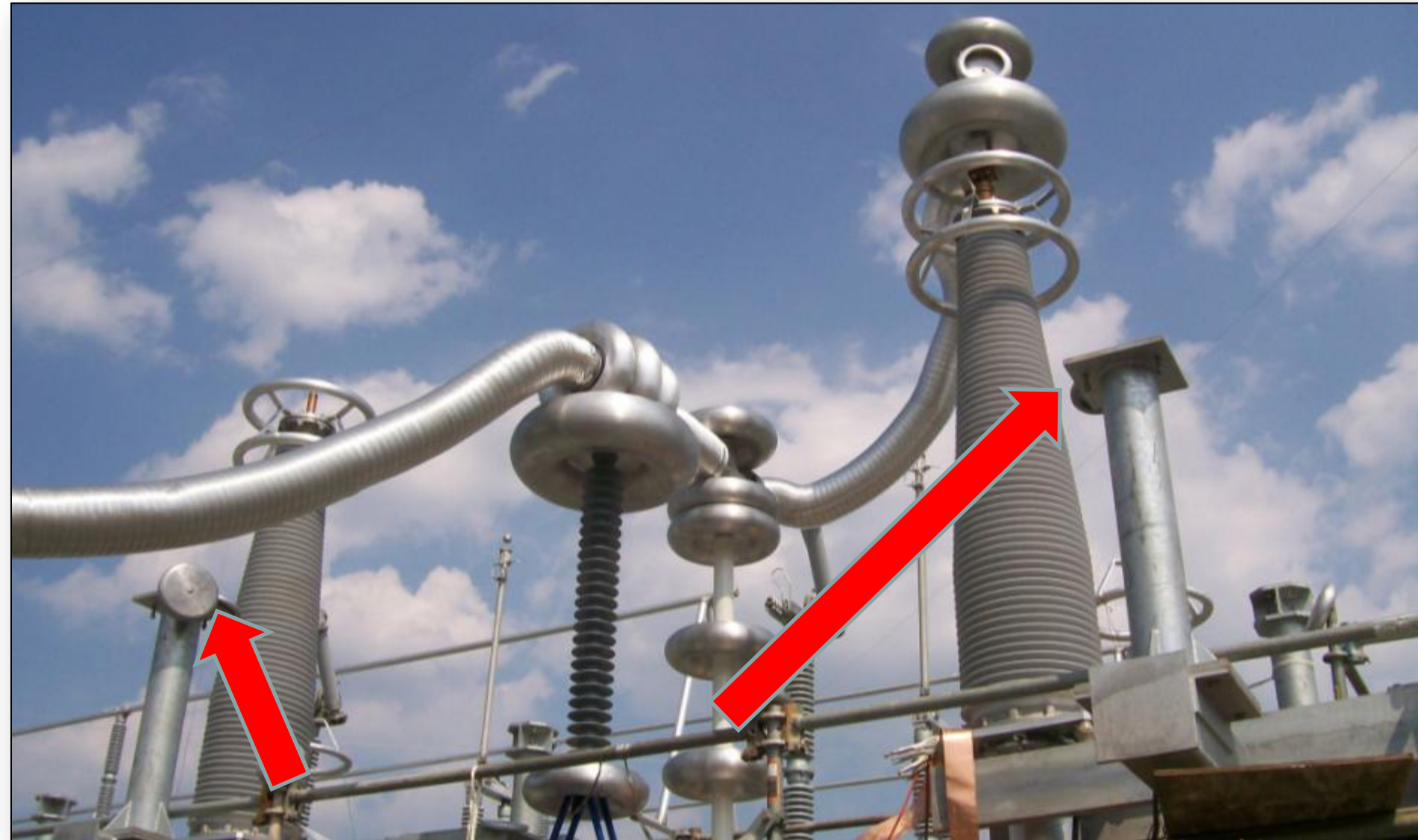
Preliminary Sensitivity Assessment for System B (3,784 ft)

- No shield interrupts
- Sensitivity is better than 5pC for the entire system
- Probable test capabilities:
 - detect & locate PD from anywhere in cable, joints, or terminations
 - better than 5pC sensitivity
 - Observe PD activity during ramp up/down and withstand

System B Results

- Single sensor directly connected to one termination.
<5pC sensitivity achieved
- A & B phases exhibit external corona at the near end terminations at $\sim 1.5U_0$
- Corona rings added on adjacent to equipment with sharp edges to distribute electric stress
- PDIV of external corona goes to $\sim 1.7U_0$
- No other PD sources detected
- A& B phases pass withstand for 60 minutes

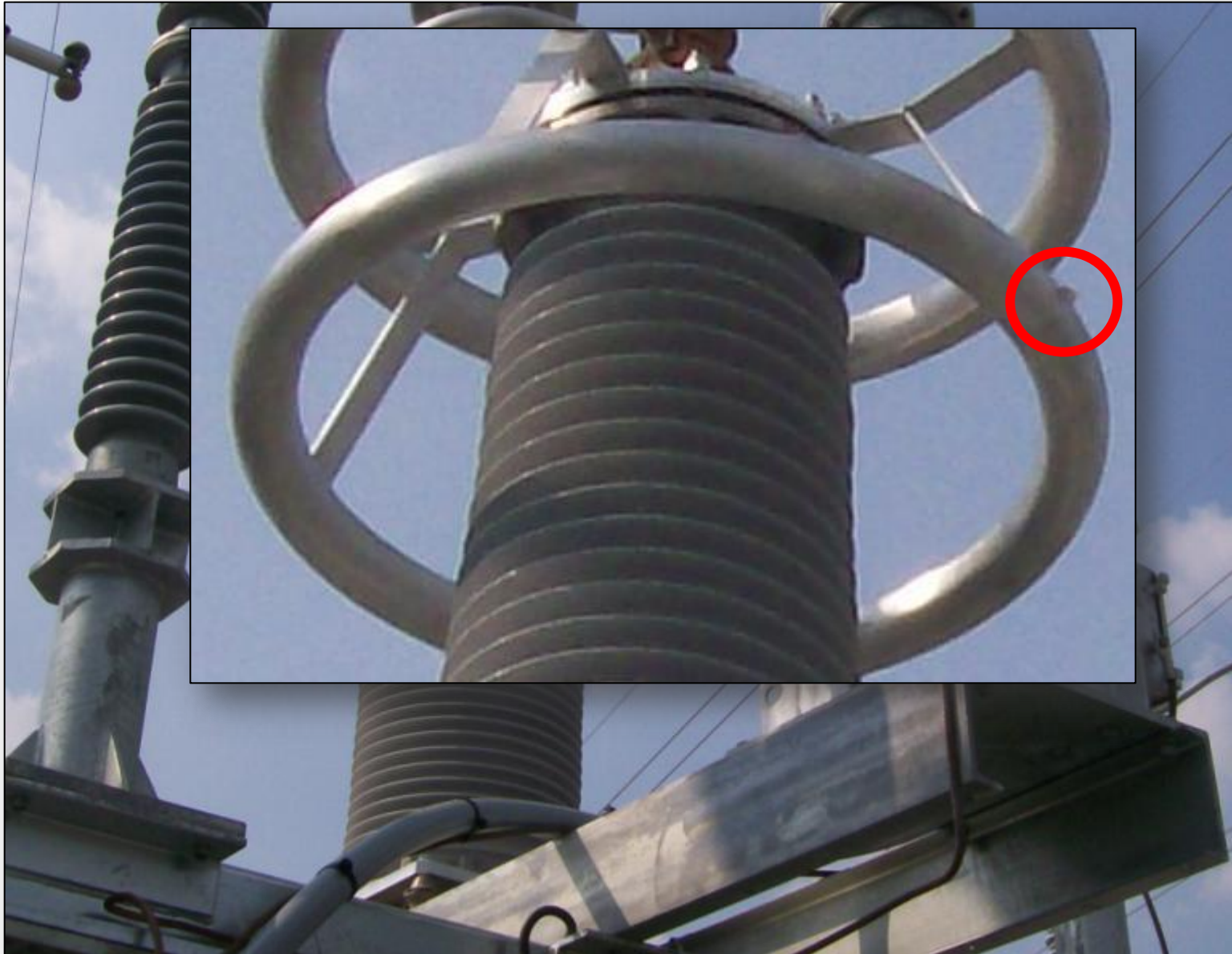
System B Results –corona sources



System B Results con't

- C phase exhibits PDIV $\sim 1U_0$ at far end termination
- PD crew recommends inspection
- Withstand crew continues with $1.7U_0$, 60 minute withstand per cable owner's specification
- Termination did not fail
- Inspection of the far end termination reveals...

Far End Termination Inspection



Positive System Design Attributes

- Aluminum shield with concentric wires
 - Excellent PD signal propagation performance
 - Helps achieve higher sensitivities on long lengths
- Joints have significant capacitive coupling across the shield interrupt
 - Segment testing at every other manhole
 - Terminal testing longer length cable systems (preferred method)

Future Design Considerations

- Accessible bonding lead terminals
 - jumper shield interrupts
 - extend reach of preferred single or double ended terminal tests
- Help cable owner design substation structures which
 - minimize clearance issues
 - use rounded devices

Conclusions

- System construction/ design can significantly impact test options
- Some designs enhance test options
- Preliminary sensitivity assessment is necessary to prove proposed test option
- A meaningful commissioning test includes:
 - Voltage source capable of supplying a realistic transient stress (e.g. $1.7U_0$)
 - A PD test which can provide results comparable to factory tests