PV Interconnection Inspections Conducted for Duke Energy

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Inspection Background

- Conducted as part of Advanced Energy's 2014 ratepayer funded service account projects
- Half-day interconnection inspections and performance evaluations in Duke Energy Progress (DEP) NC territory
- 15 customer owned PV plants, 0.5 MW – 3.3 MW
- Inspections conducted Sept – Dec 2014

Inspection Scope

1. Transformer compliance with inverter requirements
2. Inverter and transformer compliance with interconnection documentation on file with DEP
3. Interconnection protection settings
4. Electrical code compliance at AC equipment pads
5. High-level system performance evaluation

Transformers and Inverters

- Customer owned transformers convert PV plant low voltage (<1 kV) power to utility distribution level voltage (12-23 kV)
- Inverters convert PV array DC power to utility compatible AC


SUNNY CENTRAL 750CP-US
UTILITY
GRADE
PHOTOVOLTAIC SYSTEM
AC DISCONNECT

Key Findings

- Transformer requirements
- Interconnection documentation vs. actual installation
- Interconnection protection settings
- Electrical code violations
- Performance evaluations

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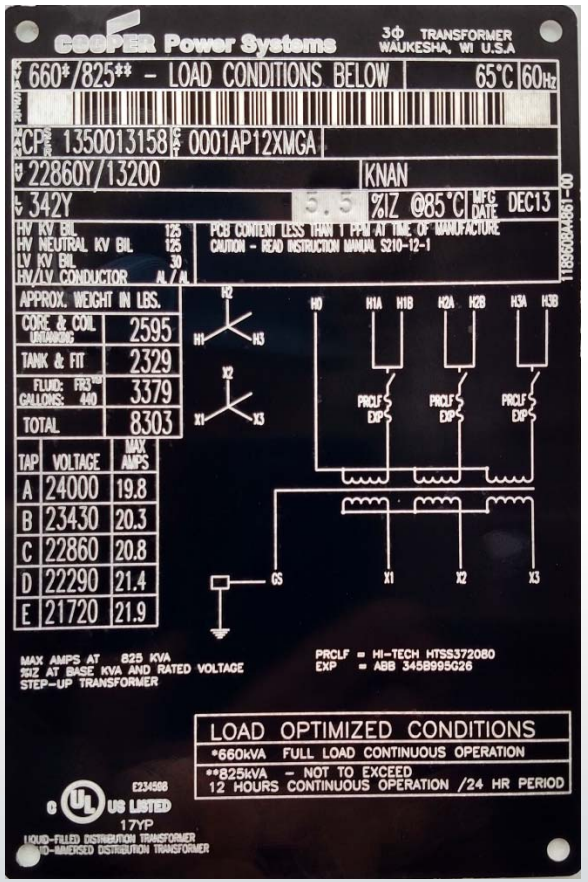
Transformer Requirements

- Inverter manufacturers specify the types of transformers that can be used with their inverters
- Advanced Energy (AE) found that with some transformer types, inverters do not always detect a loss of single phase power on the three phase utility distribution line
- 4 of the 15 sites inspected have a transformer type that desensitizes the inverter's ability to detect a loss of single phase power on a three phase line
- This is a potential safety concern and Duke Energy has taken measures to address the issue



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Interconnection Documentation

- DEP has a customer interconnect requests (IR) and interconnection agreements (IA) on file for each site
- The as-built site configuration for 9 of the 15 sites did not agree with the interconnection documentation filed by site owner

Site No.	Parameter Differing from Interconnection Documentation			
	AC Rating (kW)	Inverter Type	Transformer Size	Transformer Type
Site 3				X
Site 8		X		X
Site 9			X	X
Site 10	X	X		
Site 11				X
Site 12	X	X	X	X
Site 13				X
Site 14		X		X
Site 15	X			

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Interconnection Protection Settings

- Inverter interconnection protection settings prevent PV plants from energizing utility lines during an outage
- DEP requires inverter interconnection protection settings for voltage and frequency to be adjusted from factory default

Utility Required Interconnection Protection Settings		
Parameter	**Setpoint**	**Time Delay (sec)**
Under voltage #1 (27-1)	0.90 per unit	0.16
Under voltage #2 (27-2)	0.90 per unit	0.16
Over voltage #1 (59-1)	1.10 per unit	0.16
Over voltage #2 (59-2)	1.10 per unit	0.16
Under frequency (81U)	57.0 Hz	0.16
Over frequency (81O)	60.5 Hz	0.16

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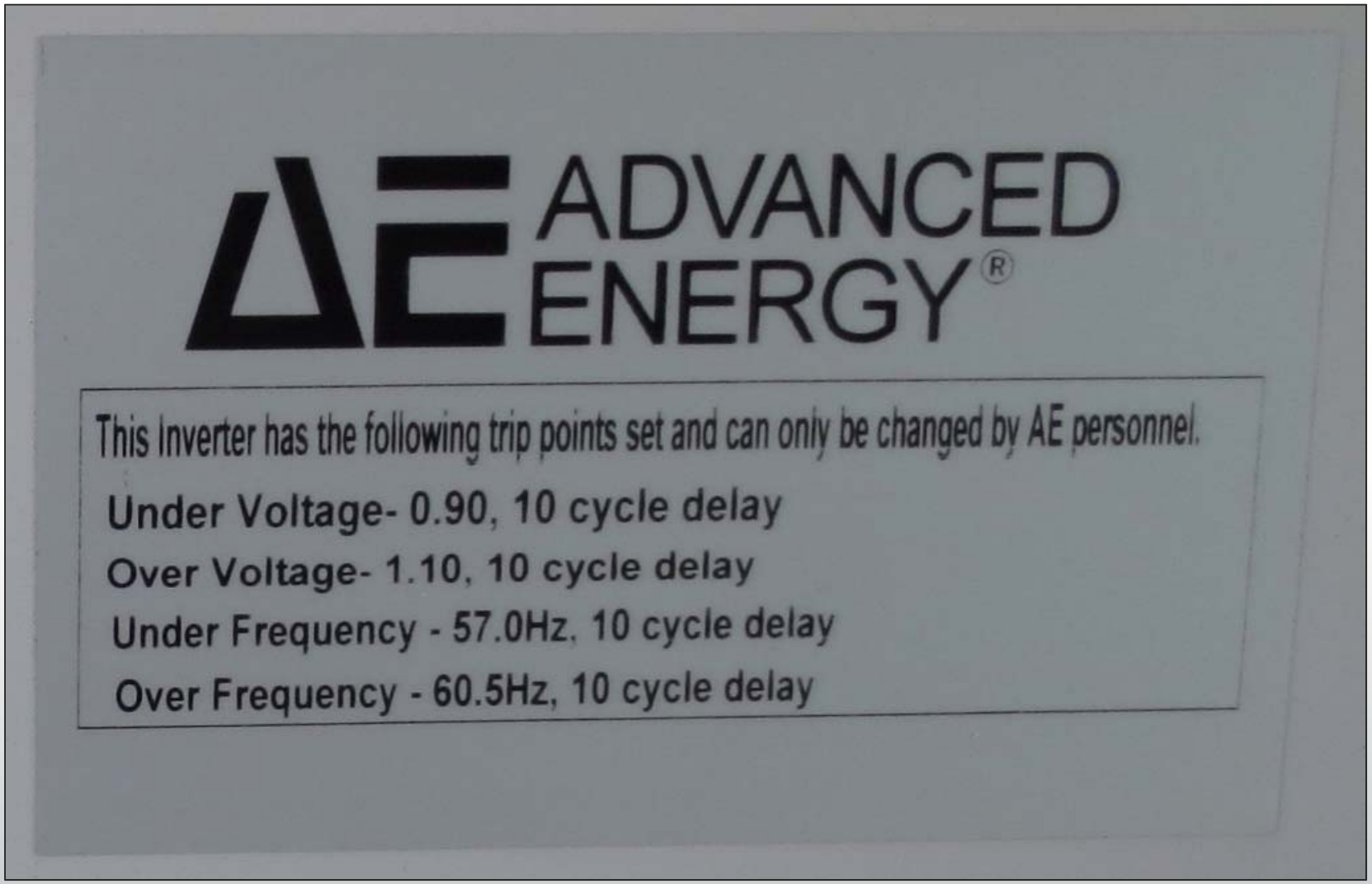
Interconnection Protection Settings

- No sites fully comply with the utility's required interconnection protection settings
- Under Frequency
  - All sites will trip offline due to under frequency before desired by the utility
- Under Voltage and Over Voltage
  - All sites will take longer to trip offline due to abnormal voltage than desired by the utility

Interconnection Protection Settings



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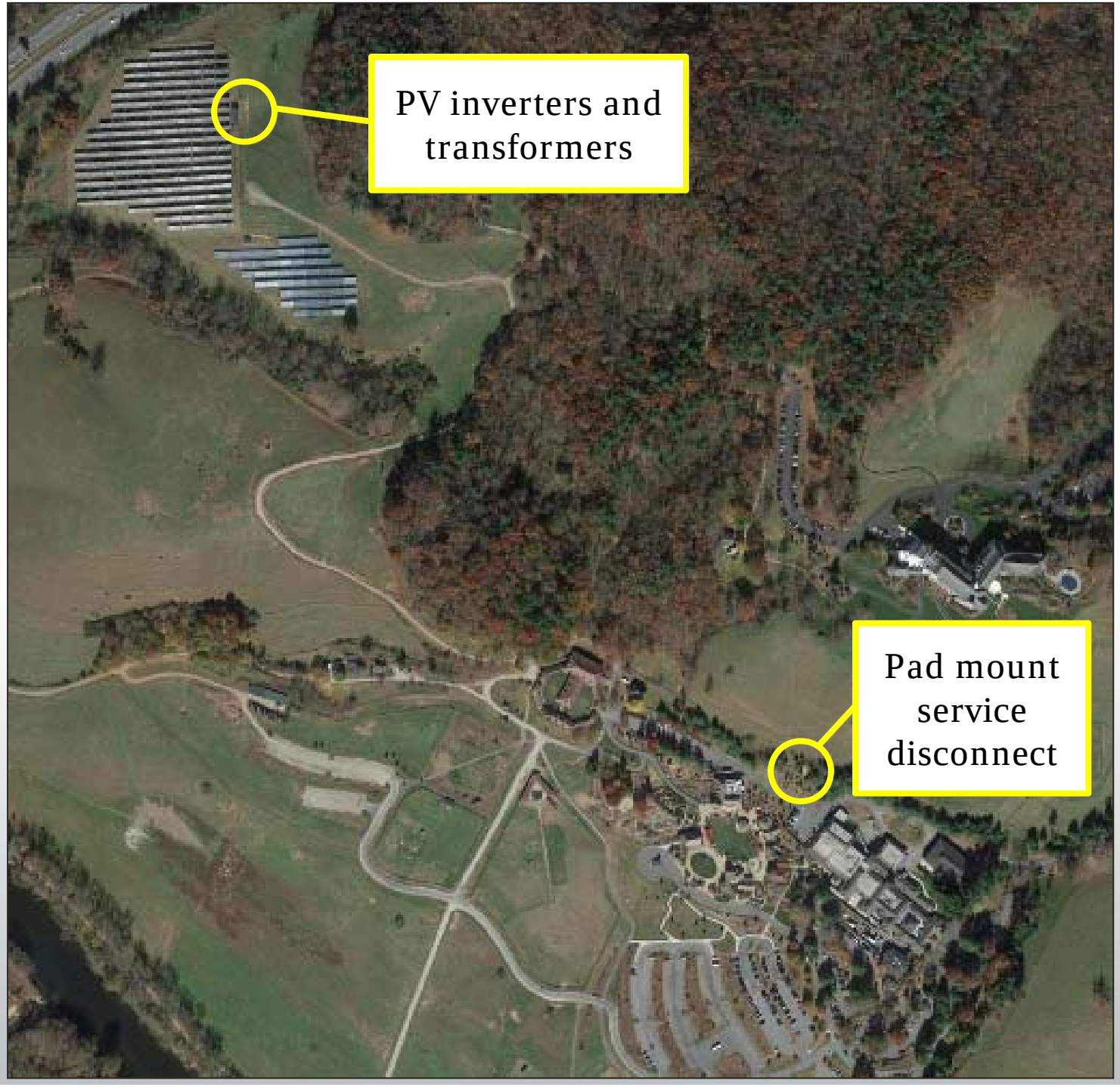
Electrical Code Violations

Missing Service Disconnect

- 2 of the 15 sites do not have a customer owned service disconnect located at the PV site, creating unsafe situations
- 1 of these 2 does have a customer owned service disconnect, but it is located ½ mile away at a poorly marked pad-mount disconnect switch


PV inverters and transformers
Pad mount service disconnect

Electrical Code Violations

Missing AC Ground Detectors

- 8 of the 15 sites do not have the required AC ground detectors on ungrounded AC inverter feeders

Key Findings

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Performance Evaluations

- Site performance is given in terms of performance factor (PF):

  PF = measured kW ÷ expected kW

- At the time of inspection, weather conditions were acceptable for testing at 10 of the 15 sites

Performance Evaluations

Site No.	AC Rated Capacity (MW)	Performance Factor (PF)	Notes
Site 1	1	80.2%	8% of array was out of service
Site 2	0.50	94.0%	
Site 3	0.55	93.1%	
Site 4	2	79.8%	
Site 7	1	92.5%	
Site 8	2	98.7%	
Site 9	2	85.9%	Substantial vegetation shading
Site 10	0.52	85.5%	
Site 13	1	86.2%	4.4% of array was out of service
Site 14	2	91.8%	
Total	**12.57**	--	
Weighted PF	--	**88.6%**	

Performance Evaluations

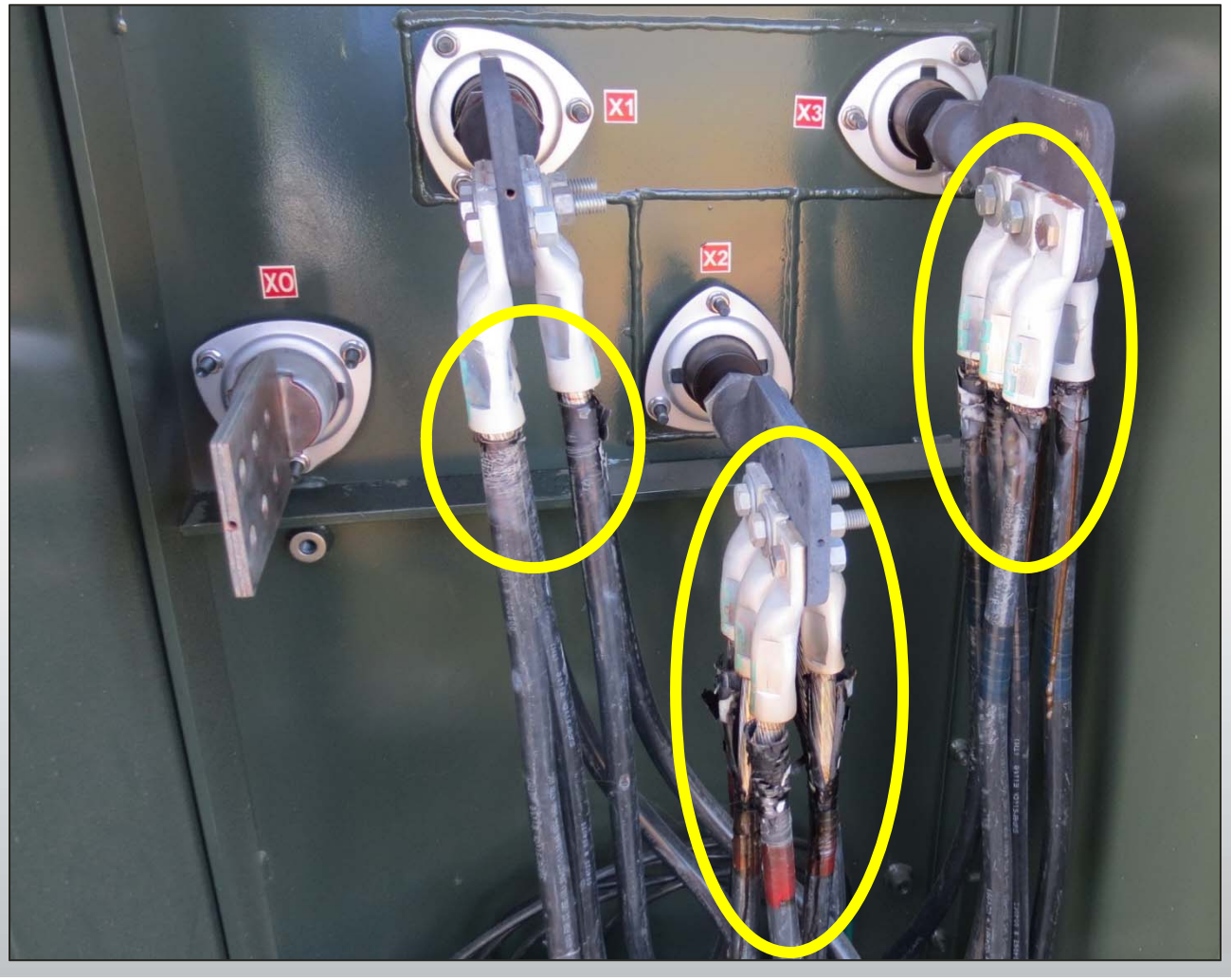
Solar/tree farm – 85.9% performance factor

Another Interesting Finding

- At one site, owner and contractor were not aware they owned the transformers
- They didn't have keys to open the transformers
- It took two hours, three trips to a hardware store, a broken bolt cutter and a battery powered angle grinder to open the transformers
- When they did get the transformers open…

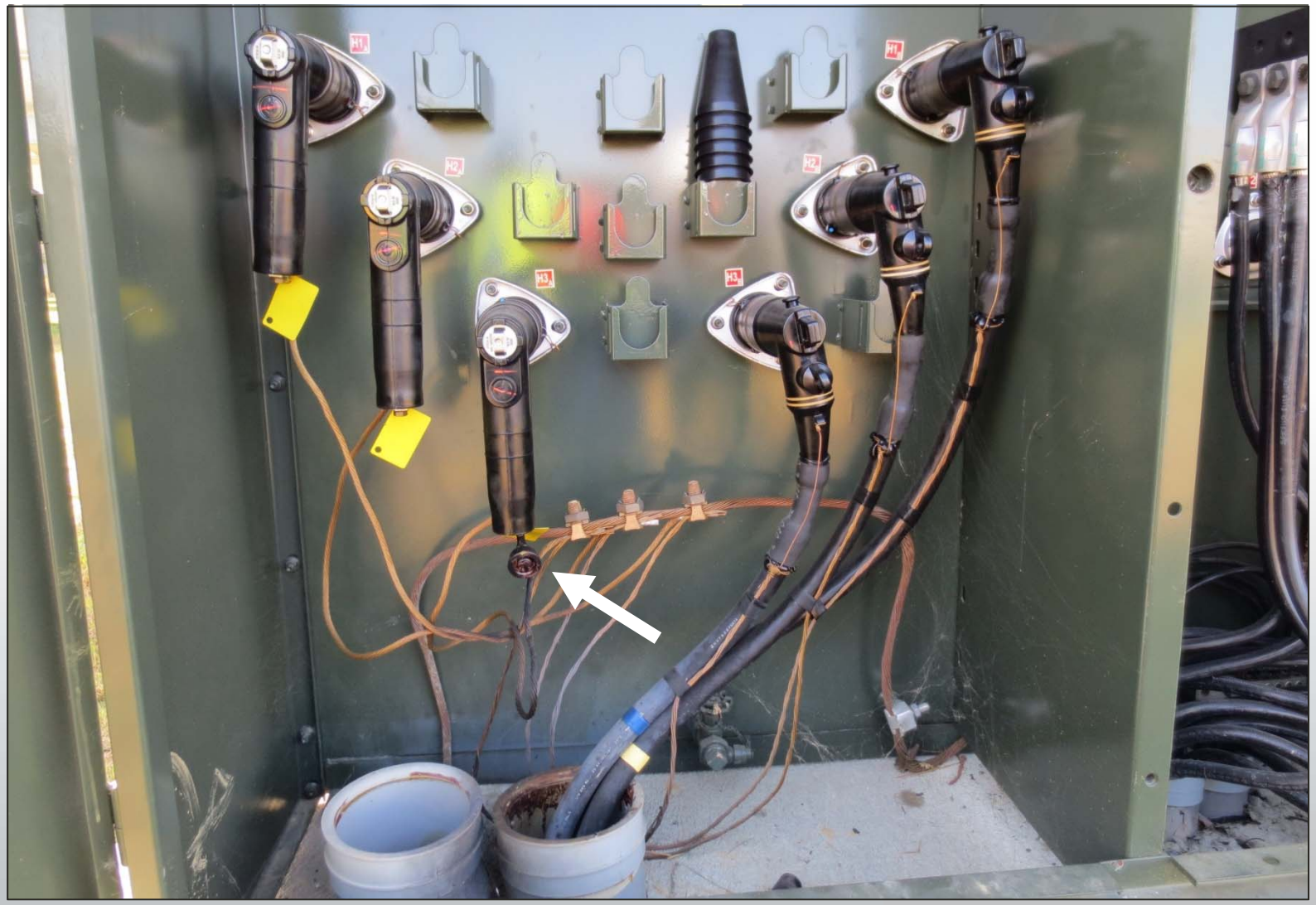
Another Interesting Finding

- Insulation was burned off the secondary conductors within one transformer



Another Interesting Finding

- One surge arrestor was blown out



Inspections Summary

- 27% of sites have a transformer type that may create an open phase safety problem
- As-built configuration at 60% of sites does not comply with interconnection documentation on file with the utility
- No sites fully comply with the utility's required interconnection protection settings
- 53% of sites have obvious electrical code violations
- Weighted avg. performance factor = 89%

Inspection Follow Up

- AE shared these findings during two meetings with DEC/DEP staff and a meeting with the Public Staff in 2015
- AE presented these findings at the Utility Solar Conference in San Diego in April 2015
- Duke Energy is requiring PV plant owners to make changes to the interconnection protection settings
- Duke Energy has implemented extra safety measures for sites with open phase concerns
- In 2015 Advanced Energy is conducting interconnection inspections at 42 additional sites in DEP and DEC territories in NC

Thank You

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