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The Future of Power over Ethernet (PoE) and Smart Energy Transfer Technologies

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UL

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Session 4: *New Powering Solutions*
March 24, 2022

PoE and Smart Energy Transfer Technologies — Agenda

1. History
2. Technologies – Fault-Managed Power Equipment (Class 4)
3. Installation and Use – NEC 2023 Updates
4. Safety Concerns
5. Safety Standards
6. Applications

History

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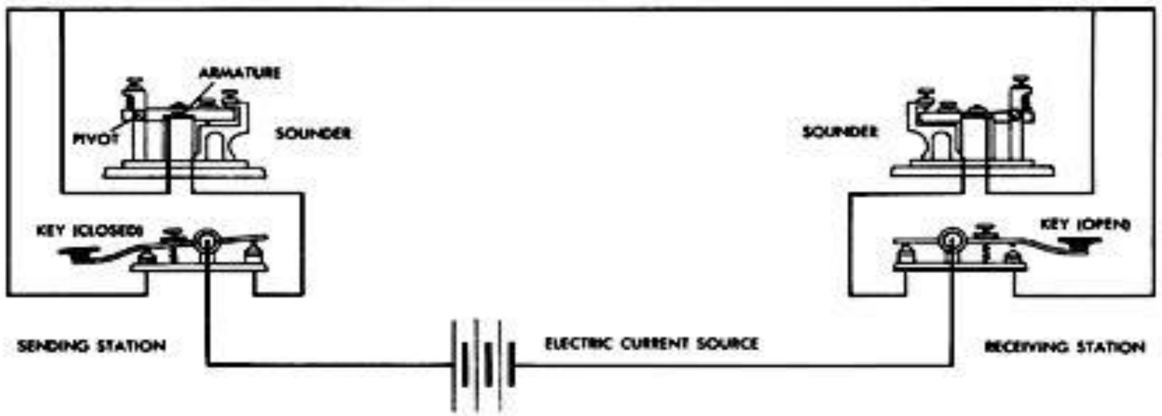
PoE and Smart Energy Transfer Technologies — History

Power over communications cable:
A general term for technologies that enable network cables to carry electrical power.

1. Power over Ethernet (PoE) – IEEE
2. Power over Ethernet Plus (PoE+) – IEEE
3. High Power PoE (PoE++) – IEEE
4. Universal Power over Ethernet (UPoE) – Cisco
5. Power over Data Lines (PoDL) – IEEE single pair
6. Power over HDBaseT (PoH) – HDBaseT Alliance
7. Power over Cable (PoC) – non-standardized/proprietary systems
8. Packet energy transfer/fault-managed equipment (Class 4 power systems)

PoE and Smart Energy Transfer Technologies — History

- 1938 – Simple morse telegraph — power was also the signal



PoE and Smart Energy Transfer Technologies — History

Power over Ethernet — Power Capabilities

1. 2000 – Inline power (Cisco) ~ 7 Watts
2. 2003 – IEEE 802.3af ~ 15 Watts
3. 2009 – IEEE 803.2at ~ 30 Watts
4. 2011 – Universal Power over Ethernet ~ 60 Watts
5. 2019 – IEEE 802.3bt ~ 90 Watts – 100 Watts

PoE and Smart Energy Transfer Technologies — History

Limitations of traditional Power over Ethernet:

1. Transmission distance is limited – only transmits data up to 100 meters

2. Power is limited – comparable to Class 2 outputs

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Technologies — Fault-Managed Power Equipment

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PoE and Smart Energy Transfer Technologies — FMPS

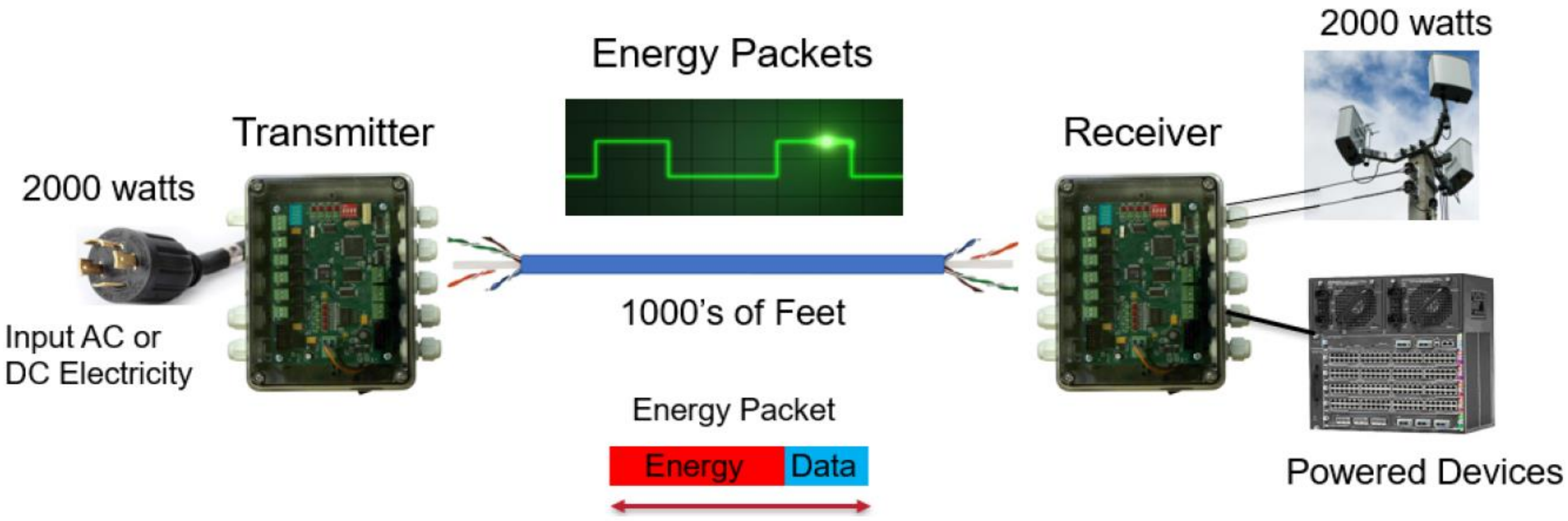
What is a Fault-Managed Power System (FMPS)?

- Fault-Managed power systems consist of a Fault-managed power transmitter and a Fault-managed power receiver connected by a cabling system. These systems are characterized by monitoring the circuit for faults and controlling the power transmitted to ensure the energy and power delivered into any fault is limited. Fault-managed systems differ from Class 1, Class 2, and Class 3 systems in that they are not limited for power delivered to an appropriate load. They are power limited with respect to the risk of shock and fire between the transmitter and receiver.

- Class 4 circuits shall be supplied from a power source (transmitter) that has a peak voltage output of not more than 450 volts line to line or 225 volts line to ground.

- No power limitation on the output.

PoE and Smart Energy Transfer Technologies — FMPS



Example of a Fault-Managed System

PoE and Smart Energy Transfer Technologies — FMPS

How do FMPS (Class 4) systems work?

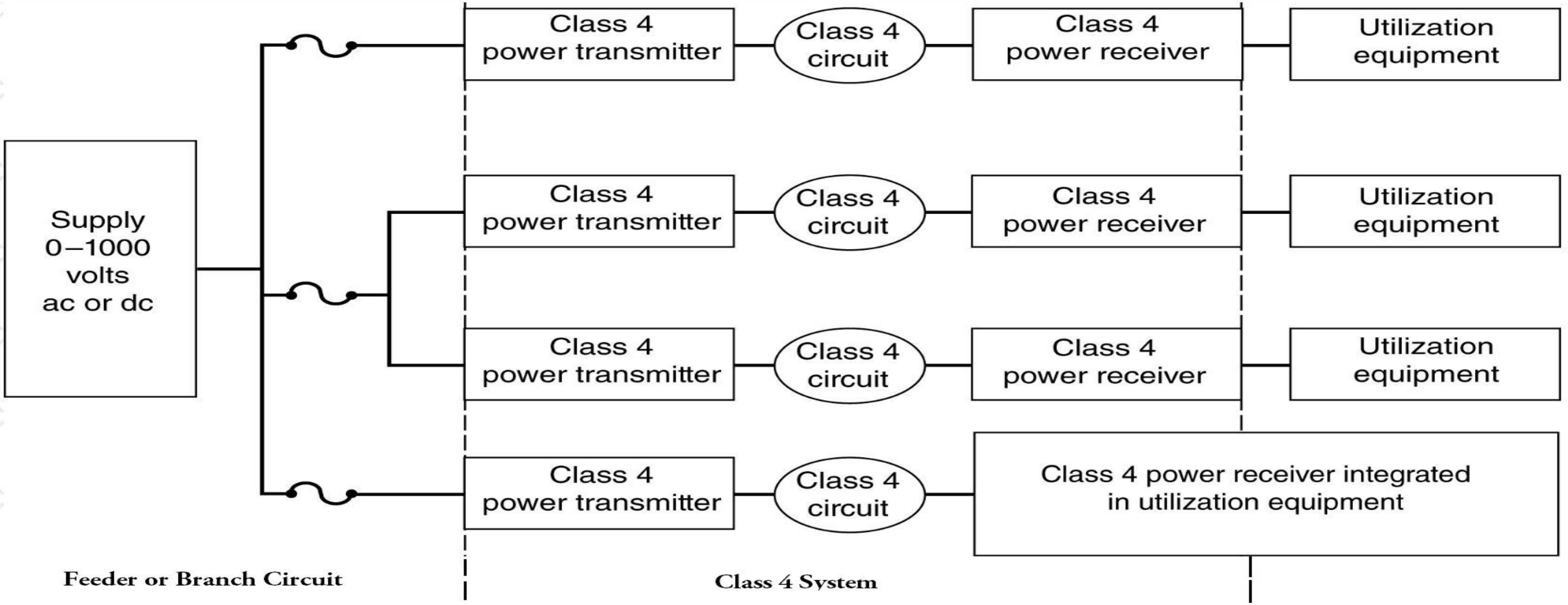
- Send – a pulse ~ 500 per second
- Stop
- Look – for lost energy between the transmitter and receiver (a fault or some other issue)
- Verify – if safe, send another pulse — if not, stop
- Convert – receiver converts back to analog electricity

PoE and Smart Energy Transfer Technologies — FMPS

Hazards Mitigated by FMPS

- High current/short circuit – circuit breaker
- Ground fault – ground fault circuit interrupter
- Arc fault – arc fault circuit interrupter
- Resistive fault/loose connection
- Touch fault

PoE and Smart Energy Transfer Technologies — FMPS



PoE and Smart Energy Transfer Technologies — FMPS

Advantages of Fault-Managed Systems:

1. Transfer of significant power – 1000-2000 Watts
2. Able to transfer power over significant distances – thousands of feet
3. Ease of installation – less cost, no conduit required, less copper, more affordable technician labor
4. Safety – system parameters are continuously monitored for any type of fault (short circuit, faulty wiring, etc.)
5. Wiring methods – allows the use of higher voltages and the delivery of considerably more power without reverting to NEC Chapter 3 wiring methods, while maintaining an acceptable level of safety

Installation and Use NEC 2023 Updates

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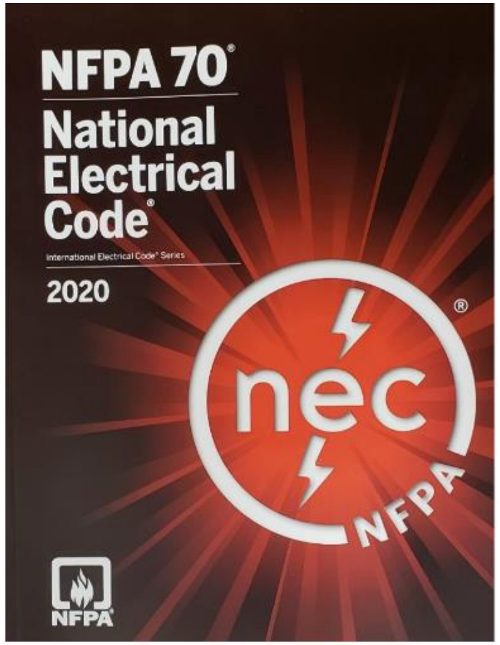
PoE and Smart Energy Transfer Technologies — NEC 2023 Updates

1. Article 726 (New) – Class 4 Power Systems

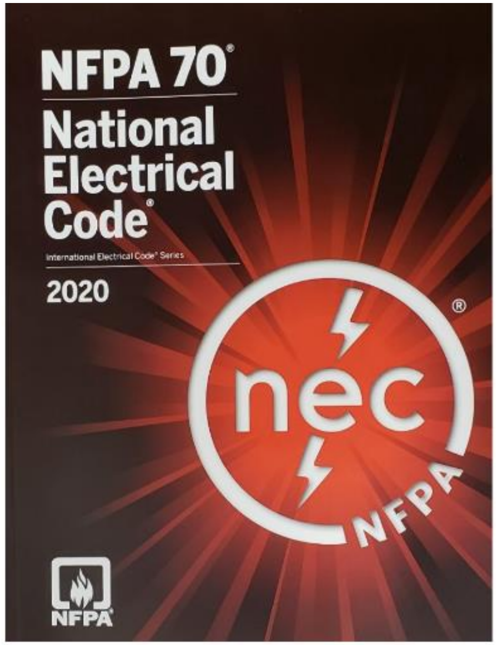
- Covers installation of wiring and equipment of Class 4/fault managed power systems (FMPS), including utilization equipment incorporating parts of these systems.
- Excludes installation in dwelling units
- Transmitter output voltage is not more than 450 V peak
- Transmitter must be listed (UL 1400-1, the Outline of Investigation for Fault-Managed Power Systems, Part 1 – General Requirements, is referenced)
- Cables should also be listed UL 1400-2: FMPS – Cables
- Connecting hardware shall be listed
- Class 4 cable shall not be placed with any Class 1 circuits unless separated by a barrier
- Class 4 cables can be permitted in the same cable assembly as Class 2, Class 3 and communications circuits provided the insulation is at least that required by Class 4 circuit.



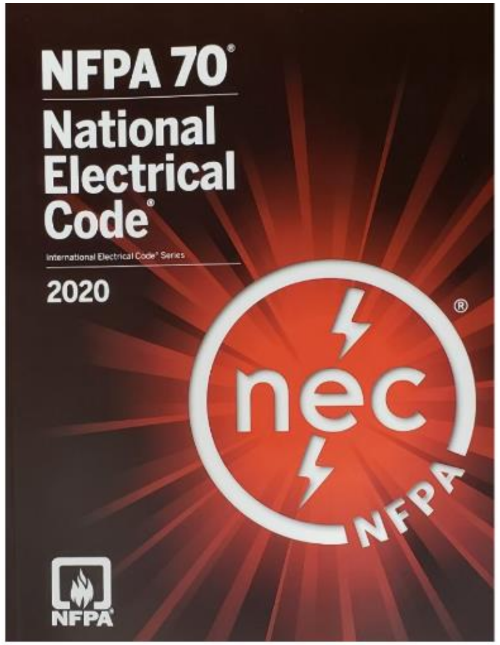
PoE and Smart Energy Transfer Technologies — NEC 2023 Updates

1. **A FMPS/Class 4 transmitter must be able to interrupt an energized FMPS/Class 4 circuit under any any of the following conditions:**

   - A short circuit
   - A line-to-line fault condition that presents an unacceptable risk of fire or electric shock
   - A ground-fault condition that presents an unacceptable risk of fire or electric shock
   - An overcurrent condition
   - A malfunction of the monitoring or control system presents an unacceptable risk of fire or electric shock
   - Any other condition that presents an unacceptable risk of fire or electric shock



PoE and Smart Energy Transfer Technologies — NEC 2023 Updates



1. **Article 722 (new) – cables for fault-managed power/Class 4 circuits**

   - Covers general requirements for the installation of single- and multiple-conductor cables used in Class 4 fault-managed circuits, and optical fiber installations.
   - Conductor sizes not smaller than 24 AWG
   - Insulation shall be rated not less than 450 V DC
   - Temperature rating shall be not less than 60 C (140 F)
   - Class 4 cables are required to be listed (UL 1400-2, the Outline of Investigation for Fault Managed Power Systems, is referenced)

Safety Concerns

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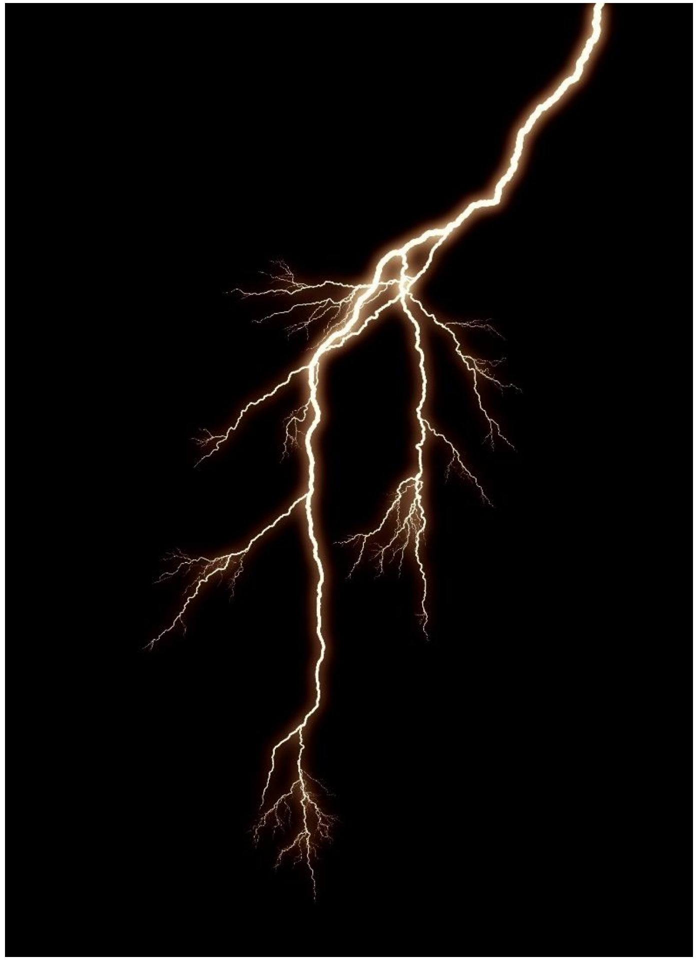
PoE and Smart Energy Transfer Technologies — Safety Concerns

1. Shock Hazards

- New technology
- Lack of available data on failure modes
- Power and voltage rating of the systems



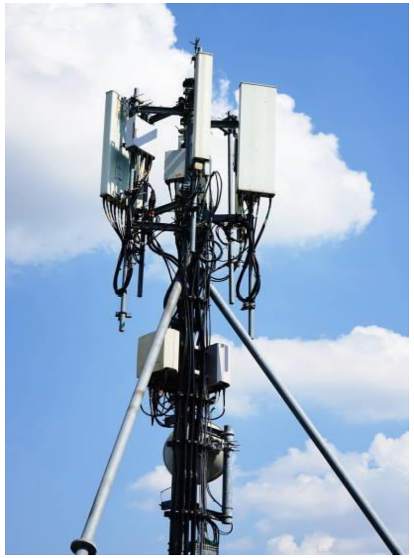
PoE and Smart Energy Transfer Technologies — Safety Concerns

1. Overheating of Cable

- Larger bundles and higher currents produce excessive heat

PoE and Smart Energy Transfer Technologies — Safety Concerns

1. Exposure to transients – concerns with exposure to radiofrequency (RF) and microwave radiation



- The race for 5G – small cell towers everywhere
- The number of cell towers needed to make 5G work: hundreds of thousands, maybe millions

Safety Standards

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PoE and Smart Energy Transfer Technologies — Safety Standards

UL Standard

1. **Standards development started in earnest in March of 2021 (Chaired by Randy Ivans)**
   - UL established a working group with industry members with the following goals:
     - Develop safety Standards for FMPS – equipment and cables

2. **Industry members participating in UL's working group**

1. ATIS
2. Belden
3. Cisco
4. Alpha Technologies
5. Corning Cable Systems
6. Leviton
7. Hubbell
8. Voltserver
9. Southwire
10. Commscope
11. Daikin America
12. Schneider Electric

PoE and Smart Energy Transfer Technologies — Safety Standards

UL Standard

1. Challenges

- New technology – not a lot of data available (kind of a magical black box)
- Create a standard that is technology agnostic
- Create a standard that addresses Ventricular Fibrillation AND Let-Go
- What are the different "states" of the system: On, Off, other transmitting modes?
- How should the system react after a fault?
- Re-Energization Times after a fault?

PoE and Smart Energy Transfer Technologies — Safety Standards

UL Standard

1. Challenges

- Define appropriate waveforms
- Creating new test methodologies
  - Test method for evaluating waveforms for electric shock has proven to be difficult
  - Must account for accumulation of multiple pulses
  - Many different types of waveforms to account for:
    - Continuous DC
    - Pulsed DC
    - Sinusoidal AC
    - AC + DC
    - Pulsed DC + DC

PoE and Smart Energy Transfer Technologies — Safety Standards

1. **UL 1400-1, the Outline of Investigation for Fault-Managed Power Systems, Part 1 – General Requirements**

UL Standard

Scope: This Outline of Investigation specifies requirements for fault-managed power systems, also referred to in the National Electrical Code® as "Class 4 Power Systems". Class 4 Power Systems consist of a Class 4 power transmitter and a Class 4 receiver connected by a Class 4 cabling system.

Status: not published

PoE and Smart Energy Transfer Technologies — Safety Standards

1. **UL 1400-1, the Outline of Investigation for Fault-Managed Power Systems, Part 1 – General Requirements**

UL Standard

- General requirements are based on UL 62368-1, the Standard for Audio/video, information and communication technology equipment - Part 1: Safety requirements
- Functional Safety – analysis of all potential hazards (including a failure modes and effects analysis)

a. Unwanted auto restart
b. Exceeding fault power limit
c. Exceeding arc energy limit
d. Ground fault
e. Overvoltage
f. Overcurrent
g. Stored energy
h. Not able to keep FMPS within safe limit

PoE and Smart Energy Transfer Technologies — Safety Standards

UL Standard

1. **Some of the required tests – UL 1400-1**

- Electric shock tests – evaluation for let-go and ventricular fibrillation
- Available fault power – parallel and series faults
- Arc-fault protection

PoE and Smart Energy Transfer Technologies — Safety Standards

UL Standard

1. Fault analysis is done using a simulated body impedances against an established shock curve.

		Ohms	
	Heart Current Factor	Minimum	Intermediate
Across the line (Hand-to-hand)	0.4	575	2000
Each Line to Ground (Hand to both feet)	1.0	500	2000

Simulated Body Impedances For Short Fault Duration Tests

NOTE 1: For the purpose of this test, the impedance is purely resistive.

PoE and Smart Energy Transfer Technologies — Safety Standards

UL Standard

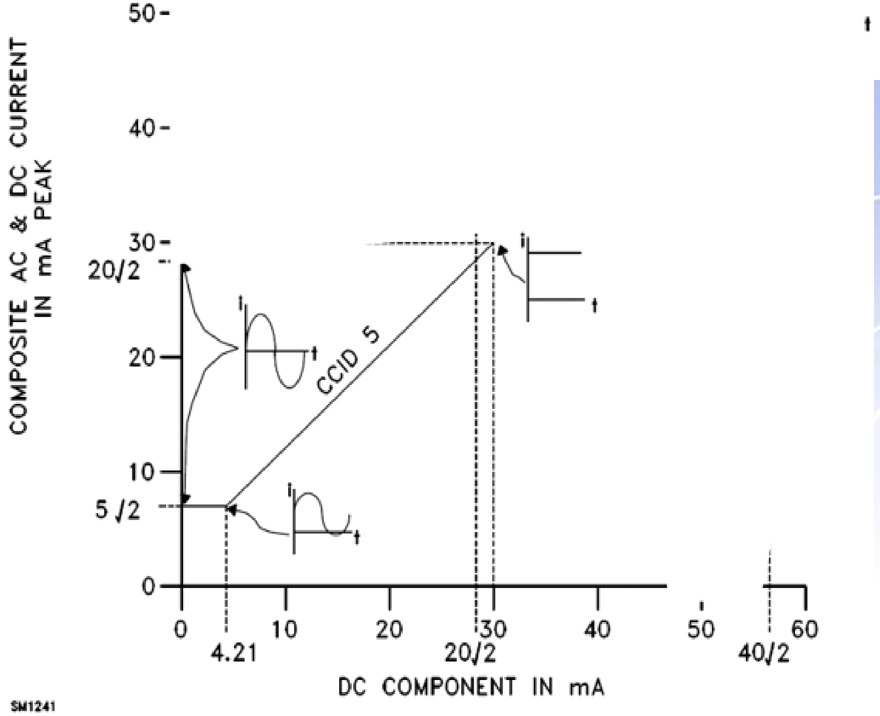
1. Fault analysis is done using a simulated body impedances against an established shock curve.

	Heart Current Factor	Ohms (Note 1) Max DC (Note 2)	Ohms (Note 1) Max AC (Note 3)
Across the line (Hand-to-hand)	N/A	$V_{peak}/0.030$	$V_{peak}/0.005$
Each Line to Ground (Hand to both feet)	N/A	$V_{peak}/0.030$	$V_{peak}/0.005$

Simulated Body Impedances for Long Fault Event Duration Tests

PoE and Smart Energy Transfer Technologies — Safety Standards

UL Standard

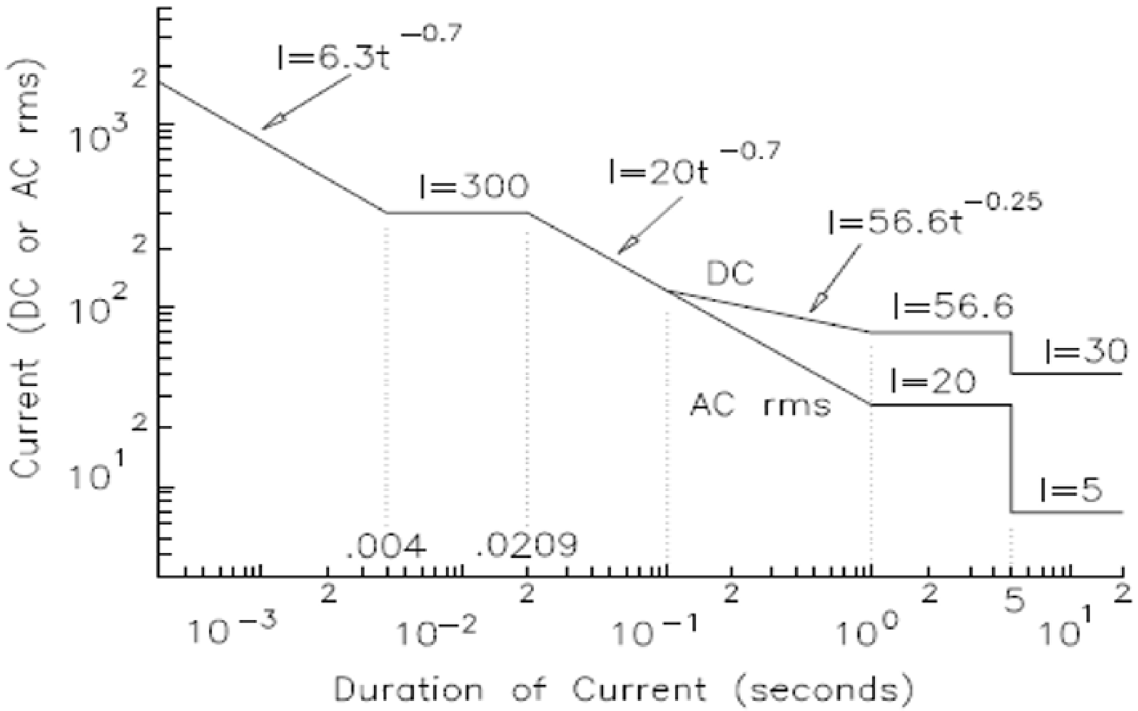


Let-go limit for combined AC and DC, and combined pulsed DC and DC

PoE and Smart Energy Transfer Technologies — Safety Standards

UL Standard

Maximum current as a function of duration



PoE and Smart Energy Transfer Technologies — Safety Standards

1. **UL 1400-2, the Outline of Investigation for Fault-Managed Power Systems, Part 2 – General Requirements for Cables**

UL Standard

Scope: These requirements cover 60 C to 250 C (140 F to 482 F) single- and multiple-conductor, jacketed cables for use as fixed wiring within buildings, may be used outdoors and/or for direct burial in Class 4 circuits in fault-managed power systems as described in Article 726 and other applicable parts of the National Electrical Code (NEC). Cables covered by these requirements include CL4P (plenum cables), CL4R (riser cables) and CL4 (general purpose cables).

Status: Published Jan. 6, 2022

PoE and Smart Energy Transfer Technologies — Safety Standards

UL Standard

1. **Some of the required tests – UL 1400-2**

- Cold bend test of insulation and of complete cable
- Smoke and flame test
- Sunlight resistance test
- Long term insulation resistance in water for wet-rated and direct burial cables
- Short term insulation resistance
- Test for oil resistance
- Cable heating test for 18 AWG and smaller cables
- Dielectric tests
- Crush resistance for thin-wall insulation

Applications

PoE and Smart Energy Transfer Technologies — Applications

1. Sports stadiums and arenas – 5G applications
2. Hotels and resorts
   - The Sinclair Hotel in Fort Worth, Texas, uses FMPS to power all the switches in the hotel
3. Office buildings
4. Airports or other passenger terminals
5. Manufacturing facilities
6. Wireless access points
7. Routers and servers
8. Smart displays and digital signage