Fault Managed Power Systems (FMPS)

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PROTECTION ENGINEERS GROUP

Four-Legged Stool of Success for a New Powering Technology

Use Outdoors or areas controlled by utilities
- GO95 – 128
- NESC

Indoor and customer premise use
- NEC
- UL Listing Requirements

Different Flavors of 5G

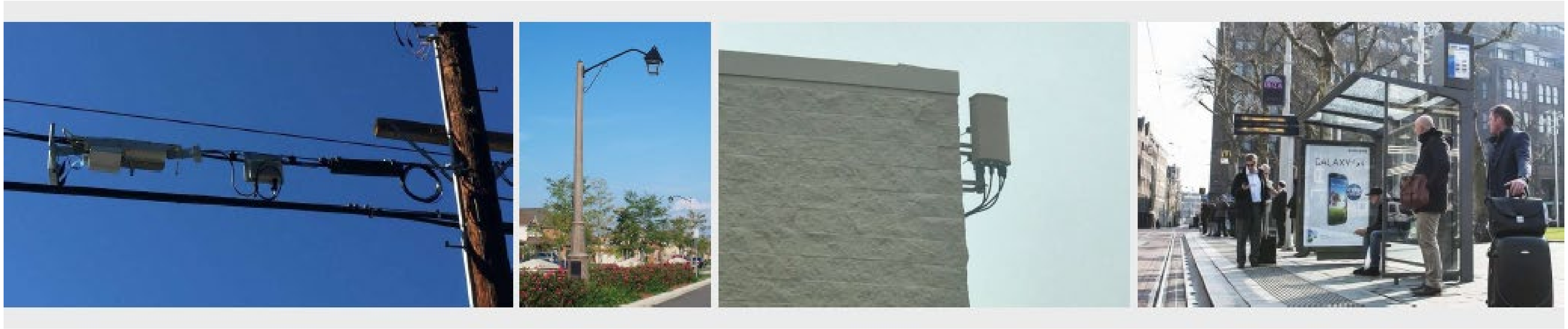
- **Lower-band 5G** provides a blanket layer for wide coverage, sometimes referred to as the coverage layer. Low-band refers to frequencies below 1 GHz used to roll out substantial 5G coverage as quickly as possible. A low-band cell site can cover hundreds of square miles as well as deliver a downlink data rate from 30-75 Mbps download.

- **Mid-band 5G** is suited to provide solutions in major metropolitan areas. Mid-band 5G uses mid-range frequencies (spanning 1 GHz and 6 GHz) that strike a balance between coverage and capacity, with operators currently deploying 2.5 GHz in the U.S. This is sometimes referred to as Sub-6 or Sub-6 GHz 5G and provides service over a fairly large service areas and provides download speeds around 115-223 Mbps.

- **High-band or millimeter Wave (mmWave) 5G** is also well suited to provide high-speed connectivity in major metropolitan areas. Peak speeds of nearly 1 Gbps, and upload speeds near 50 Mbps.

What Is a Small Cell?

Small cells are low-cost radio access points with low radio frequency (RF) power output, footprint and range



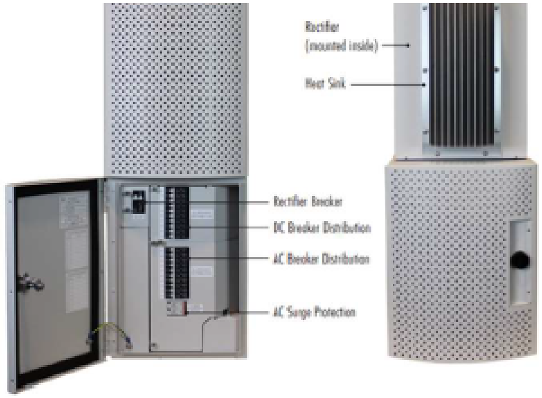
- Typically mounted on or in variety of places including poles, on walls, or within "street furniture"
- Types of small cells: Micro Cells | RRH/RRU/Street Macro

Power Deployment Obstacles

- Compromise between radio site optimization and infrastructure availability
- Utility power availability
- Cost of power tap
- Time for utility to provide power
- Power meter – cost and location
- Timing of the permitting and approval processes
- Lack of control over the approval and deployment process
- Future expandability

Local Power

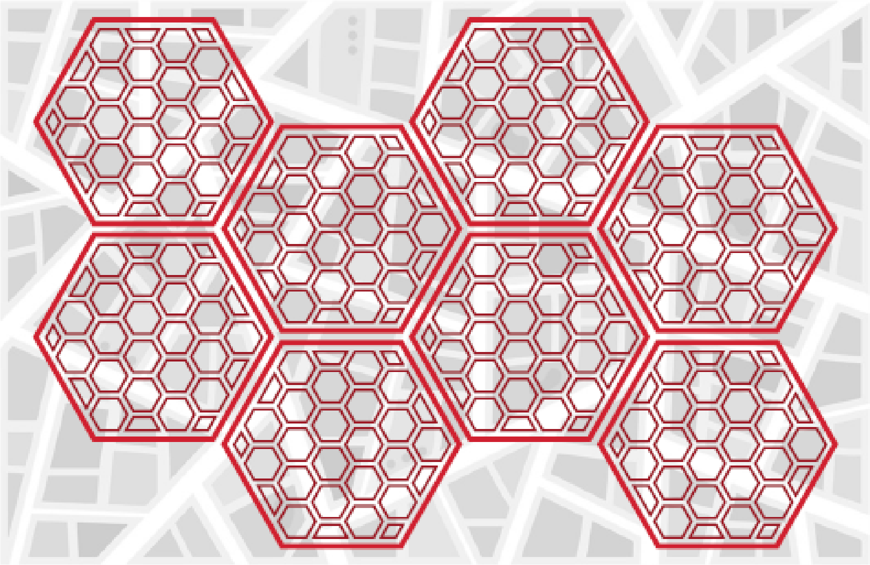
- AC power directly into the radio
- DC power supply unit for RRH/RRU

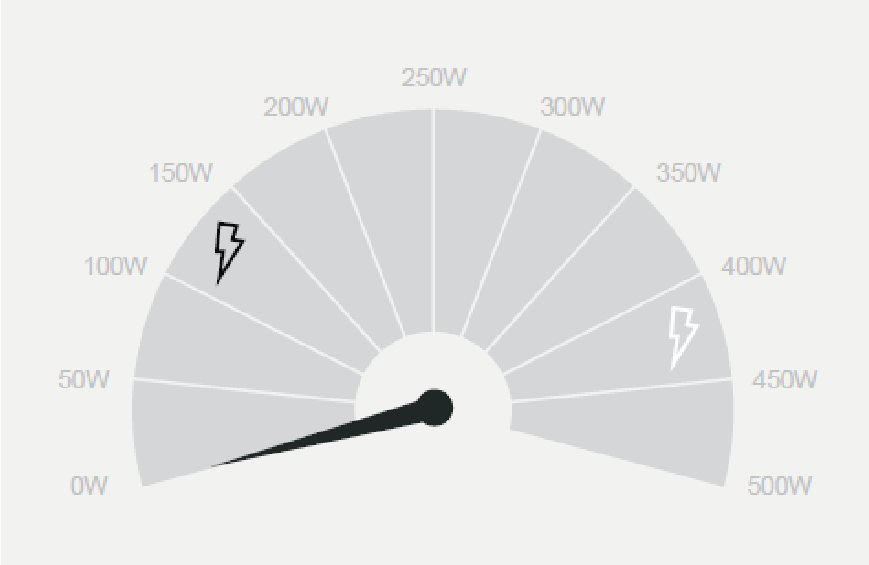


PROS	CONS
✓ Very simple installation	× AC power may not align with small cell location
✓ Well understood, existing standards	× Every radio needs a power drop
✓ Readily available in many cases	× Time to permit and/or run new power lines can be lengthy
	× Backup will be expensive from a TCO perspective for each site

High Power Demand

Small Cell Densification	High Power Demand



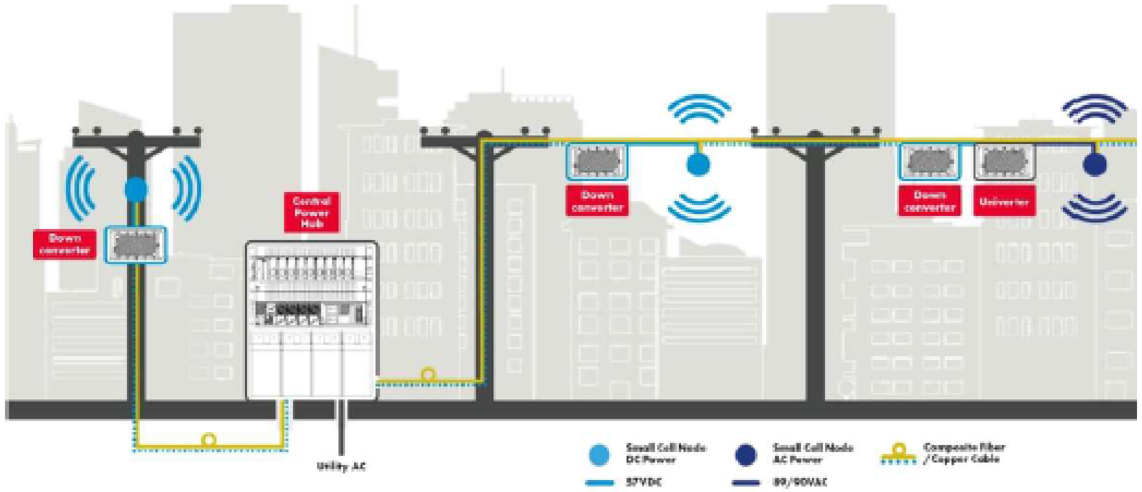


Bandwidth demand →
new spectrum (mid/mm), densification

Power hungry radios →
Current safety standards limit safe power distribution

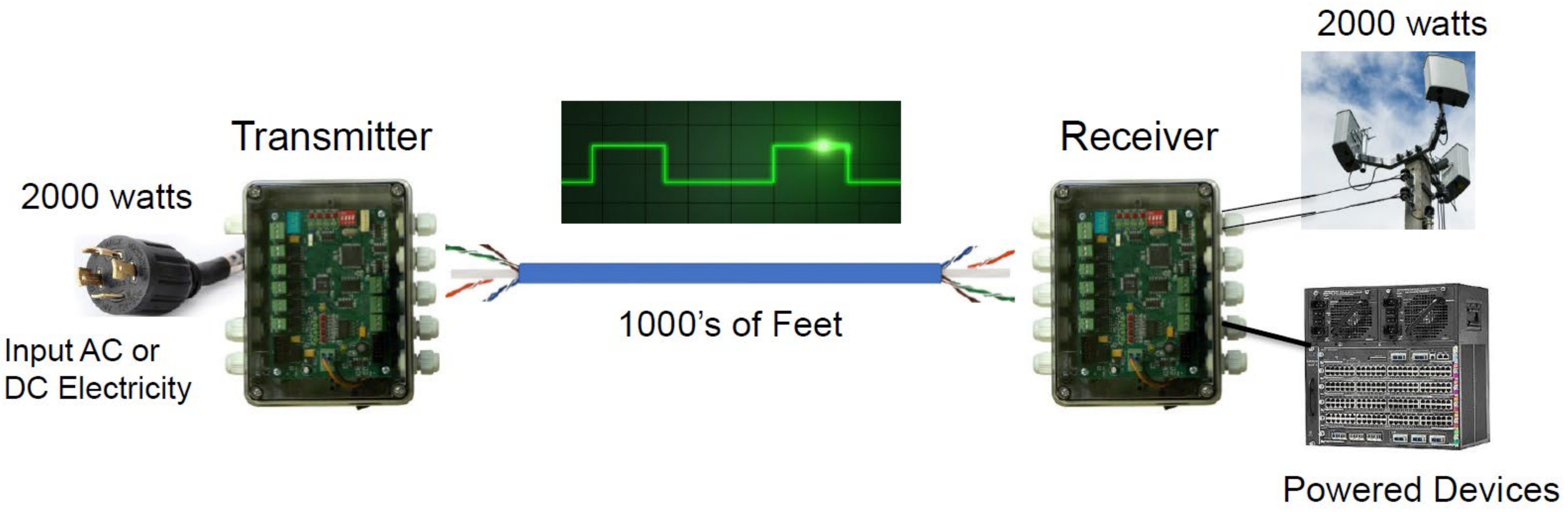
RFT-V Power
(Remote Feeding Telecommunications, Voltage Limited)

- Elevated voltage: +/-190Vdc
- Power limited to 100W per circuit

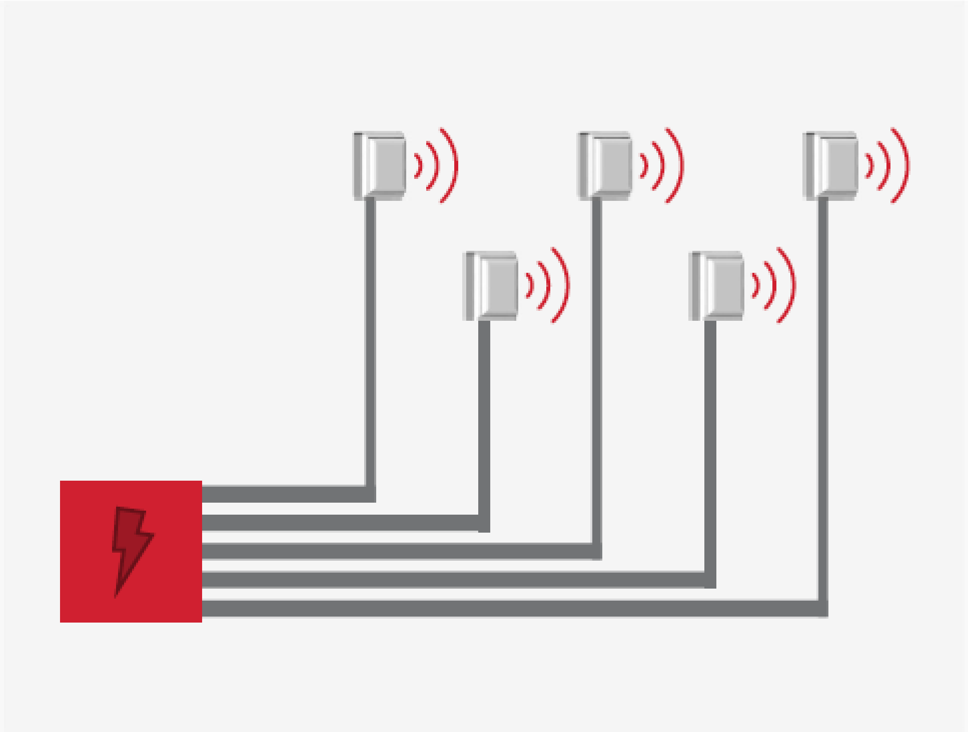


PROS	CONS
✓ Long standing safety standard	× Larger loads require many 100W circuits
✓ Accelerates network build schedule	× Inefficient use of copper conductor
✓ Ability to reduce power tap cost	
✓ Backup easily implemented and managed	

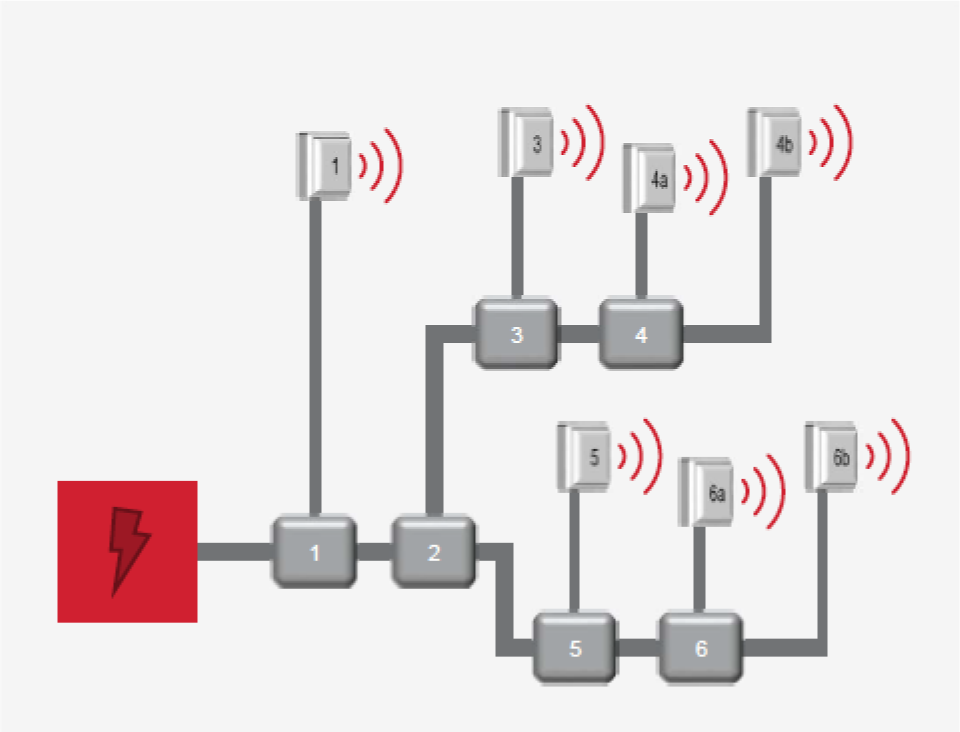
A new powering alternative



Power Topologies

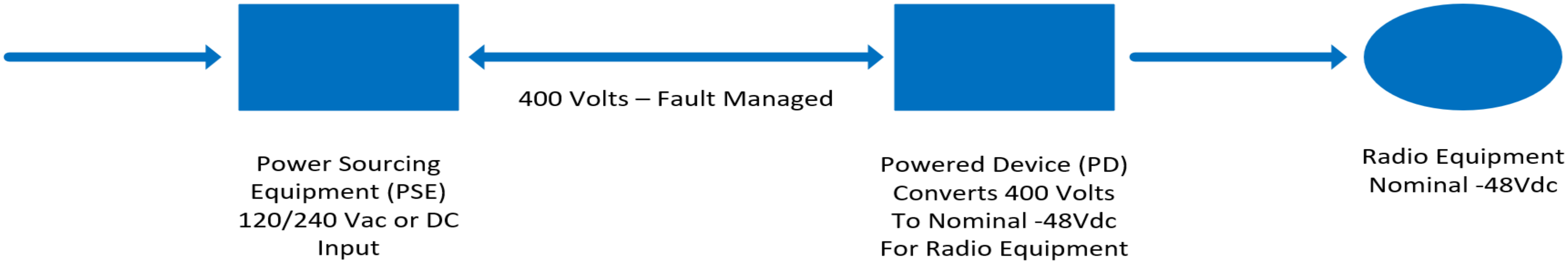


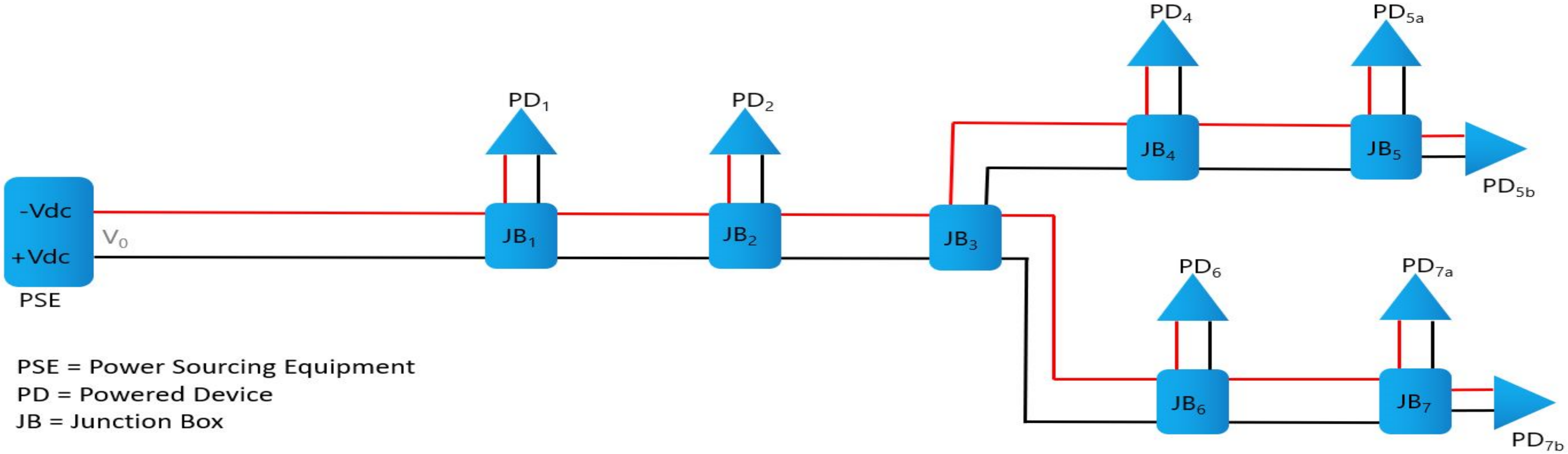
Point to Point Topology



Bus Topology

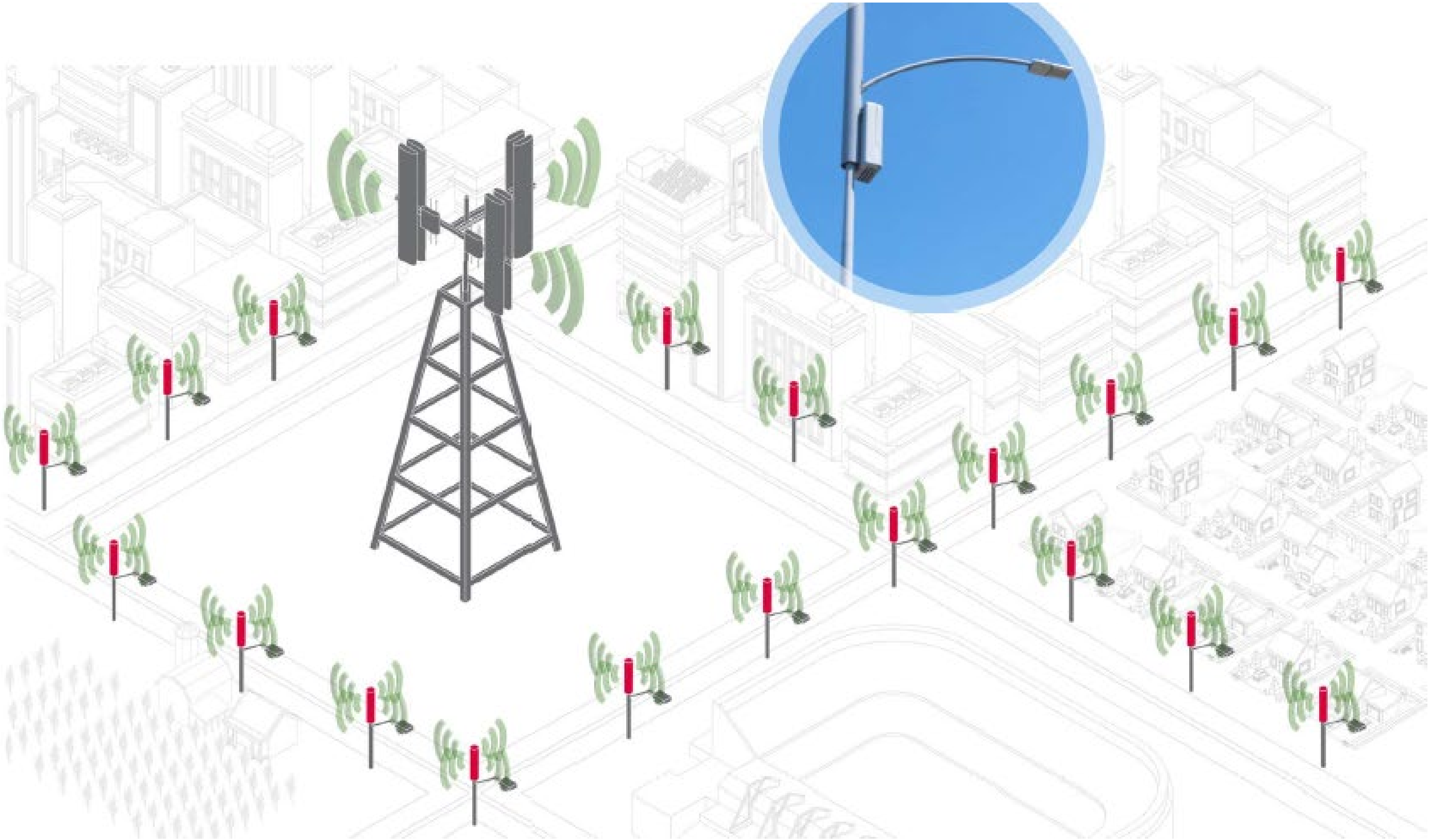
Examples of FMPS powering architectures





A new powering alternative

Facilitates efficient centralized battery back-up



Evolution of centralized powering techniques

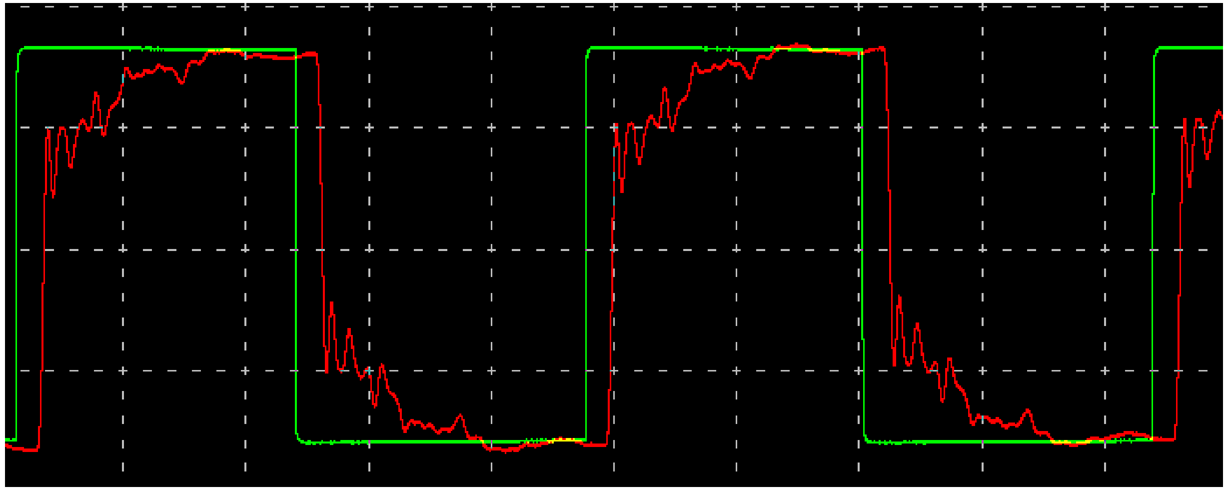
Since ~1893, Analog telephone circuits have relied solely on limiting voltage to nominal 48Vdc to mitigate shock hazard.
Very limited power delivery capability over typical loop lengths.

Beginning in the 1970s, digital telephone services require more power. RFT-V allows for up to 400Vdc but limits power to 100VA per circuit to mitigate shock hazard.
Limited power per circuit requires multiple circuits per Network Element. Cumbersome and inefficient.

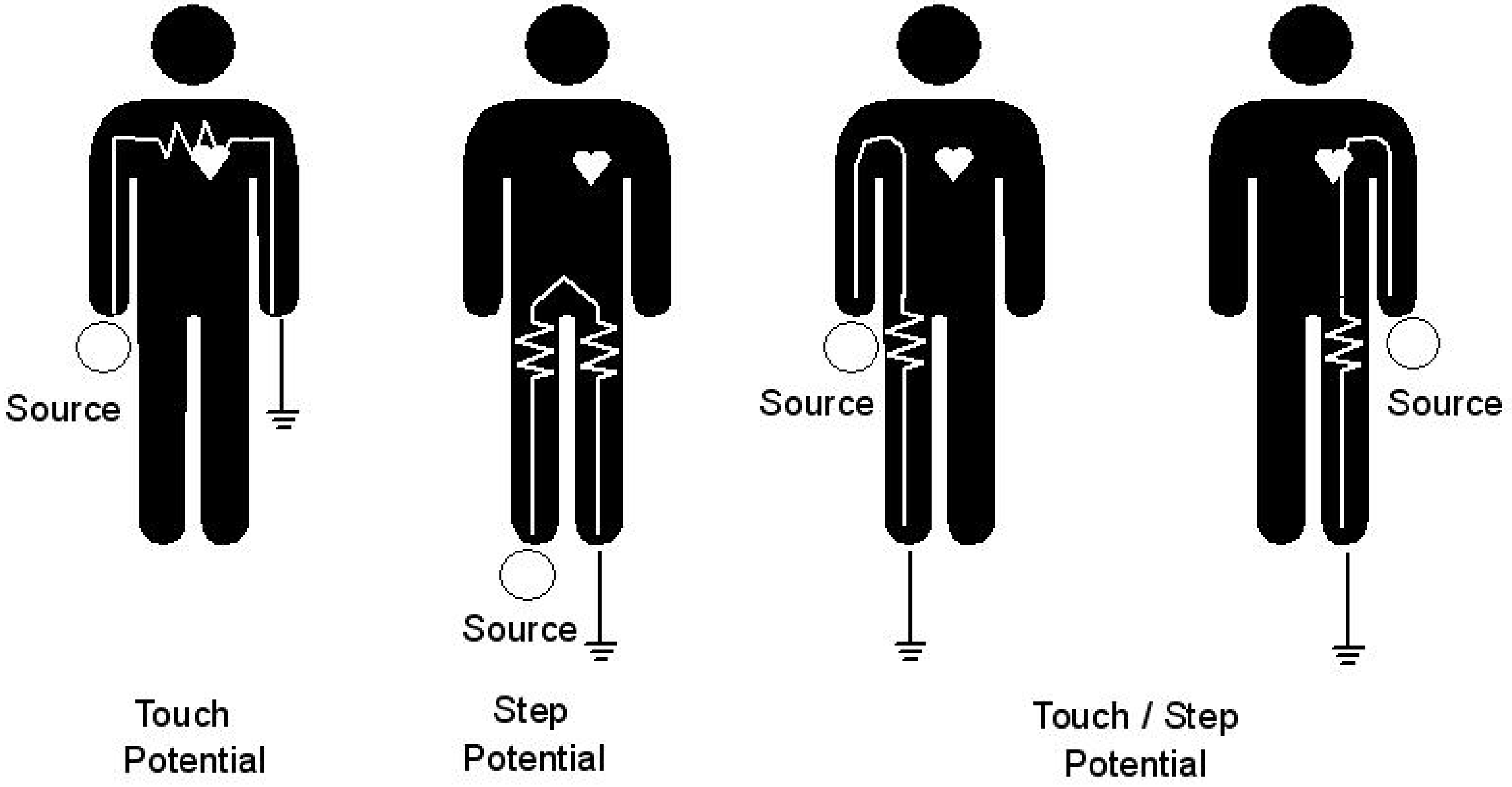
Today's 5G cellular radios require much greater power to deliver increased bandwidth and reduced latency while covering a small propagation footprint.
FMPS technology provides the capability to efficiently transport higher power levels while eliminating shock hazard. FMPS technology precisely controls and limits energy transferred during a fault. No limit for power delivered to a load.

Safety and Protection Concerns

- Electric Shock
- Available fault energy
- Functional safety
- Cables
- IEC 60479-1: Effects of current on human beings and livestock –Part 1: General aspects
- IEC 60479-2: Effects of current on human beings and livestock –Part 2: Special aspects



Shock Hazard



Shock Hazard

Direct contact with electrical current can be deadly. While some electrical burns look minor, there may be serious internal damage, especially to the heart, muscles, or brain.

Electric current can cause cardiac arrest due to the electrical effect on the heart.

Electric current can cause muscle, nerve, and tissue destruction when passing through the body.

Electric current can cause thermal burns from contact with the electrical source.

Be especially aware when working at height, as a shock may lead to a fall or injury.

Let - Go

- Can cause muscles to lock up
- Varies with frequency
- Not a factor with DC
- 40 to 150 Hz are most serious
- At 60 Hz

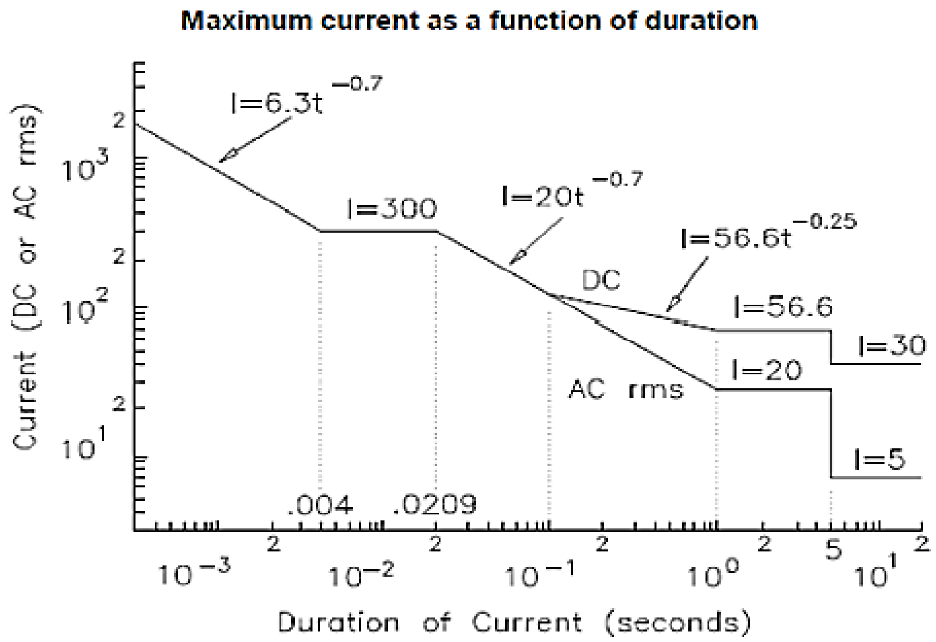
	Females	Males
Lower limit:	6.0 mA	9.0 mA
Average:	10.5 mA	15.5 mA

- Threshold of **let-go** is the maximum value of touch current at which a person holding electrodes can let go of the electrodes.
- The inability to let go can be caused by any time-varying current as the changing current can cause the muscles to involuntarily contract.
- Let-go isn't a concern in a DC system with minimal ripple as the current only changes when coming into and out of contact with the voltage.
- The let-go threshold is different for wet versus dry environments

1 Second Exposure 60 Hz

Shock is a function of voltage, current flowing through the heart, body/skin resistance, (wet-dry) time and frequency

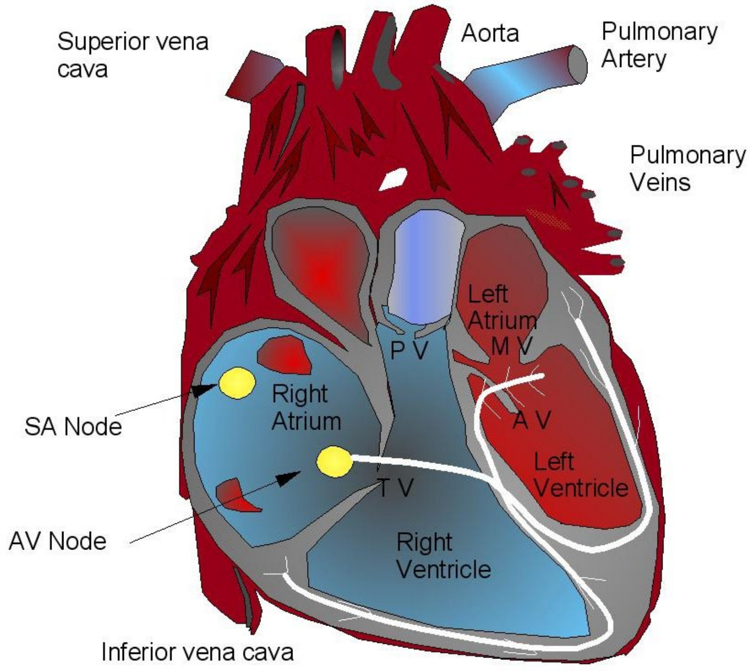
Current	Effects
3+ Milliamps	Shock
10+ Milliamps	Muscular Contractions
30+ Milliamps	Respiratory Paralysis
40+ Milliamps	Heart Paralysis
100+ Milliamps	Ventricular Fibrillation
4+ Amps	Heart Paralysis
5+ Amps	Tissue Burning

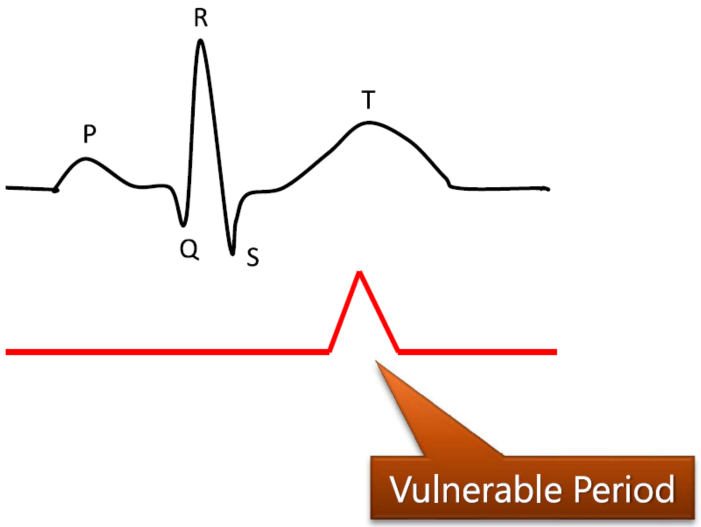


UL Shock Curve

Ventricular Fibrillation

- Ventricular fibrillation (VF) is the primary risk of harm from shock
- VF can only be triggered during the so-called “vulnerable period”
- This chance comes around once per cardiac cycle
- Short events (milliseconds) are **much** less likely to trigger VF
- Long duration (minutes) events are almost guaranteed to trigger VF





Safety and Protection Concerns

Shock hazard = Body current magnitude, current flow duration and current path

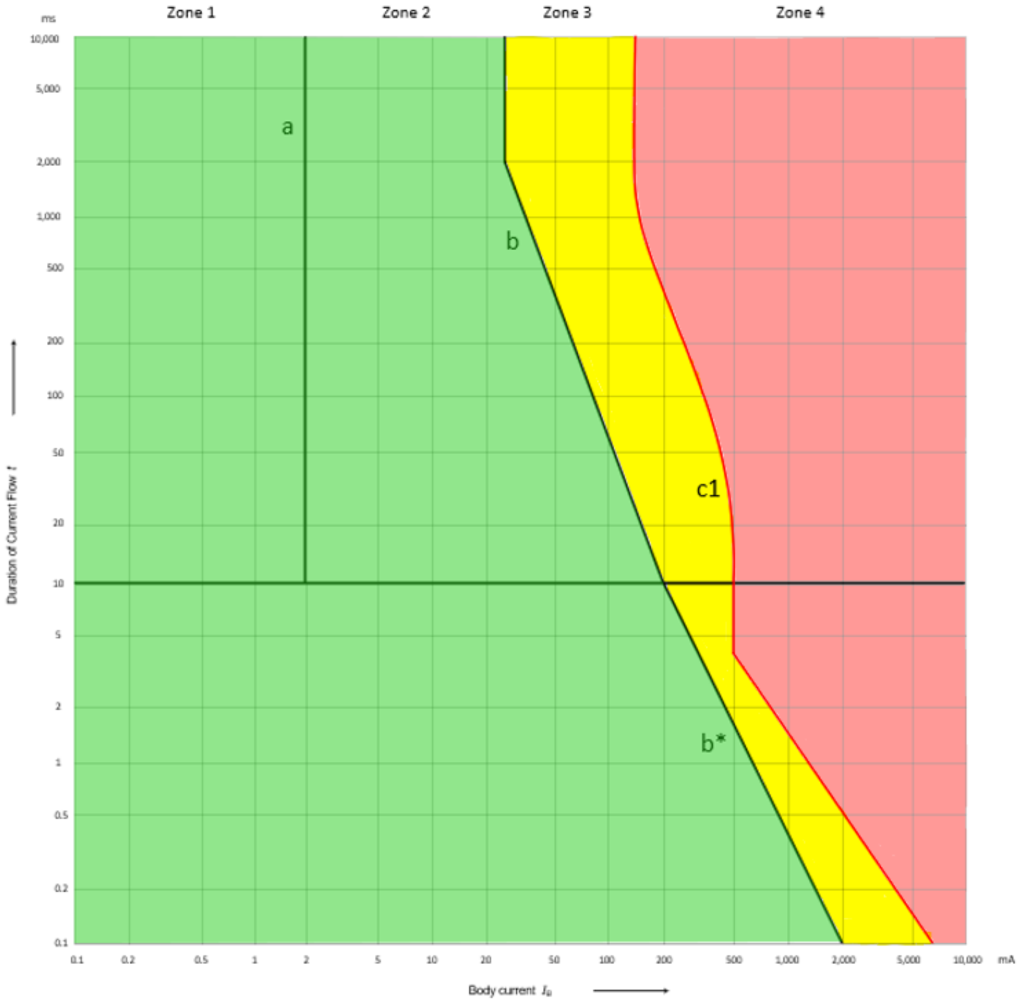


Figure 22/23 Conventional time/current zones of effects of DC current on persons for a longitudinal upward current path

Zones	Boundaries	Physiological effects
DC-1	Up to 2 mA curve a	Slight pricking sensation possible when making, breaking or rapidly altering current flow.
DC-2	2 mA up to curve b	Involuntary muscular contractions likely especially when making, breaking or rapidly altering current flow but usually no harmful electrical physiological effects.
DC-3	Curve b and above	Strong involuntary muscular reactions and reversible disturbances of formation and conduction of impulses in the heart may occur, increasing with current magnitude and time. Usually no organic damage to be expected.
DC-4 [a]	Above curve c_1	Patho-physiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time.
	c_1-c_2	DC-4.1 Probability of ventricular fibrillation increasing up to about 5 %.
	c_2-c_3	DC-4.2 Probability of ventricular fibrillation up to about 50 %.
	Beyond curve c_3	DC-4.3 Probability of ventricular fibrillation above 50 %.

Fault Managed Power Systems (CL4)

System response to all human contact fault scenarios must fall to the left of the “b line” per ATIS Technical Report 0600040 Fault Managed Power Distribution Technologies – Human Contact Fault Analysis

Existing RFT-V Power Limited Systems

System response to some human contact fault scenarios can reside in DC Zone 3 (to the right of the “b line”) under certain fault conditions even though each circuit is limited to 100VA.

Hundreds of thousands of RFT-V circuits currently operating safely in the OSP environment.

ATIS, NEC, NESC, UL, IEC

- ATIS Technical Report ATIS-0600040

  Fault Managed Power Distribution Technologies –Human Contact Fault Analysis
- NEC – Article 726 – Class 4 (CL4) Power Systems
- UL 1400-1 (Class 4 Equipment)
- UL 1400-2 (Class 4 Cables)
- IEC 60479-1: *Effects of current on human beings and livestock –Part 1: General aspects*
- IEC 60479-2: *Effects of current on human beings and livestock –Part 2: Special aspects*
- *Max Power Delivered: System Dependent (e.g., 2000 W @ 400 V)*
- *Power Delivery Reach: Systems Dependent (e.g., 2000 m)*
- NESC National Electrical Safety Code
- California General Oder Documents GO95, GO126

Standards?

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NEC – New Article 726 Class 4 Power Systems

Article 726 Class 4 (CL4) Power Systems

Part I. General

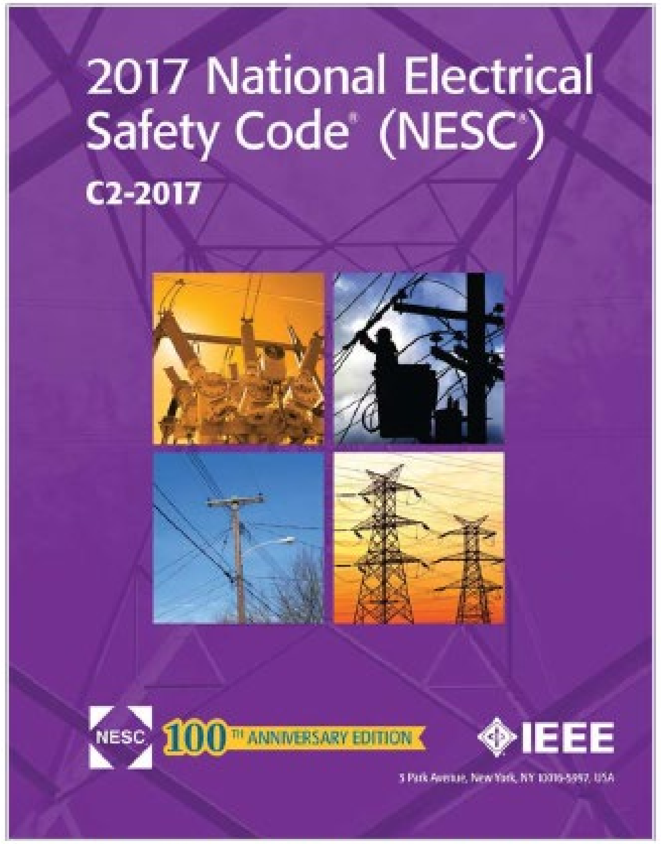
726.1 Scope.

This article covers the installation of wiring and equipment of fault-managed power (FMP) systems, including utilization equipment incorporating parts of these systems.

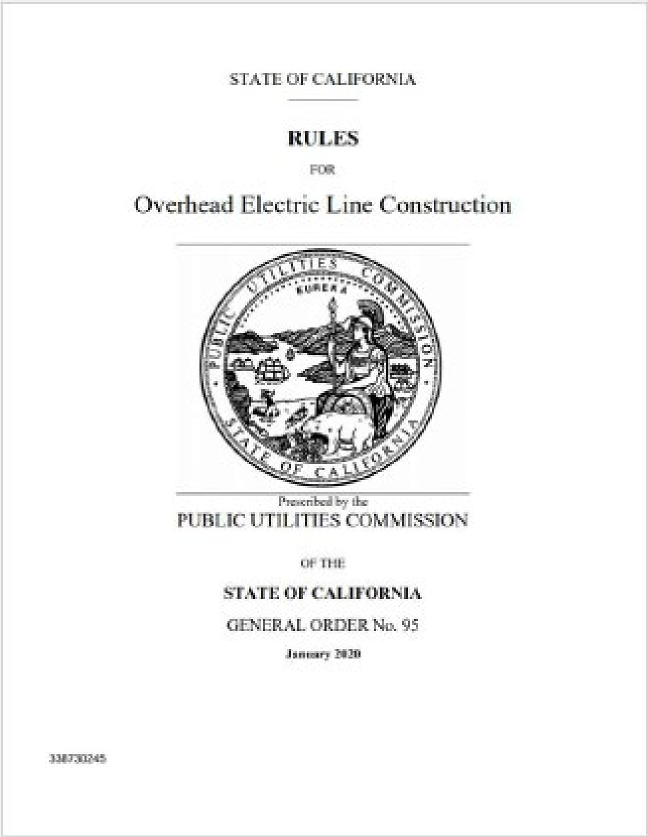
Informational Note No. 1: See Article 100 for definitions related to this section.

Informational Note No. 2: Class 4 power systems consist of a Class 4 power transmitter and a Class 4 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. Class 4 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 risk of shock and fire between the Class 4 transmitter and Class 4 receiver.

Safety Standards



Code Updates delayed due to COVID-19. Target 2023 (1 year delay)


STATE OF CALIFORNIA

RULES

FOR

Overhead Electric Line Construction

Prescribed by the

PUBLIC UTILITIES COMMISSION

OF THE

STATE OF CALIFORNIA

GENERAL ORDER No. 95

January 2020

Functional Safety Certification Requirements for FMPS

- Ensure that safety-related control functions perform reliably to minimize risk
- Fault and failure-mode analysis
- Fail-safe modes
- MTBF (critical components)
- Critical component redundancy
- Safety-related software analysis
- What if the monitoring system fails?

FMPS and the NESC

2021 & 2022

- SCs recognized that FMPS was a technology that needed review before next code is issued
- SC4 initiated a Working Group (WG 4.8) to review applicability of, and possible gaps in, NESC Rules and definitions

WG 4.8 concluded that

- Current NESC Rules generally cover the necessary safety criteria needed for FMPS applications
- A clear definition of FMPS would be beneficial for code clarity
- The requirement in Rule 224B and 344 for a metallic shield could be relaxed for FMPS systems.
- Change Proposals (CPs) were prepared and submitted – 1 on 224B, 1 on 344, and 2 on definitions

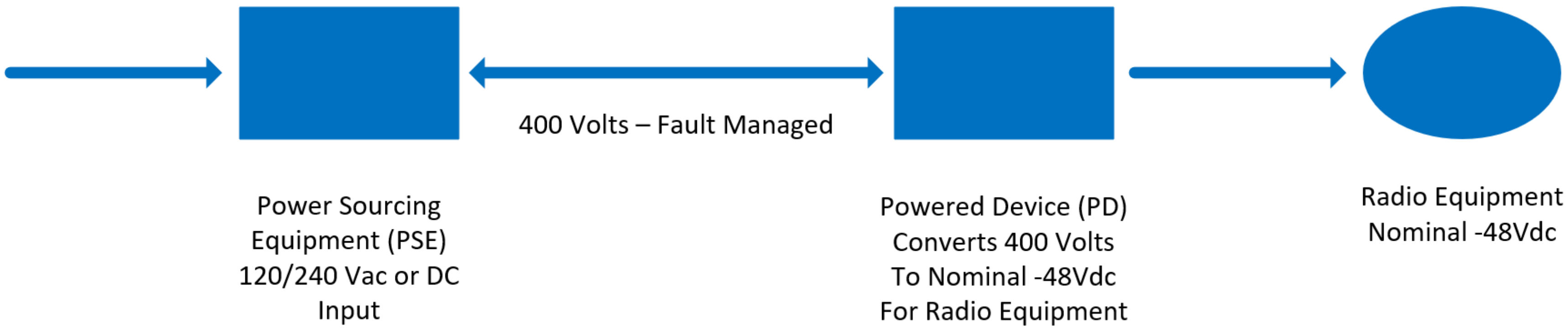
2022 & 2023

- Fast Track process initiated
- SC4 (aerial) – accepted CP on Rule 224B with some modification and reviewed proposed definitions
- SC7 (underground) – CP passed ballot on Rule 344 with some modification
- SC1 – currently considering CPs on 2 definitions pertinent to FMPS
- If SC1 votes to accept, then the CPs need to go to the Main Committee for final review and incorporation into the current NESC

FMPS Panel Discussion

Examples of FMPS powering architectures

P2P



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