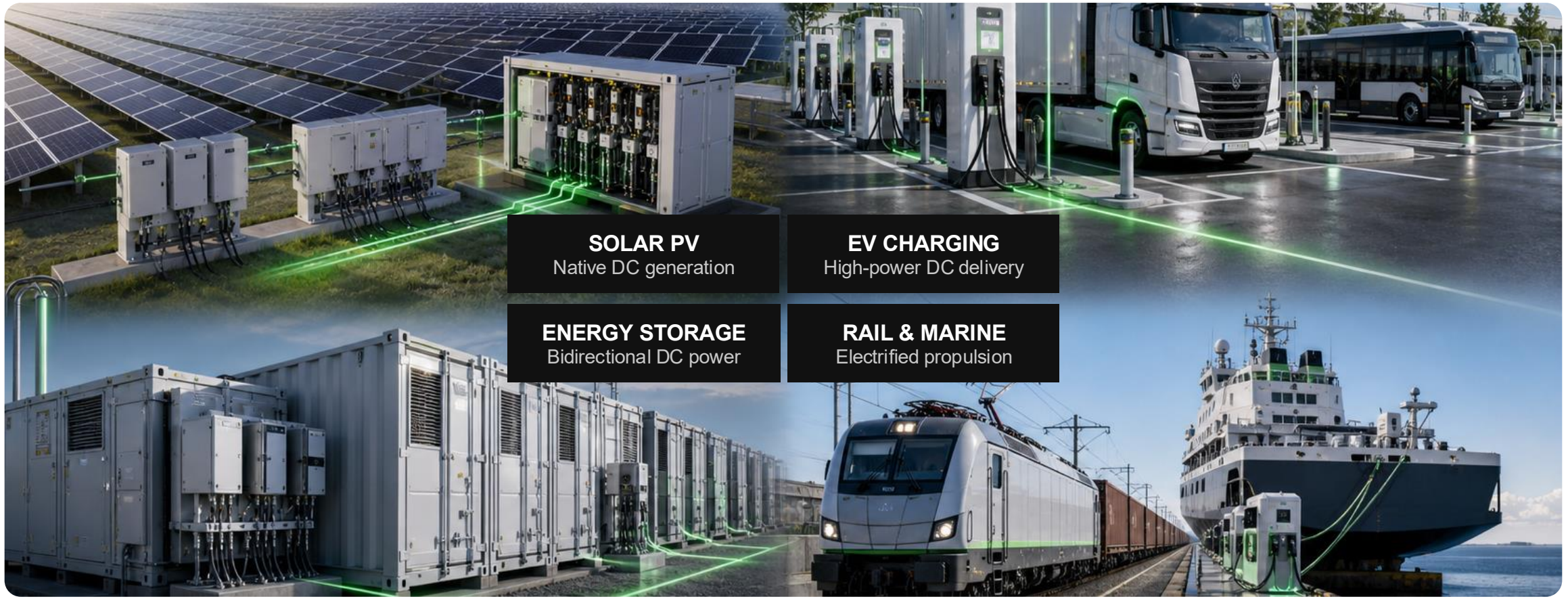
Designing Safe 800 VDC Systems:
Protection, Fault Management, and Operations

Xianyong Feng *[Principal Electrical Engineer, Microsoft]*

Mike Tu, P.E. *[Principal Electrical Engineer, NVIDIA]*

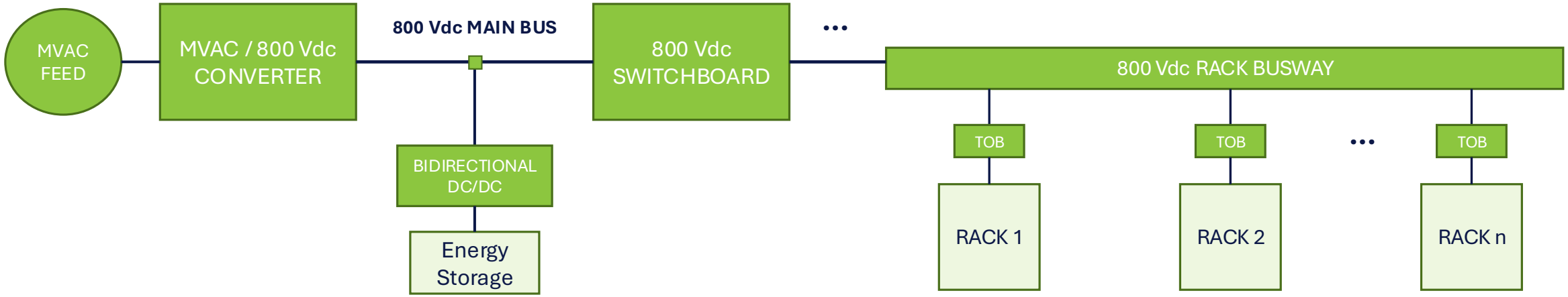
Sai Somayajula *[Principal Electrical Engineer, NVIDIA]*

MW-Scale DC Distribution Is Already Proven Across Industry



Transfer proven DC practices for AI Data Center application.

Simplified 800 VDC Data Center SLD



Key considerations of 800 VDC data centers

1. **Converter-dominated system —** Power electronics govern power flow, dynamic response, and fault behavior.
2. **Low-impedance system —** Disturbances propagate quickly between connected loads.
3. **Native 800 VDC rack feed —** Direct busway connection reduces in-rack delivery current.
4. **EDPP transient impact —** Rapid rack load currents cause voltage transients and obscure series-arc signatures, complicating fault detection.

800 VDC Data Center Protection System

Protection must act fast, reliably, selectively, and across the full DC system

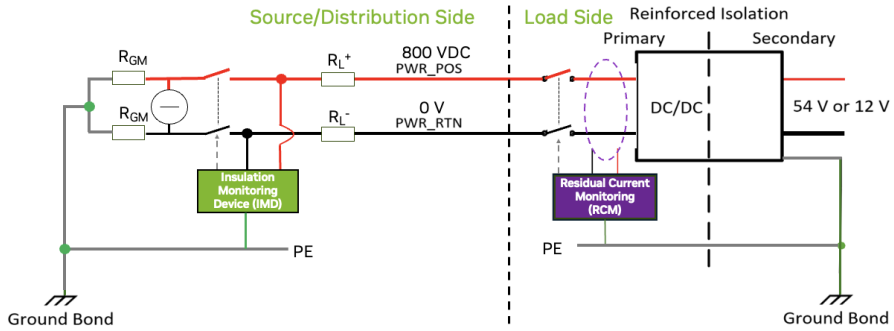


Key protection requirements in 800 VDC data centers

1. **Fault Identification —** Detect and classify electrical faults quickly, accurately, and reliably.
2. **Ground-fault location —** Rapidly locate ground faults for various grounding system setup.
3. **Fault Clearing time —** Use DC-rated interrupting devices to quickly clear high-di/dt faults
4. **Protection Coordination —** Isolate only the affected section while maintaining power to healthy loads.
5. **Arc and surge control —** Detect DC arcs, reduce incident energy, and limit transient overvoltage.

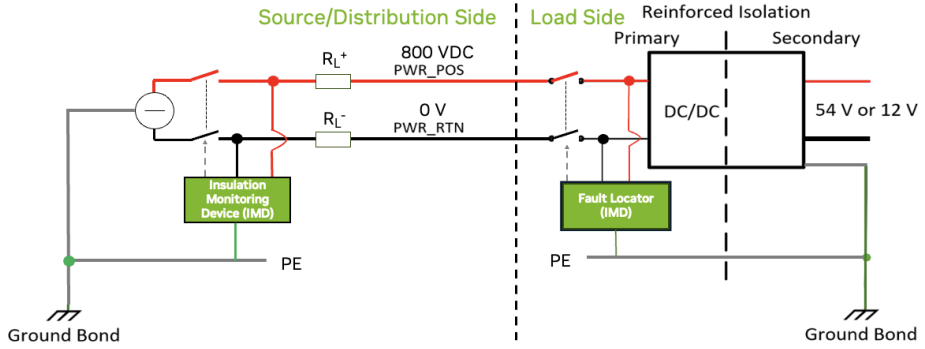
Grounding System Options

High Resistance Midpoint Grounding (HRMG)



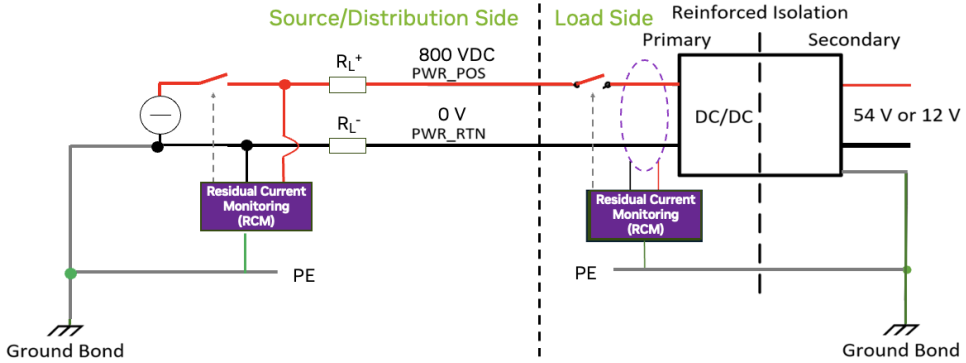
- Balanced conductor-to-ground voltage
- Controlled ground-fault current for personnel safety
- IMD + RCM enable reliable fault detection
- Good balance of safety, uptime, and fault visibilit

Floating/Ungrounded



- Minimal ground-fault current
- First ground fault allows continued operation
- IMD required for insulation monitoring
- Fault location can be more challenging

Solid Grounding



- Fast and sensitive fault detection
- Simplified protection architecture
- Higher available ground-fault current
- Requires current limiting and fast protection devices

DC Fault Detection

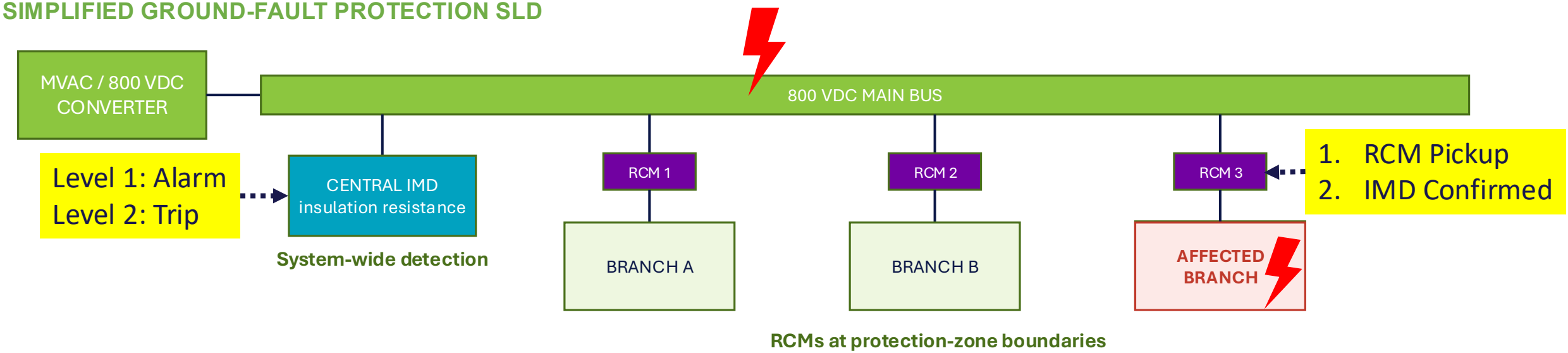
DC Fault Detection: Two-Zone Architecture

- **Zone 2 — Source / Main DC Bus**
- **Insulation Monitoring Device (IMD)**
  - Continuously monitors insulation resistance to ground
  - Detects the first insulation fault in floating or HRG networks
  - Provides early warning before a second fault creates a hazardous path
  - Initiates fault-location logic across downstream branches
- **Zone 1 — Branch Circuit / Compute Rack**
- **Residual Current Monitoring (RCM)**
  - Hall-effect sensor measures current imbalance
  - Detects leakage current from the branch circuit to ground
  - Identifies the affected rack or branch
  - Supports targeted isolation without interrupting healthy loads

Ground-Fault Detection and Localization

Central IMD detects system-wide insulation degradation; zonal RCMs identify the affected branch.

SIMPLIFIED GROUND-FAULT PROTECTION SLD



PROTECTION SEQUENCE

01 DETECT
IMD flags insulation degradation

→ **02 LOCALIZE**
RCMs compare branch leakage current

→ **03 CONFIRM**
Correlate central and zonal indications

→ **04 ISOLATE**
Clear only the affected branch

DC Interrupting Devices

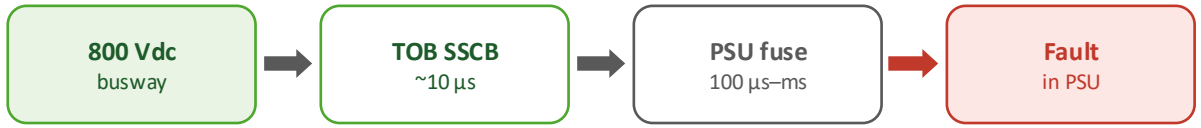
Device	Clearing	Key feature	Typical use	Advantages	Limitations
MCCB	**Tens of ms**	Compact molded case; thermal-magnetic or electronic trip	Switchboards, branch and feeder protection	Compact; economical; resettable; familiar coordination	Slow; curve-dependent; arcing and wear
SSCB	**≈10 µs**	Semiconductor interruption; fast sensing and energy clamp	Converters, batteries, and fast bus protection	Fastest; no arc; resettable; programmable	Conduction loss and cooling; higher cost; semiconductor failure rate
Hybrid CB	**~ms**	Low-loss mechanical path + semiconductor commutation	High-power DC where speed and efficiency are both critical	Fast interruption with low steady-state loss	More components, controls and coordination; higher complexity/cost
Fuse	**100s µs - ms**	Melting element; current limiting; no control power	Branch protection, module protection	Low cost and loss; high interrupt rating	Replacement/downtime; slower at low overcurrent levels
E-fuse	**<2–10 µs**	MOSFET/SiC switch with current limit and reset	Low/medium-power rails, EV auxiliaries, data centers	Ultra-fast; resettable; configurable; no arc	Semiconductor loss/thermal limits; bounded v and i range
Pyro-fuse	**<2 ms**	Externally triggered with galvanic isolation	EV/ESS battery crash or severe-fault isolation	Low on-state loss; fast and decisive isolation	One-shot; needs trigger logic; not general overload protection

DC Protection Needs End-to-End Coordination

Coordinate protection as one integrated system

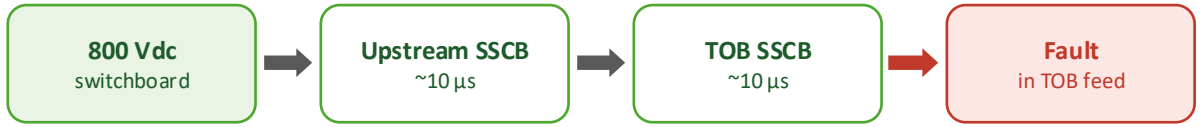
- **Speed mismatch —** SSCBs act in microseconds; fuses and MCCBs act in milliseconds.
- **Failure mode —** A fast upstream device can trip first and disconnect healthy loads.
- **Design rule —** Set the fault window first, then align I–t curves, let-through energy, and delays.

Case 1 — Fast SSCB ahead of a slower PSU fuse



Risk — TOB SSCB clears first; one PSU fault drops the TOB.

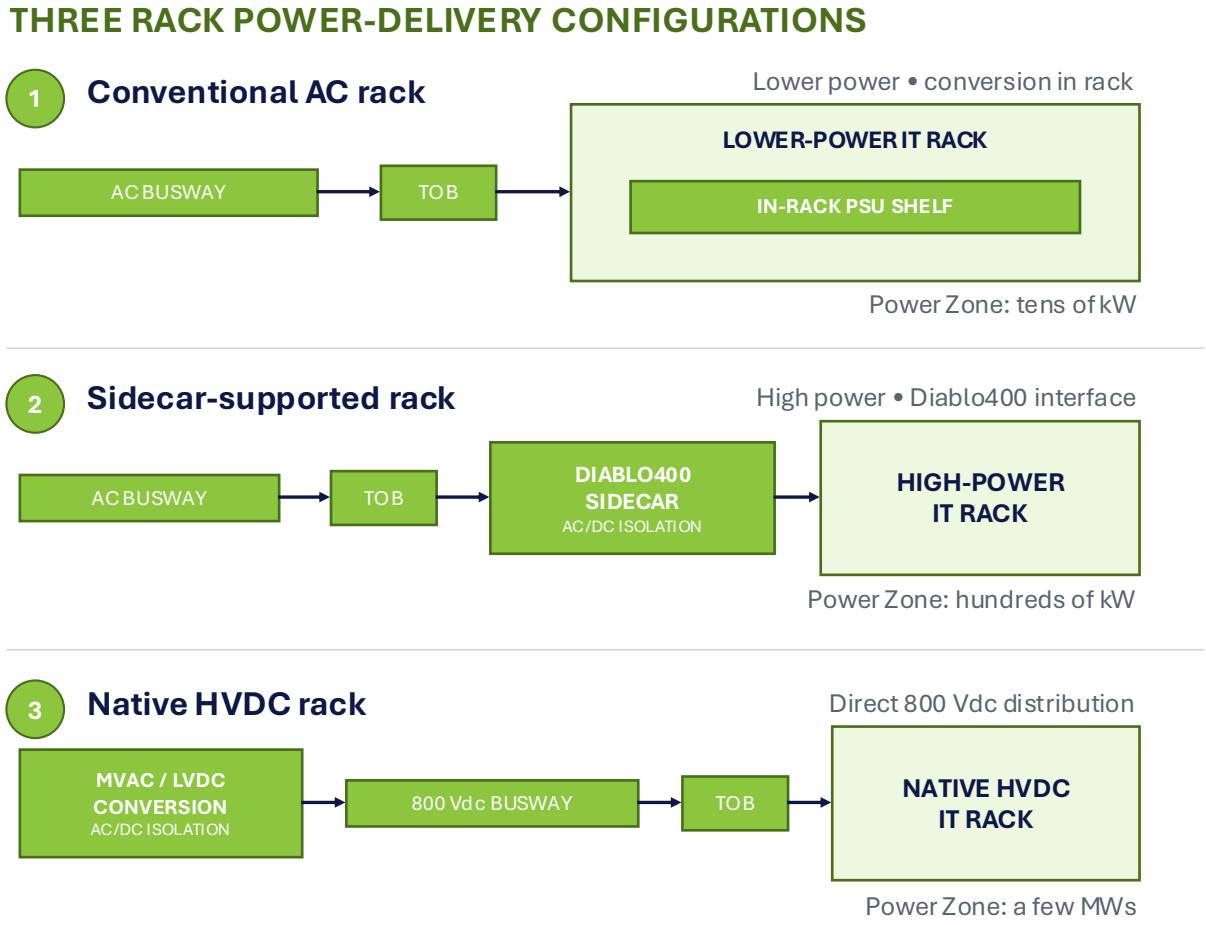
Case 2 — Two SSCBs with near-identical speed



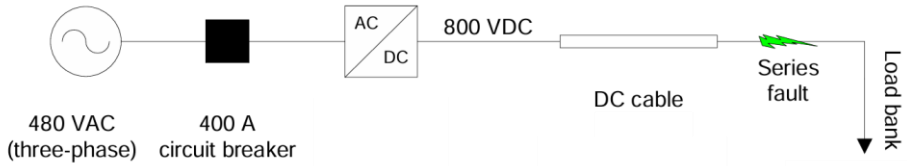
Risk — Both SSCBs may trip without explicit discrimination.

AFIE Control for High Impedance Fault

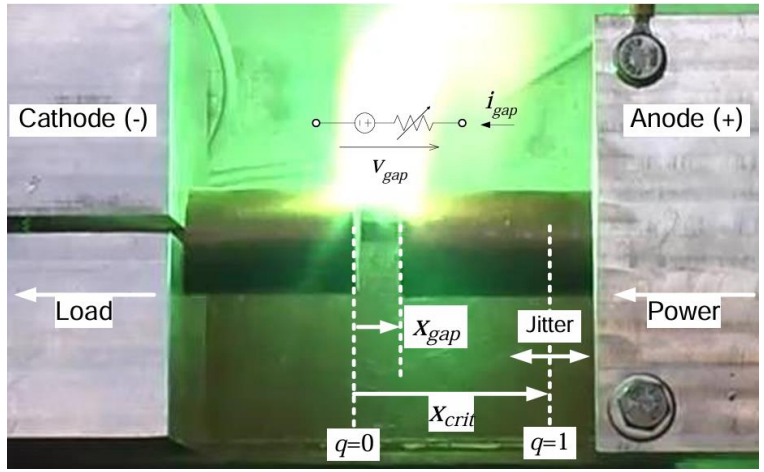
- **Detection challenge —** Fault current may remain below protective-device or power-supply OCP thresholds, delaying fault clearing.
- **Arc-flash risk —** Longer clearing time increases arc-flash incident energy.
- **Enhanced sensing —** Supplement current sensing with temperature or other advanced sensors for faster, reliable detection.

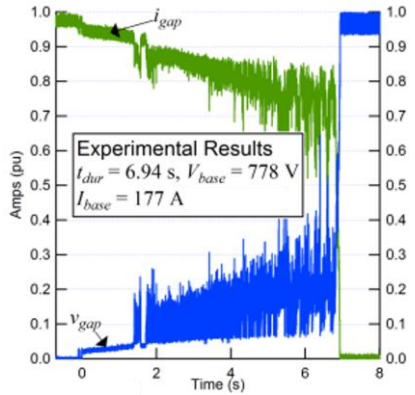


DC Series Arc Fault Detection

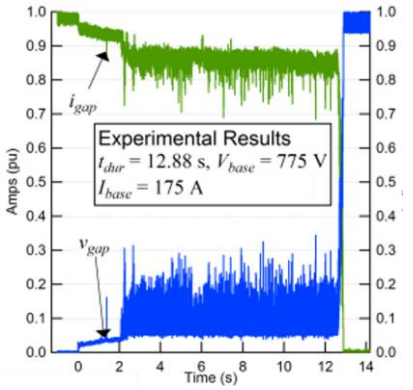


- **Initiation —** Loose or degraded contacts create an air gap that sustains a DC series arc.
- **Hidden hazard —** Line current may not rise, allowing the arc to persist and create a fire risk.
- **Variable signature —** Depends on current, materials, gap geometry, environment, circuit R-L-C, and load.
- **Detection challenge —** Shall separate intermittent arc signatures from normal converter/load transients.





(1) constant speed electrode separation (0.1"/s)*



(2) fixed gap electrode (0.25")*

*Ref: [A DC Arc Model for Series Faults in Low Voltage Microgrids]

Call to Actions

- Current Limiting Devices adoption & approval
- Solid State Circuit Breaker development & certification
- DC protective relays and fault sensing methods
- 800 VDC System-Level and SST Spec Development
- DC Arc Fault behavior, testing, code update

Thank You!

