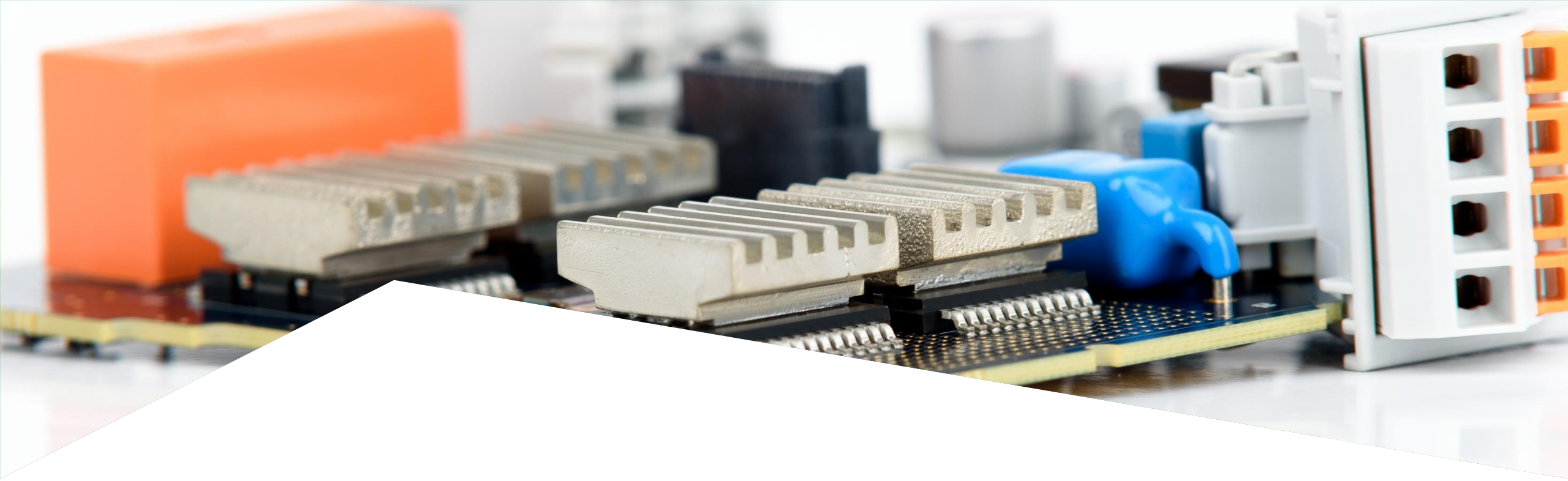
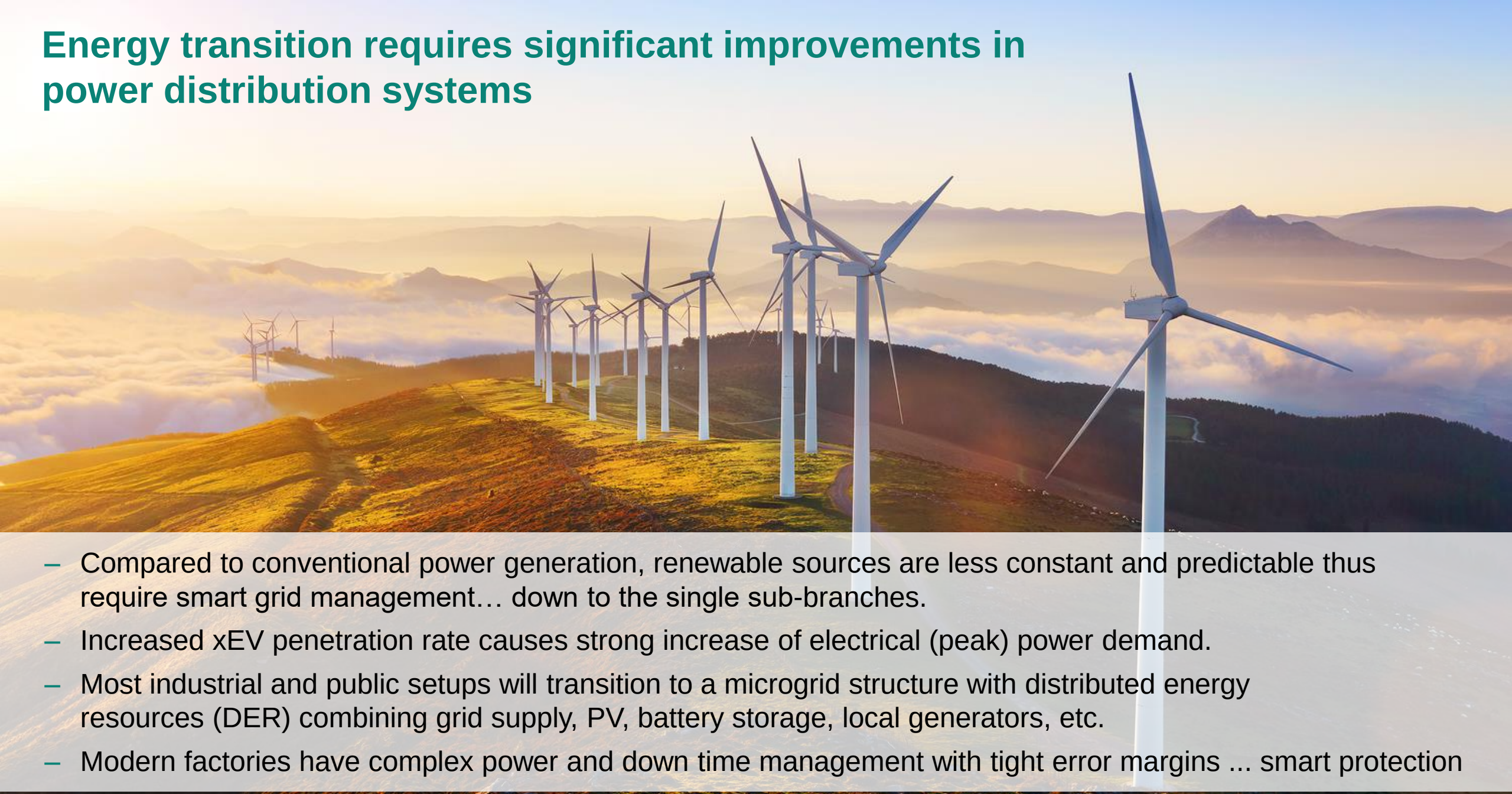


Solid-State Circuit Breakers

Aichriedler, Slama

March 2024

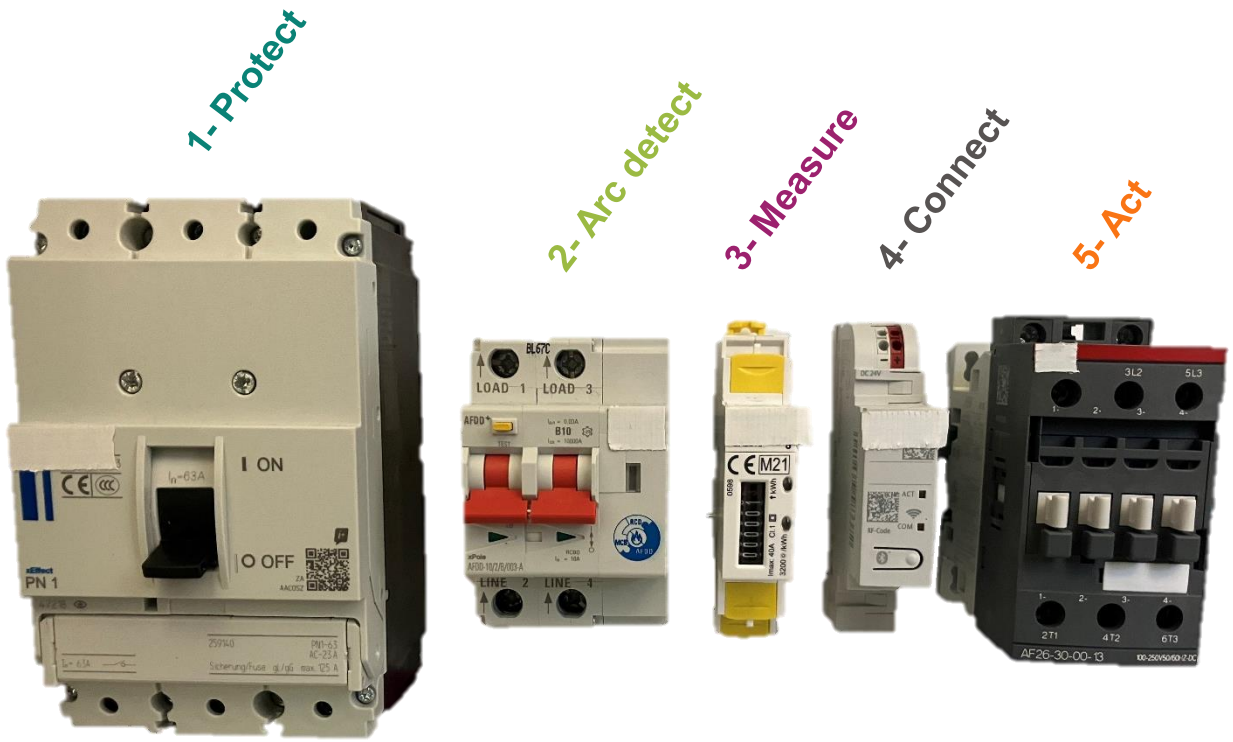
Energy transition requires significant improvements in power distribution systems



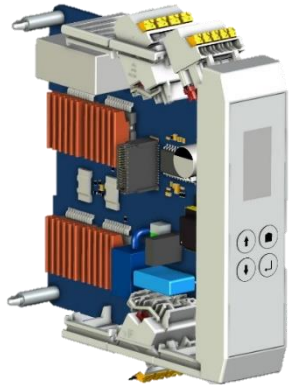
- Compared to conventional power generation, renewable sources are less constant and predictable thus require smart grid management… down to the single sub-branches.
- Increased xEV penetration rate causes strong increase of electrical (peak) power demand.
- Most industrial and public setups will transition to a microgrid structure with distributed energy resources (DER) combining grid supply, PV, battery storage, local generators, etc.
- Modern factories have complex power and down time management with tight error margins ... smart protection

Power distribution going smart

Smart Circuit Breakers integrate multiple functions into one single device



Integrate all five functions into one single device:



5- Act

4- Connect

3- Measure

2- Arc detect

1- Protect

IMAGINE
a Circuit Breaker, that…

… matches the form factor of today's MCBs

… supports smart billing, even for sub-branches

… captures and logs data in real time

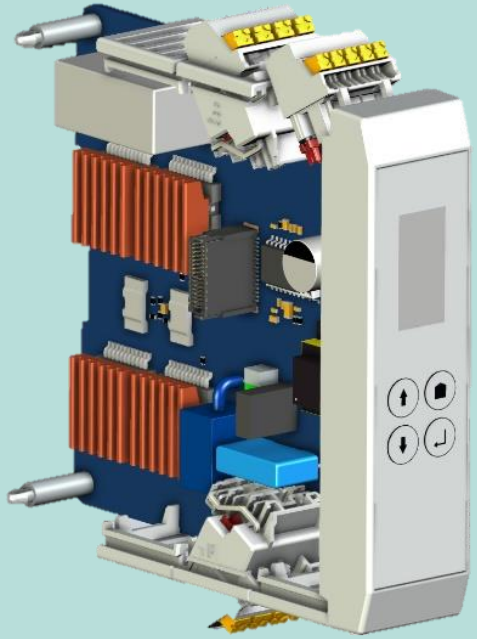
… offers secure web/IoT connectivity

… provides noise-less and wear-free load switching with real-time control capability

… supports OCP, AFDD/AFCI and RCD/GFCI – all in one

… enables remote load control and diagnostic in real time

… provides state-of-health diagnostics of connected loads



… complies with industrial certification standards

… supports ZVS and ZCS for smart and soft switching

… enables smart power balancing and control of peak loads

… combines protection, load control, diagnostic and metering in one single device

… can be applied for AC and DC grids

… provides highly accurate and user programmable tripping characteristics

These segments primarily require smart power distribution

Efficiency, reliability and availability allow for increased installation cost

Power distribution going smart

Smart circuit breakers integrate multiple functions into a single device

Monitoring and Connectivity

- Real-time monitoring of load/supply condition
- Connectivity to Power Domain Controller
- Advanced smart billing concepts
- System optimization using AI
- State-of-health diagnostics of connected loads
- Embedded security solution

Protection

- Overcurrent and overload protection
- Programmable, accurate tripping characteristics
- AC and DC switching capability
- Arc-fault detection and interruption (AFDD, AFCI)
- Residual current/ground fault protection (RCD, GFCI)

Actuation

- Safe, reliable and wear-free actuation of branches
- Real-time, remote controllability
- AC and DC switching capability
- Zero-voltage and zero-current switching capability
- Smart power balancing, peak power control

Compatibility

- Compliance to applicable IEC60947 (-10) standard
- Backward compatibility to existing infrastructures (AC) and loads
- Enablement of new distribution systems (DC)
- Compatible form factor to legacy installations

Solid-State Power Distribution

Feature enhancements vs. traditional EM implementations

Improved Tripping Characteristics	– Low-tolerance trip band to reduce tolerance stackup (wiring, selectivity) – High accuracy tripping for DER systems. (Inverter shutdown) – Digital power: software defined trip characteristic/ampacity – Faster tripping for grids with high PSCC and low residual reactance
Arc-free Operation	– Operation in critical areas (e.g. IT-space) – Wear-free switching. – Increased MTBF, high system availability.
Accurate Switch Control	– Smart switching features (ZCS, ZVS, phase control) – Inrush current management – Grid/phase synchronization, pre-charging
Smartness and Connectivity	– Load monitoring – Grid forming/power balancing features – SOH monitoring – Remote control and diagnostics, auto-recovery

Solid-State Power Distribution

Application Examples: Industrial / Server/Data Centers / Automotive

Solid-State Circuit Breaker (SSCB)

Industrial

- Programmable trip characteristic
- AFDD/GFCD (optional)
- Actuator/VS/ZCS
- Monitoring functions (V/I/THD/SOH)
- Communication

DC Circuit Breaker

Industrial

- Programmable trip characteristic
- AFDD/isolation monitor
- Actuator w/ pre-charge function
- Monitoring functions (V/I)
- Droop control
- Communication

Motor Soft Starter

Industrial

- Circuit breaker and disconnector
- Startup controller
- Motor protection
- Load SOH monitoring
- Communication

Power Distribution Unit (AC/DC)

Data Center

- Programmable trip characteristic
- AC/DC compatibility
- Monitoring functions (SOH, i^2t)
- Communication

µGrid Sync Device

Industrial

- Circuit breaker and disconnector
- Synchronization monitor
- Fast connection unit
- Communication

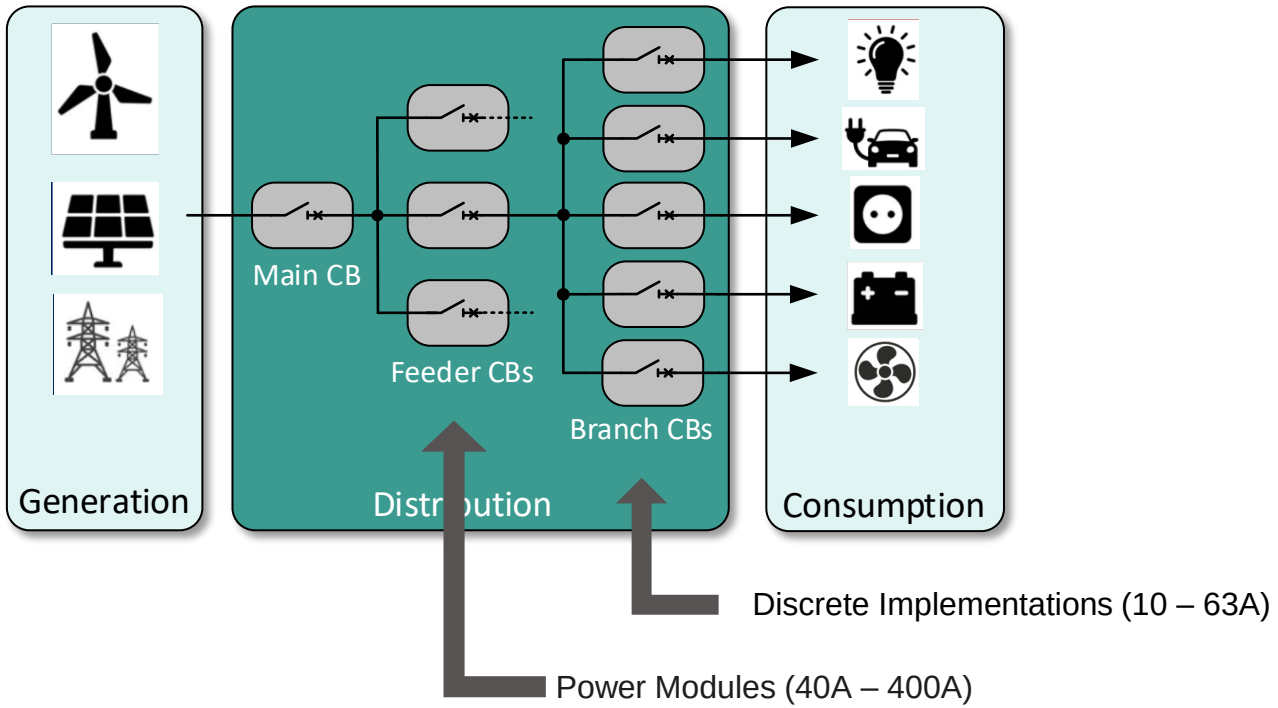
eFuse (ATV/IND) + Battery Main Switch

ATV/IND

- Programmable trip characteristic
- Precharge-unit w/ re-closing function
- Monitoring functions (SOH, i^2t, FuSa)
- Communication

Power distribution topology

SSCBs combine all required functions into one single device

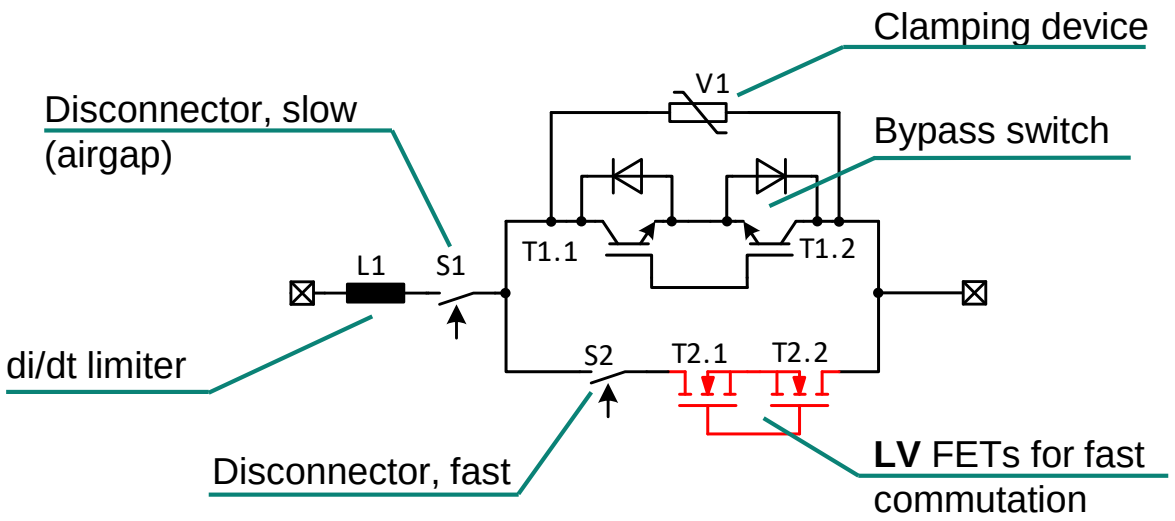


- Industrial power distribution systems typically feature 2 – 3 stacked layers with increasing current levels.
- For SSCBs, the entry level (highest benefit) is on branch CBs, followed by feeder CBs.
- While branch CBs can be implemented using discrete devices, feeder CBs will be based on power modules.

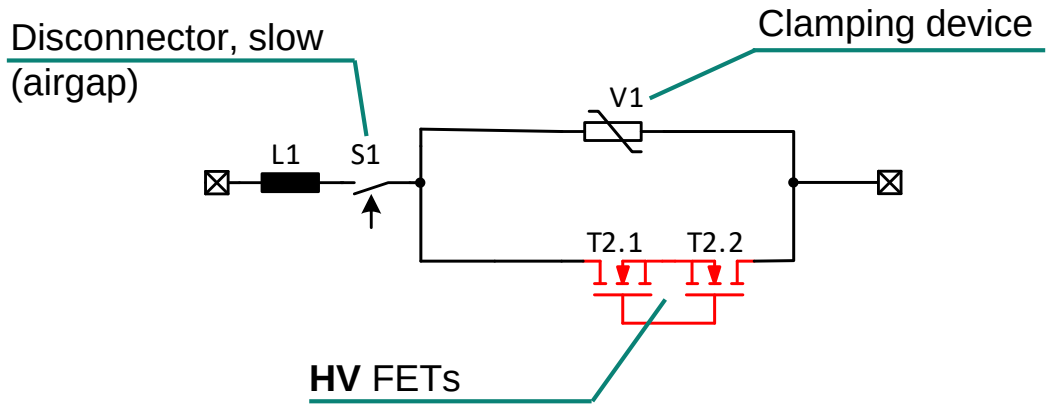
Hybrid vs. Solid-State Implementations

Hybrid implementations as bridge technology to full solid state solutions

Hybrid Circuit Breaker



Solid State Circuit Breaker



- Solid State implementations provide superior switching performance, however they cannot provide galvanic separation
- Most standards (IEC, UL) require a mechanical disconnector that provides
  - The necessary airgap
  - Zero leakage current
  - Redundancy and diversity for the disconnection element
- The presence of a disconnector supports the optimization of the semiconductor switch

Solid-State Circuit Breakers from a System Perspective

An IFX P2S Playground

µC Comm Memory

Microcontroller + Connectivity + Security + Memory (e.g. PSoC™, XMC™ ISOFACE™ EXCELON™ F-RAM)

Smartness

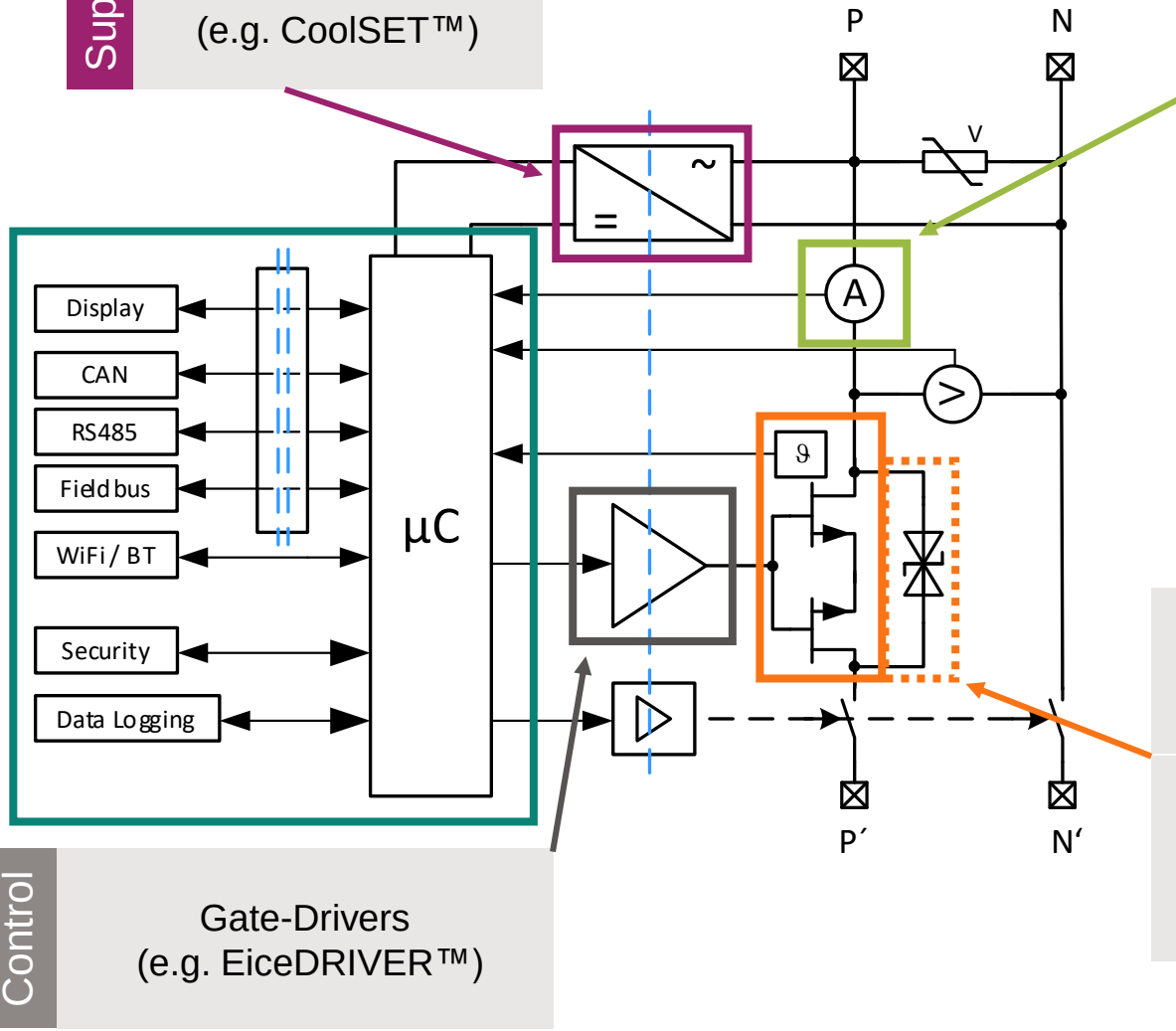
Software and Services

Security

Security (OPTIGA™)

Supply

AC/DC & DC/DC (e.g. CoolSET™)



Control

Gate-Drivers (e.g. EiceDRIVER™)

Sensing

I / V / ϑ - Sensing (e.g. XENSIV™)

Power Stage

Clamping & Protection Solution w/ companion devices

Power Switch (e.g. CoolMOS™, CoolSiC™)

Solid-State Circuit Breakers from a System Perspective

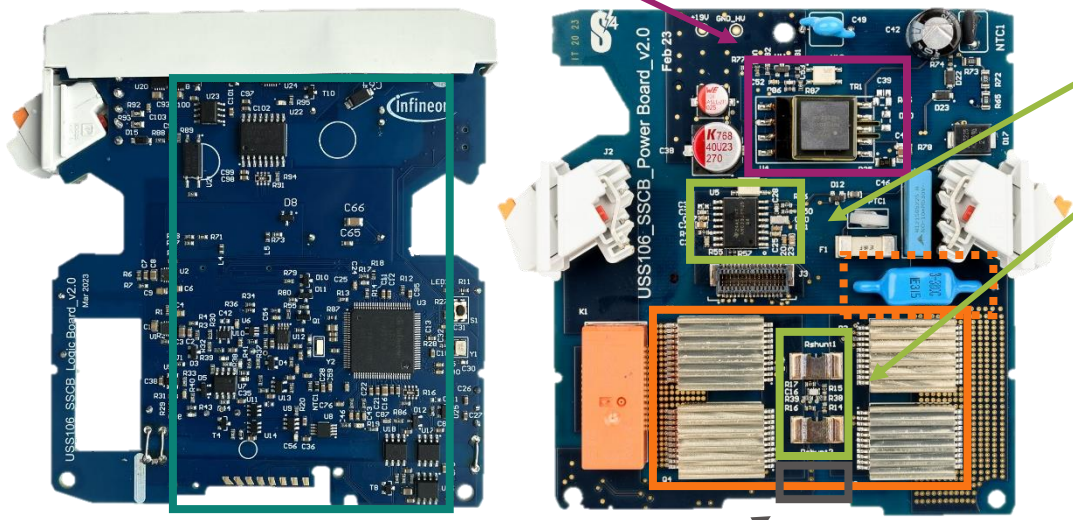
An IFX P2S Playground

µC / Comm / Memory: Microcontroller + Connectivity + Security + Memory (e.g. PSoC™, XMC™ ISOFACE™ EXCELON™ F-RAM)

Smartness: Software and Services

Security: Security (OPTIGA™)

Supply: AC/DC & DC/DC (e.g. CoolSET™)



Sensing: I / V / ϑ - Sensing (e.g. XENSIV™)

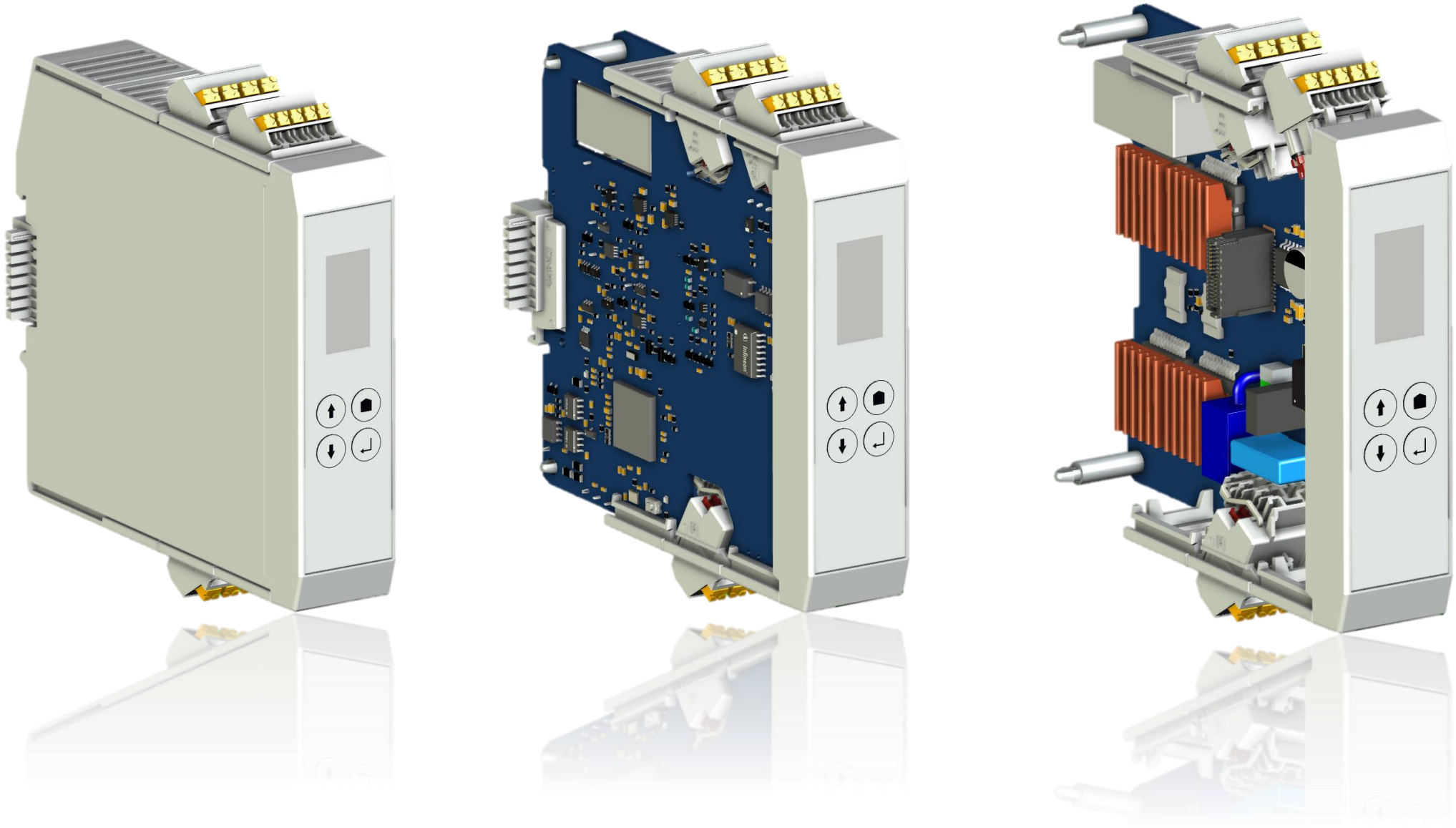
Power Stage: Clamping & Protection Solution w/ companion devices

Power Switch (e.g. CoolMOS™, CoolSiC™)

Control: Gate-Drivers (e.g. EiceDRIVER™)

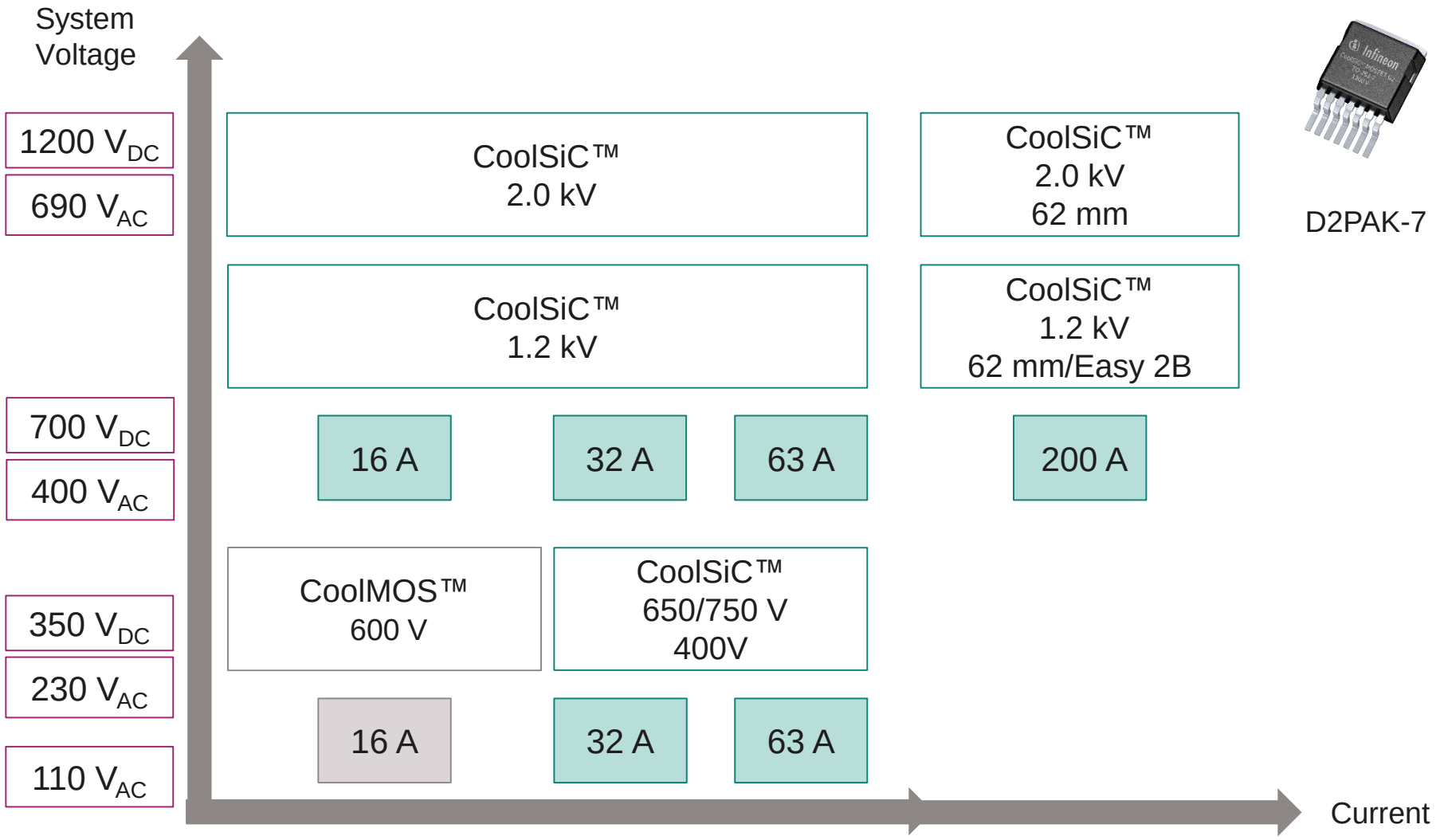
System understanding is the solid basis for our solution path

SSCB Proof-of-Concept (PoC)

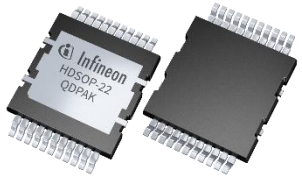


Solid-State Circuit Breakers focus areas

Complementary discrete and power module portfolio



D2PAK-7



QDPAK

TO-247

Easy 2B

62 mm


Infineon