OCP SUMMIT

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Open Rack V2.1 Standard Compliant 48V System Design

High Efficiency Power and Lithium BBU units

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Build A Green Connected World

Huawei Network Energy

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2M telecom energy systems

Telecom Energy

830 large data centers

Data Center Energy

30GW smart PV plants

Solar Energy

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OCP 48VDC Power System Design

Contents:

- Why 48 Volt?
- Overall Data Center Efficiency Analysis
- Open Rack V2.1 Design
  - 48VDC Power Shelf
  - Battery Backup Unit

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Why 48 Volt DC?

- OCP has traditionally supported 12 volt systems, with great success, so why change to 48 volt?
  - Power Density
  - Efficiency, Rack and Site Level
  - Economy of Scale

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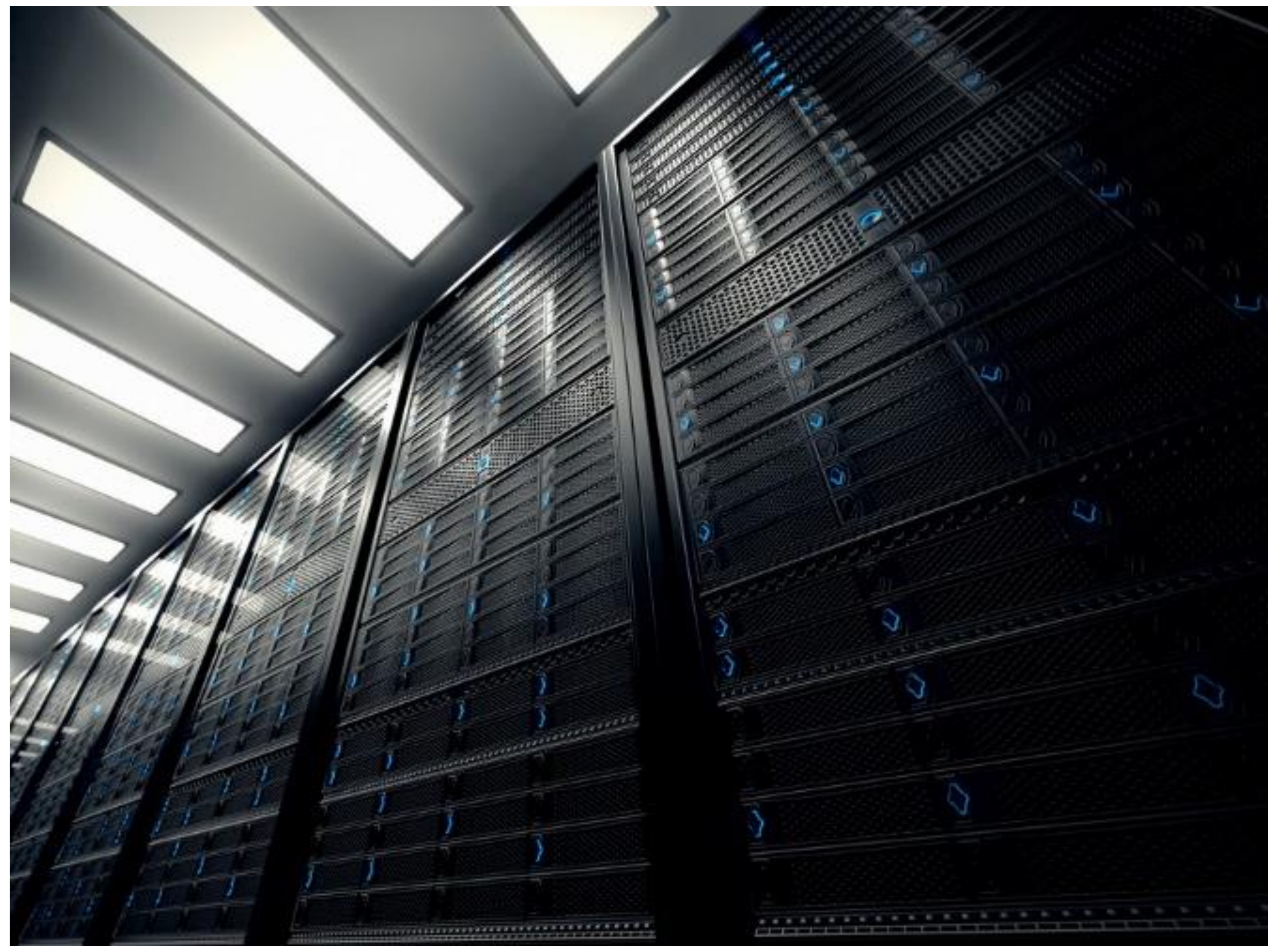
Why 48 Volt DC – Power Density

- As power densities increase, it becomes progressively more difficult to move the power to the payloads. A single 12 volt rack may require two or three 12 volt systems, each with its own bus bar, to avoid massive losses
- Each of these systems takes space away from revenue-generating payloads
- For the same wattage, increasing the voltage by 4X means reducing the current by 1/4X
- Current is directly proportional to heat and power loss, as well as to the amount of copper necessary to carry it
- ***Generally, above 15kW per rack, 12 volt systems become too inefficient to manage***



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Why not 70 or 100 VDC?

- There are two main reasons for standardizing on 48 VDC:

1. ‘**Low Voltage**’ is a recognized class of power delivery and allows for reduced safety requirements. DC power is only ‘safe’ at low voltages.
   The limits vary, but are generally below 60 VDC:

NEC limit:	49 VDC
NFPA limit:	60 VDC
OCP limit:	59.5 VDC

2. Telco has used 48 VDC as the standard for decades, so there is a wealth of existing products and technologies supporting it.

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But Telco is negative (-)48 VDC?

- Telco standard is 48 VDC, but the polarity is NEG on the 48 VDC, and the RTN is the 0(+) VDC reference (ground)
- Telco standardized on -48 VDC to reduce corrosion on the wires by moving the corrosion to the framework (ground). This is important when a large part of the Telco infrastructure is outside.
- This is not a big issue in a Data Center, but a bigger issue is the total potential voltage:
  - Consider a Data Center with both +12 VDC and -48 VDC power supplies, there is a possibility of having more than 60 volt potential between two terminals, violating the low voltage limits
- Openrack V2 allows for both +48 and -48 VDC (A.2.2), but +48VDC is easier to support in a mixed environment

NOTE: Standard Telco -48 VDC equipment may not naturally function in a +48 VDC environment – may require modifications

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So where did 54.5 VDC come from?

- The Telco 48 VDC standard is actually the nominal voltage, but systems typically run at 52.5 VDC, 54.5 VDC, etc.
- This is due to battery charging requirements, for example:
  - A lead acid cell produces from about 2.2 volts, down to 1.75 volts at full discharge
  - A standard 12 volt battery has six cell, and a 48 volt system has four 12 volt batteries, so the voltage range from Charged to Discharged is about 53 VDC to 42 VDC
  - To fully charge the battery, a slightly high voltage is needed = 54.5 VDC (float voltage)
- NOTE: Consider the ***low voltage*** issue:
  from +12 VDC (actually 13.6) to -48 VDC (actually 54.5) creates a **68 VDC total potential voltage**

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So where did 54.5 VDC come from? (continued)

- Many years ago, the Telco voltage level was actually 48 volts for the equipment, and a separate charging system handled the batteries, but this made the systems more complicated and less reliable.
- Connecting the batteries directly to the DC bus solves this issue.
- It is the simplest and most reliable method to provide backup power, but it does requires the whole common bus to follow the battery voltage range.

Per OCP: 42V – 58 Vdc, output defaulted to 54.5V

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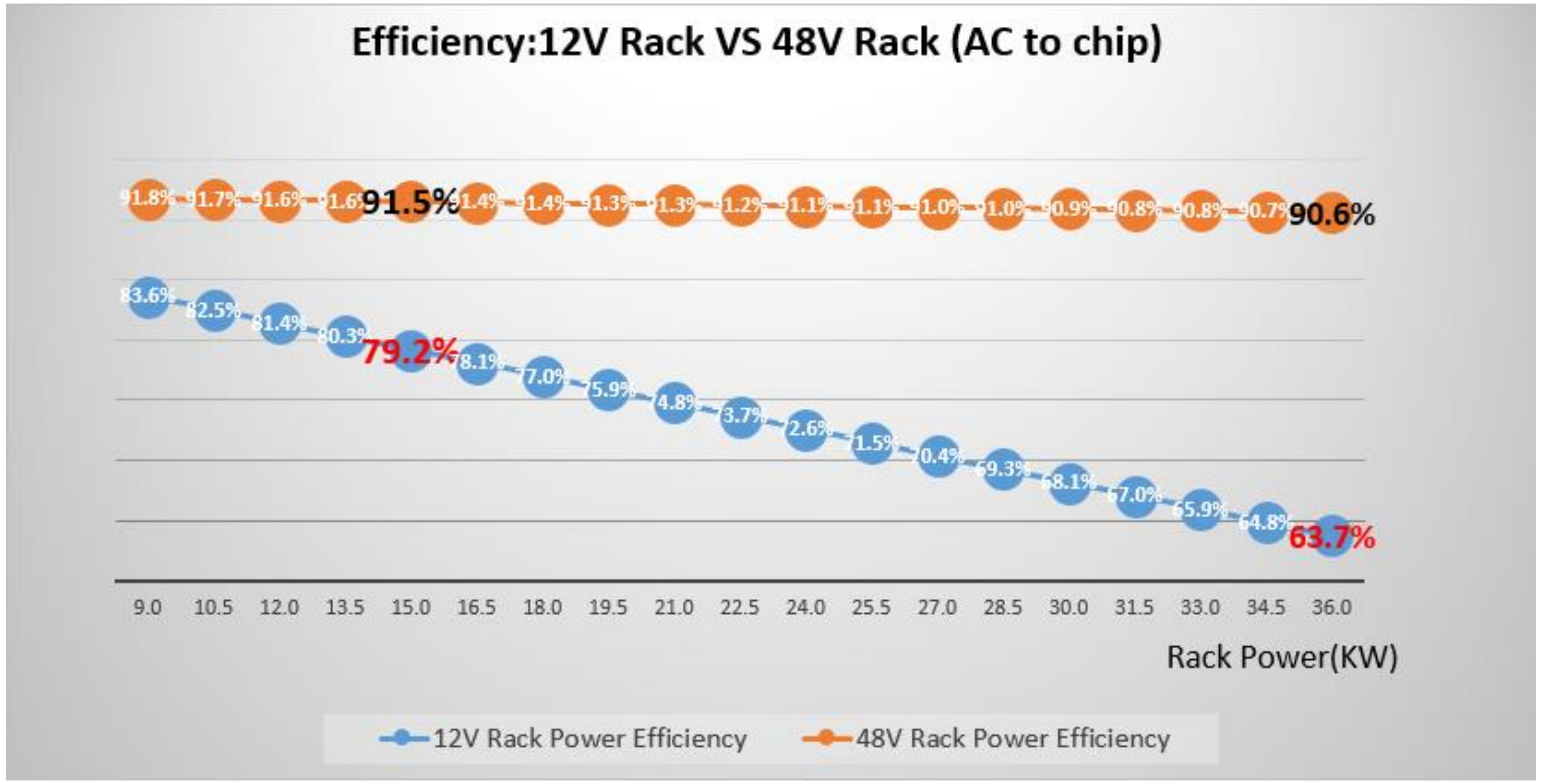
48V versus 12V, major improvement in efficiency:

The power efficiency (AC to chip) will decrease as the rack-level power goes up

- 12V system efficiency can reach 80% below 15KW
- 12V system efficiency drops faster above 15KW, only 64% @ 36KW
- 48V system efficiency stays above 89% for power above 15KW



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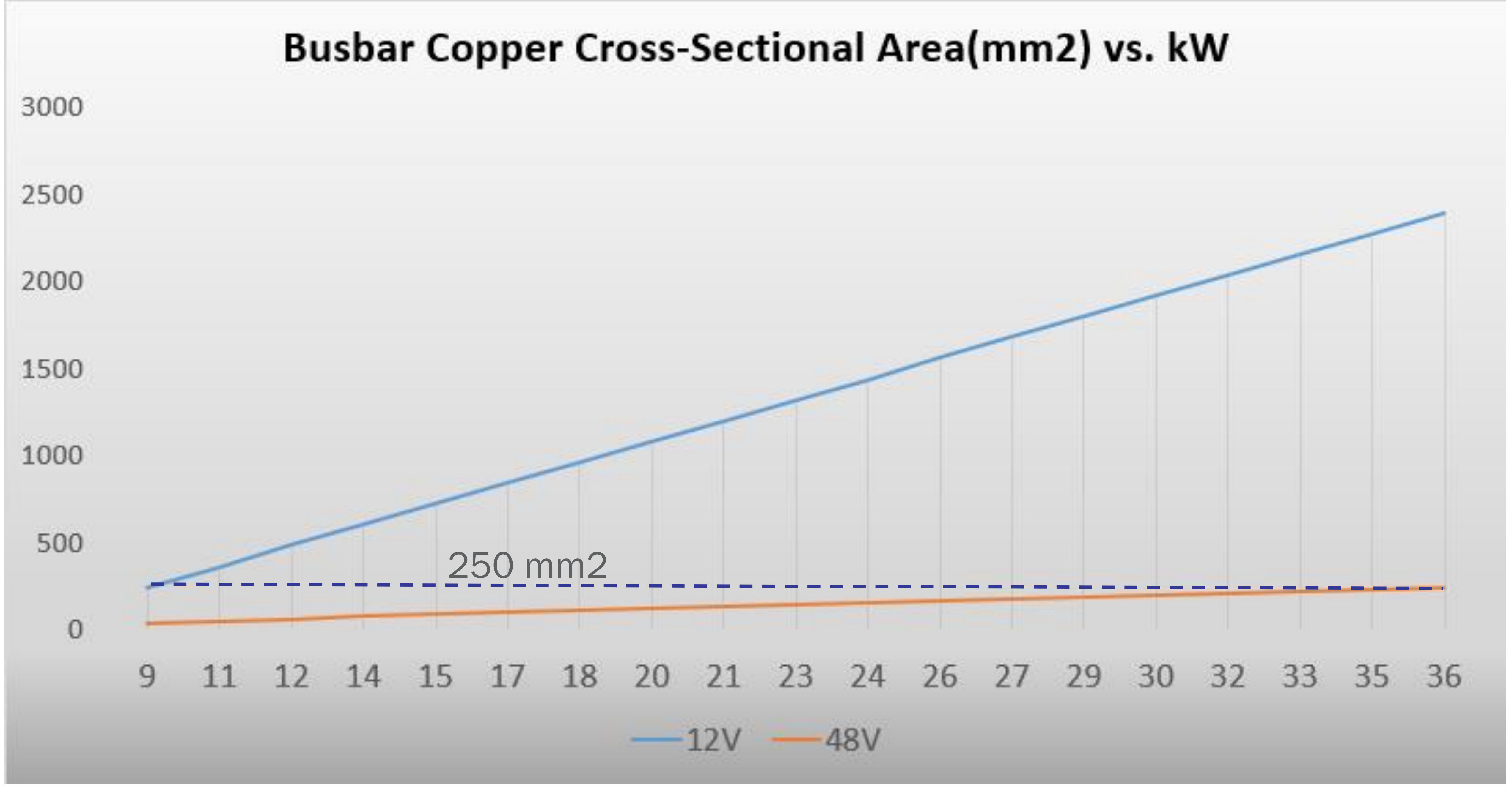
48V versus 12V, major improvement in efficiency:

The 48V DC output cables much thinner than 12V in high power applications

- Cable size can be only 1/9 compared with 12V
- Less cost on cables
- Easier to manufacture

OCP and Huawei opinion:
<15KW: 12V OCP power architecture
>15KW: 48V OCP power architecture



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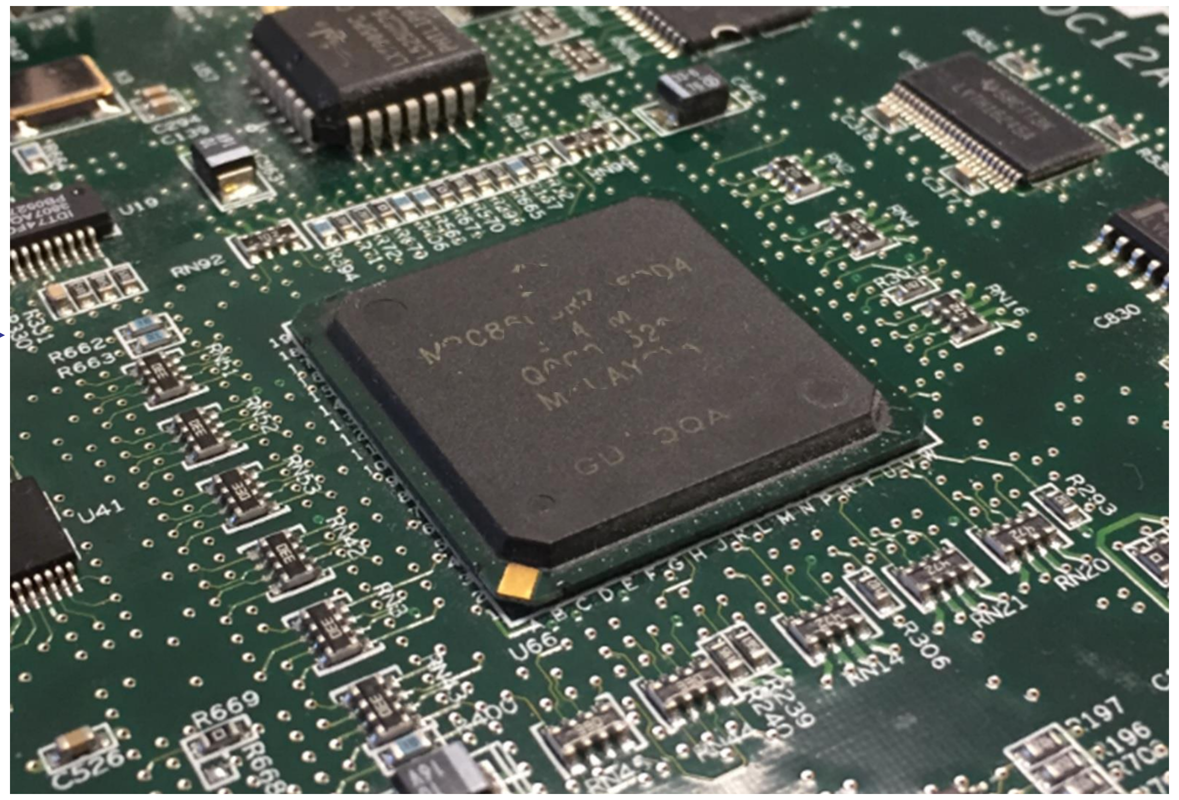
Overall Data Center Efficiency Analysis

Main Goal – Power to the Chips!

Utility Tower

Do Something to the Power

Chip



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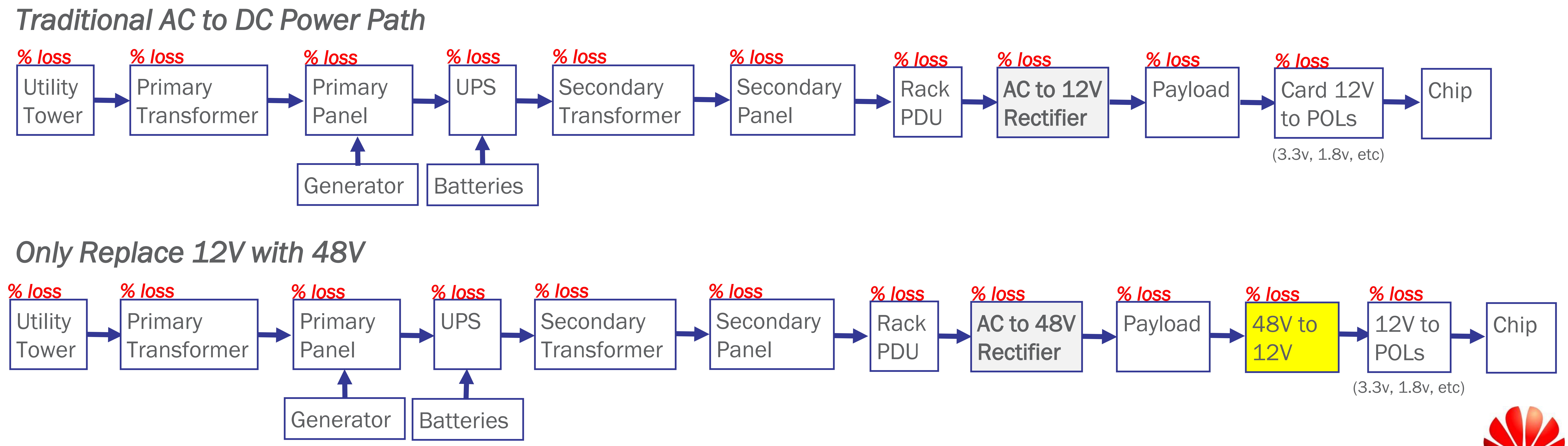
Overall Data Center Efficiency Analysis – Moving to 48 VDC alone does not fix everything:



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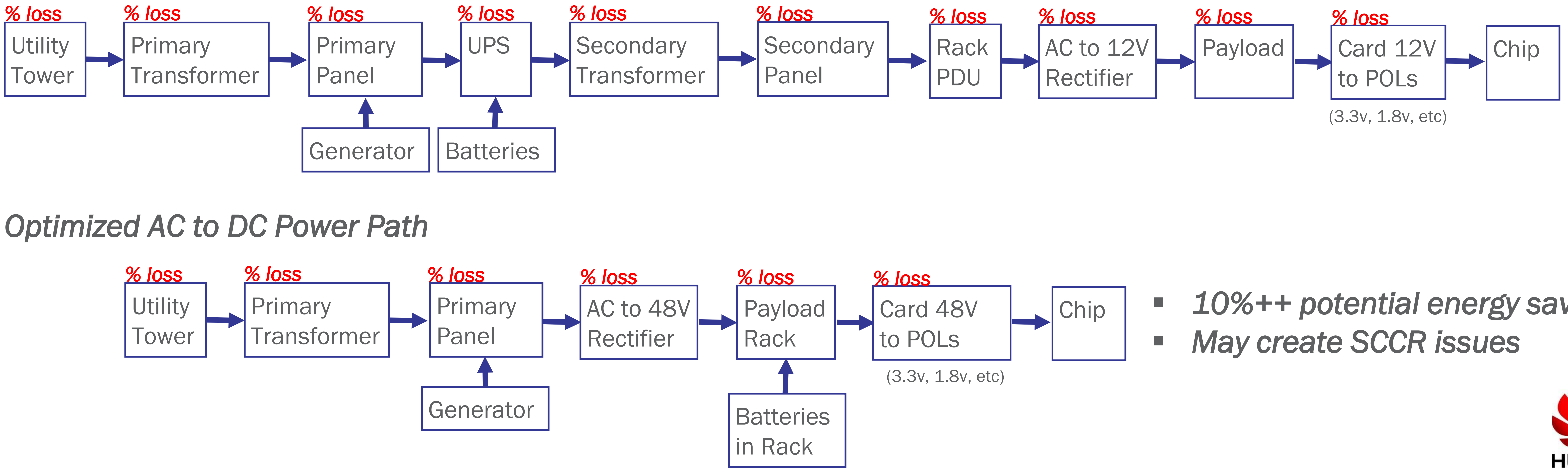
Overall Data Center Efficiency Analysis – Moving to 48 VDC alone does not fix everything:

Traditional AC to DC Power Path

Optimized AC to DC Power Path



- *10%++ potential energy savings*
- *May create SCCR issues*

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48 VDC OCP Design - Open Rack V2.1 standard compliant

Key design targets:

- *Play well with OCP Open Rack V2.1*

  Overall size, shelf latching, common 48 VDC bus bar

- *Maximum power density – up to 36kW in an OCP rack*
- *Support both single (split) phase and balanced 3-phase AC 208 to 277 VAC*
- *Include high density battery option in the rack – variable capacity*

  Maintain power until generator kicks-in – around 2 minutes

- *Allow for an optimized power architecture*

  Must survive in a high SCCR environment

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48 VDC OCP Design – Highest Efficiency Rectifier Module

Current Model:

R4850S

- Peak efficiency: 98.1%
- Output power: 3000W
- Power density: 42 W/inch3
- Temp range: -40 to 55 degC
- Size: 1*2.5U*12 inch
- Volume production in Q1, 2015

Future Model:

R4875X

- Peak efficiency: 98%
- Output power: 4500W
- Power density: 63 W/inch3
- Temp range: -40 to 55 degC
- Size: 1*2.5U*12 inch
- Release: Expected Q2, 2018

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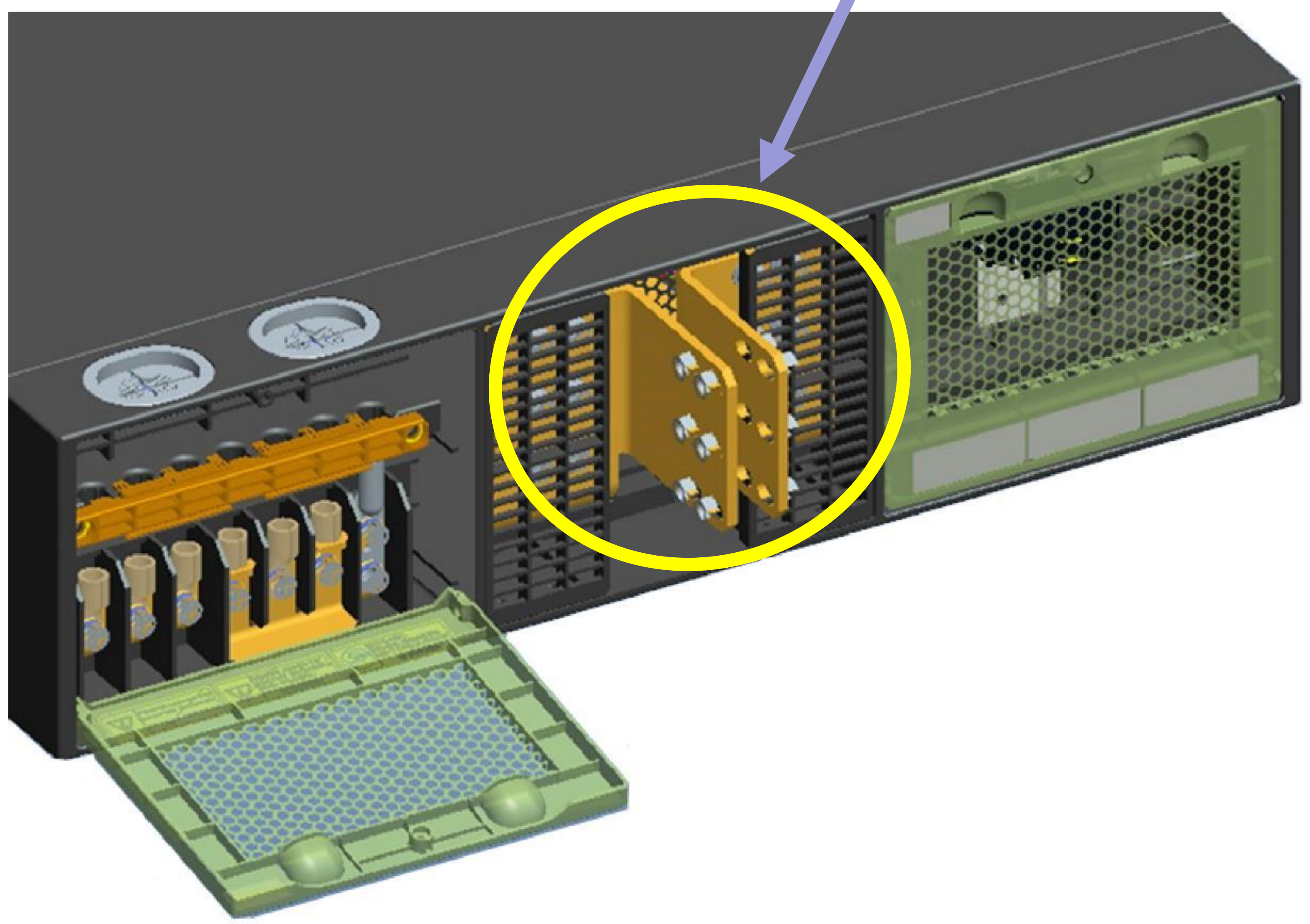
48 VDC OCP Design – Power Shelf Design, 36kW Capacity

- **Max 36kW output:** Shelf design supports 24kW and 36kW output in a 3OU space using Huawei's 98.1% efficient 3kW rectifier modules.



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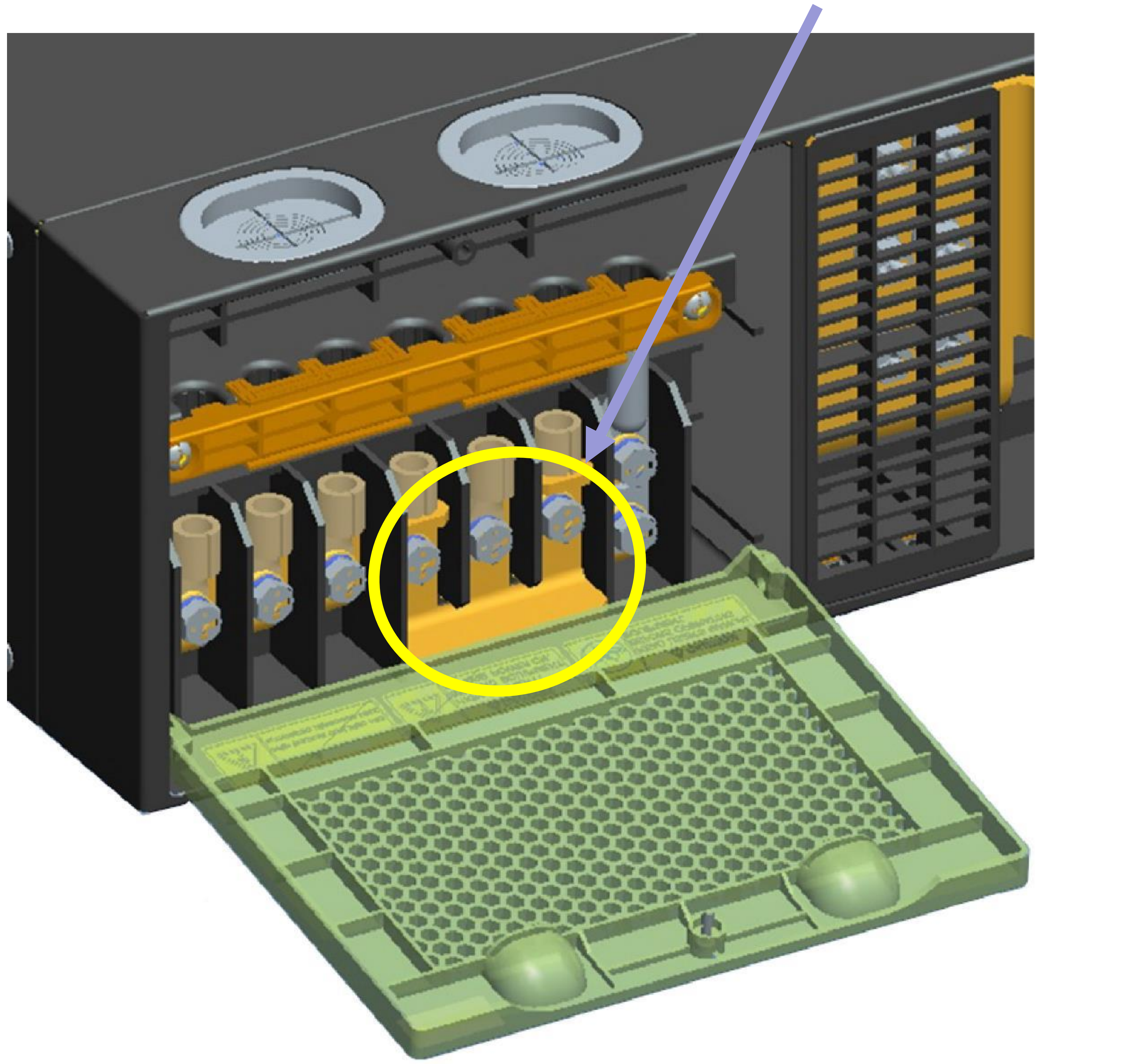
48 VDC OCP Design – Single/3-phase operation

- **3-Phase operation:** Shelf is designed with nine rectifier modules arranged in three sets of three each. Each set is connected to one of the phases. This provides a perfectly balanced load on the 3-phase feed.
- The system is also flexible, allowing the shelf to be converted to single-phase operation by simply removing a jumper.



For 240V/415V 3P4W, With A\B\C\N\PE

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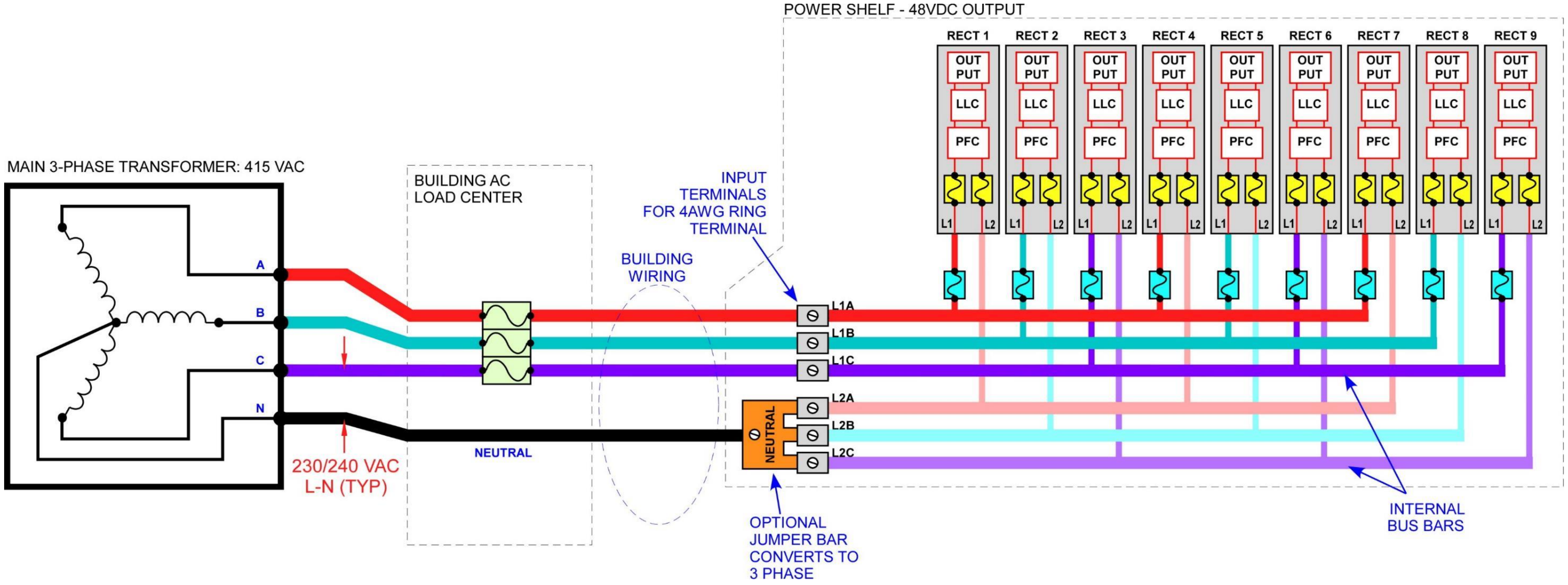
48 VDC OCP Design – Single/3-phase operation



Option for Single AC Cable

- UL/IEC 60309 Connector
- 5 PIN: L1, L2, L3, N, GND
- Current: 100 A

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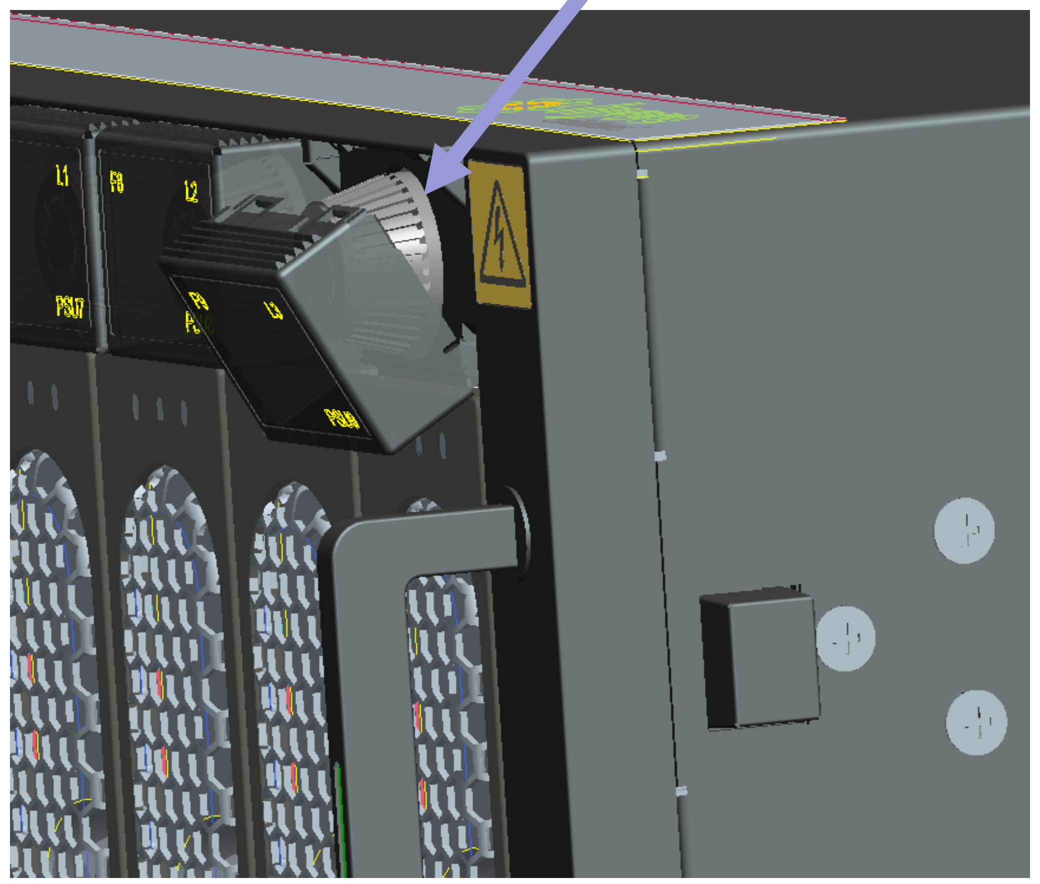
48 VDC OCP Design – High SCCR environments

- **SCCR rating:** Unit can work in a high 100kA SCCR environment with Class J fuses feeding the power shelf. The coordination between the rectifiers' internal fuses and the external Class J fuses is addressed by adding intermediate Class CC fuses in the shelf. These fuses are provided for each rectifier module, and fit within the 3OU shelf envelop.

Fuse holders with safety covers



Fuse bank – one for each rectifier module

Spare fuse

Current-limiting fuse

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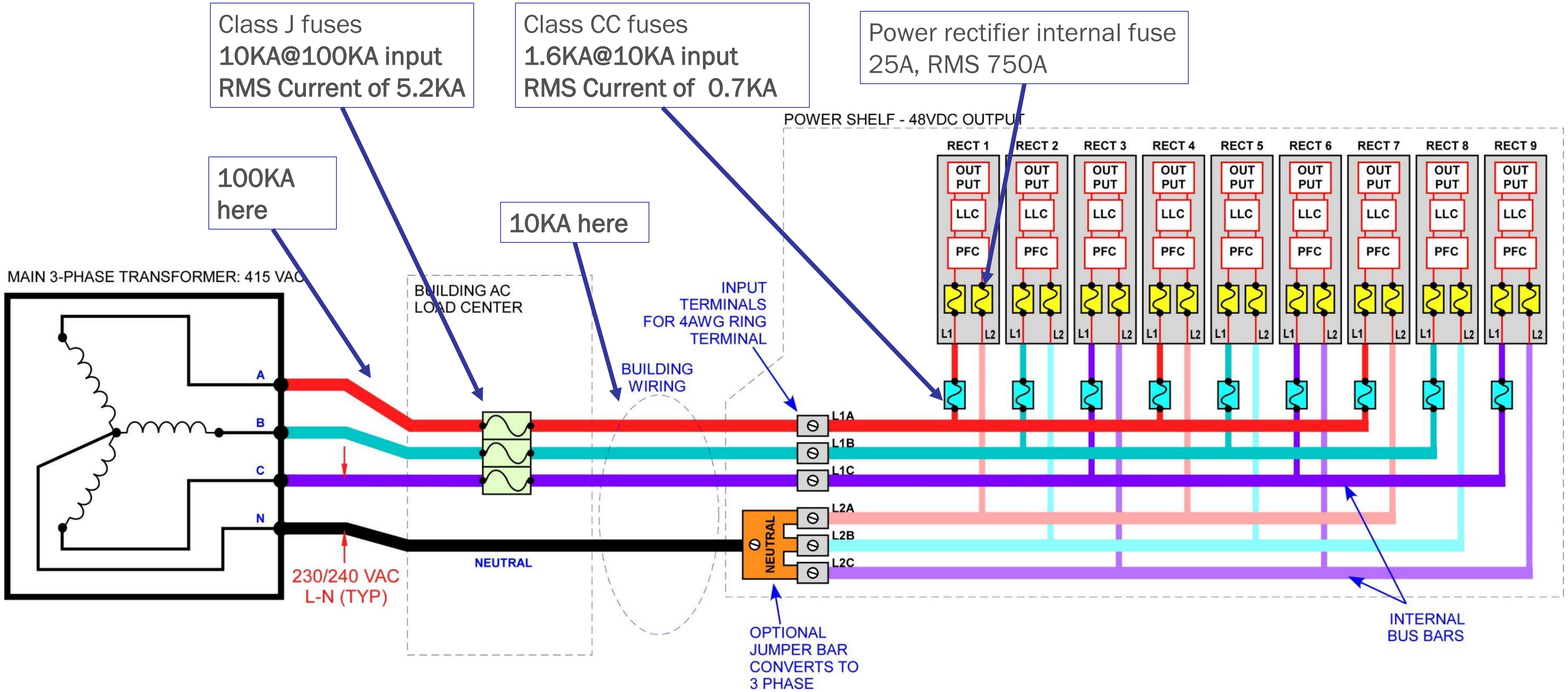
48 VDC OCP Design – High SCCR environments



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48 VDC OCP Design – BBU Architecture

- Each 1 OU shelf is made up of 3 battery modules and one communication board
- Output connector for Openrack V2 bus bar, blind-mate, 250 amp max power. Allows the customer to add or remove battery shelves as needed, without shutting down the rack.
- Maximum backup power is 7.5KW per shelf, and the backup time is 2mins@7.5KW
- Each Battery Module has its own BMS to manage charge/discharge, and battery temperatures. Max operating temperature is 60degC
- Each battery module has its own DC/DC converter. This allows the module's output to be a fixed voltage, while the individual cell voltages change during charging/discharging. This provides a much more stable power output for the payloads

- 7.5kW BBU shelf with three battery modules

- 250 AMP 48 VDC Connector – Mates to OCP Openrack V2 vertical busbar

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48 VDC OCP Design – BBU, Cell selection - Safety comparison: LFP to NMC (Tested by Sony)

- Battery modules are based on lithium-iron-phosphate battery cells that provide the best balance of safety, density, temperature resistance, and cost.
- Each Battery module is made up of 64 18650 LFP cells, connected in 4 parallel sets of 16 cells each

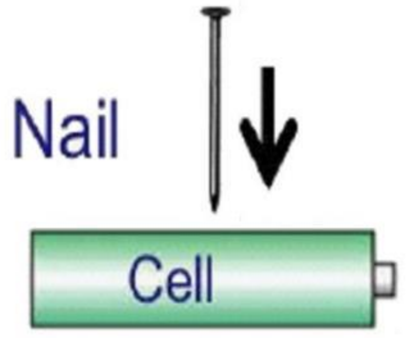
Material	Chemical formula	Energy density	Burn test	Nail test
NMC	$Li[Ni,Co,Mn]O_2$	220Wh/kg	Burns at 33s, explodes at 40s	Burns at 1s, out of control at 4s
LFP	$LiFePO_4$	160Wh/kg	Explosion valve opens at 30s, the cell does not move after combustion	Liquid leakage but no fire or explosion

48 VDC OCP Design – BBU, Safety comparison: LFP to NMC (Tested by Sony)

Safety test (Single Cell, Nail test)

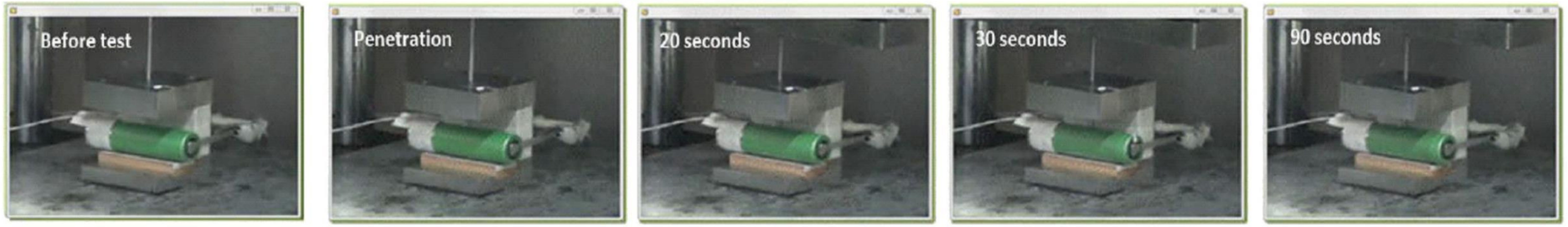
Safety

Penetration to the full charged cell.
It is a test that assumes the battery damage due to building collapse, etc..



Sony's LIB (LFP)

LFP



Company A(NCM type)

NMC

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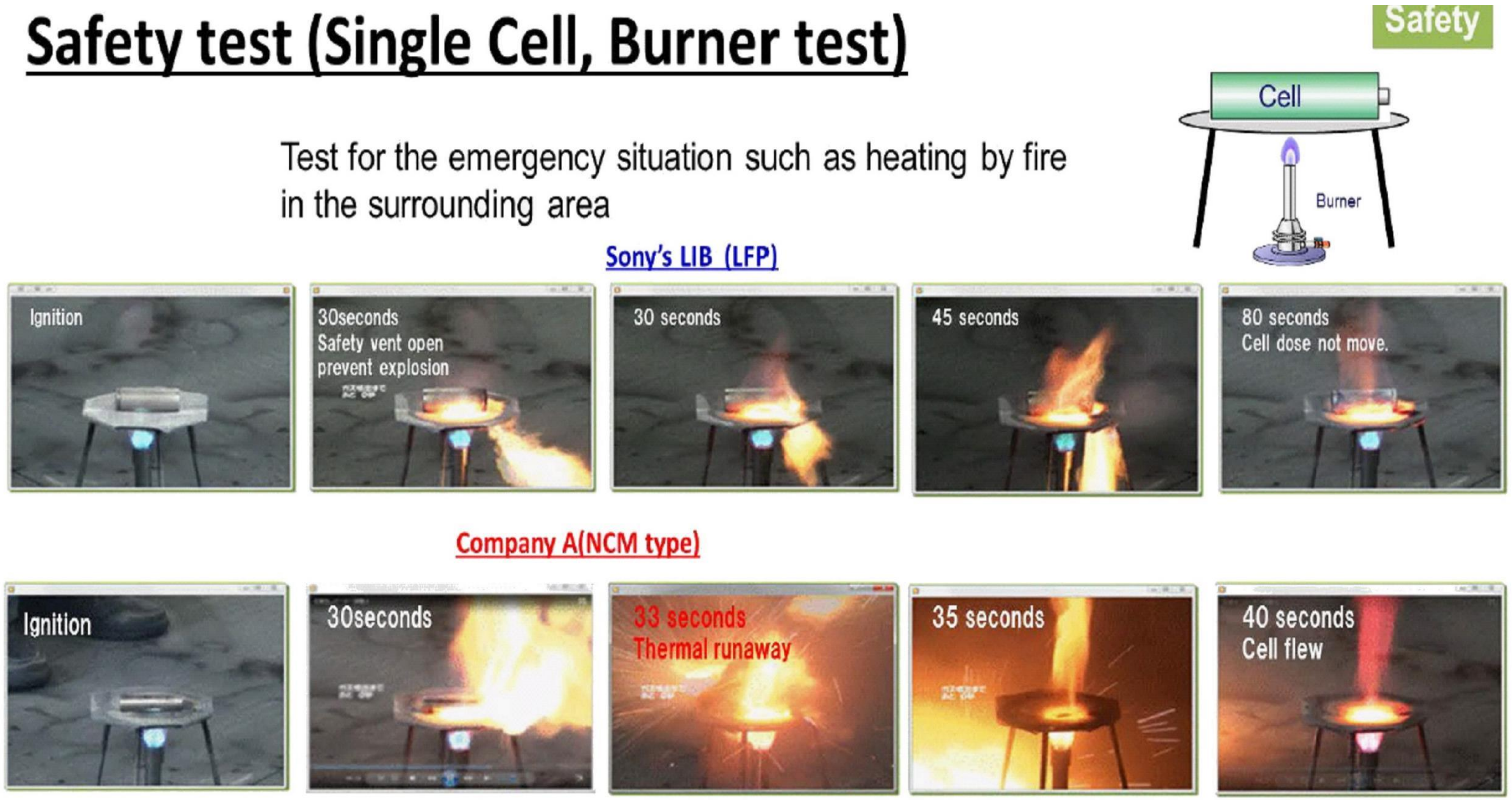
48 VDC OCP Design – BBU, Safety comparison: LFP to NMC (Tested by Sony)

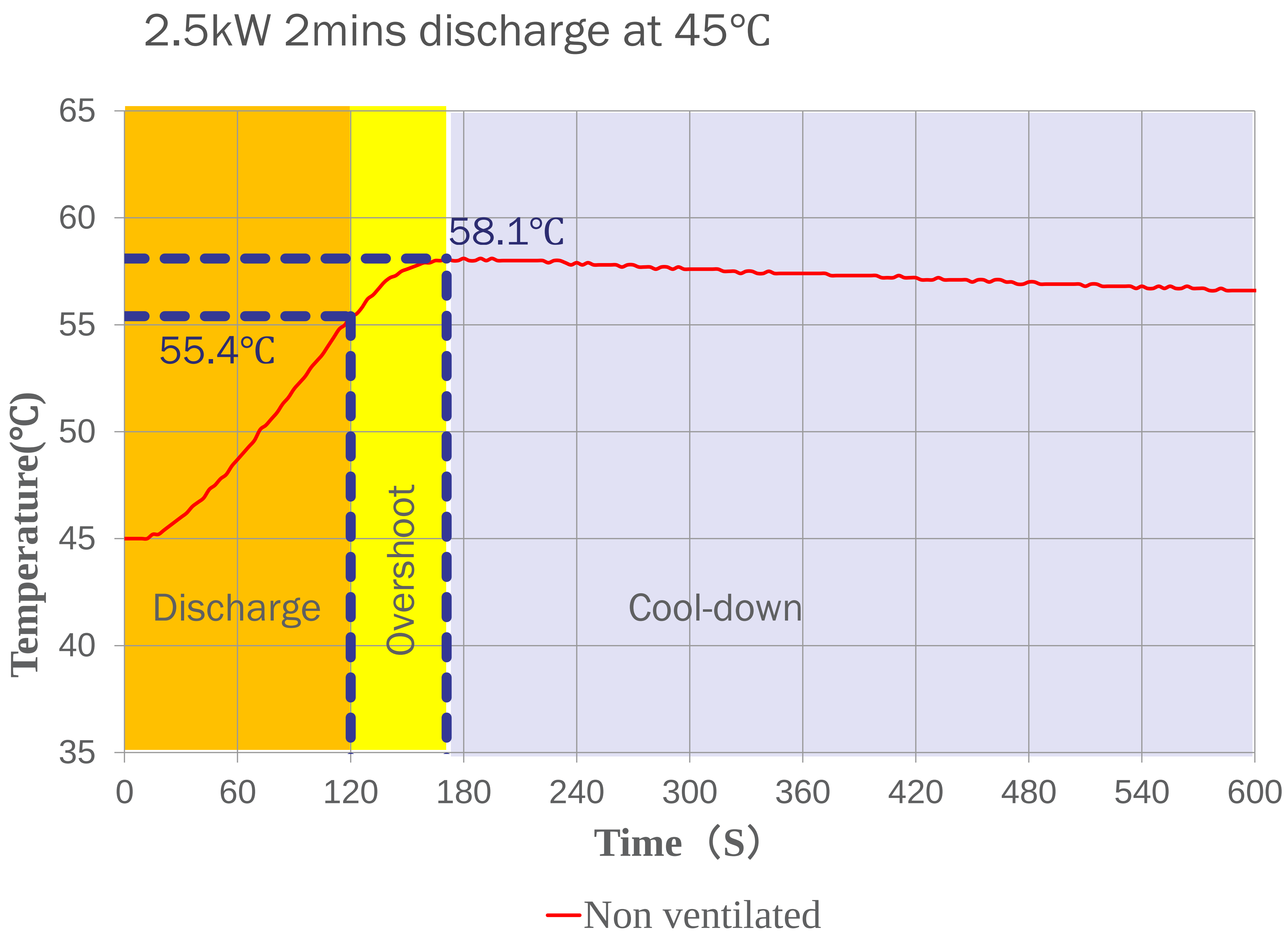


LFP

NMC

48 VDC OCP Design – BBU thermal considerations

- During discharge, the cells in the battery modules heat up dramatically
- Thermal analysis is important, but steady-state analysis does not work. Since discharge is limited to less than 2 minutes, analysis is a ***transient*** problem



- The highest temperature is 58.1℃ (13.1℃ temp rise) after 2mins @ 2.5kW discharge for sealed BBU

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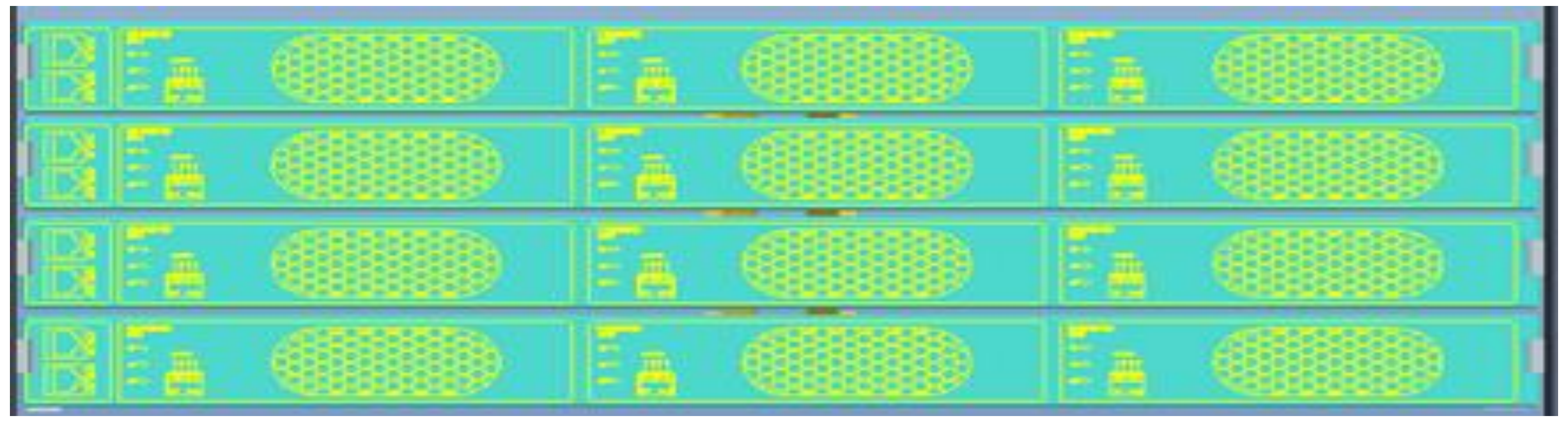
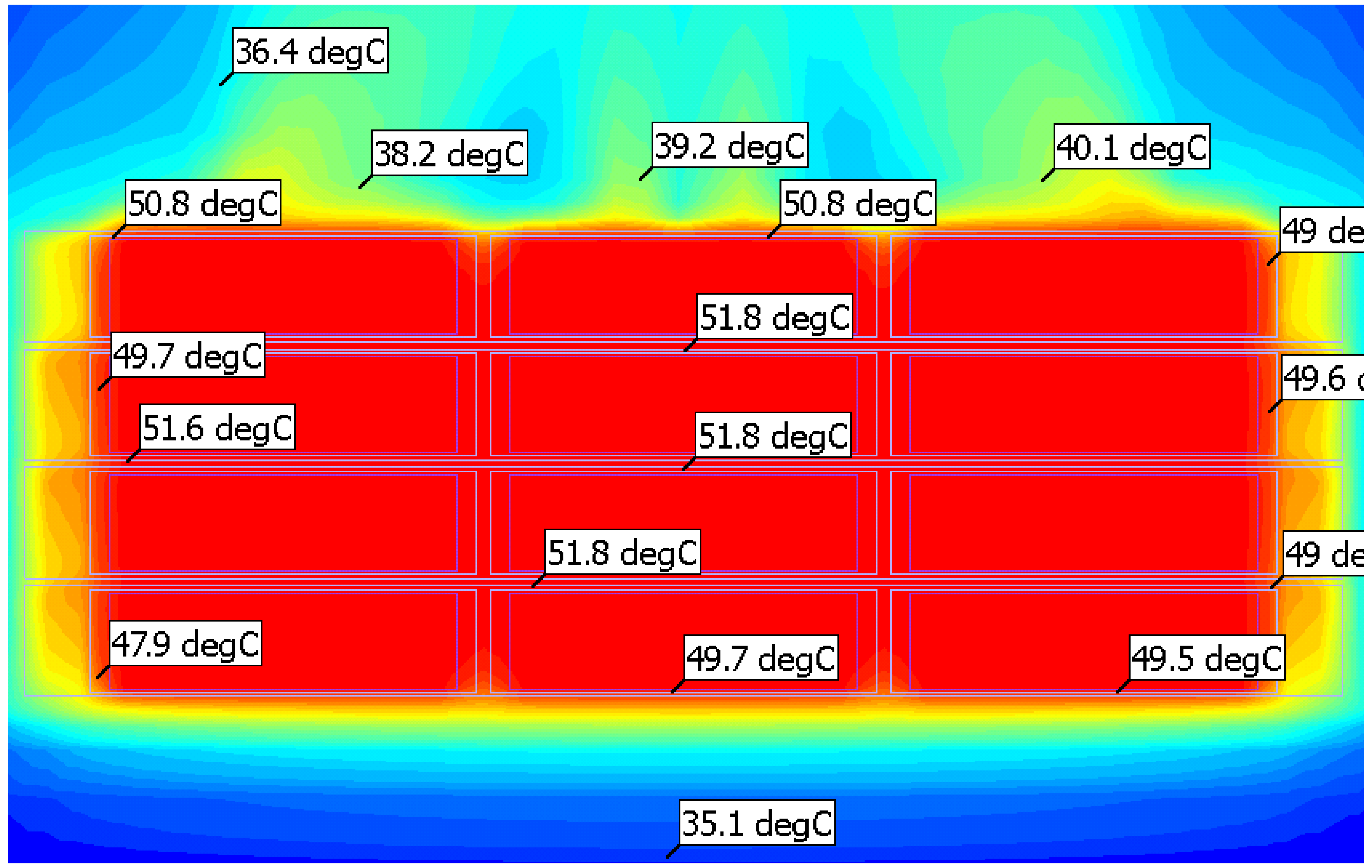
48 VDC OCP Design – BBU thermal considerations

- Analysis is also important for full system to ensure servers and other equipment are not affected
- Results:
    - Due to short heat-up duration, the heat is only starting to soak into the surroundings when the discharge ends
    - Due to the large mass of the rack and equipment, actual effect on equipment is minimal (about 1 degC)





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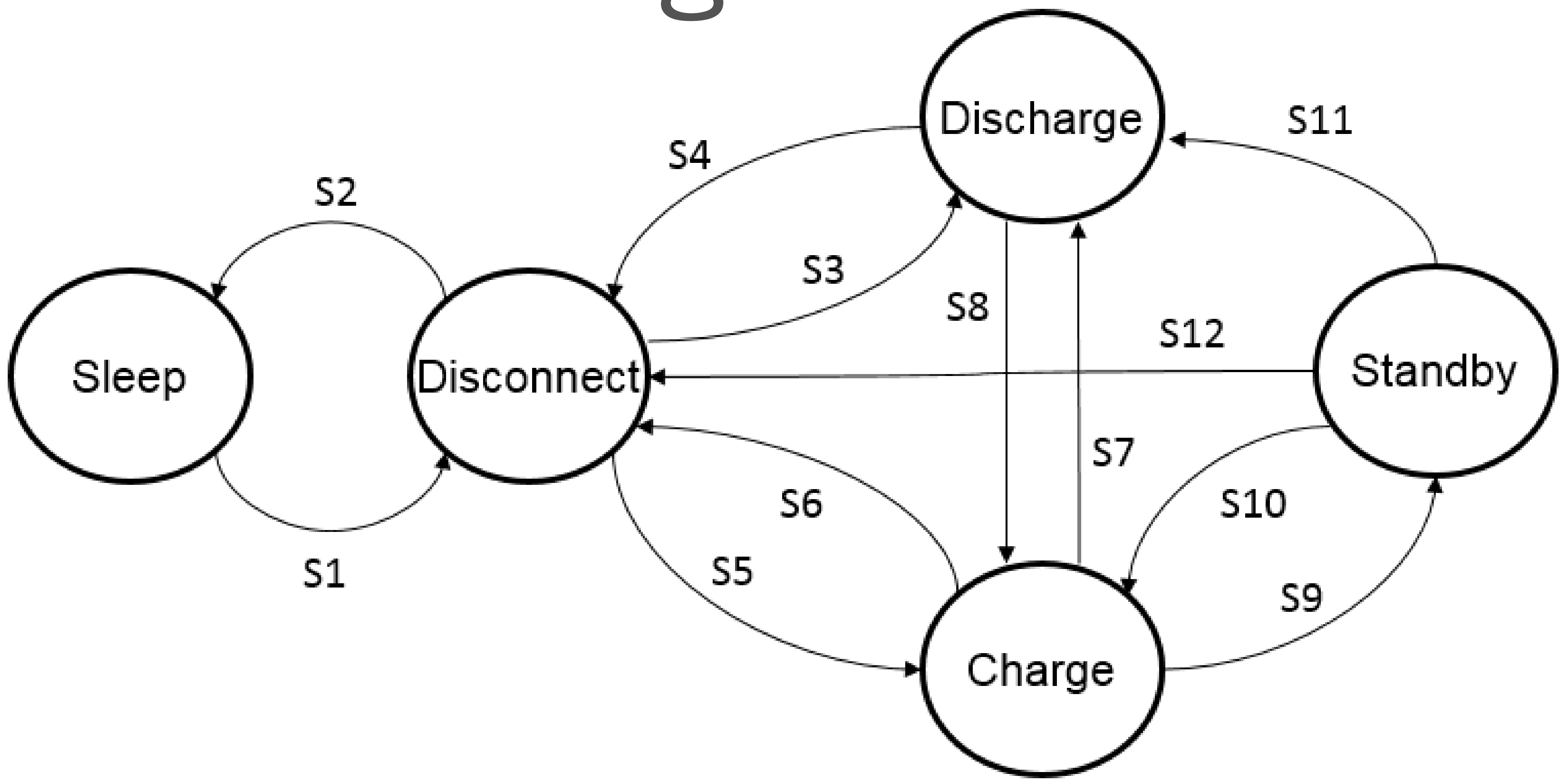
48 VDC OCP Design – BBU Control

BMS functions:
- Cell failure alarm
- Cell imbalance detect
- SOC/SOH calculation
- Charge/discharge control

Protection:
- Over temperature (several temperature sensors monitoring high heat locations to guarantee the cells operate safely)
- Over Current
- Over Voltage
- Four stages isolate faults from the battery pack, the DC/DC converter and the bus bar – guarantee cell safety and payload reliability



Sleep Mode:	Bidirectional DC/DC converter is Shunt Down, BMS Power Off, Power consumption is about 0W
Disconnect Mode:	Bidirectional DC/DC converter Shunt Down, BMS Online , Communication & Temperature Detection & Voltage Detection are operating, Power consumption ≤ 3W
Charge Mode:	BBU in Charge mode
Standby Mode:	BBU in Discharge mode
Standby Mode:	After charging the BBU, the BBU will enter Pre-Discharge mode; This mode prepares for discharge

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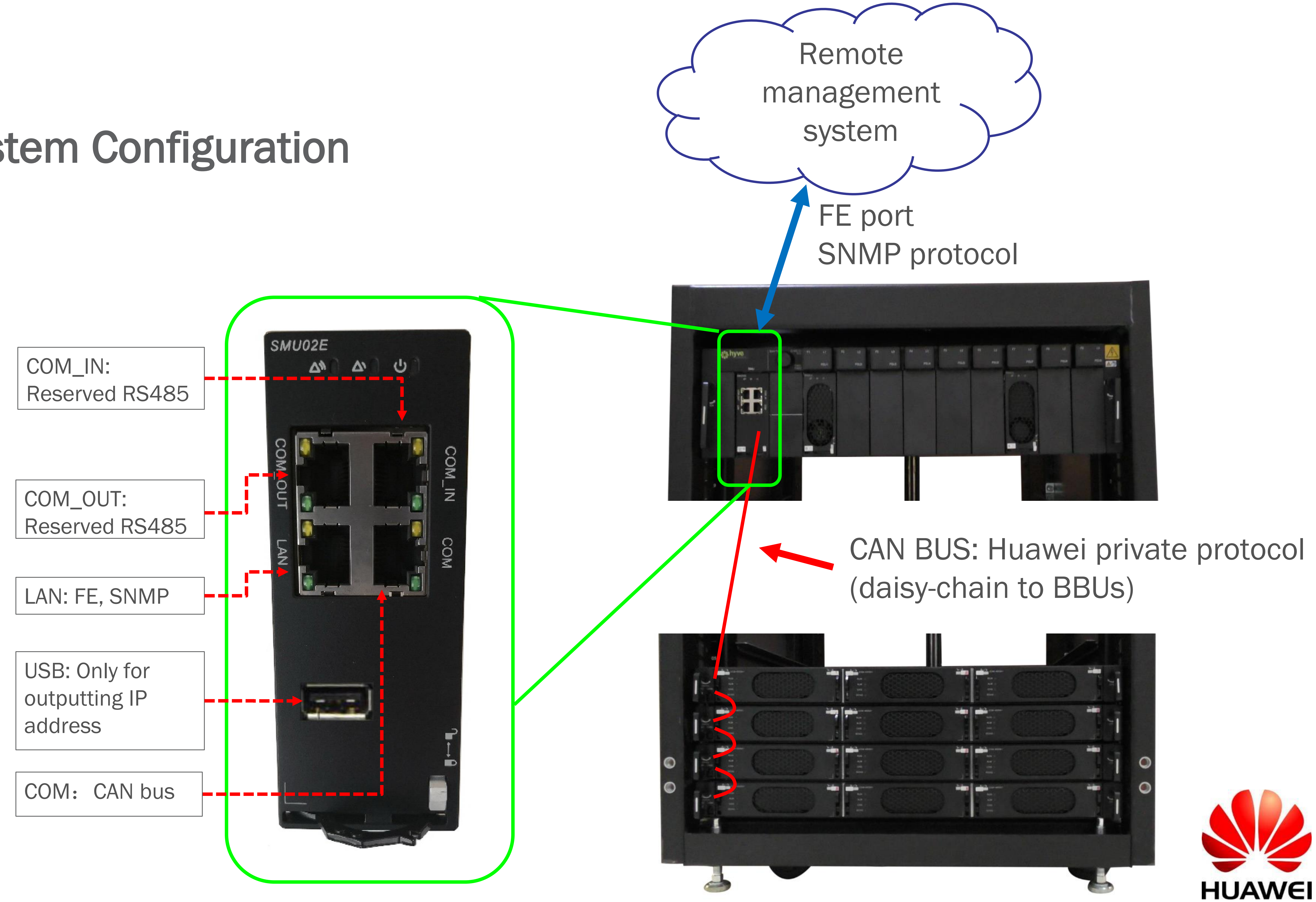
48 VDC OCP Design – Full System Configuration

- One Power shelf
  - 1 System controller
  - 9 Rectifier modules
- One or more BBUs, each with
  - 1 Communication module
  - 3 Battery modules
- BBU communication module receives health info from its battery modules, communicates to system controller
- System controller gathers BBU and rectifier module info, communicates with remote management
- Both rectifier and BBU modules function independently and safely if loss of communications



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