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Efficiency beyond the AC based datacenter designs; 400VDC power feed solution

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Introduction to the challenge

Datacenter and Telecom operators are challenged to increase the efficiency and reliability to keeping pace with growing trend of server power density and cost of electricity*. Same time exiting facilities trend to outgrown beyond designed power capacity.

By adopting new energy efficient power feed architecture 400VDC we can solve the many problems with AC distribution and also in -48VDC distribution and reduce the TCO.

*U.S. Energy Information Administration; Annual Energy Review

Energy savings by reducing conversion stages

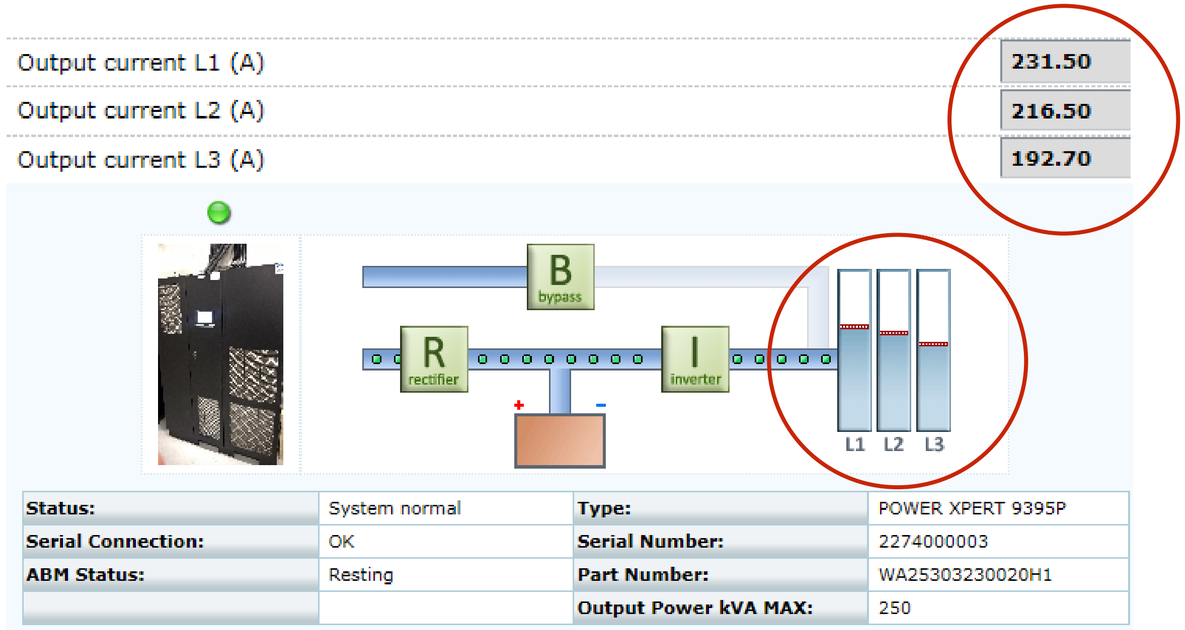
Potentially three AC conversion stages can be eliminated by using 400VDC distribution:

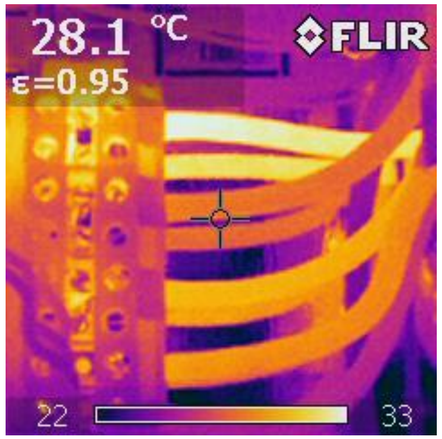
1. AC UPS DC-to-AC inverter stage
2. 480VAC to 208VAC conversion stage on US datacenters
3. Power Factor Correction (PFC) AC-to-DC stage

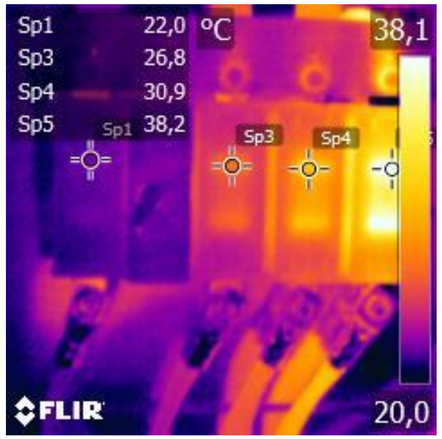
Problem: Harmonics and phase balancing in three phase AC systems

Most common challenges in 3-phase AC distribution systems in datacenter:

- Maintain phase load balance. Heavily unbalanced loads cause increase of neutral currents.
- Keep THD low. The current harmonic distortion caused by AC PSU cause neutral the current increase and increased power losses to transformers and conductors

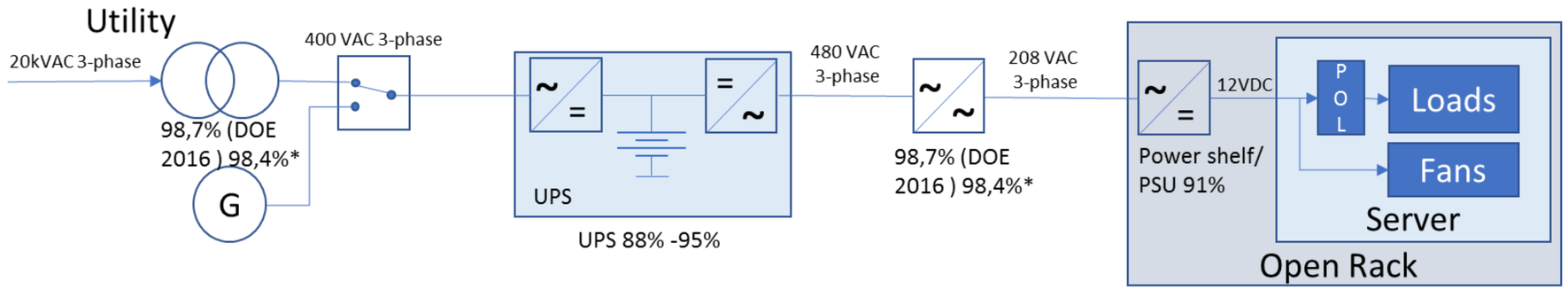




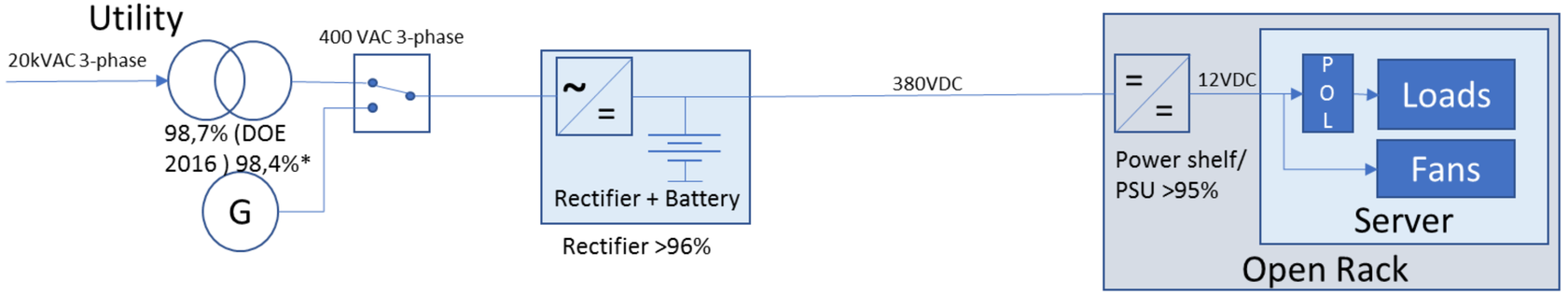


Overheated neutral, by courtesy of ARE Oy

Efficiency improvements by reducing conversion stages and eliminating harmonics



Best in class:	98,7%	x	95%	x	98,7%	x	91%	= 84%
Typical with harmonics:	98,4%	x	88%	x	98,4%	x	91%	= 77%



Typical :	98,7%	x	96%		x		95%	= 90%

*U.S. Department of Energy (US *DOE*) Limit. Transformer losses can increase 17% due the harmonics. Transformer losses in windings increase as the square of the THD_i and that core losses increase linearly with the THD_u

Efficiency TCO impacts

200 pcs of 25kW Open Rack, total 5MW load

Power feed architecture	System efficiency	Input Power at utility transformer	Energy cost per year, *Finland 6,7c/kWh	Energy cost per year, *US 10c/kWh
Typical AC datacenter	77%	6,49MW	3,8MEUR	5,7MUSD
Best in class AC datacenter	84%	5,95MW	3,5MEUR	5,2MUSD
Typical 400VDC datacenter	90%	5,56MW	3,3MEUR	4,9MUSD

*Finland electrical cost based EUROSTAT 2017. US average electricity cost: *https://www.eia.gov/electricity/state/*

Solution for Harmonics and phase balancing problem in three phase AC systems

400VDC power distribution eliminates the challenge of phase balancing

There is no problems about harmonics (no need for PFC nor compensators in power distribution)

Additional advantages are simplified wiring, less circuit breakers, reduce power equipment footprint 33-percent* and increase reliability of power distribution system by 200-percent.*

*Intel 400Volt Direct-current white paper, Evaluating 400V Direct-Current for Data Centers

Problem: Limited power transmission distance with -48VDC systems

Case study:

Existing -48VDC central office location. Battery room and rectifiers one floor below. Aisle length 40m total cable route approx. 60m. New high power racks:

Open rack with 4 x -48VDC feeds

Total rack power 25kW, 12,5kW/zone

-48VDC backup battery string 24VRLA cells at lowest discharged voltage 1,75V per cell, total -42VDC

160A current -> 200A MCB -> 95mm^2 (AWG4/0) power cables

Max cable length with 2V max voltage drop -> 34m (112 feet), Not feasible

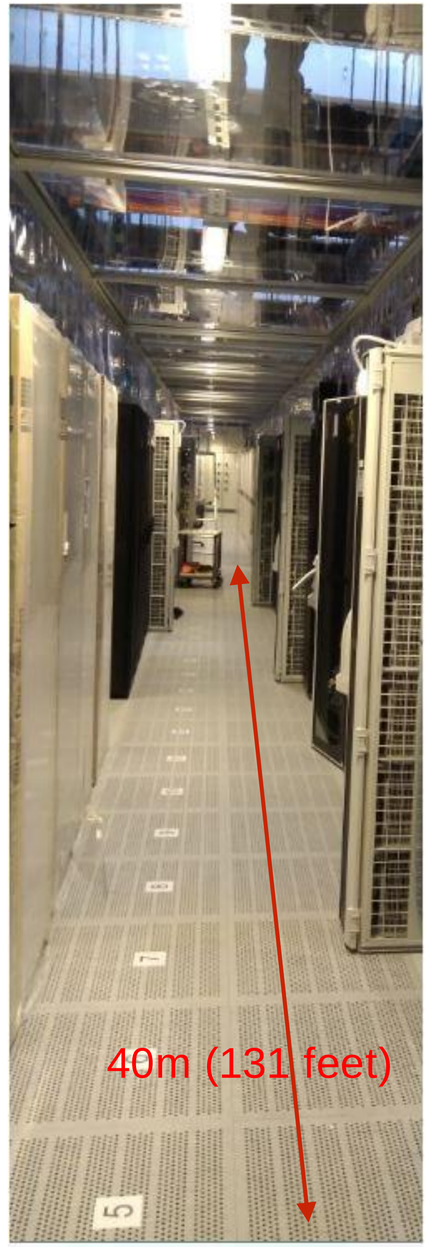
Open rack with 4 x 400VDC feeds

Total rack power 25kW, 12,5kW/zone

HVDC backup battery string (168 VRLA cells in series) at lowest discharged voltage 1,75V per cell, total 294VDC

22A current -> 32A MCB -> 25mm^2 (AWG 3) power cables

Max cable length with 2V max voltage drop -> 66m (217 feet), Feasible



400VDC; Solution to modernize -48VDC telco sites

- Solution for high power density distribution where -48VDC not possible
- By distributing the power by 400VDC is reducing the nominal currents by factor 7 compared to -48VDC distribution. In practice amount of copper cable can be reduced by factor 8 to 12. This allows greater flexibility to modernize existing telecom sites with existing battery rooms.
- Existing 48V battery strings can be reused.
- Reduces the MCB size and short circuit currents

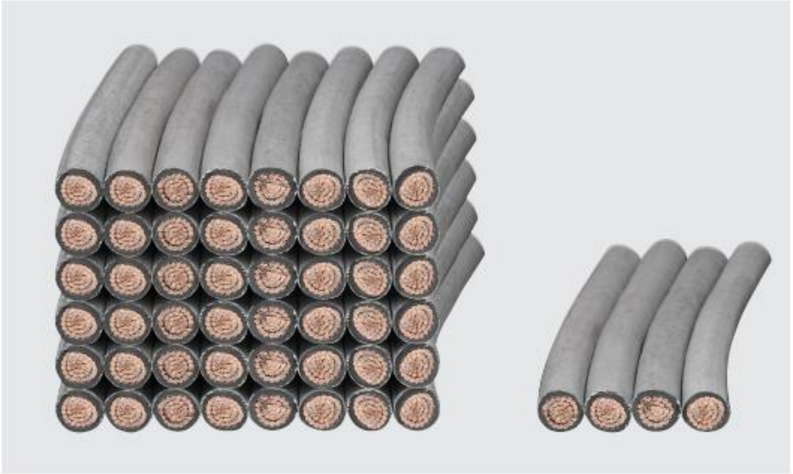
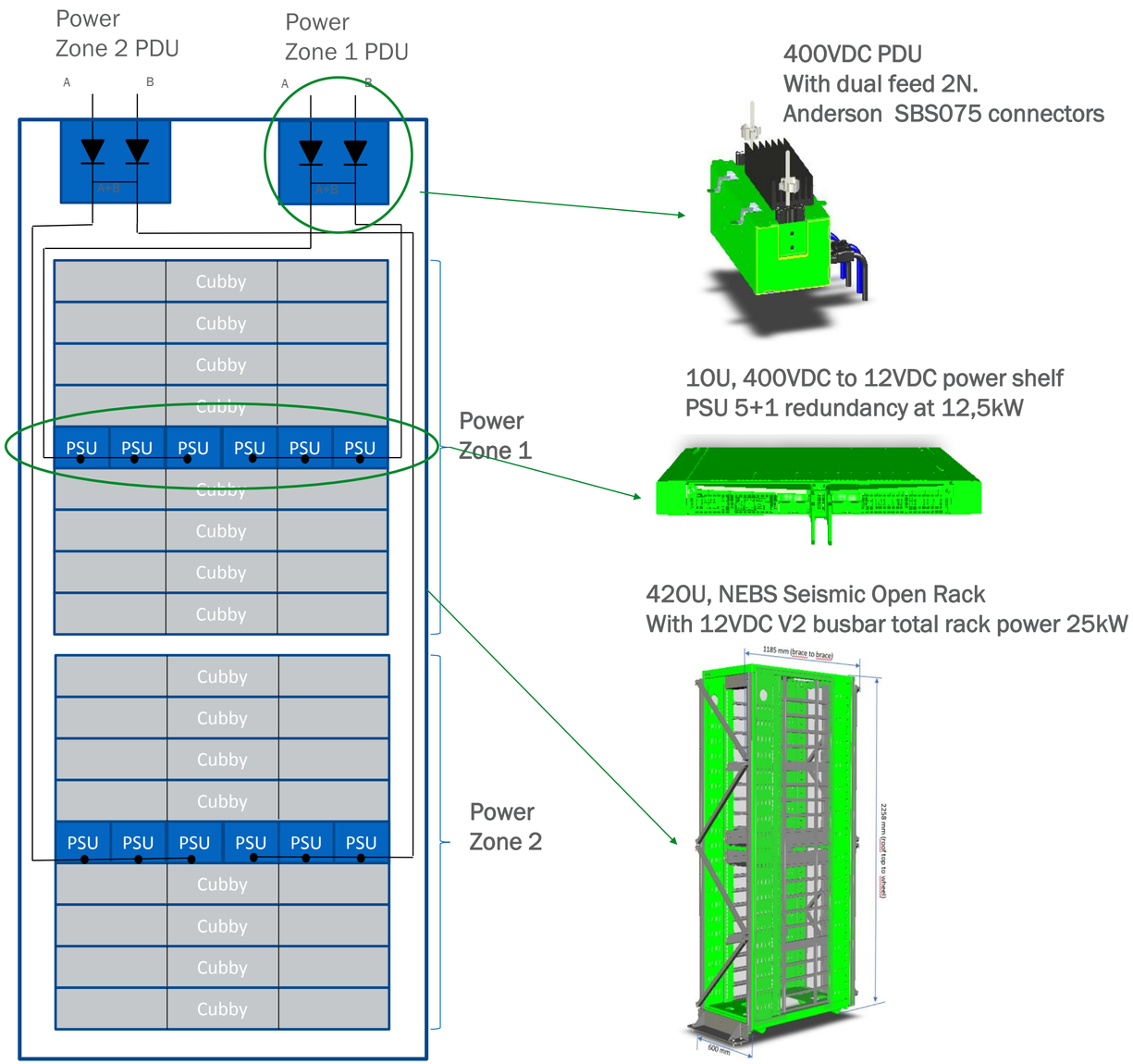


Figure 1. Cable required to transport 200 kW of current 245 feet with 48V DC compared to 400V DC.

By courtesy of Vertiv

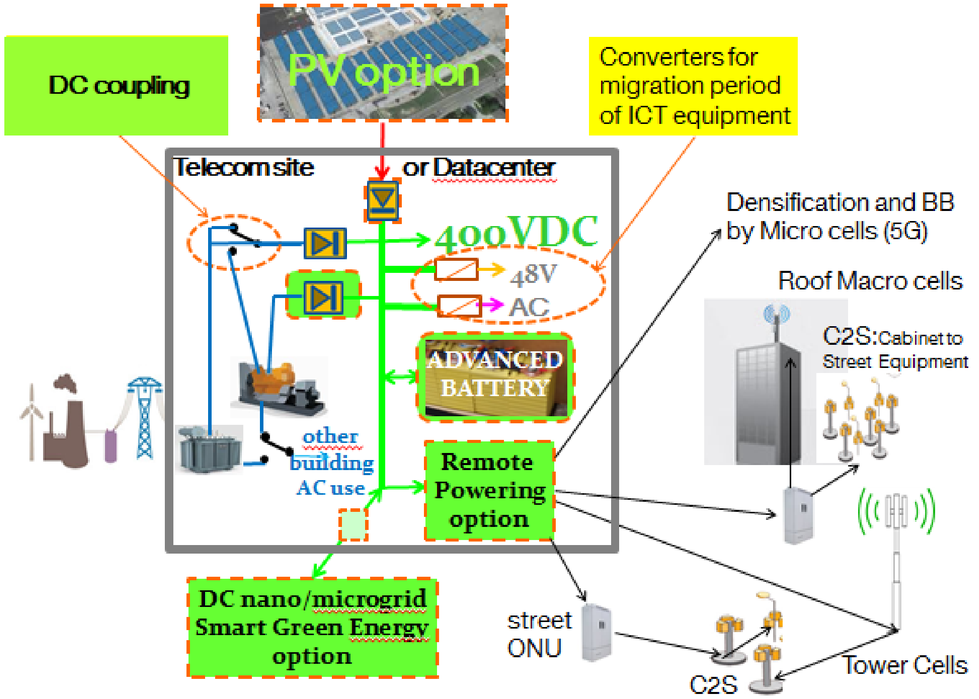
Nokia ETSI EN 300132-3-1 compliant 400VDC interface for Open Rack

- Power shelf & PDU Compatible with Open Rack v2 standard with 12VDC busbar
- Please visit Nokia Booth B6 explore the 400 VDC solution for Open Rack



400VDC Orange Expectations **Simpler, reliable, efficient, cheapest…**

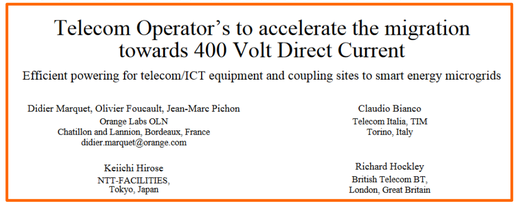
- ✓ **Costs Saving:**
  - ✓ > 10 % : **90% copper saving**
    (5t in 48VDC → 500 kg in 400VDC),
    3 less copper vs AC :
    4 AC wires&power → 2 DC wires
  - ✓ Significant installation costs reduction
  - ✓ > 20 % expensive ICT m² saved by removing 48VDC stations (decentralized 400VDC power station & Batteries)
  - ✓ Meanwhile all equipment are in 400VDC :
    - ✓ small 400/48 conversion capex
    - ✓ > 20% initial and replacement capex saving as no UPS battery : UPS replaced by 400/AC conversion



- ✓ > **20 % Maintenance savings** compare to expensive contract on UPS
- ✓ **More progressive capex than UPS**: due to much higher DC modular scalability
- ✓ 3 times less electronic : **Higher reliability** increase par modularity effect
- ✓ high opex saving by **higher Energy Efficiency** Energy Architecture
- ✓ Possible extended use for all sites > 10 kW (NGPoP, access nodes, …)
- ✓ Possible to connect access network sites via **400VDC remote** powering removing access network batteries and local Electricity supplier contracts
- ✓ Solar energy use in a simpler way (ITU-T L.1205 and ETSI)

Orange launch a 400VDC pilot Coresite in 2017, several news sites in 400VDC for the end of 2018

- ✓ *More details see Intelec 2018 paper http://ieeexplore.ieee.org/document/8214134/* =>


Telecom Operator's to accelerate the migration towards 400 Volt Direct Current

Efficient powering for telecom/ICT equipment and coupling sites to smart energy microgrids

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Summary

- With 400VDC power feed solution compliant with OCP 400VDC datacenter design guide operators solve many challenges faced in AC based power distribution
- 400VDC distribution is way to modernize also existing -48VDC systems to new era of efficiency.
- 400 VDC power feeding reduces intermediate power conversion stages (e.g., the inverter and power factor compensator can be eliminated).
- Servers equipped with HVDC power supplies reduce total power consumption, reduces heat, increase power feed reliability and decrease maintenance requirements.

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