NTT FACILITIES

DC powered data centers in the world

Keiichi Hirose, Ph.D.
Senior Research Engineer
R&D Headquarters
NTT Facilities, Inc.
Tokyo Japan

LVDC Workshop
SMB Strategic Group 4
on LVDC distribution systems
up to 1 500 V

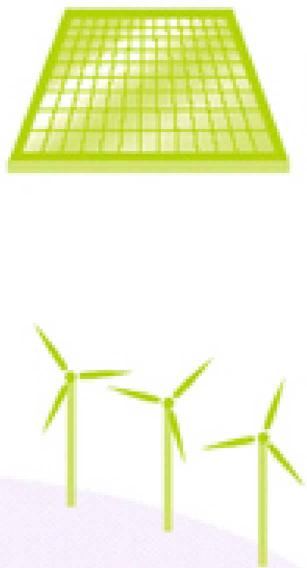
29th & 30th of September 2011
(Dresden/Germany)

Research & Development

Motivation

「Green of ICT」 and 「Green by ICT」

Use of natural energy, green procurement



Green by ICT

Services and Solutions

Telephone, IP Video Conferencing [Biz Communicator, Warp Vision]	Online Storage Service [cocoa GIGA STORAGE]
IC Card (Eco-point System)	Environment Information Portal [eco-goo]
ISP Service [OCN Hikari service]	IPv6 Sensor Network (Electronic Measurement and Control)
Video Distribution [Hikari TV]	e-work (Telecommuting)
Remote Access [Mobile Connect]	Paperless Fax [050 Green Fax]
Virtual Call Center [Customer Connect]	Services and Solutions [Outline explanation]

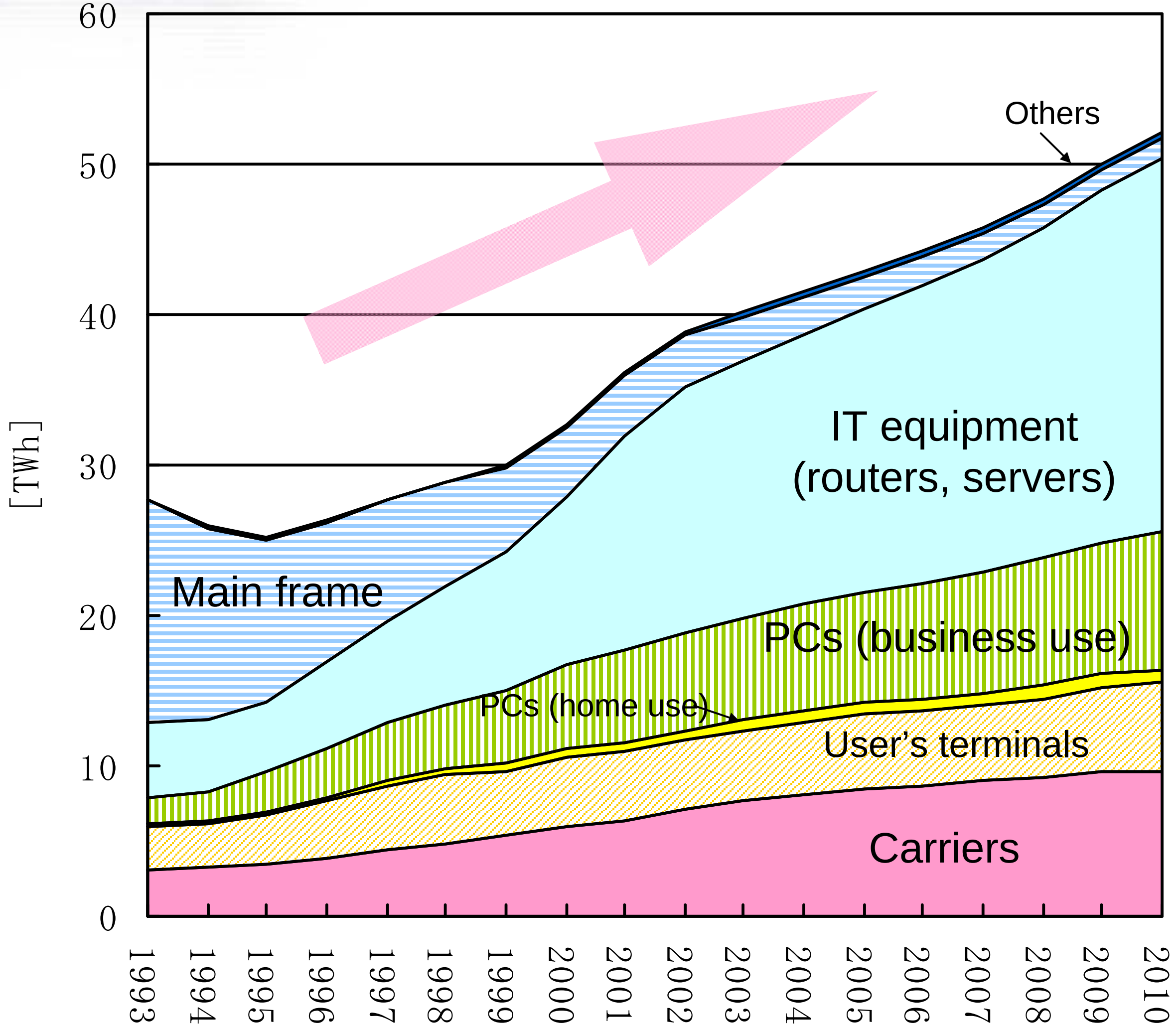
Green of ICT

Platform	Green Hosting
	Thin clients
Data Centers	High-Efficiency Air Conditioner
	Switch to direct current
	Housing
Network	Switch to direct current
	Shift to Simple Network

Logistics, cessation of transport of people and goods, and dematerialization (digitalization)

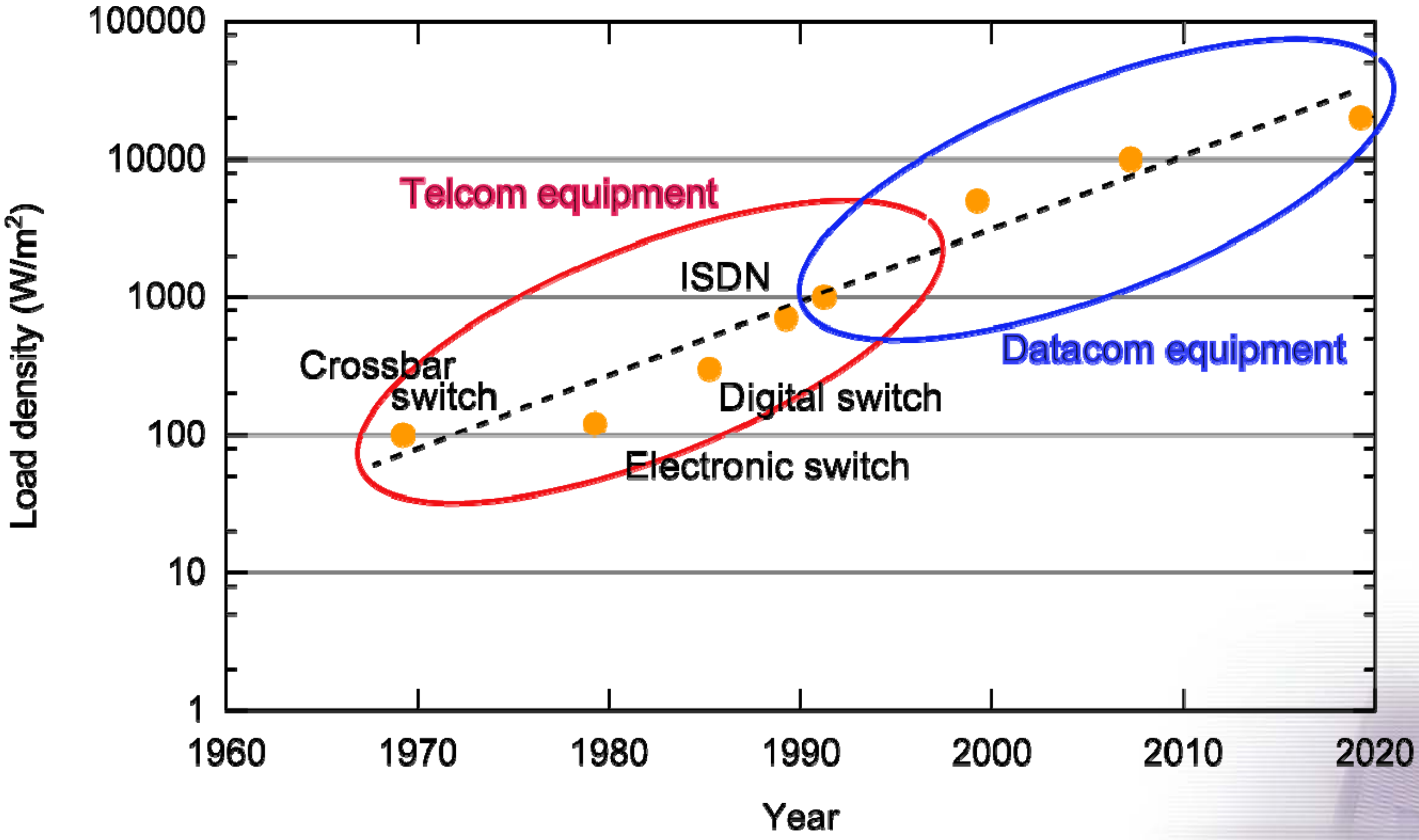
Use of DC power

The trend of energy for telecom and computer (e.g. in Japan)

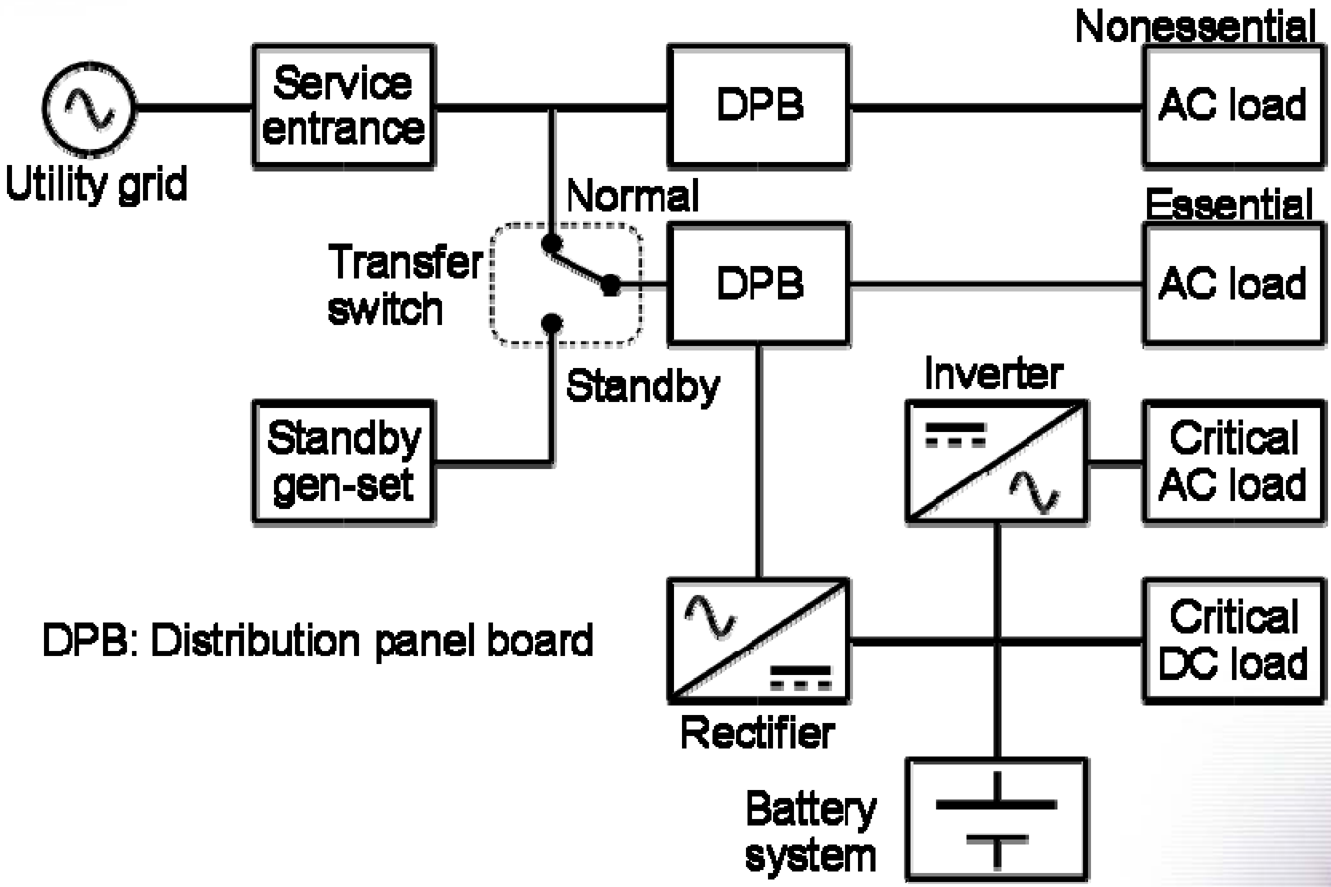


- 18% increase in 5 years
- 1% of total energy consumed in Japan
- 4% of all electricity consumed in Japan

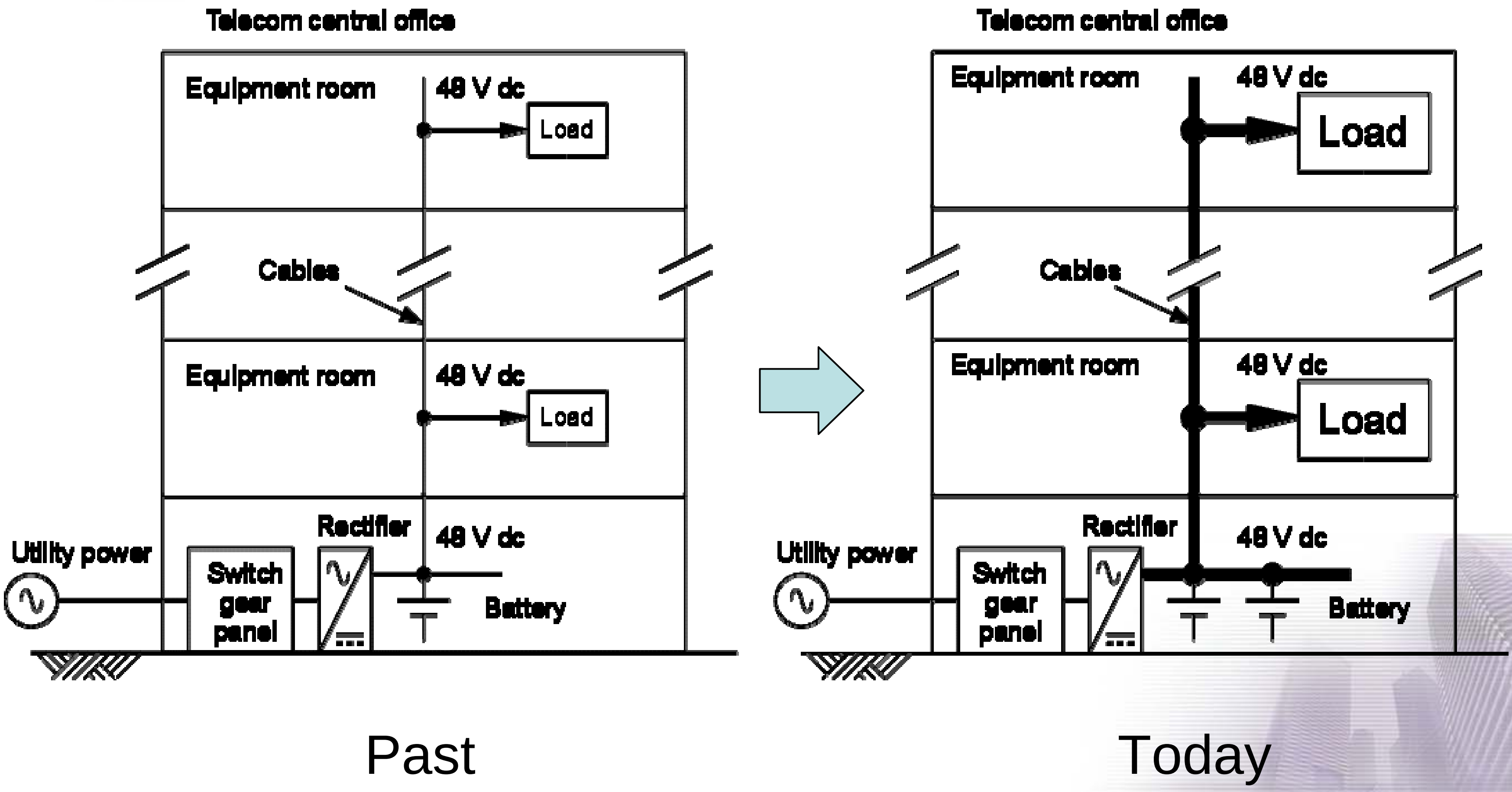
Increasing load power



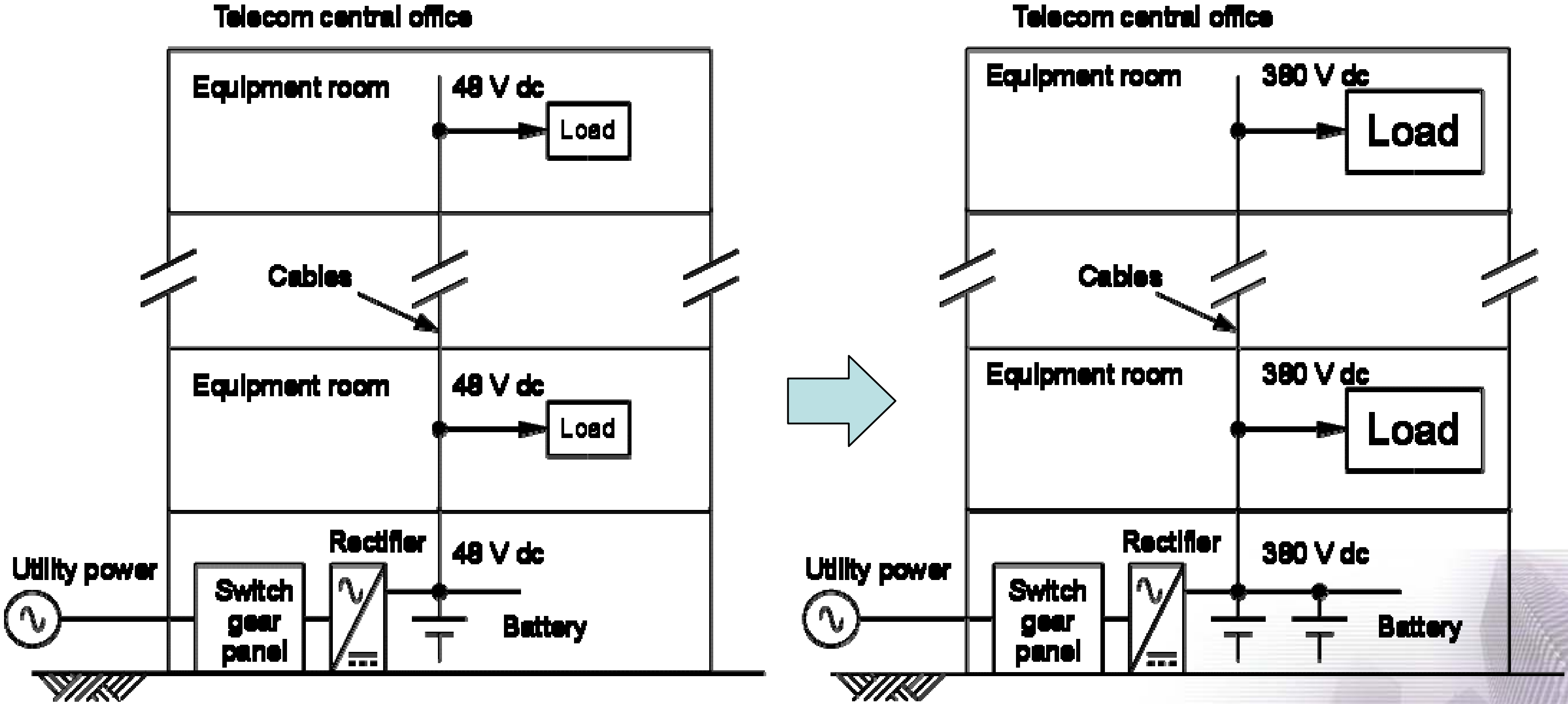
Telecom power supply system



An Issue in telocom central office



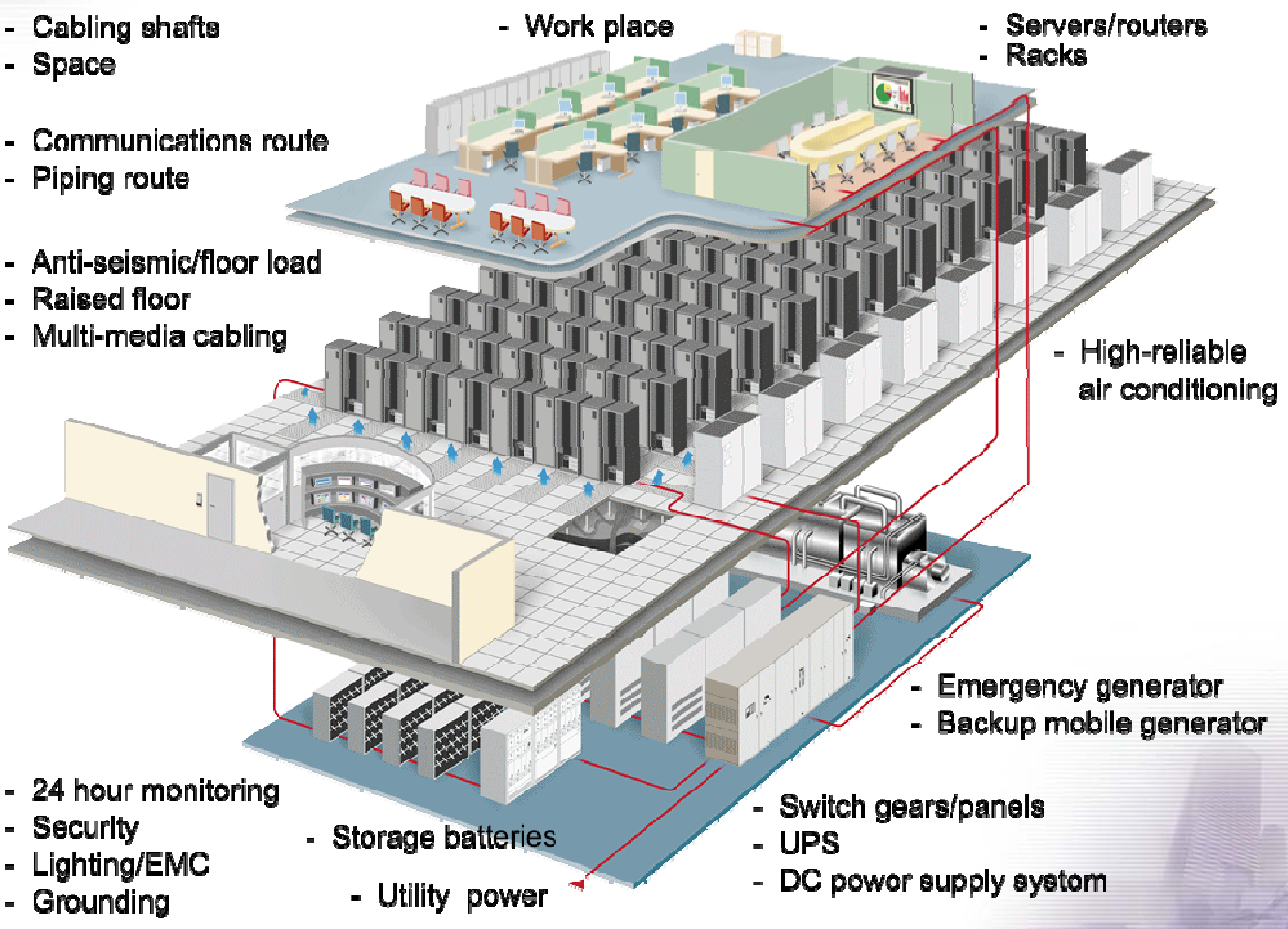
Best solution to the issue



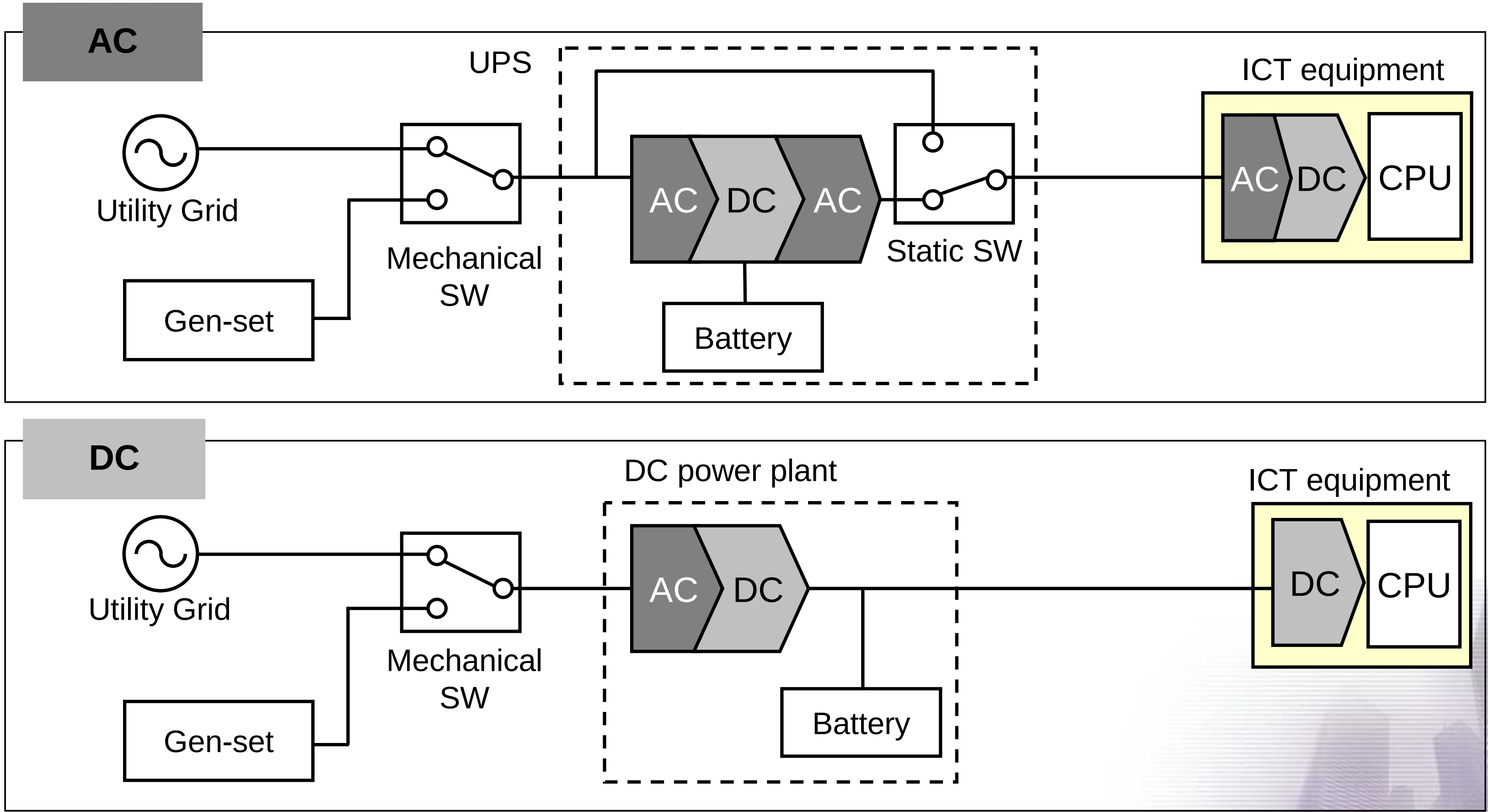
Past

Today

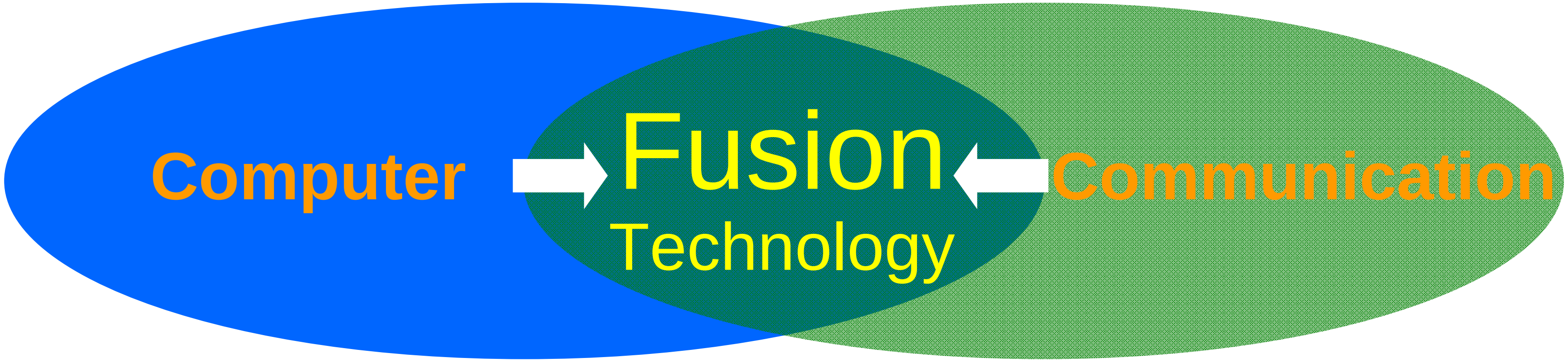
What is a data center?



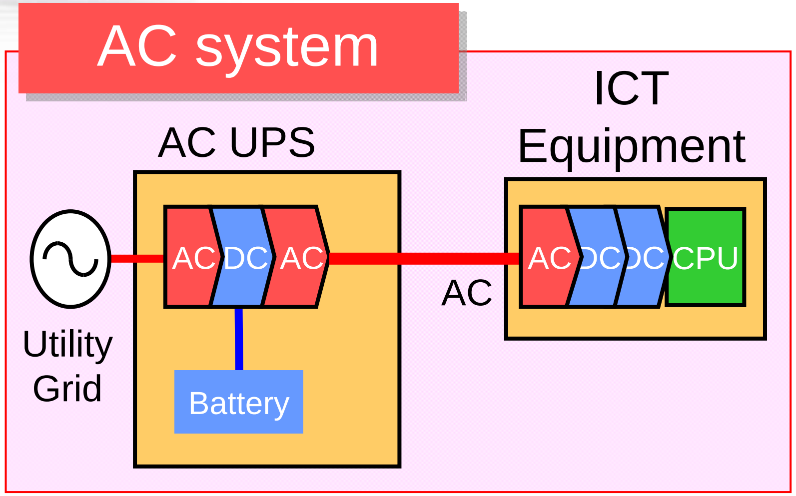
Typical AC and DC power systems in Data Centers

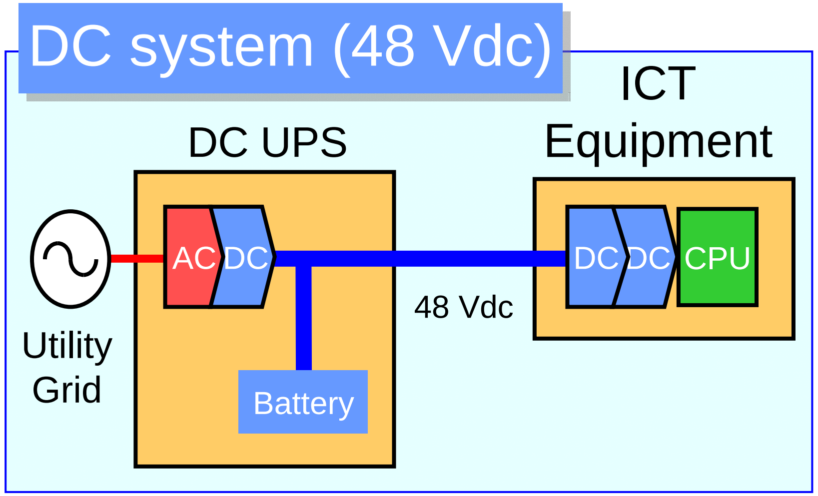


AC or DC ?

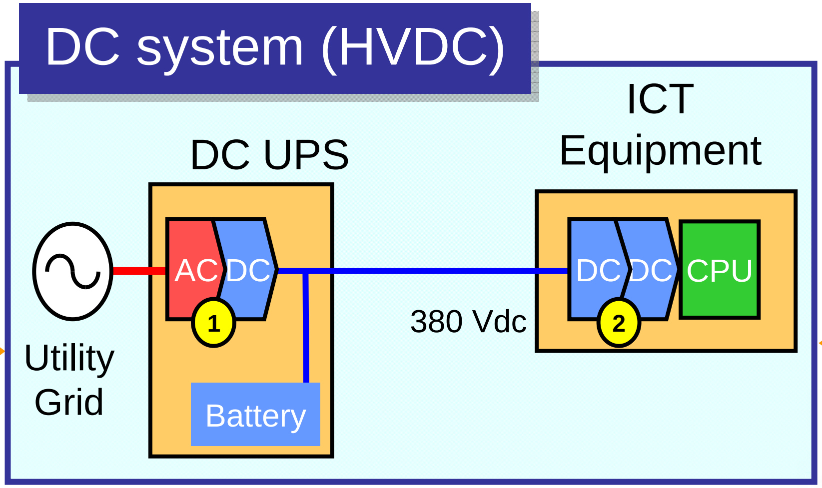


Comparison of AC, 48 Vdc, and HVDC Systems





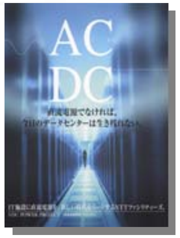
- High efficiency operation
- High reliability
- No phase balancing
- No Harmonics issues



- Reduce in voltage drop
- Wire size reduction
- Equipment footprint reduction, simpler interfaces, and potentially lower costs

- Easy integration with renewable energy resources

NTT-F's Activities (History)



DC Power Promotion 2000

In-house IT System 2001

DC powered Data Center 2006

Telecom System

Low Voltage DC (-48 Vdc)

NEDO Sendai Project 2004

HVDC Distribution System With Intel 2007

NTT News release June 2008

High Voltage DC (300~400 Vdc)

NTT-F Launched a 48 VDC-powered Data Center on December 2006

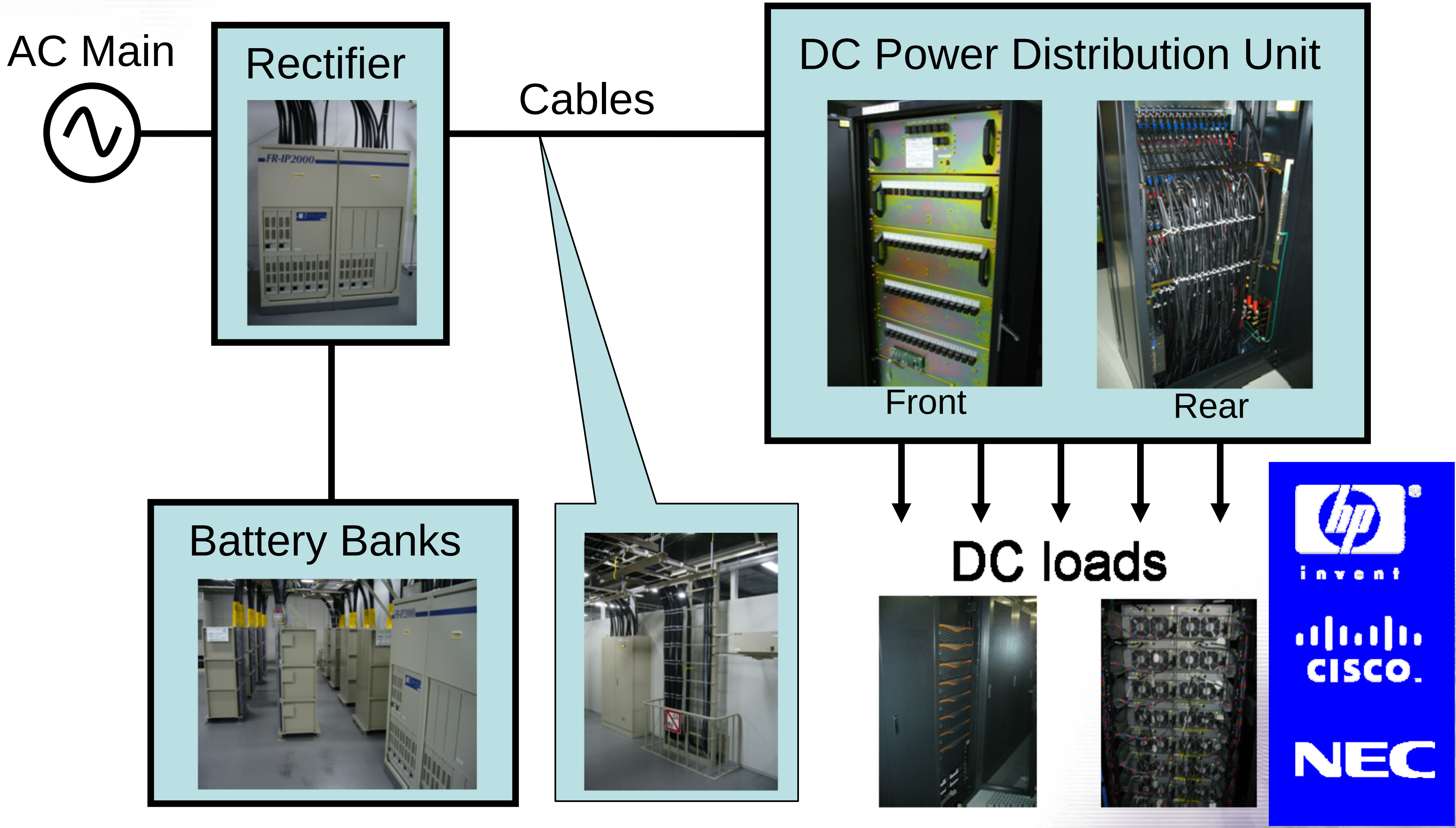
NTT East Saitama Shin-toshin Building

Racks for operation and monitoring system

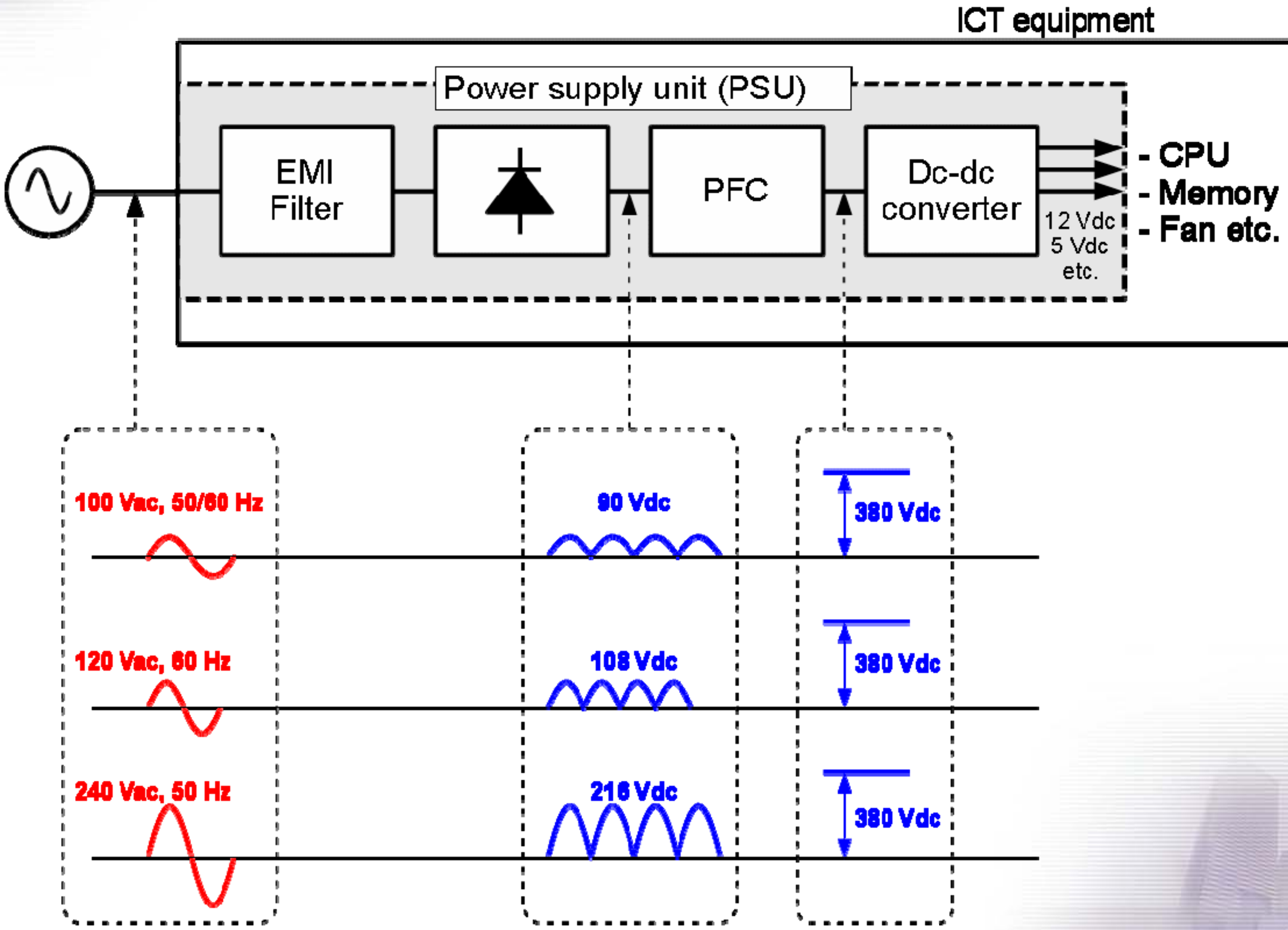
Operation center

1,200A@DC48V
30 Racks

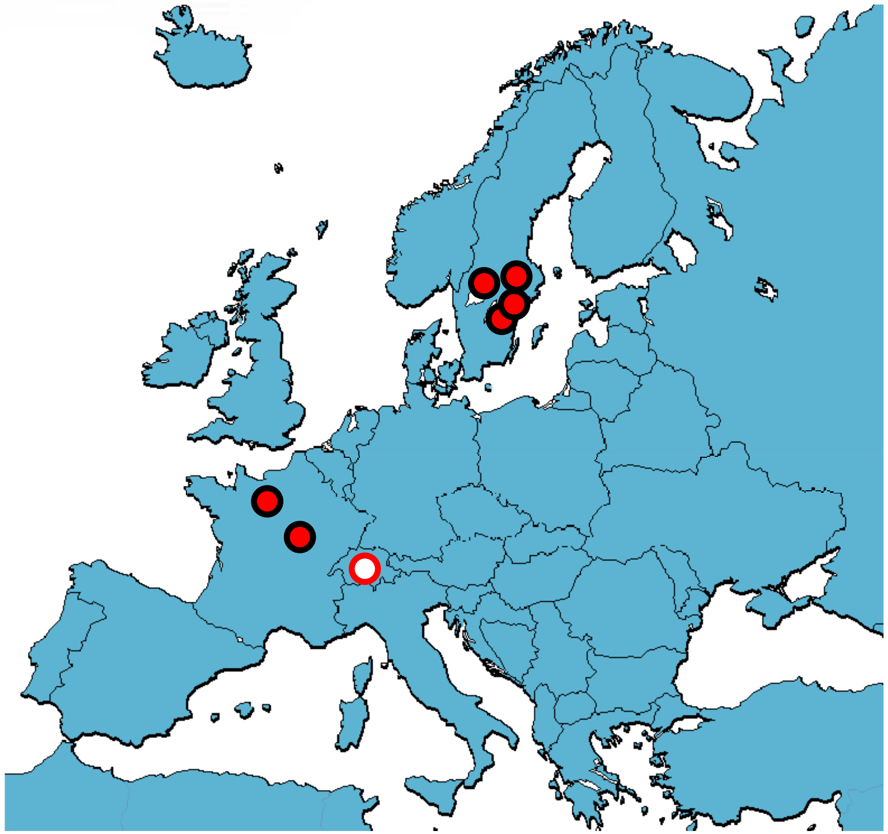
Low Voltage 48 VDC power system

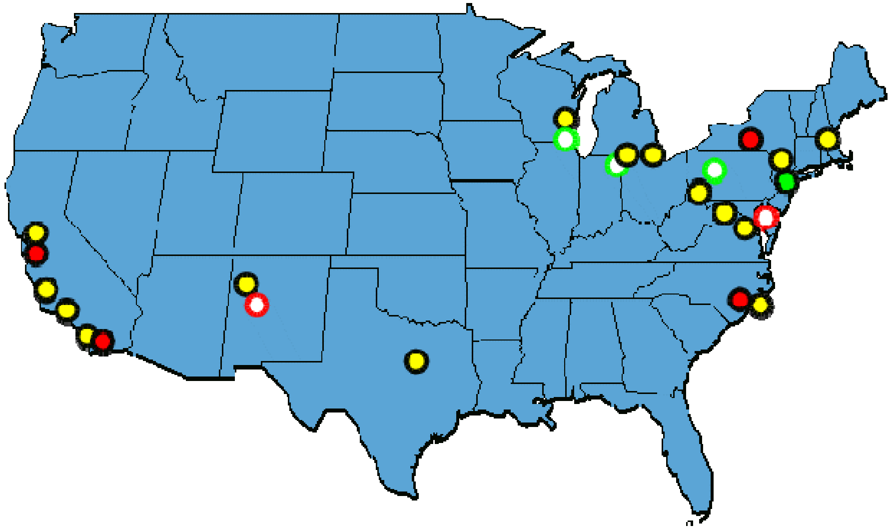


DC voltage converted from AC power source

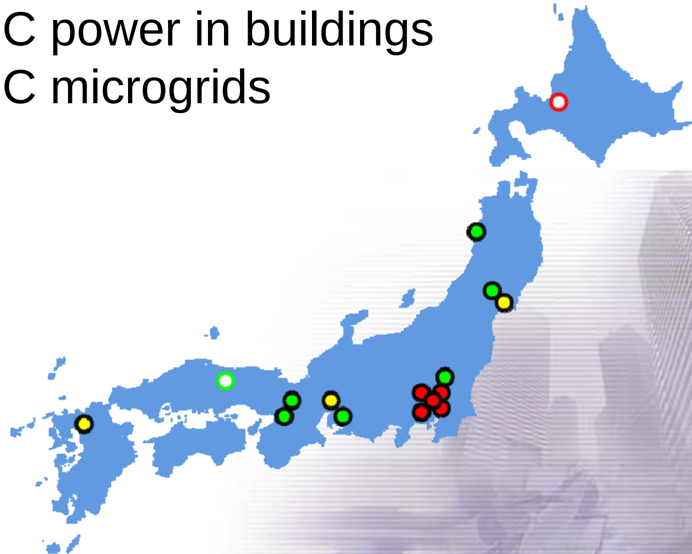


DC powered sites in Europe, US, and Japan



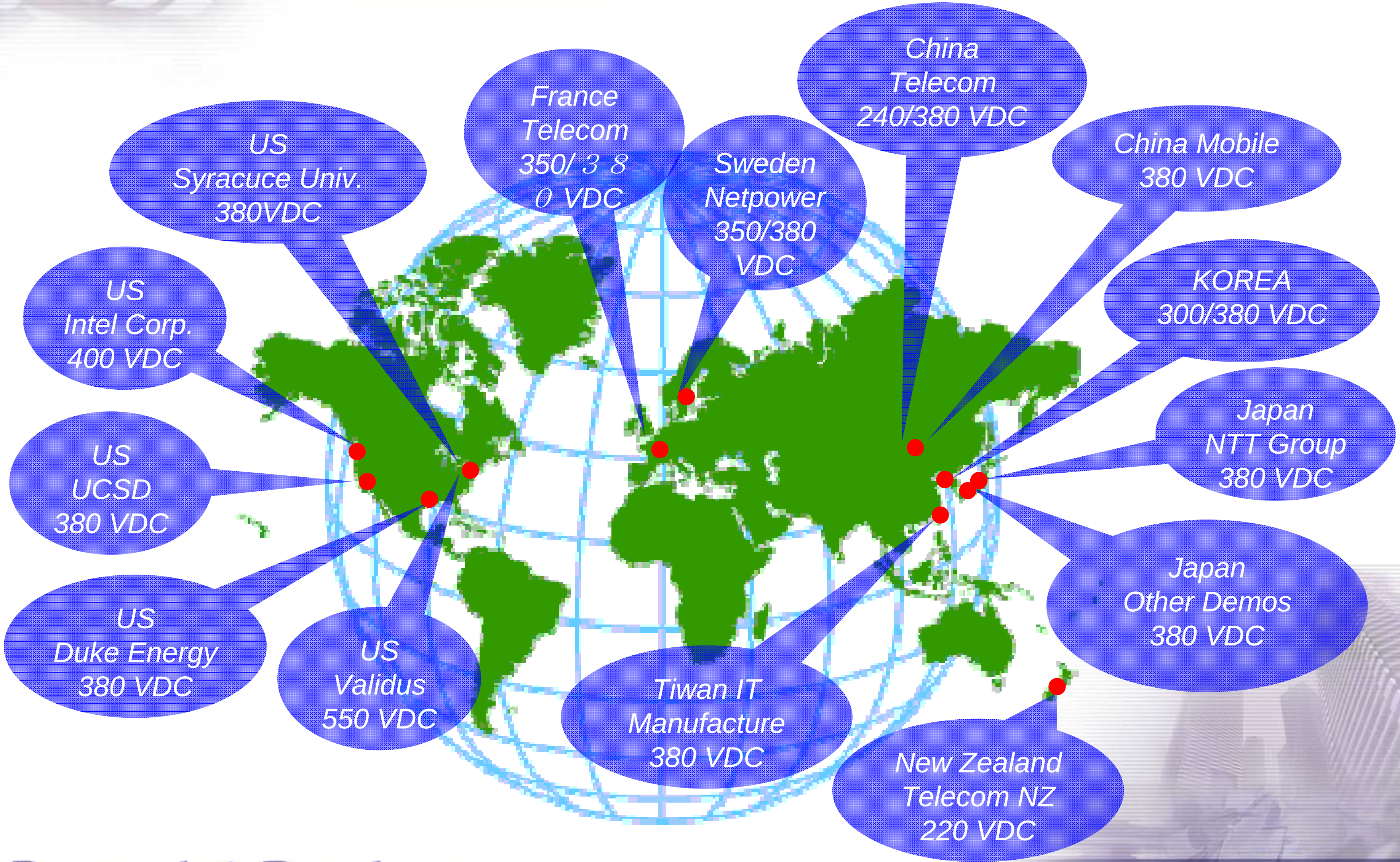


- DC power in buildings
- DC microgrids



- Operating data centers
- Planned datacenters

DC powered 0perational/Demo Sites for ICT use

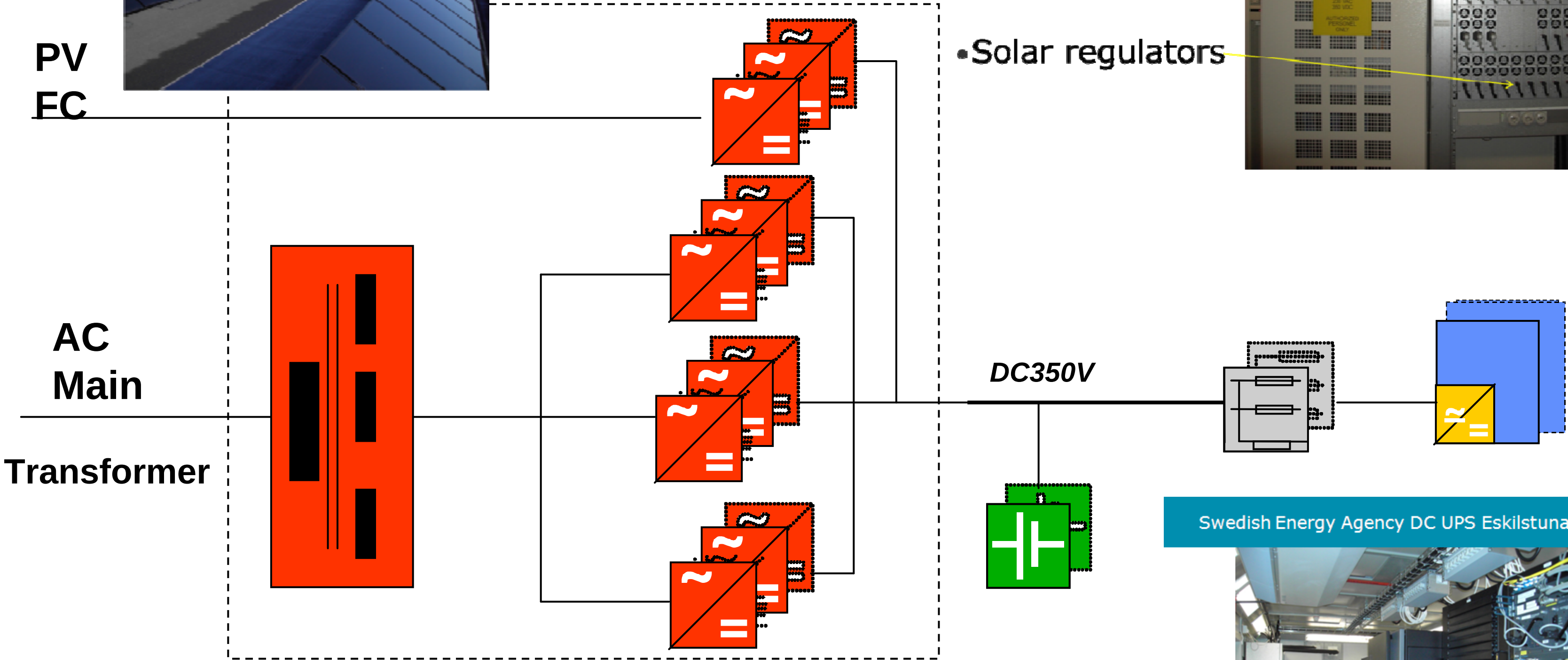


300-400VDC Operational and Demo Sites Worldwide

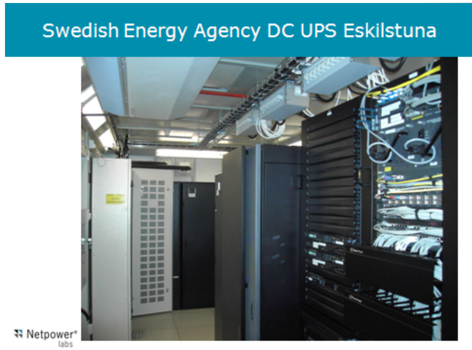
Site	Location	Op Date	Max kW
Gnesta Municipality	Gnesta	Mar-06	9kW
Elicom	Toreboda	Mar-06	4.5kW
NTT NEDO Project	Sendai	Feb-07	20kW
NTT Univ. Microgrid	Aichi	May-07	50 kW
France Telecom	Lannion France	Nov-07	31.5kW
Ericsson	Stockholm	Mar-08	4.5kW
Soderhamm Teknikpark	Soderhamm	Jun-08	6kW
NTT Data Corp	Mitaka City,Tokyo	Jan-09	100 kW
NTT Lab.	Mitaka City, Tokyo	Jan-09	100 kW
NTT Facilities	Toshima-ku, Tokyo	Jan-09	100 kW
Compare Test Lab	Hammaro Karlstad	Jun-09	4.5kW
Korea Telecom	Seoul, Korea	Jun-09	N/A
Univ of Calif/San Diego	San Diego, CA	Nov-09	20 kW
Syracuse Univ	Syracuse, NY	Dec-09	150 kW
Swedish Energy Agency	Eskilstuna	Jan-10	18 kW
Compare Test Lab	Hammaro Karlstad	Oct-10	500 kW
Duke Energy	Choriotte, NC	Aug-10	30 kW
NTT EAST	Tokyo	Dec-10	100 kW
NTT	Atsugi City, Kanagawa	Feb-11	100 kW

Gnesta Project, Sweden

Hammaro/Eskilstuna/Toredoba, HVDC(DC350V)

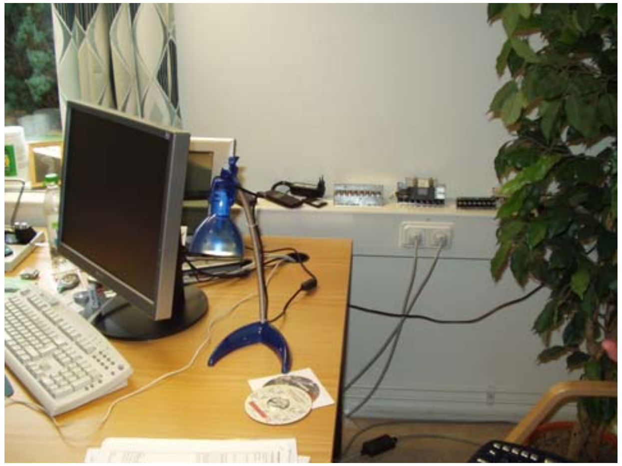


- Rectifiers
- Solar regulators



Hammaro 10 kV
Eskilstuna 0.4 kV
Toreboda 0.4 kV

DC power in office, Toredoba, Sweden



- ***Smart grid data center***
  - Providing intelligent energy management across systems and facilities

webcam view

Construction May 29, 2009
Installation September 2009
Launched November 2009

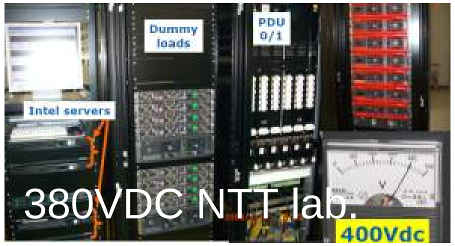
Server room in the data center

DC Power Demonstrations by NTT Facilities

380VDC NTT Data Corp.

380VDC NTT Facilities

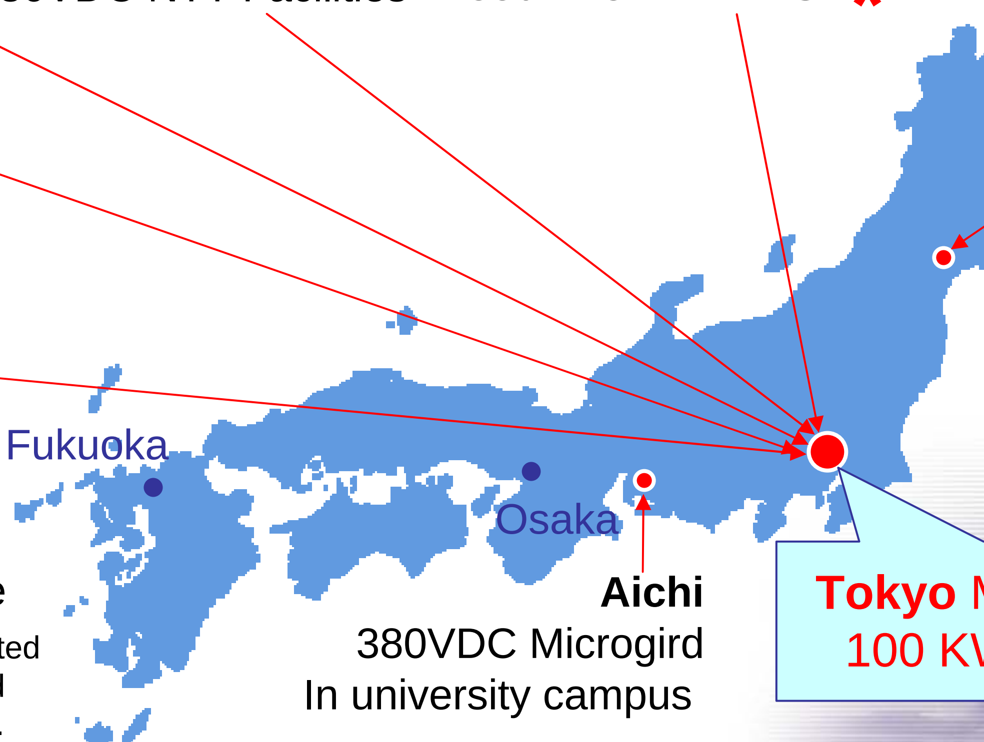
380VDC NTT EAST *



380VDC NTT lab.

380VDC NTT container type

*: The demonstration was supported by Ministry of Internal Affairs and Communications, Japan in 2010.



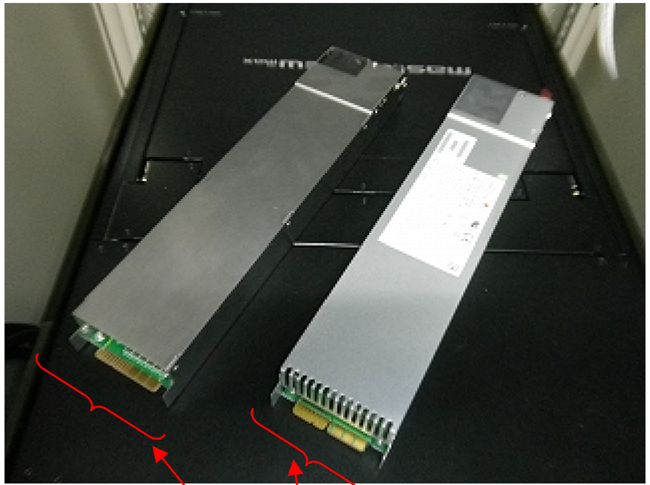
Sendai
NEDO Project
300VDC Demo

Aichi
380VDC Microgird
In university campus

Tokyo Metropolitan
100 KW x 5 sites

Modular type data center powered by 380 VDC

Power supply unit (PSU)

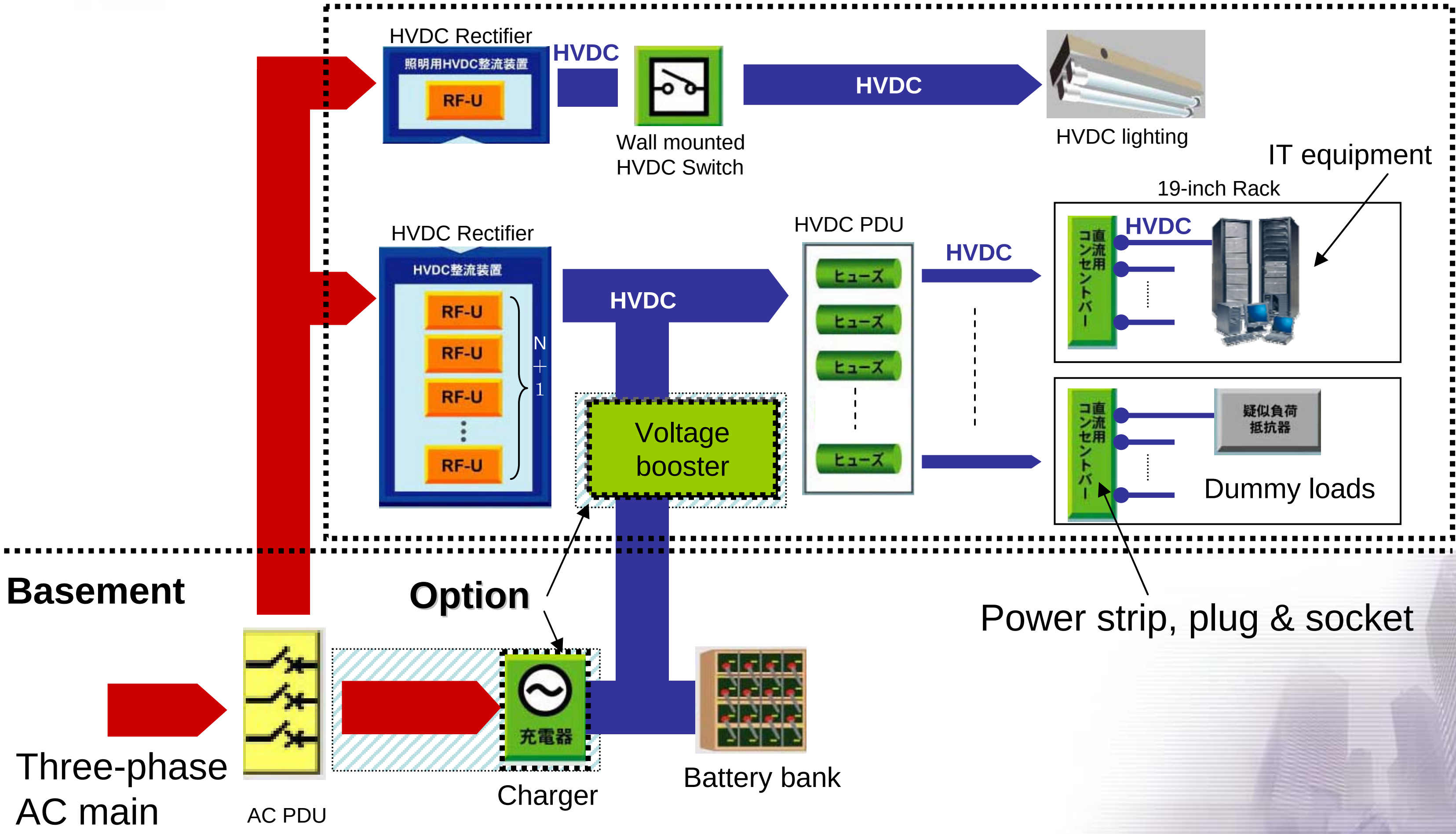


380 Vdc

100-240 Vac

Same output for servers (same dimensions)

A Basic configuration of 380 VDC power system



NTT-F's site

For basic characteristics of HVDC power system,
short circuit tests, transient tests, voltage dips, and so on···

- 3 types of HVDC power system
- Power Distribution Units
- Dummy loads
- Intel's HVDC servers

- 100-kW simulated DC server loads

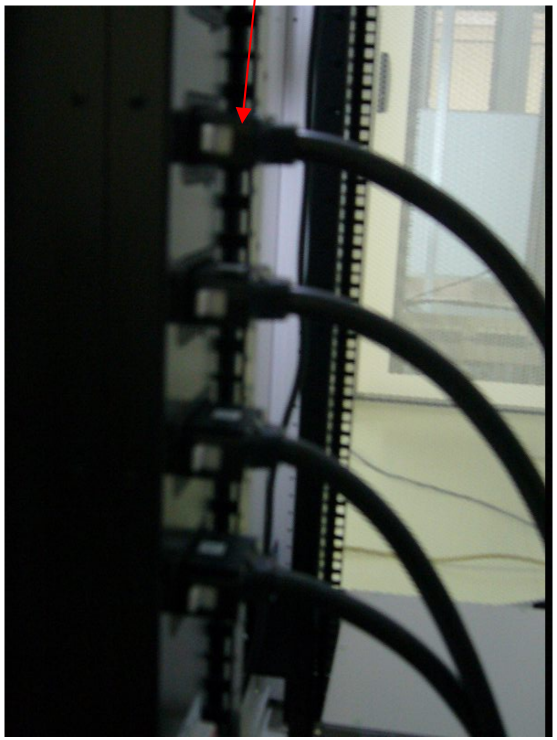
380VDC lighting in NTT DATA's site

Existing ac lighting and new dc lighting

New dc lighting

380 VDC Power strip in the 19 inch's rack

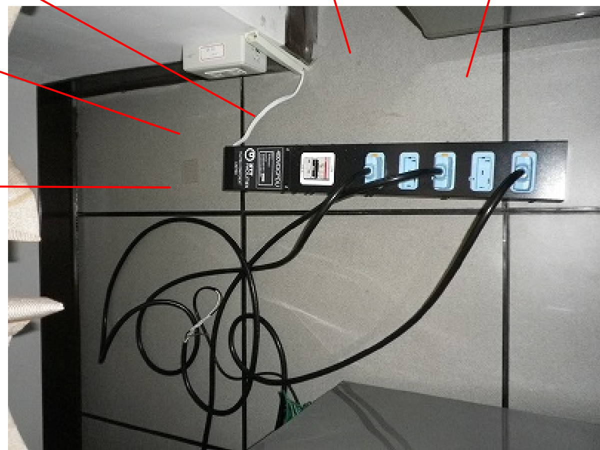
Plug



Other use of 380 VDC plug & socket-outlet





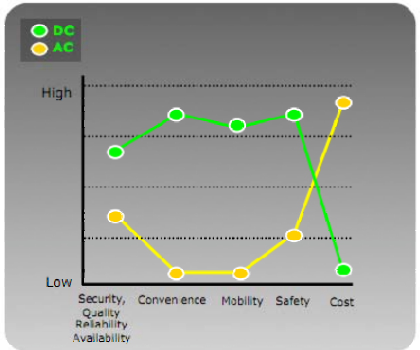



Chung Cheng University in Taiwan
September 2010

Future plan by Korea telecom

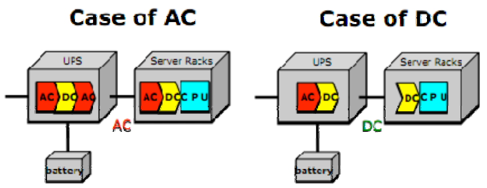
First Step of Green IDC : AC → DC

For a full implementation of Green IDC, the power source must be converted from AC to DC to decrease steps in current conversion



<Advantages of DC>

- **Nam-Suwon IDC** : Partial DC implementation in '06
- **Bundang, YoungDong, MokDong IDC** : Partial DC implementation in '09



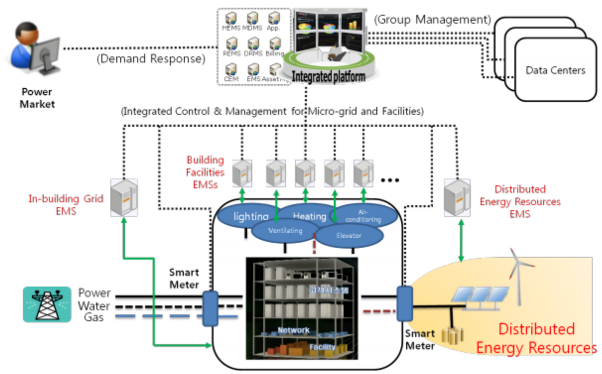
Many conversions of current leads to energy loss

13~25% Increase in energy efficiency

Energy Efficiency of IDC is 16% up !

Third Step of Green IDC : Microgrid-based

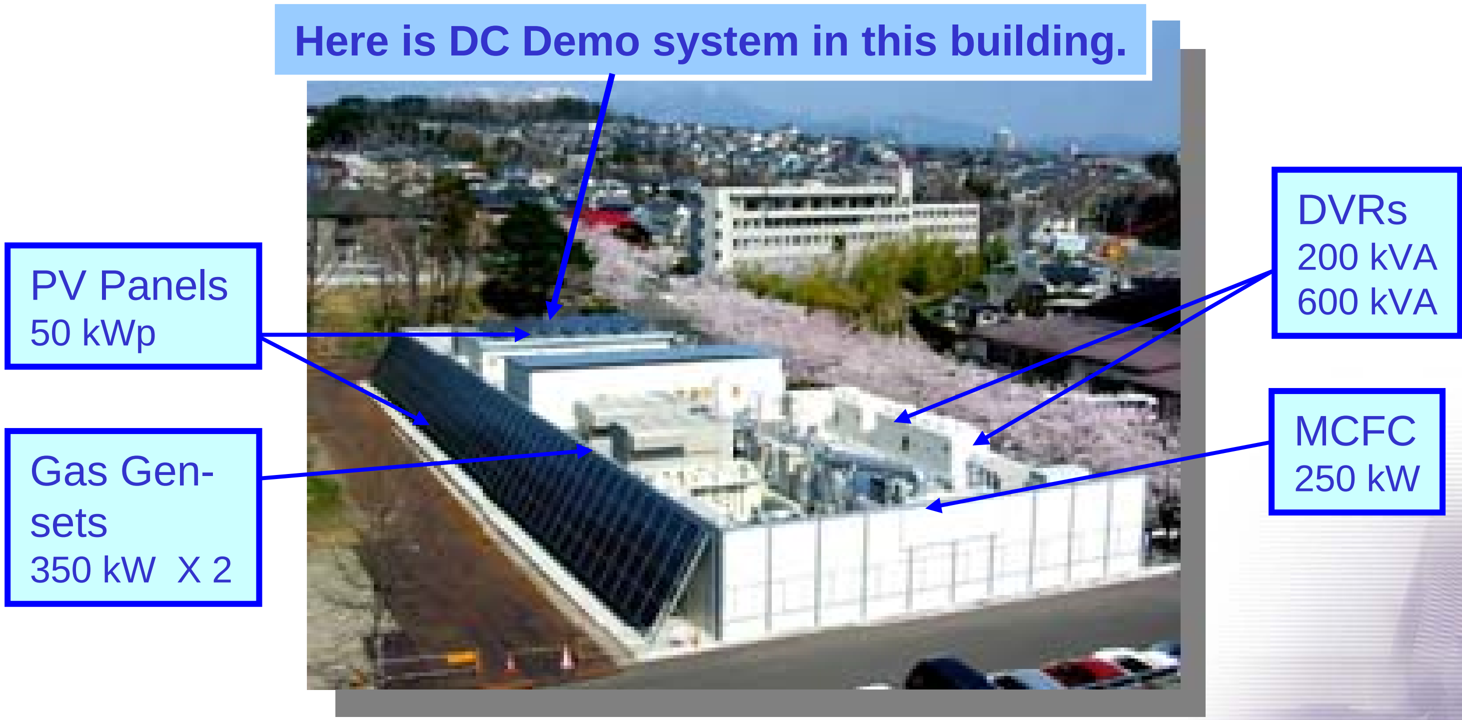
Distributed generation of renewable energy, energy storage, demand response, fuel cell, Energy Management System, etc. should be implemented as well.



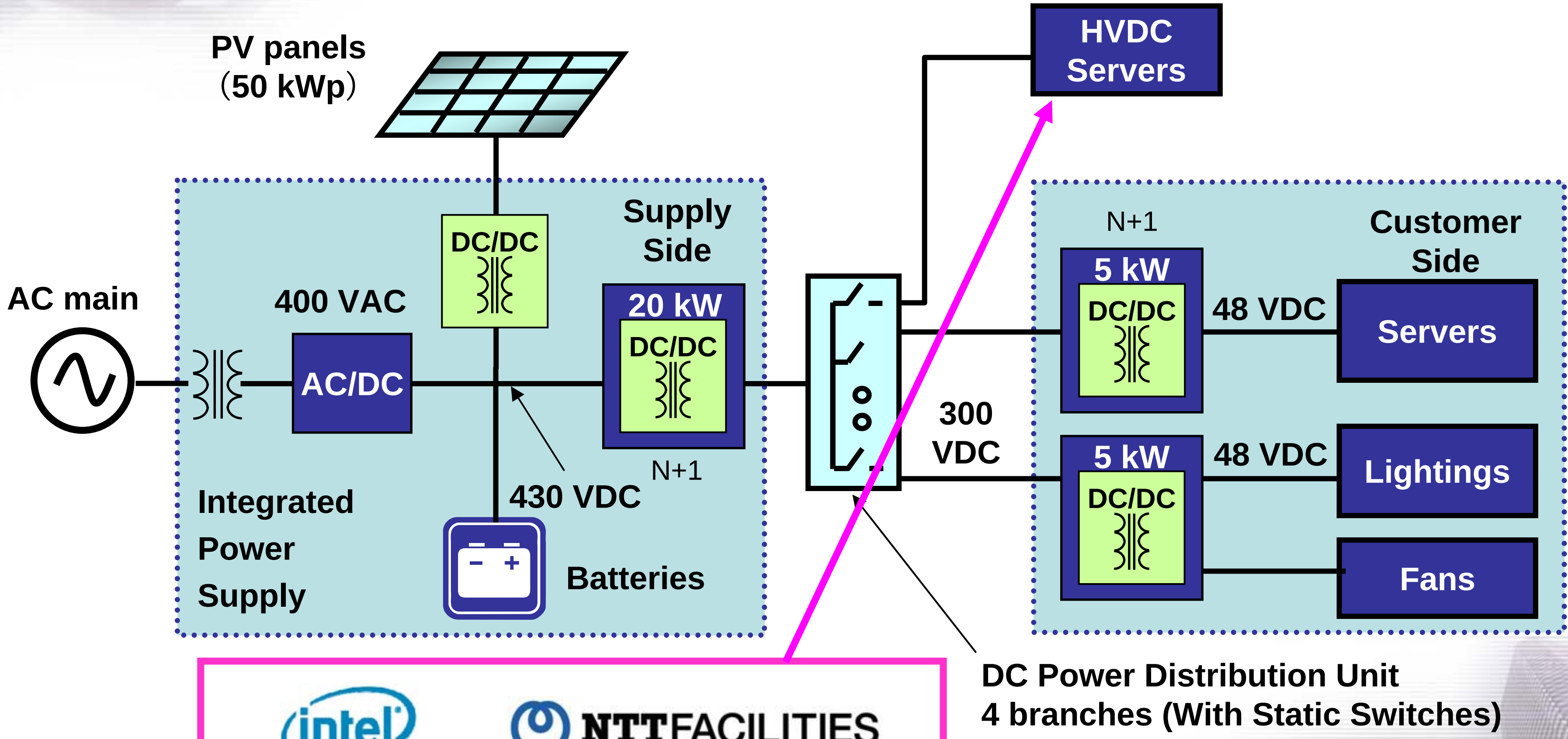
- Based on Integrated Management Platform,
  1) improve energy efficiency,
  2) implement distributed energy resources (fuel cell, PV, E/S), and
  3) interact with energy market through demand response, FMS, BEMS.

What is NEDO Sendai Demonstration?

- 4 year project (FY 2004 - 2007)
- Multiple power quality supply (4 AC and 1 DC)
- A demo for the future ICT society



DC Circuit System Configuration

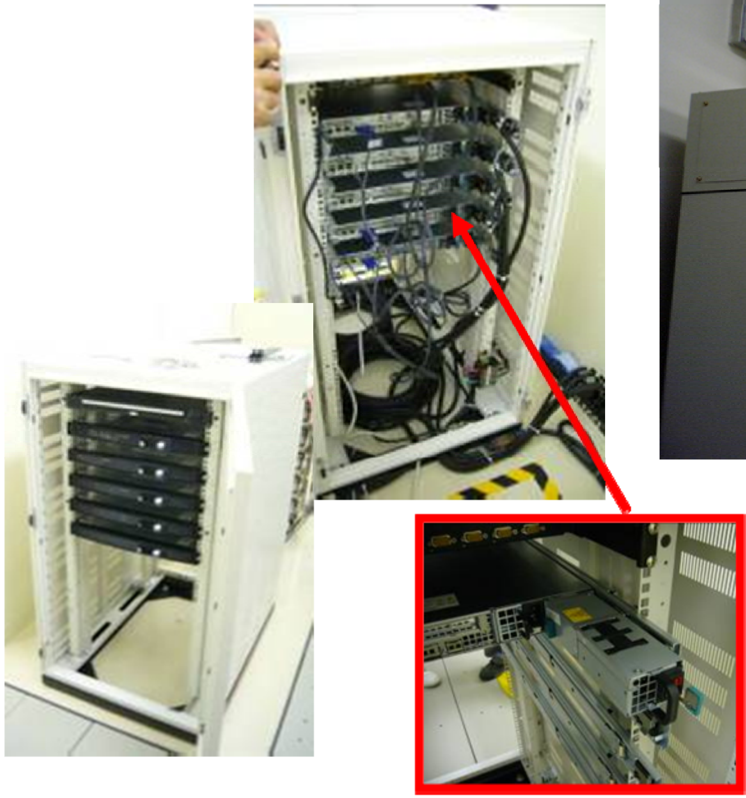


intel NTTFACILITIES

Intel and NTT-F are cooperating on the 300 Vdc test during the NEDO Sendai project.

DC Loads

Intel's HVDC servers



Fan (DC -48V)

Lighting (DC -48V)

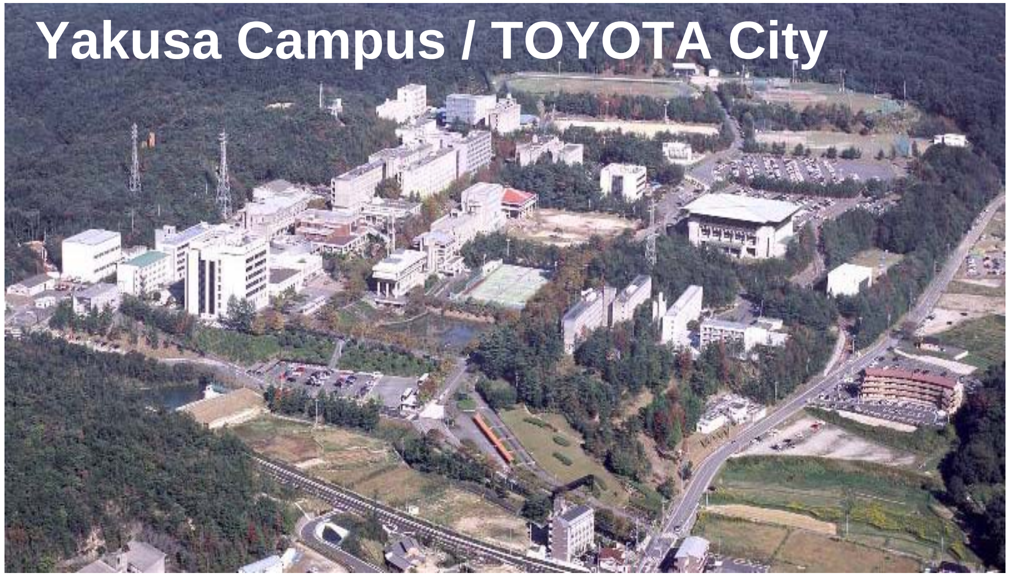
Servers (DC-48V)
(HP BL20p)

Campus DC Microgrid in Aichi Institute of Technology

This project is supported by the Ministry of Education, Culture, Sports, Science and Technology.


Library


Educational Facility




PV Panels


Batteries


Power Station
for DGs

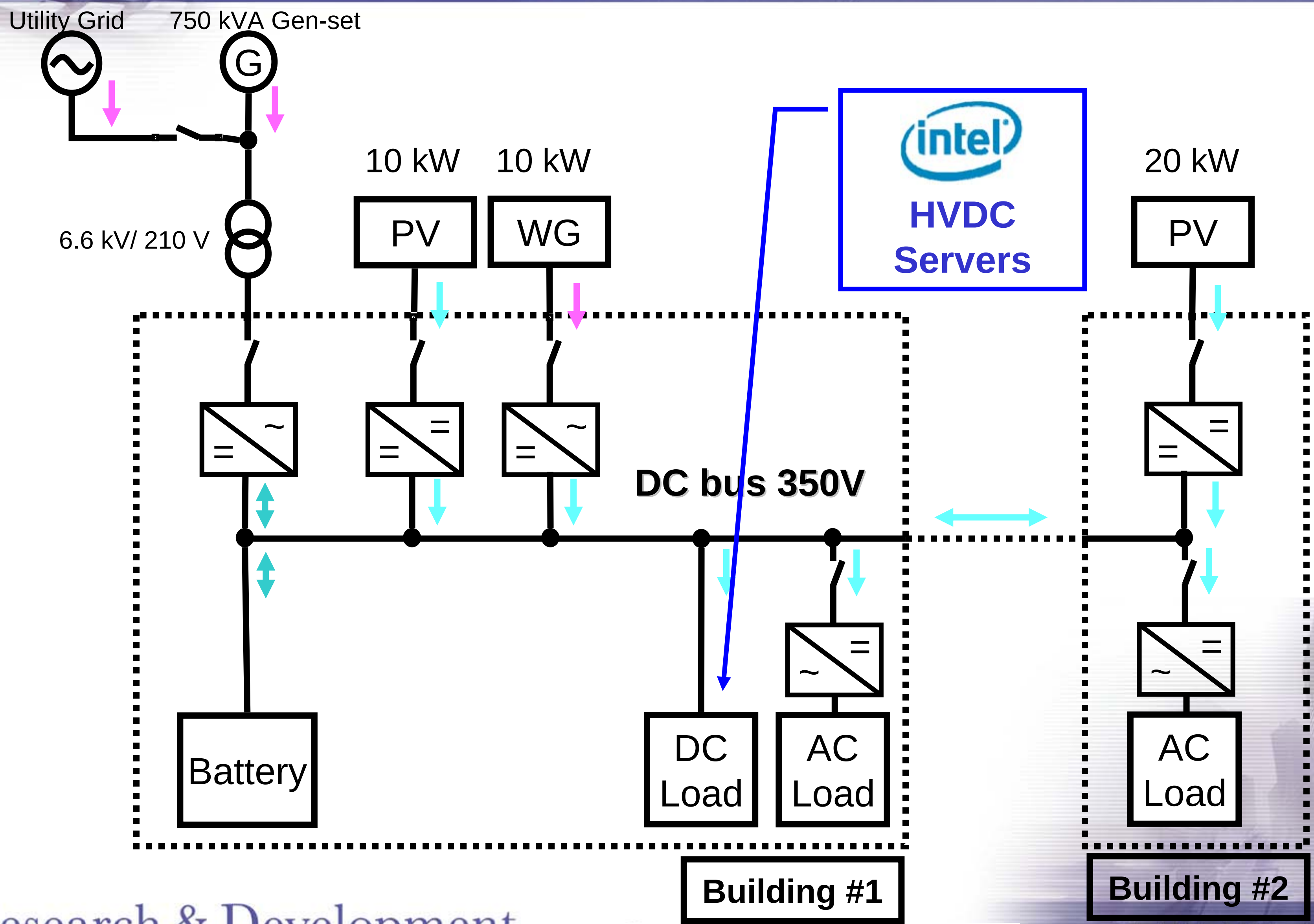

Hydro Power




Wind Turbines


DC Power Plant

DC Microgrid Project: Campus



Barriers to 380/400VDC power system

Technical Issues

- -Breaking-current
- -Earthing, EMC, Noise
- -Power quality and reliability
- -Power architecture
- -Power electronics engineering (e.g. SiC)

Legal and Standard Issues

- -Common voltage and system configuration
- -Safety requirements
- -Working groups and committees

Market promotion

- -Cost evaluation (total cost of ownership)
- -PR / Advertising
- -Consortium of HVDC power suppliers for ICT Systems

DC power workshops in the U.S and Japan

US workshop

- EPRI DC Power Production, Delivery and Use Workshop
- June 1-2, 2006
- At George Washington Univ. (Washington D.C)
- No. of Attendees: 70 persons
  Manufacture: 21, Engineer: 20, Researcher: 10, Utility: 7, etc.

George Washington Univ.

Japan workshop

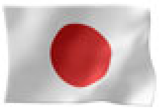
- IEEJ Research committee for survey on "DC power distribution and application"
- At Tokyo
- No. of Attendees: 20 Persons
  University prof. : 7, Manufacture: 6, Engineer: 3
  Researcher: 2, Utility: 2

Question:
What is the most important item for DC power applications?

Important items for DC power (in 2006)

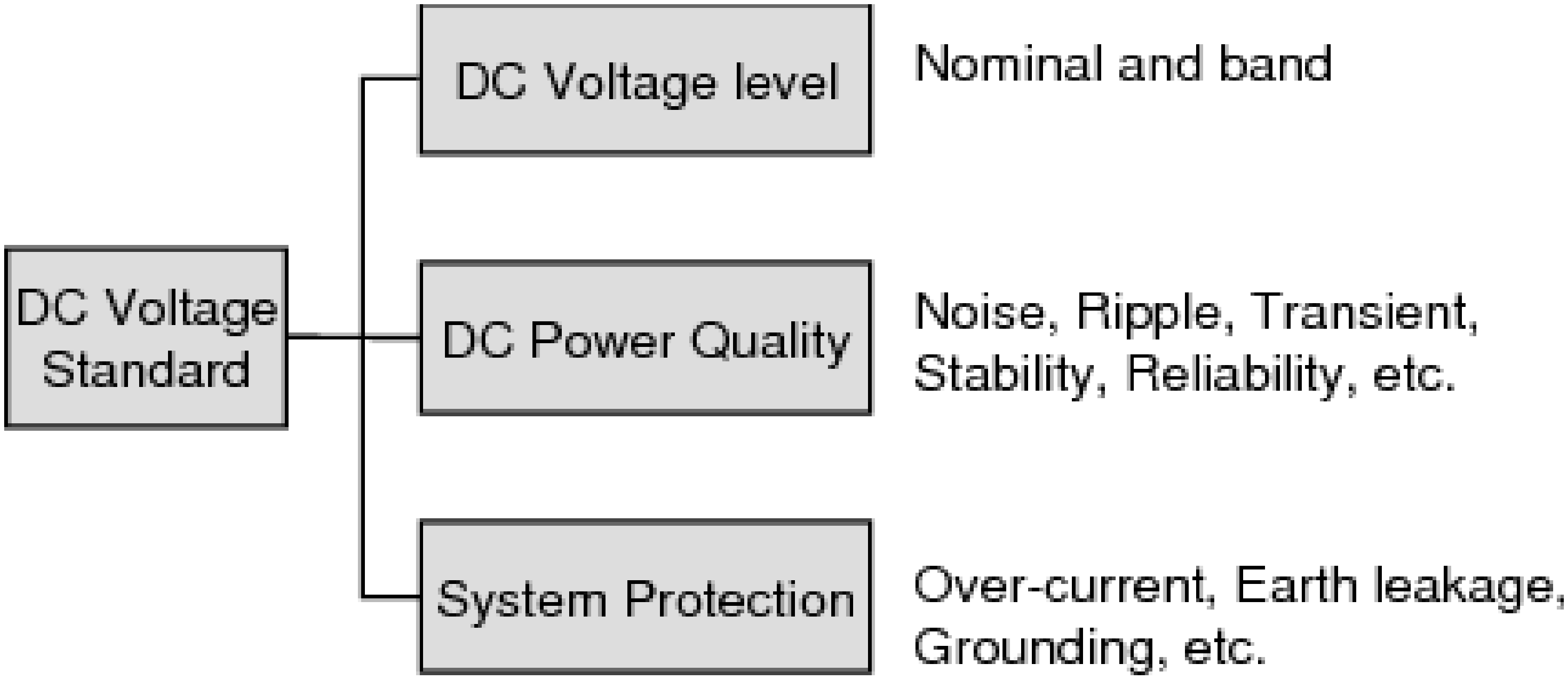
Items	Note
1. Standards, codes	International standards (Voltage, range)
2. Safety and Protection	Intelligent circuit breaker
3. Connector	Plug & socket-outlet
4. Experience	Actual operation, Know-how DC type appliances
5. Economics	Cost-benefit analysis
Others	Circuit topology, promotion, etc.

c.f. US NEC covers both AC and DC, and the products can be UL listed today. (LVDC workshop in Washington DC, April 8, 2011)

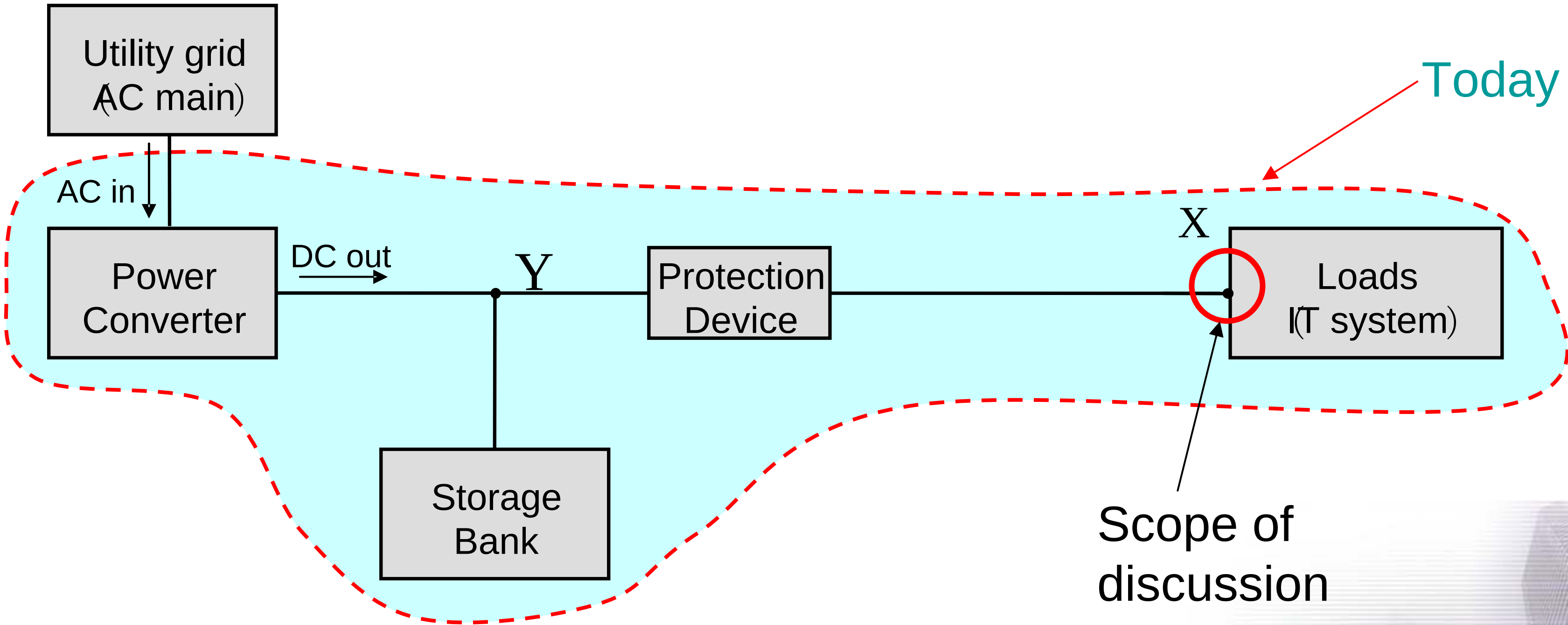


Items	Note
1. Standards, codes	International standards (Voltage, range), regulation and law
2. Safety and Protection	DC circuit breaking, Prevention electric shock, etc.
3. Experience	Actual operation, Know-how, DC type appliances
4. Economics	Cost-benefit analysis

DC Voltage Standard



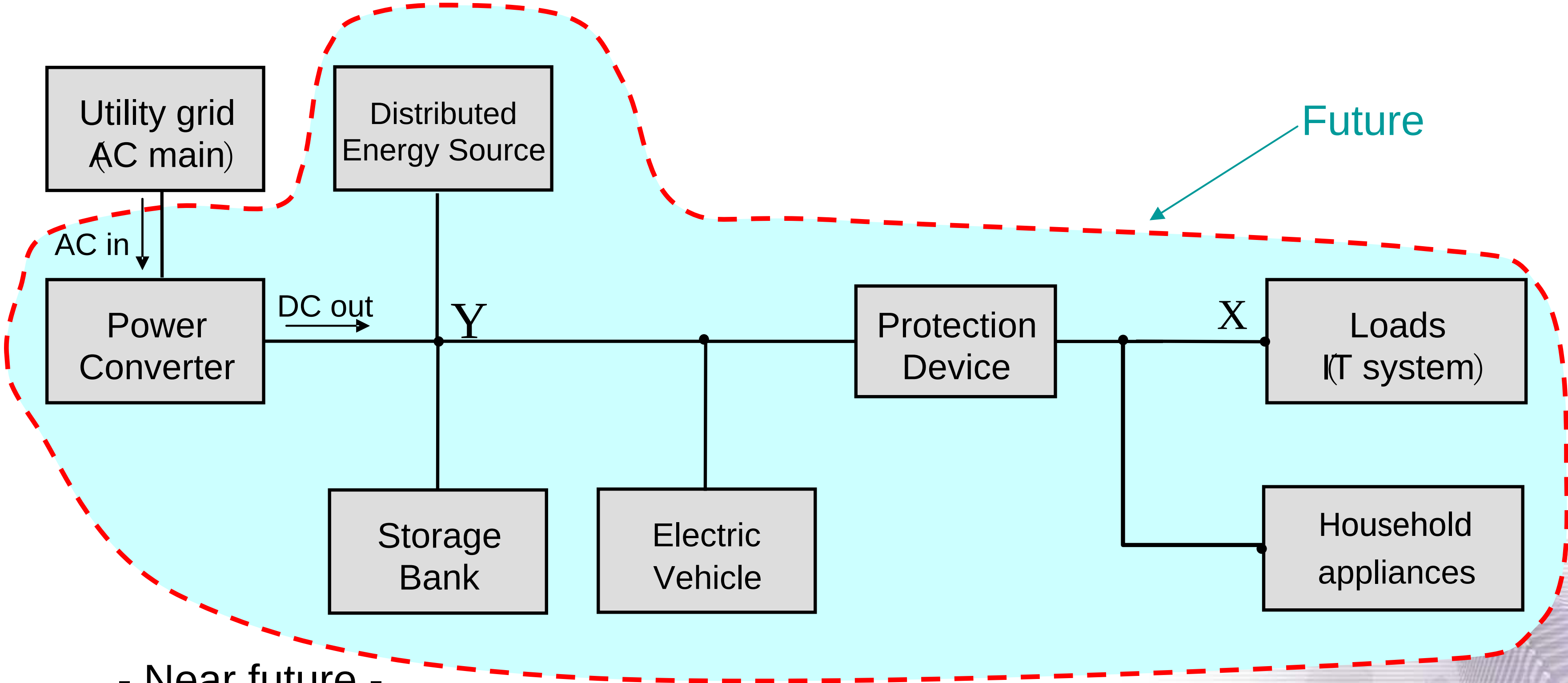
400 Vdc system (today)



- Near future -

The 400 Vdc class system is capability to expand another loads (electrical vehicle and household appliance).

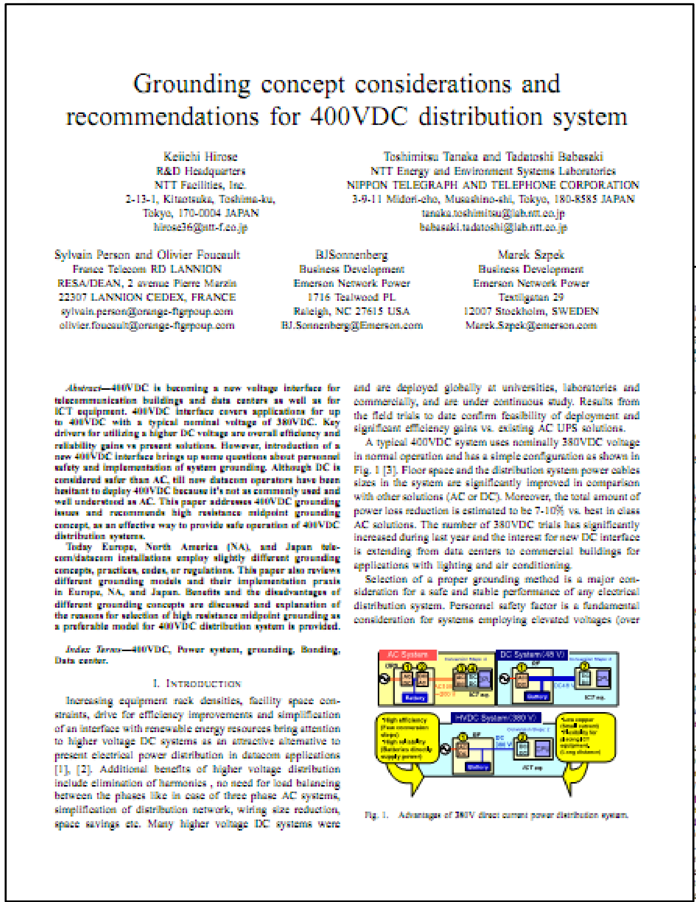
400 Vdc system (Option)



- Near future -

The 400 Vdc class system is capability to expand another loads (electrical vehicle and household appliance).

International cooperation



Grounding concept considerations and recommendations for 400VDC distribution system

Keiichi Hirose
R&D Headquarters
NTT Facilities, Inc.
2-13-1, Kitaotsuka, Toshima-ku,
Tokyo, 170-0004 JAPAN
hirose36@ntt-f.co.jp

Toshimitsu Tanaka and Tadatoshi Babasaki
NTT Energy and Environment Systems Laboratories
NIPPON TELEGRAPH AND TELEPHONE CORPORATION
3-9-11 Midori-cho, Musashino-shi, Tokyo, 180-8585 JAPAN
tanaka.toshimitsu@lab.ntt.co.jp
babasaki.tadatoshi@lab.ntt.co.jp

Sylvain Person and Olivier Foucault
France Telecom RD LANNION
RESA/DEAN, 2 avenue Pierre Marzin
22307 LANNION CEDEX, FRANCE
sylvain.person@orange-ftgroup.com
olivier.foucault@orange-ftgroup.com

BJSonnenberg
Business Development
Emerson Network Power
1716 Tealwood PL
Raleigh, NC 27615 USA
BJ.Sonnenberg@Emerson.com

Marek Szpek
Business Development
Emerson Network Power
Textilgatan 29
12007 Stockholm, SWEDEN
Marek.Szpek@emerson.com

Abstract—400VDC is becoming a new voltage interface for telecommunication buildings and data centers as well as for ICT equipment. 400VDC interface covers applications for up to 400VDC with a typical nominal voltage of 380VDC. Key drivers for utilizing a higher DC voltage are overall efficiency and reliability gains vs present solutions. However, introduction of a new 400VDC interface brings up some questions about personnel safety and implementation of system grounding. Although DC is considered safer than AC, till new datacom operators have been hesitant to deploy 400VDC because it's not as commonly used and well understood as AC. This paper addresses 400VDC grounding issues and recommends high resistance midpoint grounding concept, as an effective way to provide safe operation of 400VDC distribution systems.

Today Europe, North America (NA), and Japan telecom/datacom installations employ slightly different grounding concepts, practices, codes, or regulations. This paper also reviews different grounding models and their implementation praxis in Europe, NA, and Japan. Benefits and the disadvantages of different grounding concepts are discussed and explanation of the reasons for selection of high resistance midpoint grounding as a preferable model for 400VDC distribution system is provided.

Index Terms—400VDC, Power system, grounding, Bonding, Data center.

I. Introduction

Increasing equipment rack densities, facility space constraints, drive for efficiency improvements and simplification of an interface with renewable energy resources bring attention to higher voltage DC systems as an attractive alternative to present electrical power distribution in datacom applications [1], [2]. Additional benefits of higher voltage distribution include elimination of harmonics , no need for load balancing between the phases like in case of three phase AC systems, simplification of distribution network, wiring size reduction, space savings etc. Many higher voltage DC systems were and are deployed globally at universities, laboratories and commercially, and are under continuous study. Results from the field trials to date confirm feasibility of deployment and significant efficiency gains vs. existing AC UPS solutions.

A typical 400VDC system uses nominally 380VDC voltage in normal operation and has a simple configuration as shown in Fig. 1 [3]. Floor space and the distribution system power cables sizes in the system are significantly improved in comparison with other solutions (AC or DC). Moreover, the total amount of power loss reduction is estimated to be 7-10% vs. best in class AC solutions. The number of 380VDC trials has significantly increased during last year and the interest for new DC interface is extending from data centers to commercial buildings for applications with lighting and air conditioning.

Selection of a proper grounding method is a major consideration for a safe and stable performance of any electrical distribution system. Personnel safety factor is a fundamental consideration for systems employing elevated voltages (over

Fig. 1. Advantages of 380V direct current power distribution system.

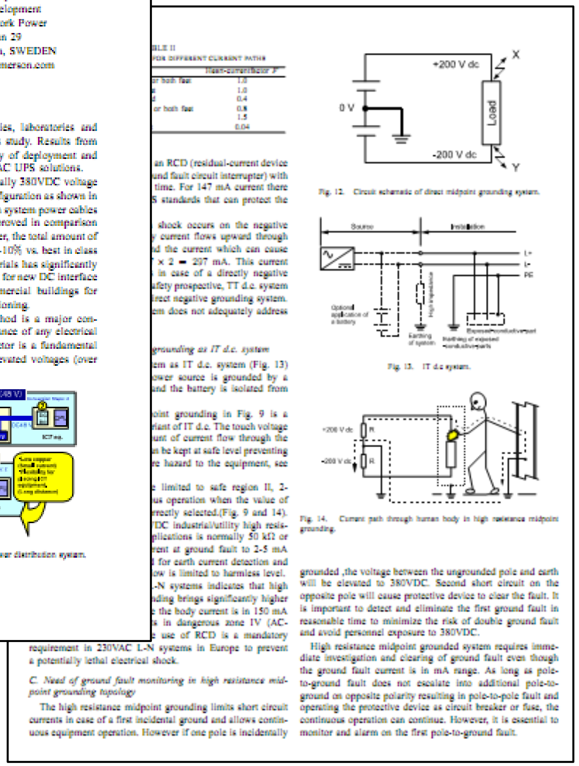


Fig. 12. Circuit schematic of direct midpoint grounding system.

Fig. 13. IT d.c system.

Fig. 14. Current path through human body in high resistance midpoint grounding.

requirement in 230VAC L-N systems in Europe to prevent a potentially lethal electrical shock.

C. Need of ground fault monitoring in high resistance midpoint grounding topology

The high resistance midpoint grounding limits short circuit currents in case of a first incidental ground and allows continuous equipment operation. However if one pole is incidentally grounded ,the voltage between the ungrounded pole and earth will be elevated to 380VDC. Second short circuit on the opposite pole will cause protective device to clear the fault. It is important to detect and eliminate the first ground fault in reasonable time to minimize the risk of double ground fault and avoid personnel exposure to 380VDC.

High resistance midpoint grounded system requires immediate investigation and clearing of ground fault even though the ground fault current is in mA range. As long as pole-to-ground fault does not escalate into additional pole-to-ground on opposite polarity resulting in pole-to-pole fault and operating the protective device as circuit breaker or fuse, the continuous operation can continue. However, it is essential to monitor and alarm on the first pole-to-ground fault.

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Questions?