HVDC power supply system implementation in NTT Group and next generation power supply

2015.2.3

Toru Tanaka
NTT Energy and Environment Systems Laboratories,
Nippon Telegraph and Telephone Corporation, Tokyo Japan

Outline

HVDC power supply system

1. Introduction
2. Advantages of HVDC
3. NTT group’s strategy and technical requirement
4. Application of HVDC

Next generation power supply system

1. System topology
2. Study of voltage levels

Summary

Introduction of NTT energy and environment systems lab.

We, NTT Group, is changing from only being telecom company to that which promotes global cloud business. Our lab promotes environmental load reduction of NTT group.
We aim to achieve sustainable and low-carbon society.

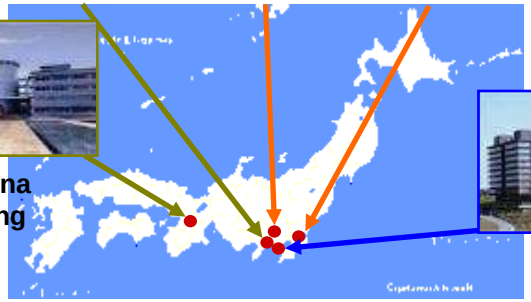
NTT groups


Atsugi R&D center


Musashino R&D center


Tsukuba R&D center


Keihanna building




Yokosuka R&D center

- Information Network Laboratory Group
  - **Energy and Environment Systems Lab.**
  - Network Service System Lab.
  - Access Network Service System Lab.
  - Network Technology Lab.
- Service Innovation Laboratory Group
- Science and Core Technology Laboratory Group

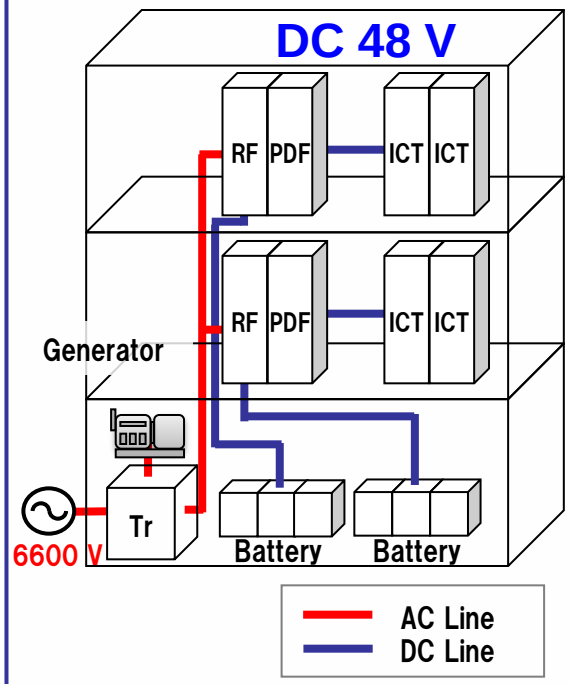
Our lab's fields and technology

Power supply ⇒DC power supply
Air conditioning ⇒ DEMS
EMC ⇒ Thunder and noise
Materials ⇒ Recycling and prolonging environmental impact assessment

DC power supply system for telecom buildings

NTT has been introducing DC power supply system for many years because DC system is highly reliable and efficient. Conventionally, DC -48 V is used as power bus.

Telecom facilities

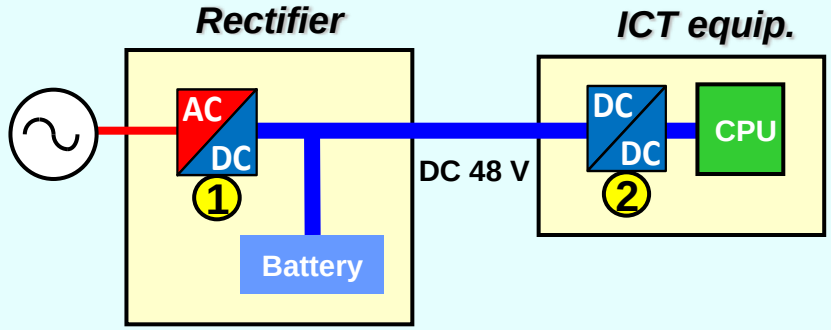


Tr: Transformer
RF: Rectifier
PDF: Power Distribution Frame

Rectifier

Power Distribution Frame

48 V DC power supply system

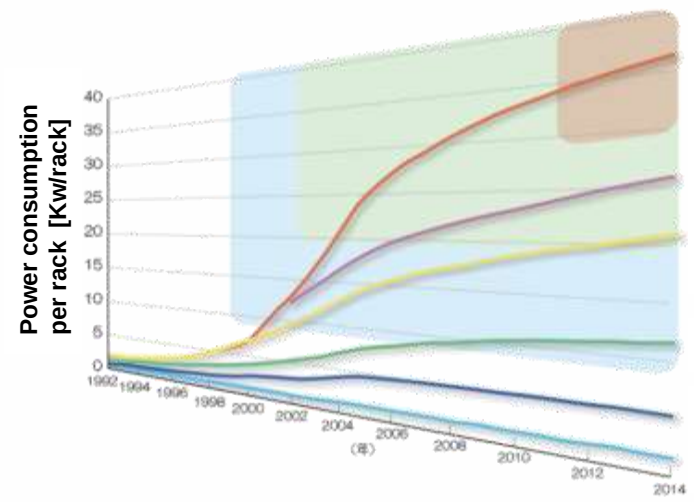


Conversion STGs=2→**simple**

Increasing power consumption

Power consumption per rack of ICT equipment is increasing due to capacity enlargement of ICT equipment. Also, scale of data centers is increasing. Therefore, reducing power consumption is important.

Power consumption per rack



Sever (1U, blade, custom)

Rooter (Core, Edge)

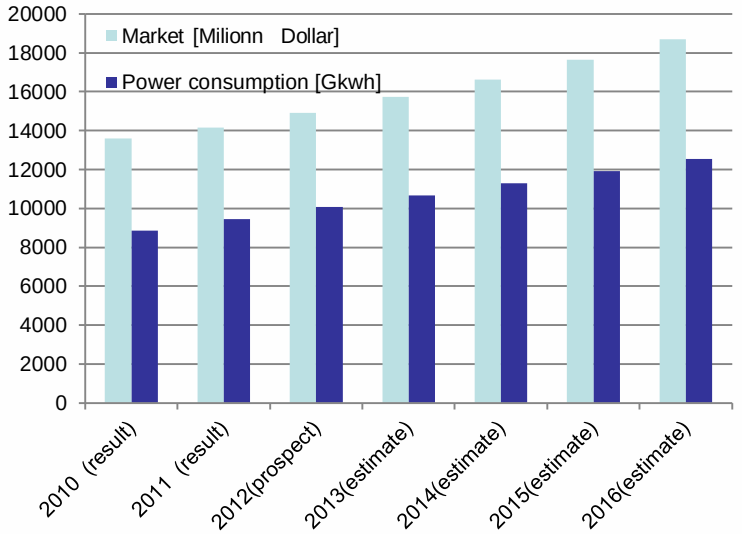
Sever (2U, Lo-end)

Storage

Work station

Tape storage

Increase in data-center market and power consumption



Exhibition: Fact-finding 2012 version of a datacenter market and power consumption

Alaxala AX6708S

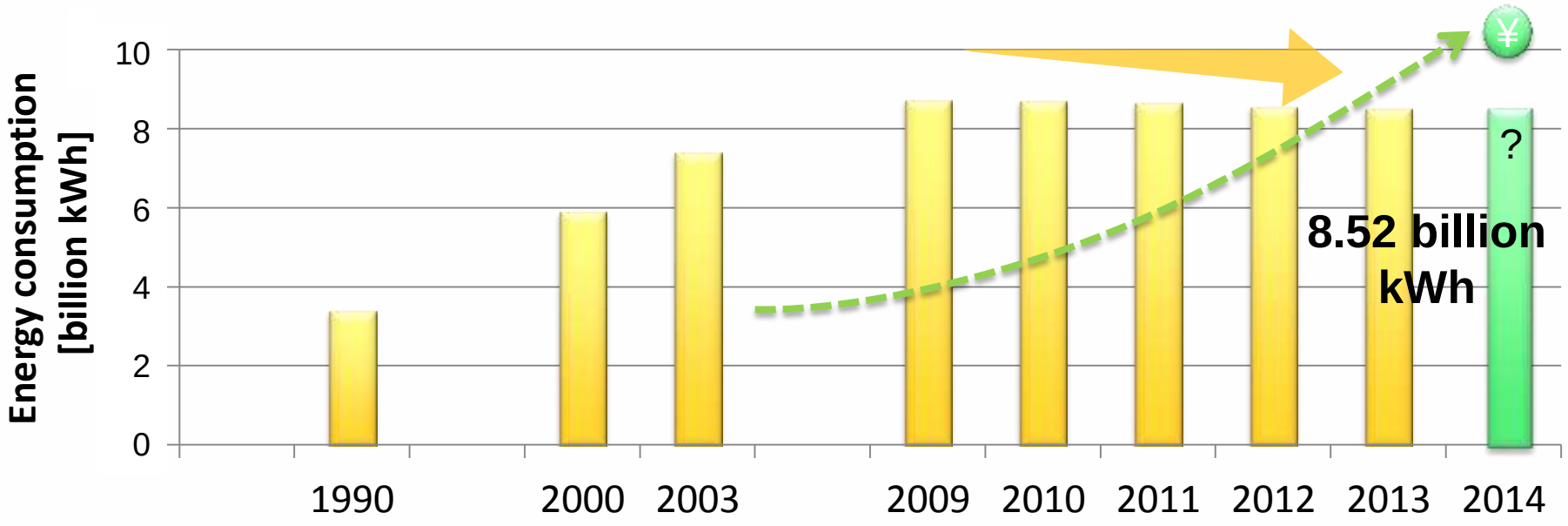
Cisco CRS-1

HP Blade System c7000

Energy Consumption of NTT Group

- **NTT Group's business activities consume electricity of about 8.5 billion kWh per year.**
- **Since 2008, energy consumption of each year is almost same. However, electrical fee has been increasing.**
- **Energy saving is important issue because "CLOUD" and "IP" services are spreading widely and they consume large amount of electricity.**

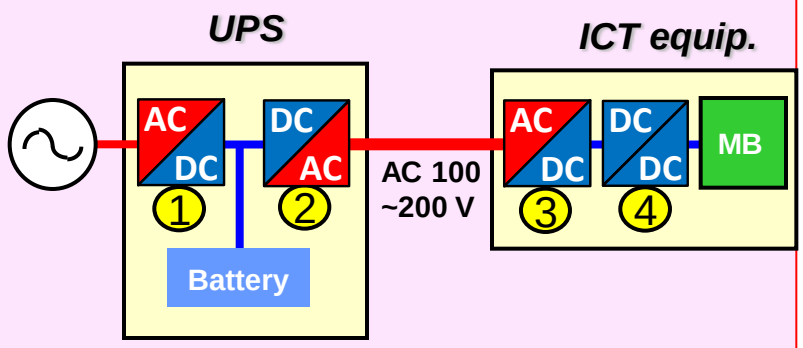
This is equivalent to 1% of total power consumption in Japan



HVDC (DC 380 V) power supply system

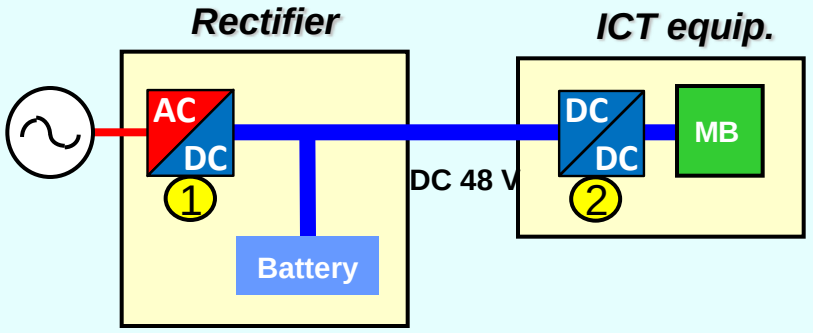
HVDC power supply systems supply DC 380 V to ICT equipment
-- HVDC systems have fewer conversion steps than AC systems.
⇒higher efficiency and higher reliability
-- HVDC systems can reduce current compared to 48-V systems.
⇒use of thinner power cables, which reduces construction costs

AC power supply



Conversion STGs=4 **Complicated**

DC power supply (-48 V)

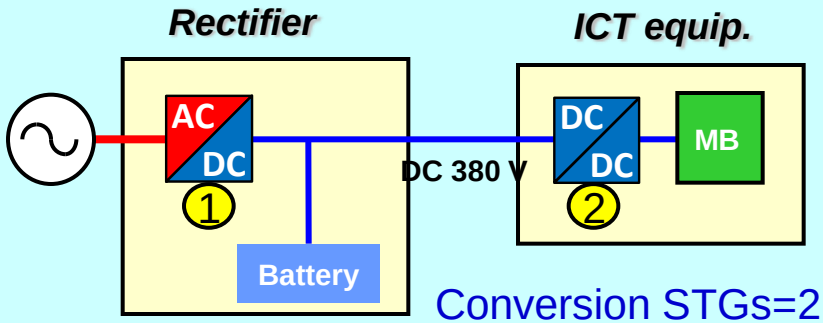


Conversion STGs=2 **simple**

-- Higher efficiency
(fewer conversion stages)
-- Higher reliability
(battery direct connecting

Total losses can be reduced

HVDC power supply



Conversion STGs=2

-- Lower installation cost
(small diameter cables are available)
-- Flexible installation

Building cost can be reduced

Advantages of HVDC system

1

-- Higher efficiency (fewer conversion stage)

Energy consumption: 10% savings

2

-- Higher reliability (battery direct connecting)

Reliability: 10 times higher

3

-- Space saving

Space: 30% savings

4

-- Low cost

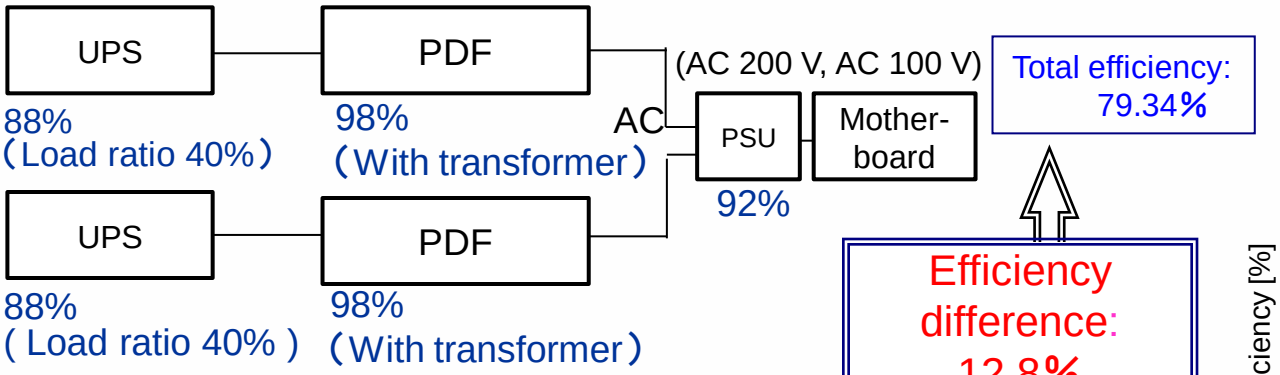
Cost: 50% savings

1 High efficiency

HVDC system include high-efficiency components (RF, PSU) and it has simple configuration.
Total efficiency of HVDC system is improved to 92% or more .

■Total efficiency from battery to ICT unit

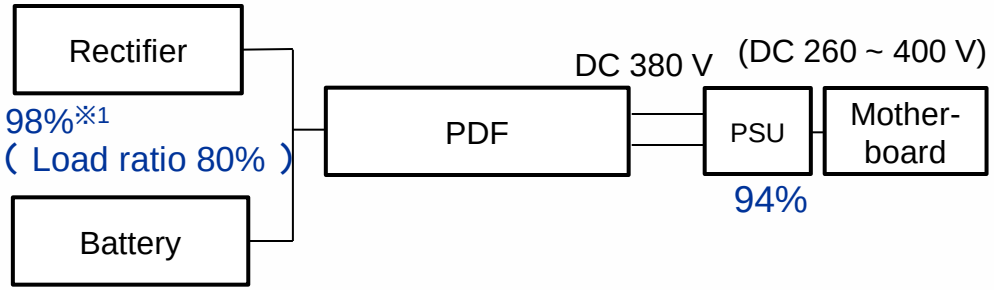
① AC power supply system with redundancy (double)



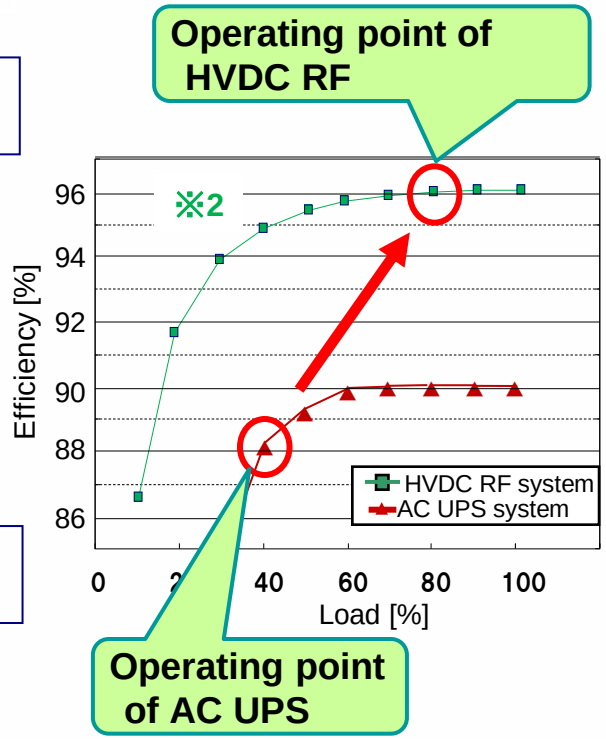
Total efficiency: 79.34%

Efficiency difference: 12.8%

② HVDC power supply system



Total efficiency: 92.12%

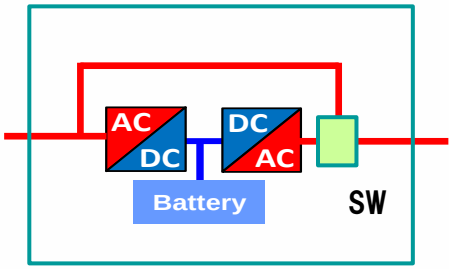


※1 Latest RF ※2NEDO Green IT data

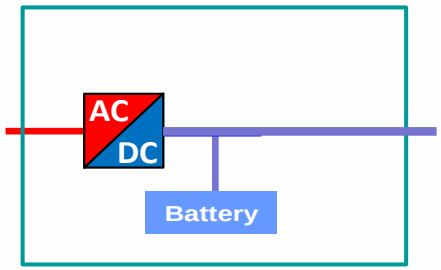
2 High Reliability

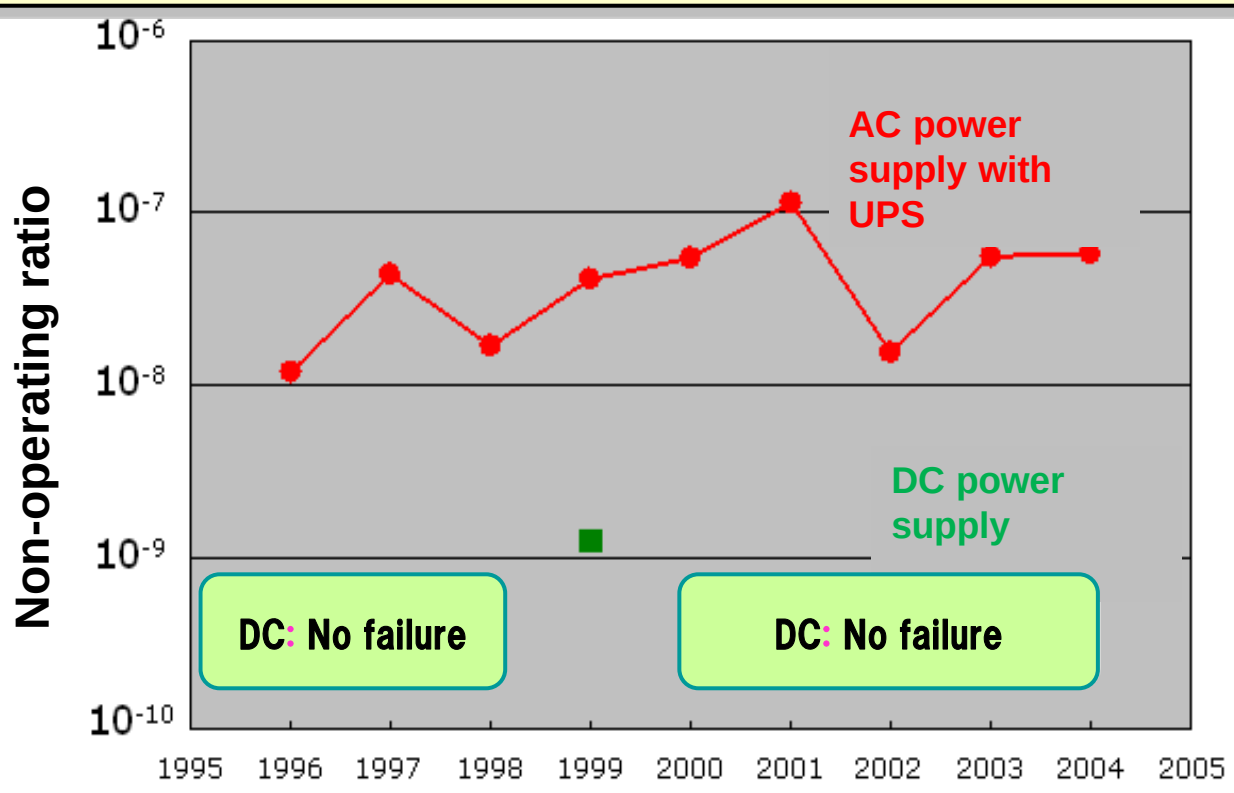
We have operated many power supply systems for many years.
■ From design reliability calculation, DC systems are 10 times more reliable than AC power systems.
■ High reliability has been verified by evaluating data in field.

AC power supply



DC power supply



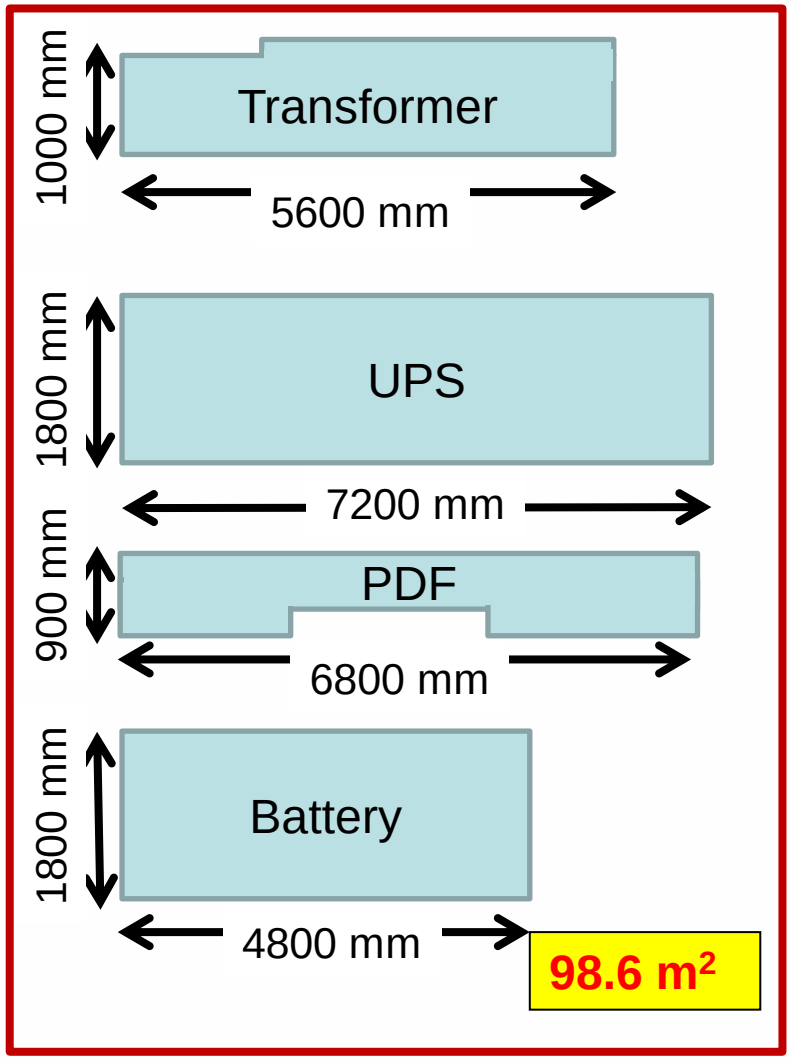


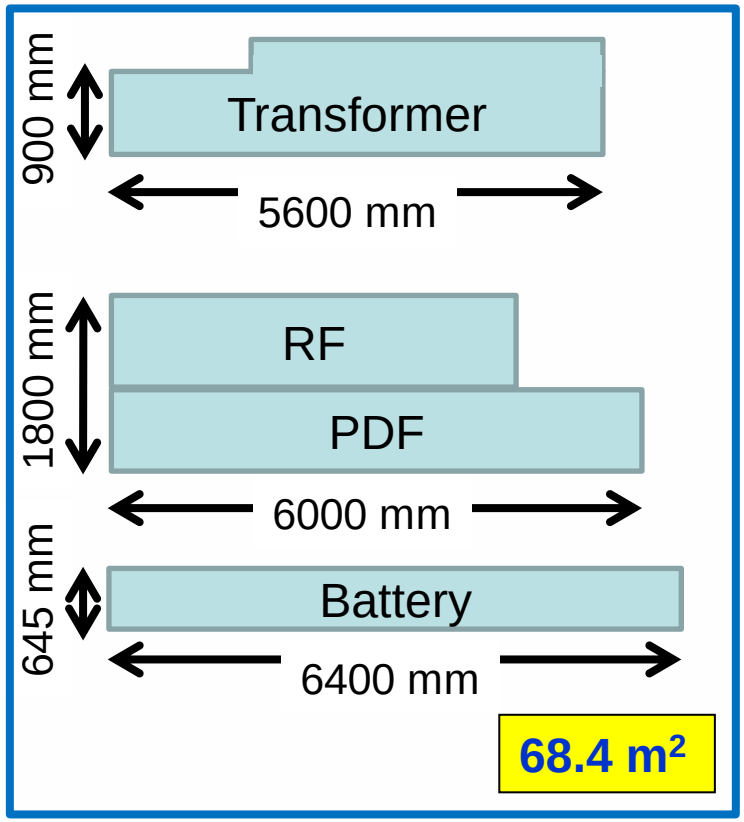
Field data
UPS: about 10,000 units, DC power supply about 23,000 units

<reference> H. Ikebe, N. Yamashita, R. Nishii: GREEN ENERGY FOR TELECOMMUNICATIONS: Intelec2007

3 Space saving

When we introduce HVDC system, we can achieve about 30% reduction in space.





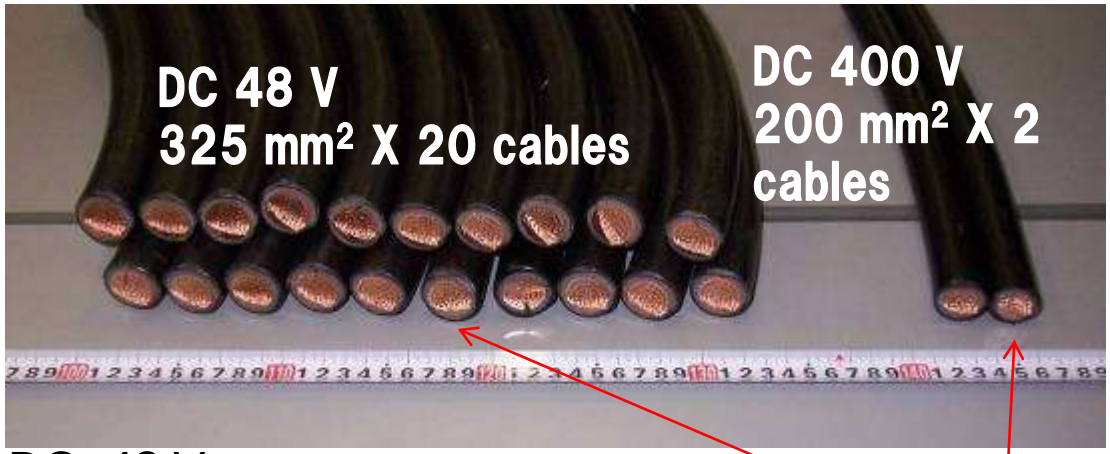
Space saving
▲31% (▲ 30.2 m²)

500-kW system
Back up time: 10 min

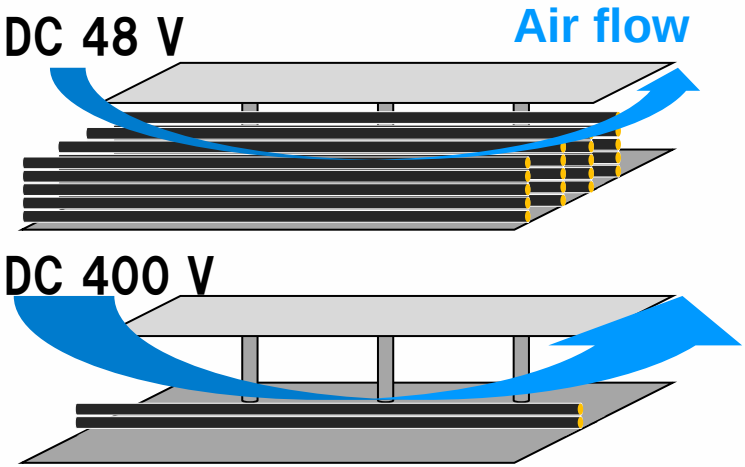
4 Reducing construction costs(thin cable)

Cross-sectional area of cables is one-tenth compared to DC -48 V system. Thus, HVDC system can reduce construction costs by – ensuring air-flow space under floor – reducing costs of cable, and improving its distribution.

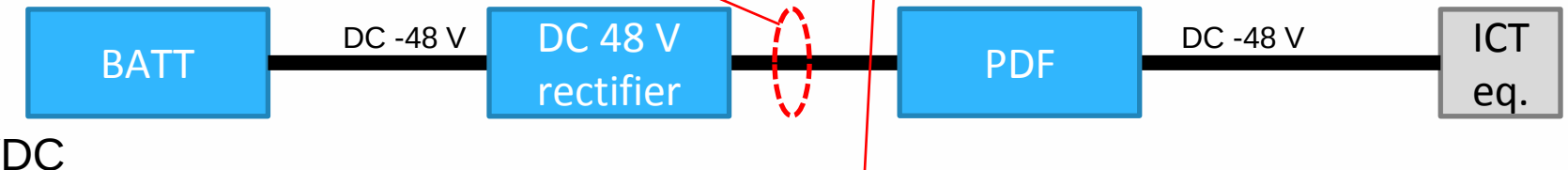
Number of cables between battery and rectifier for 100-kW system



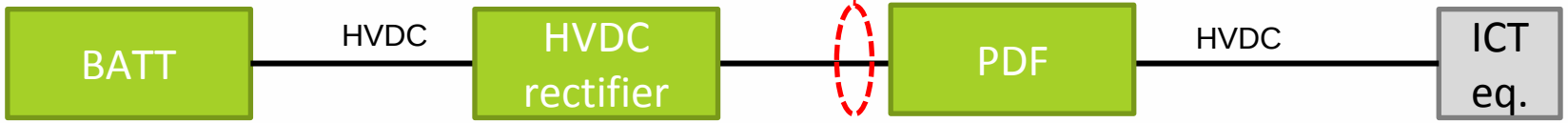
Air conditioning efficiency



DC -48 V

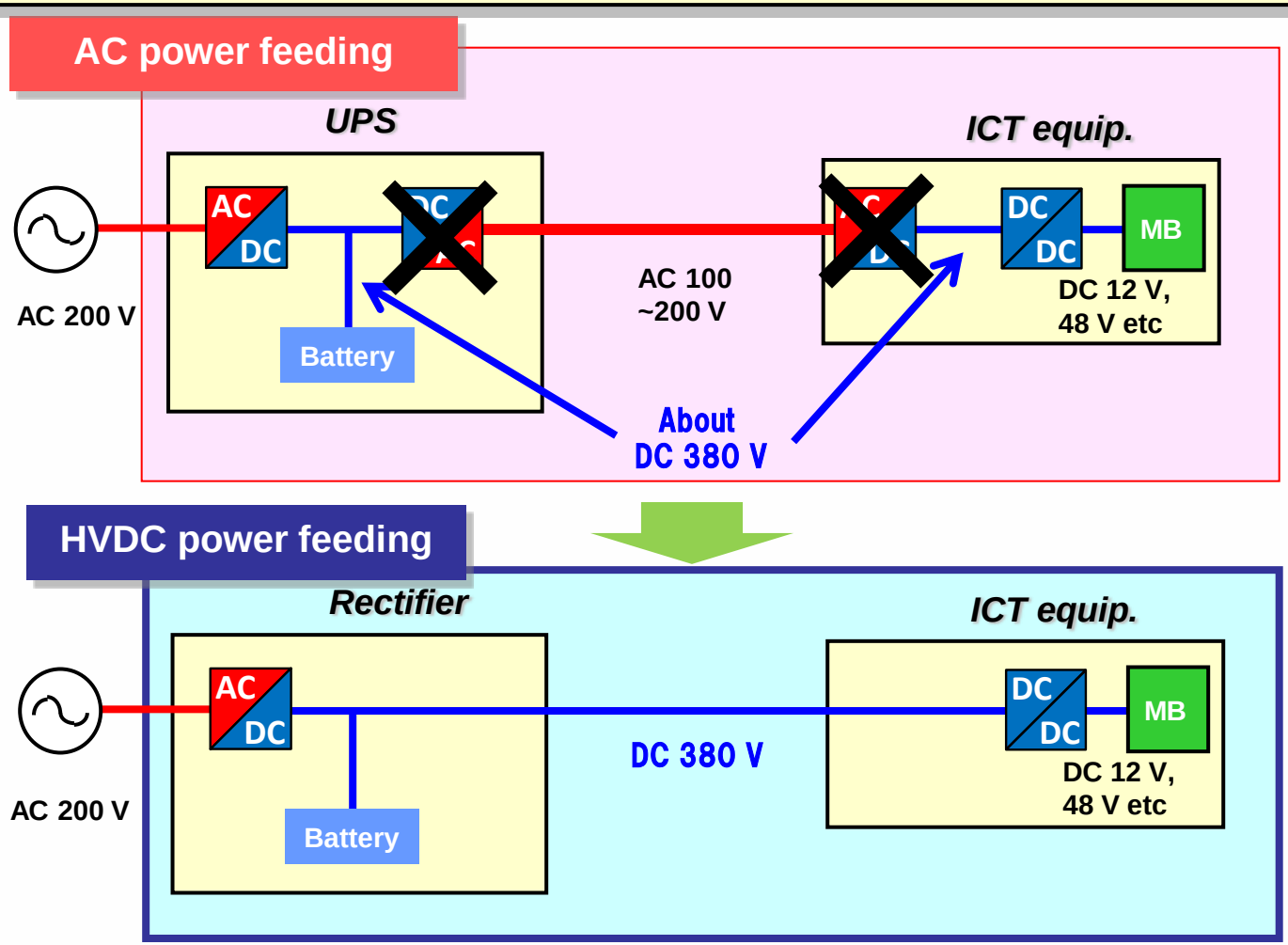


HVDC



Why 380 V？

When voltage is higher, we can reduce power loss but safety measure costs increase. Also, we have been using DC 380 V in UPS and PSU, so we can use those components for DC 380 V. Furthermore, 380 V is created by piling up 168 battery cells.



BATT: 168 cells
(24 cells ✕ 7)

Nominal Voltage
168 cells ✕ 2.0 V
= 336 V

Working Voltage
168 cells ✕ 2.23
～2.25 V
=374.6～378 V

DC 380 V

Issues of HVDC system

Technical issues

- Safety
  Electrical stability
- Line-up of power equipment

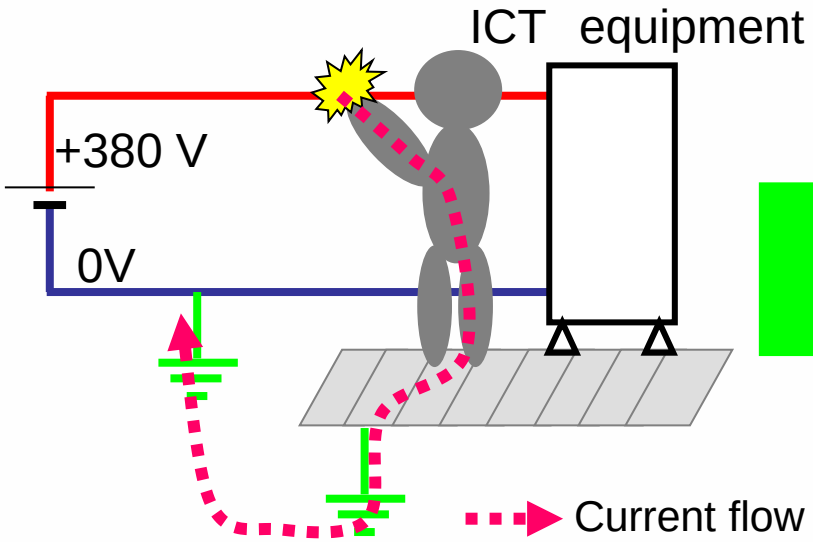
Promotion issues

- Line-up of ICT equipment
- Standardization

Earthing with electrical safety

To ensure human safety, we adopted earthed high-ohmic mid-point.
This system limits human touch current in case of human error.

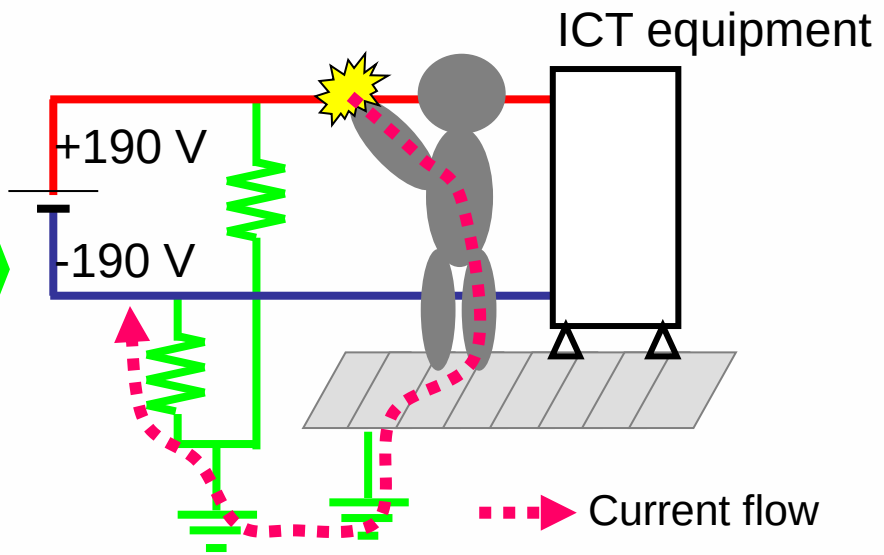
System with earthed negative line



Human touch current: about 270 mA

270 mA corresponds to Level IV in IEC 60479
It indicates **High risk** to human body

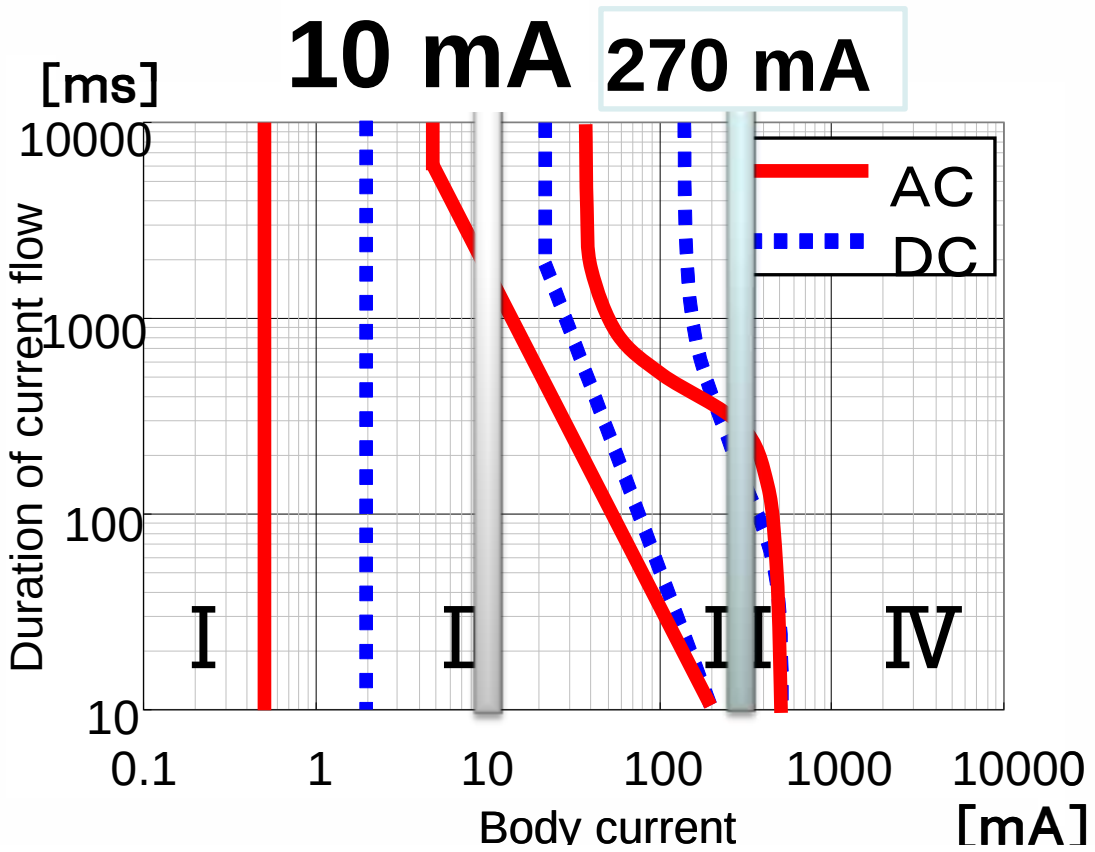
System with earthed high-ohmic mid-point



Human touch current: about 10 mA

10 mA corresponds to Level I in IEC 60479-1
It indicates **Low risk** to human body
This system is defined by ETSI EN 301 605

Human touch current (IEC standard)



Safety level

I: Electrification that humans cannot feel

II: Humans feel pain but there are no problems physiologically

III: Muscle cramps and breathing difficulty occurs: dangerous.

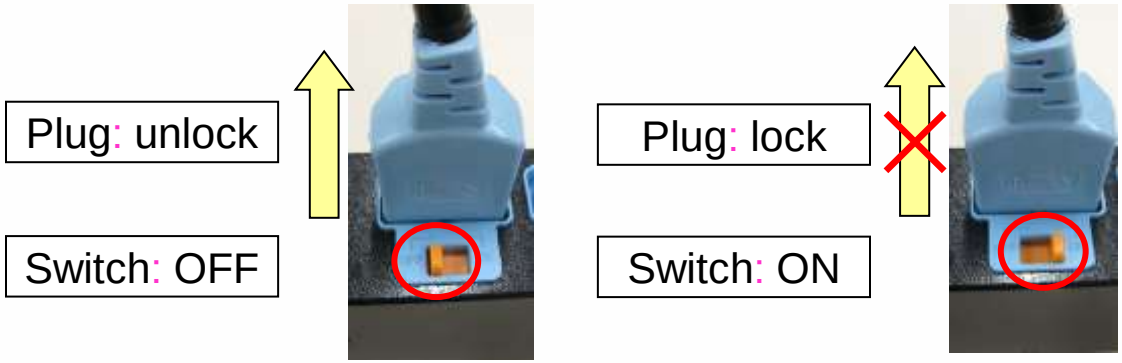
IV: Ventricular fibrillation occurs: very dangerous.

Reference：IEC/TS 60479-1 figure20,22

IEC: International Electrotechnical Commis

Socket and outlet

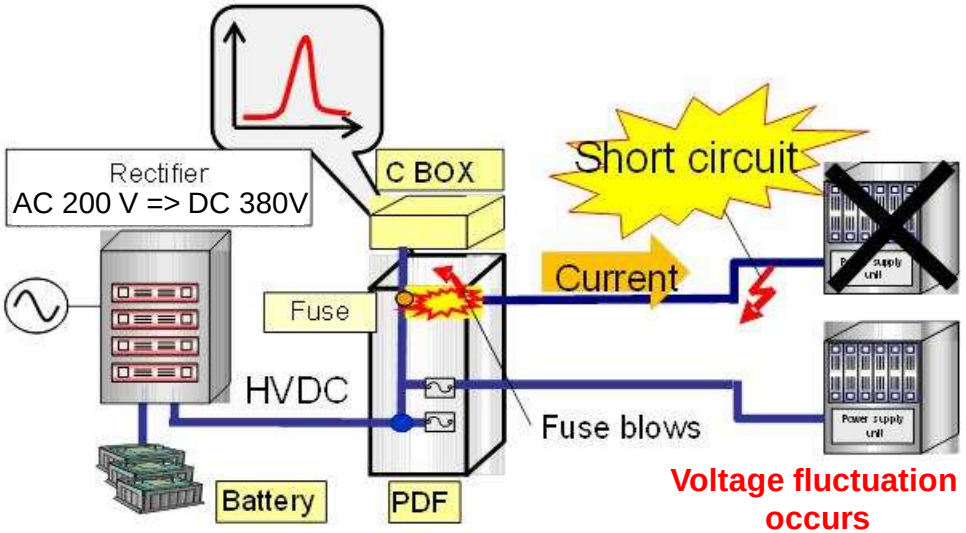
NTT Facilities collaborates with Fujitsu component, Ltd.

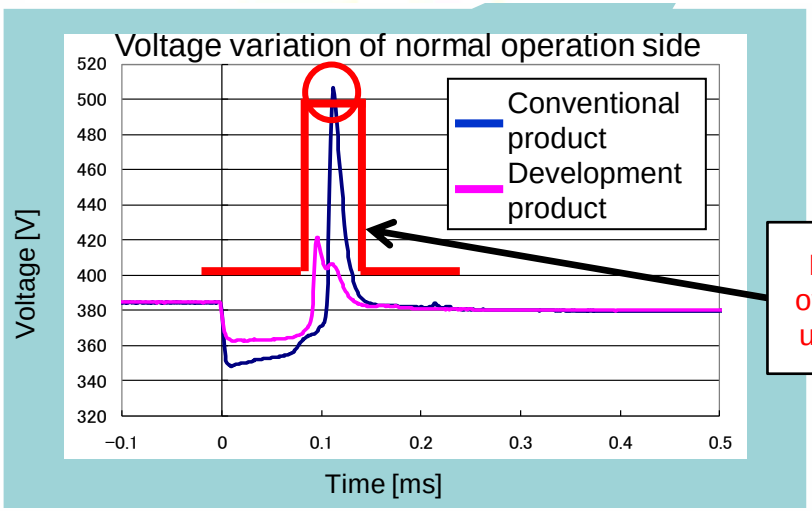


Mechanical interlock
(Combination of permanent magnet and mechanical contacts)

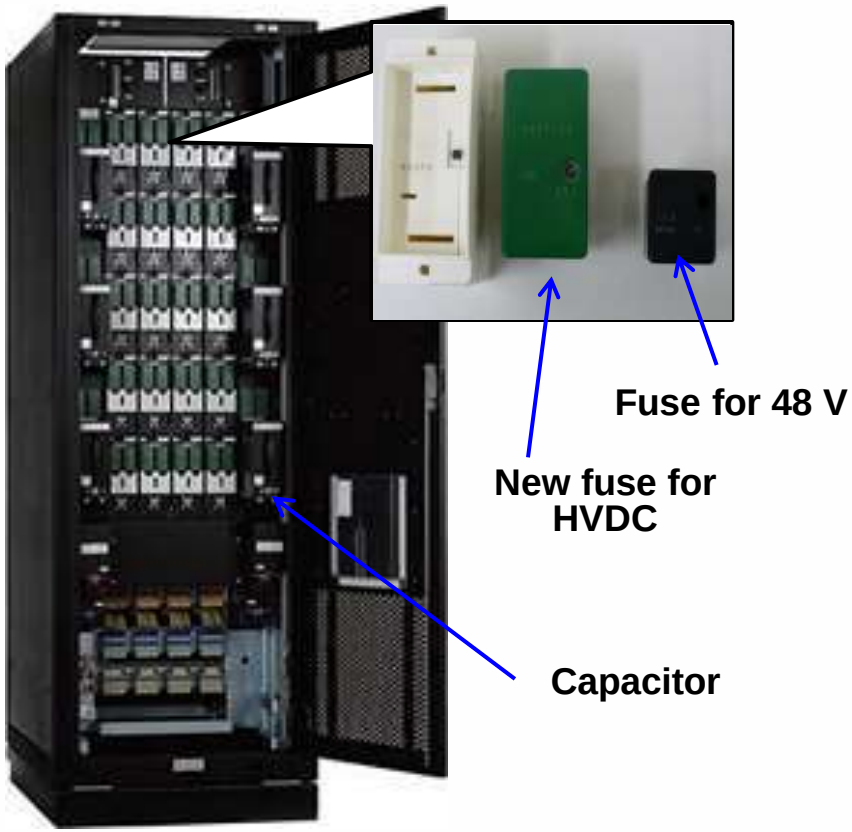
Suppressing voltage fluctuation

We can evaluate effect of voltage fluctuation at ICT equipment when short circuit occurs.
We developed fuse and PDF to suppress voltage fluctuation



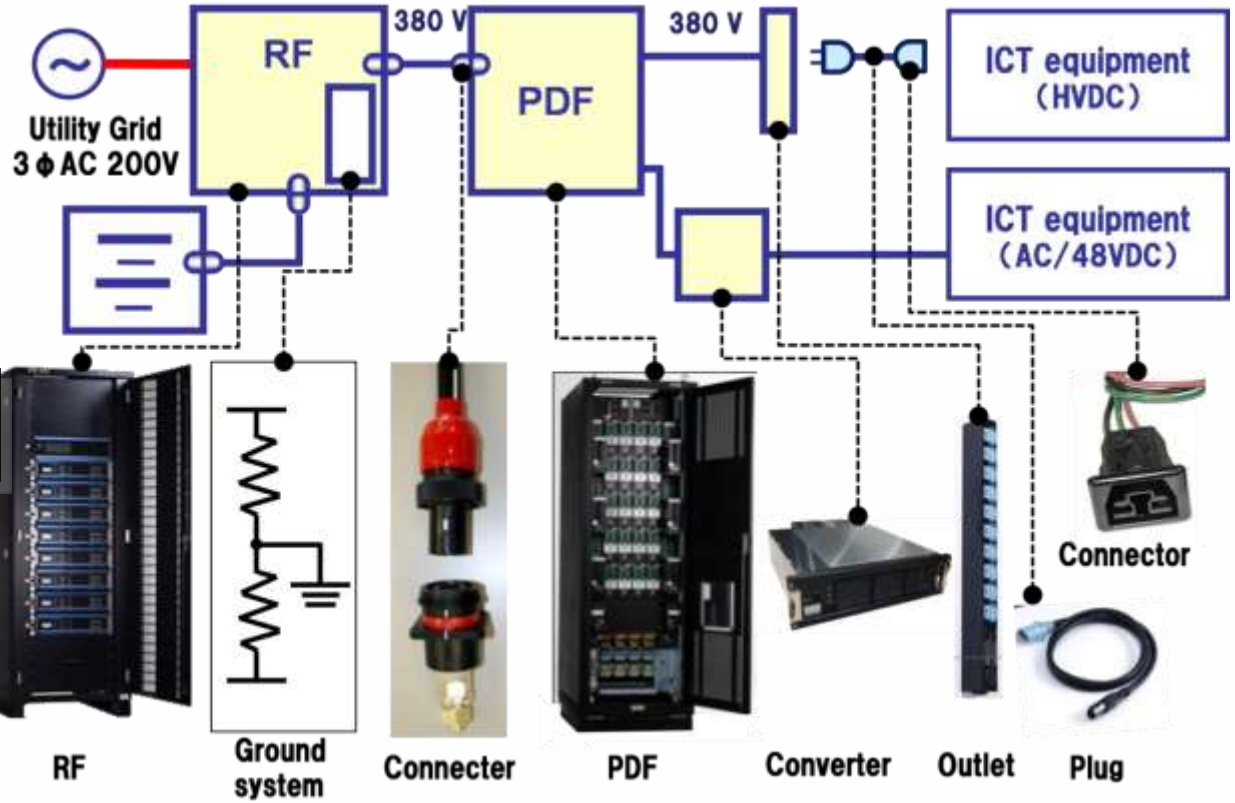


New fuse and PDF for HVDC



Lineup of HVDC power supply components

We completed development of power-supply equipment



Rectifier:
100 and 500 kW

Grounding:
Mid point grounding system

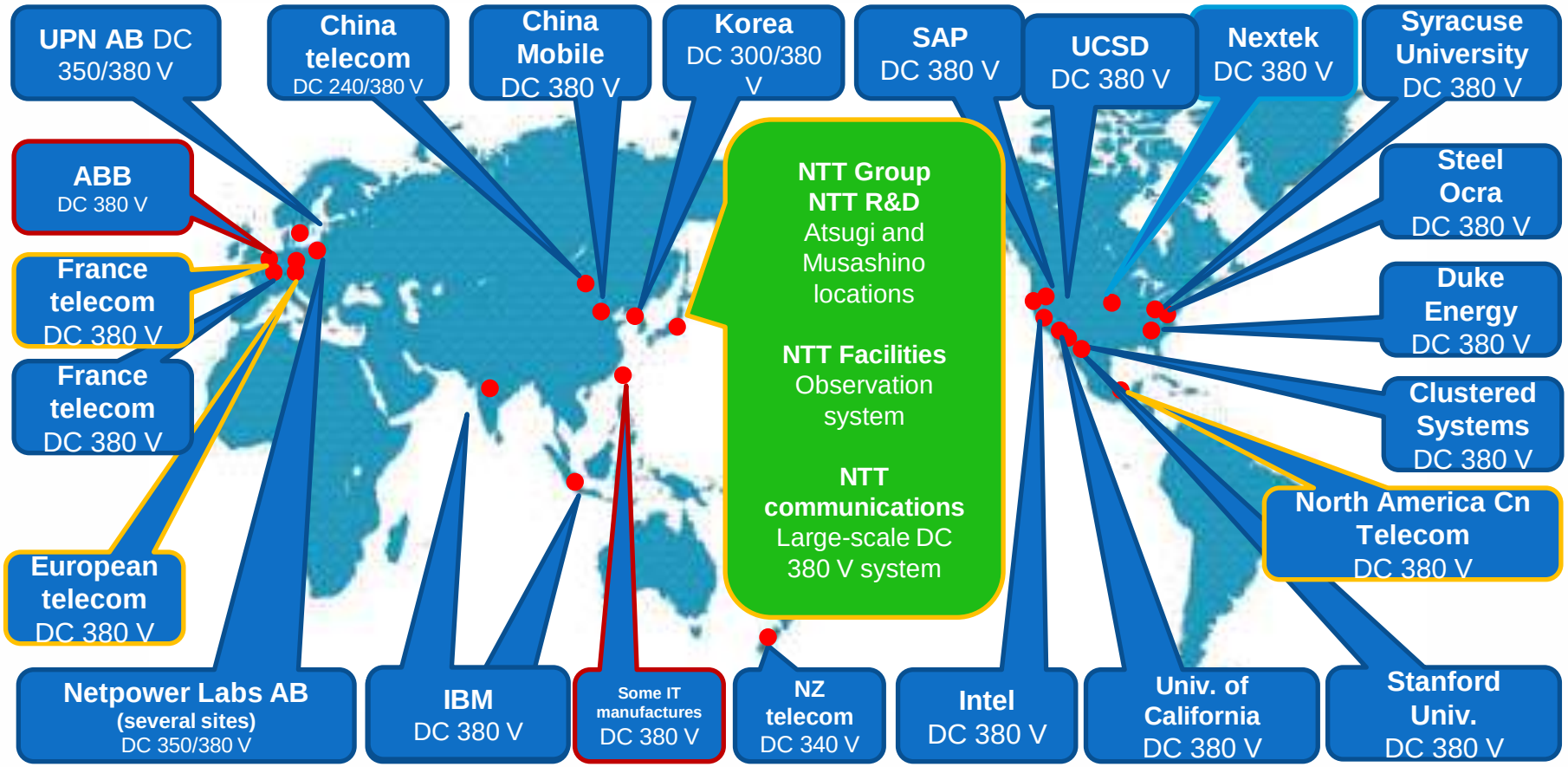
PDF:
Fuse type and MCCB type

Converter:
Convert DC 380 V to DC 48 V or AC 100 V

Outlet:
Bar, plug. and connector for HVDC

Worldwide expansion of HVDC

HVDC has been expanded as DC 380 V power supply system worldwide



The graph is modified based on NTT Facilities inc's data.

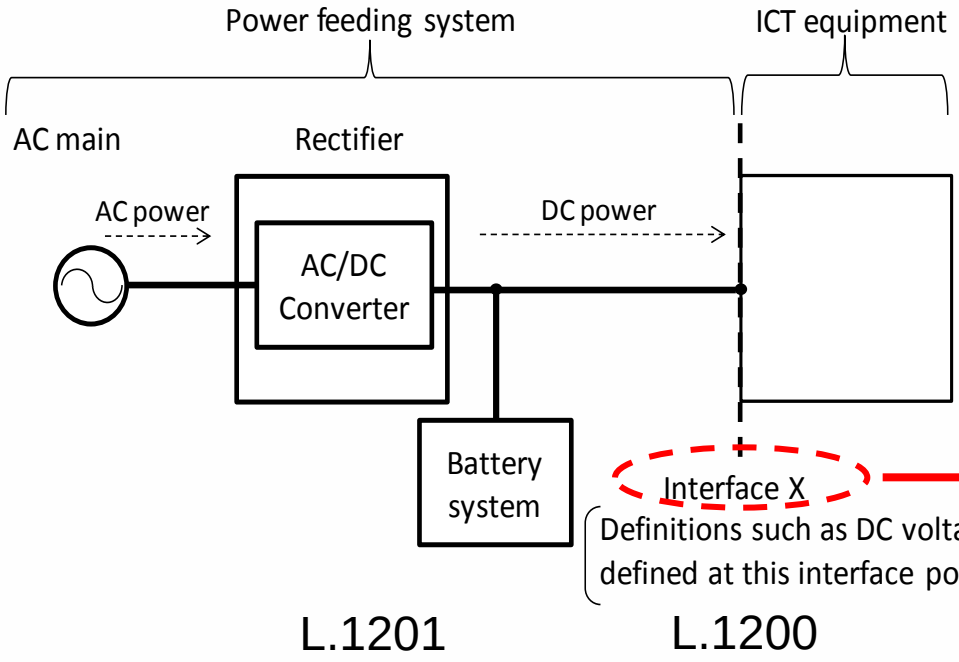
HVDC standardization progress

NTT Group worked on international standardization

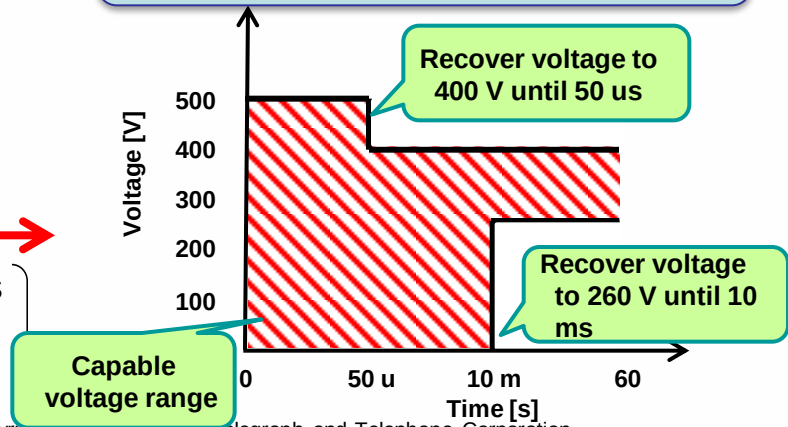
Step 1: Interface specifications at input of ICT equipment
⇒Complete, ITU-T 2012 published (L.1200)

Step 2: Power system architecture
⇒Complete, ITU-T 2014 published (L.1201)

ITU-T: International Telecommunication Union Telecommunication Standardization Sector



- Voltage range 260-400 V
- Voltage variation (dip, interruption etc)
- Serge test, inrush current



Lineup of ICT equipment for HVDC

HVDC-supported products have been released (e.g. NEC, IBM and Hewlett-Packard)
HVDC-supported products are expected to become more widespread

Main Frame

Blade

4U

3U

2U

1U

NEC: Express5800/ SIGMABLADE-M

HP: C7000

Cisco: UCS 5108

IBM: zEnterpirse 114

IBM: zEnterprise 196

HP ProLiant SL6500 scalable system

Plathome: TrusSPS series （2U, 3U, 4U）（storage ）

NEC: iStorage M series M300/M100/ M10e （storage）

HP: DL380

UNICOM: D-2000

Atworks: Stingray ZE

UNICOM: D-1000

Dilemma of promoting new system

Situation of ICT equipment venders	Situation of carrier and operator
If carrier and operator say that they will buy many types of ICT equipment, we can sell ICT equipment for HVDC.	If ICT vender will sell many types of ICT equipment for HVDC, we can introduce HVDC system.

NTT will break this cycle and introduce HVDC system.

NTT Group Strategy for Deploying HVDC system

NTT has focused on promoting HVDC system implementation.
NTT will introduce HVDC system to many NTT Group companies and promote it in earnest from 2016.

NTT
JAPANESE
Search of NTT
Font Size Small Medium Large
About NTT Group
About NTT Corporation
Press Releases | Group Companies | Social/Environmental Initiatives | NTT Facts | To Investors | R&D | Career Opportunities
NTT HOME > NTT Press Releases > 2014 > Publication of World's first Technical Requirements for the Next-generation Power supply Interface
Search Among NTT Press Releases
January 1997 – September 2014
Search
NTT Press Releases
Latest Press Releases
Back Number
Japanese is here
NTT Press Releases
August 4, 2014
Publication of World's first*1 Technical Requirements for the Next-generation Power supply Interface
High Voltage Direct Current power supply system for full-scale introduction by the NTT Group companies in 2016
The Nippon Telegraph and Telephone Corporation (NTT, Chiyoda-ku, Tokyo, Hiroo Unoura (CEO)), has published the Technical Requirements (TR) for "High-Voltage DC (HVDC) power supply system"*2 that is considered as the next-generation power supply system, by summarizing technical specifications for introducing them to telecommunication and data-center buildings in NTT group.
The document, titled "Technical Requirements for High-voltage DC Power Supply Interfaces "*3, is based on standards set by the International Telecommunications Union - Telecommunication Standardization Sector (ITU-T).
By opening to the public to this TR, NTT would like to widely stimulate use of HVDC in the information & communication fields. In addition, NTT is continuously making our efforts to tackling energy conservation throughout the ICT fields.

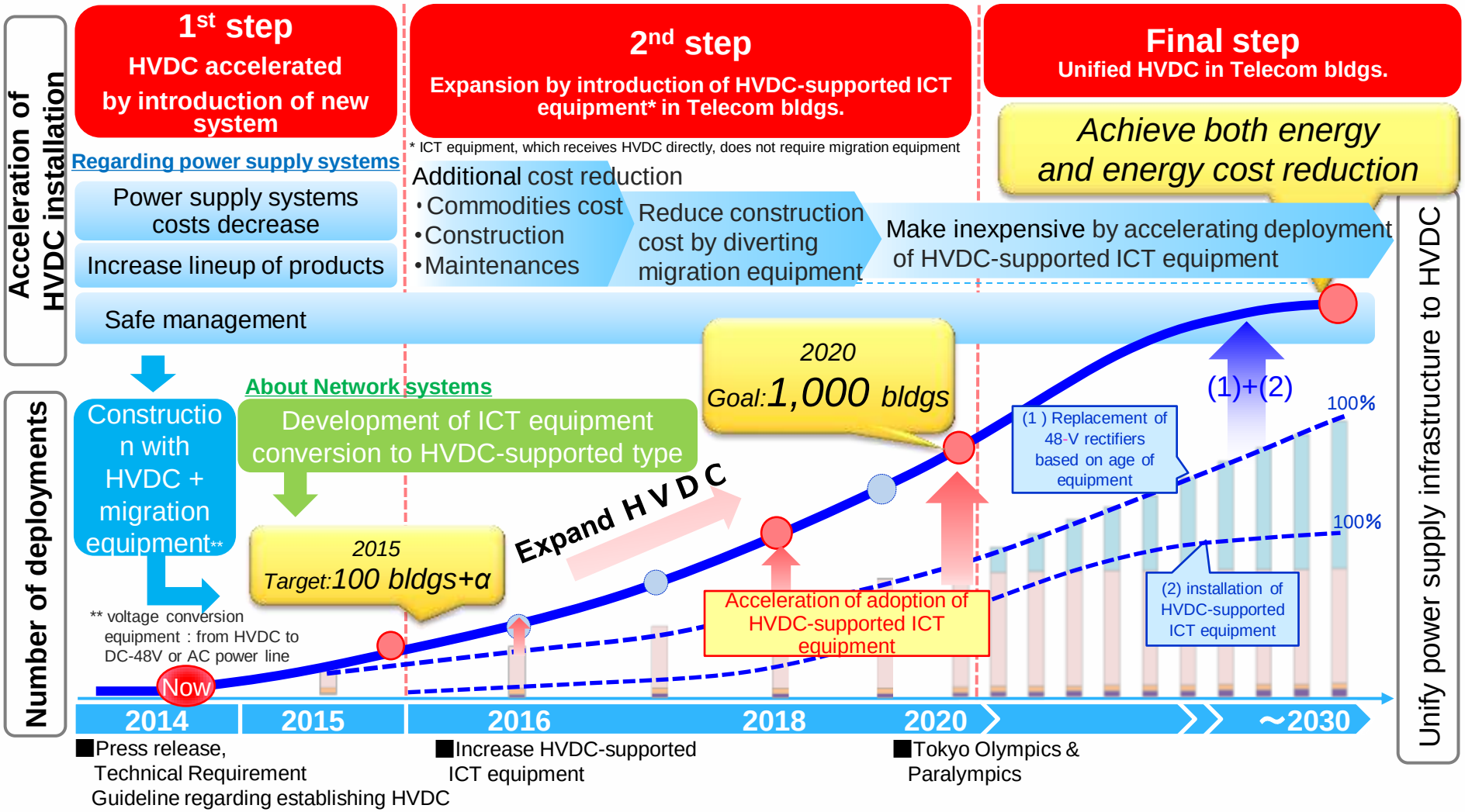
telecompaper
HOME : MOBILE & WIRELESS : INTERNET : GENERAL : FIXED : IT : BROADCAST
GENERAL
NTT publishes technical requirements for HVDC power supply
Monday 4 August 2014 | 09:46 CET | News
The Nippon Telegraph and Telephone Corporation (NTT) has published the technical requirements for High-Voltage DC (HVDC) power supply system by summarizing technical specifications for introducing them to telecommunication and data-center buildings in NTT group. The document is based on standards set by the International Telecommunications Union - Telecommunication Standardization Sector (ITU-T). NTT plans to boost the use of HVDC in the information & communication fields.
In addition, NTT tackles energy conservation in ICT fields. Under the newly-released technical requirements, the input port to ICT equipment has been specified. It is also applicable to the input to voltage converters and other points receiving high-voltage DC power. The operating voltage range is set from 260 V to 400 V and the nominal voltage is set to 380 V. In the requirements, the operating conditions in the case that the voltage is outside the operating voltage range, or supplying power exceeds rated power of the power supply unit in the ICT equipment, and the start-up current as well as various safety factors were taken into account.
NTT plans to introduce HVDC power supply system to its telecommunication and date center buildings from fiscal year 2016, in order to improve its energy efficiency. At the same time, NTT will be expanding introduction of DC power supply system, by introducing not only ICT equipment directly connected to HVDC system, but also the equipment connected to lower DC voltage (12V, 48V, etc) converted in a rack or in vicinity of a rack.

NTT HVDC World's first **search**

http://www.ntt.co.jp/news2014/1408e/140804a.html

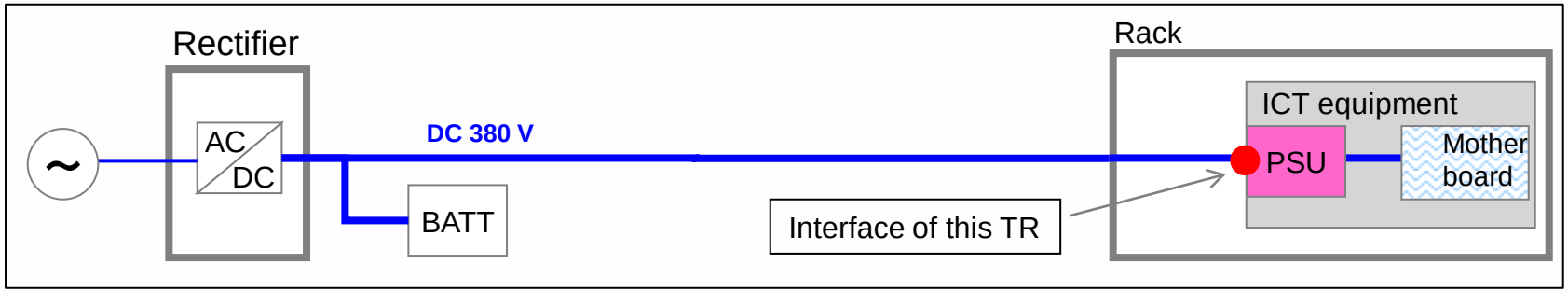
Roadmap

- NTT Group accelerates installation of HVDC systems for telecom buildings
- Reduction in energy consumption and energy cost is achieved through our strategy



Specifications of Technical Requirement (TR)

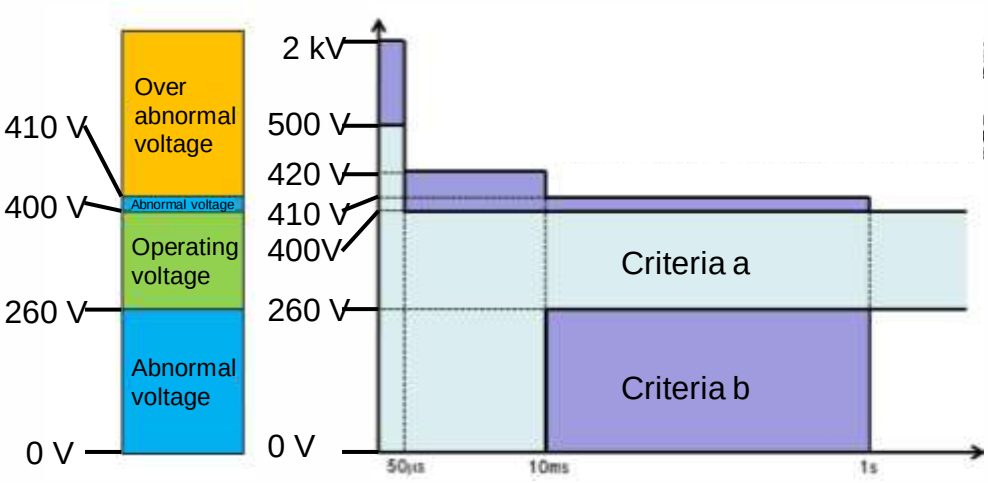
We published technical requirement for HVDC power supply interfaces of ICT equipment



Items	Specifications	
Rated voltage	380 V	*1
Operating voltage range	From 260 to 400 V	*2
Maximum rated capacity	7.8 kW	*1
Inrush current	Limit of current level and time	*2
Abnormal conditions	Voltage variation, voltage dips, short interruptions, voltage surges/transients	*2
Safety	Protection against electric shocks	*1

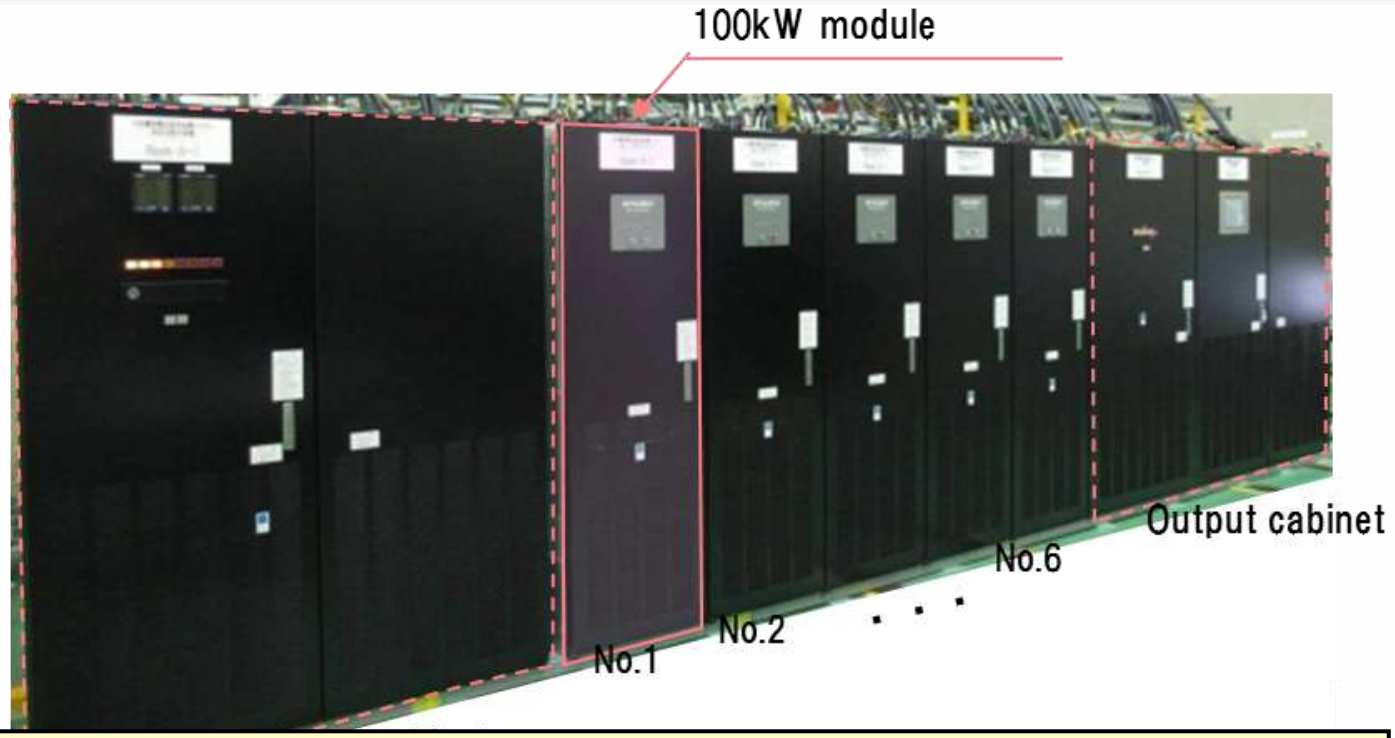
*1: NTT added in the TR.
*2: L.1200

TR for ICT equipment based on ITU-T L.1200.



Example of introduction of large-scale HVDC system

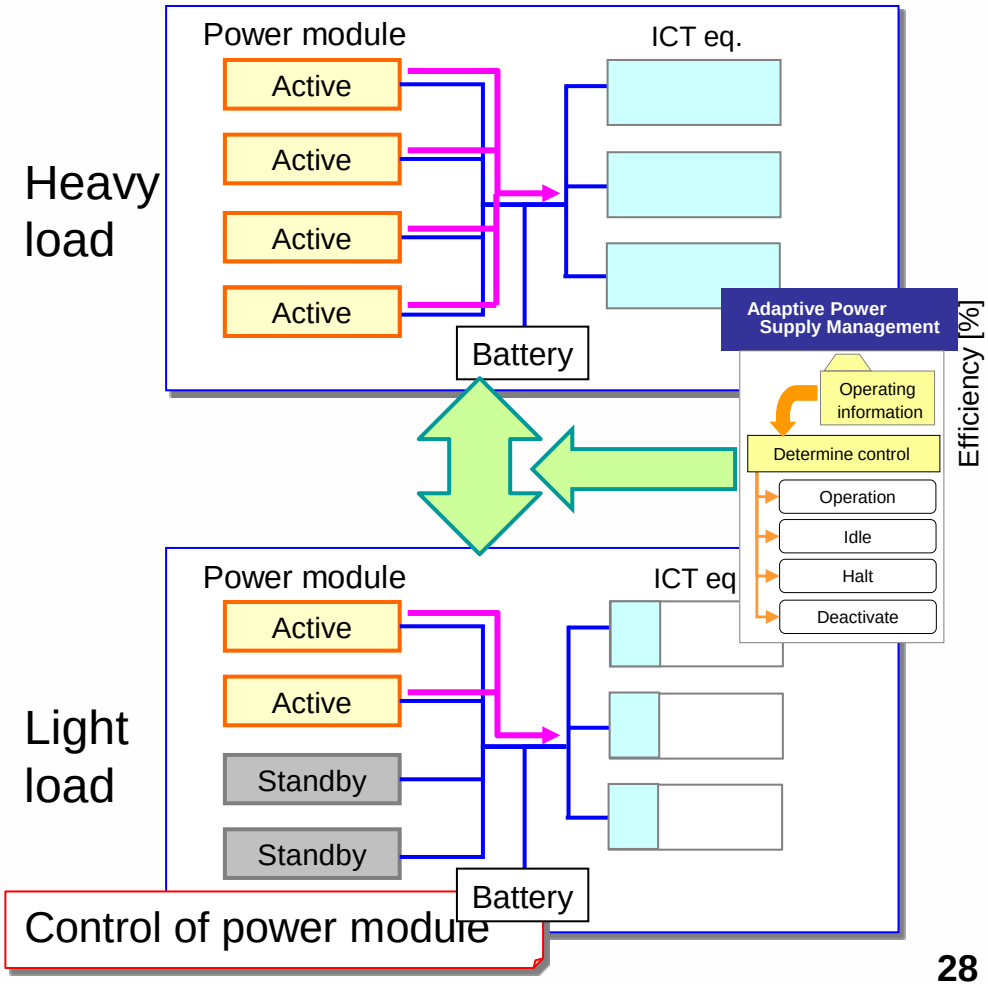
In NTT group, HVDC system has been installed not only at laboratory sites but also associated companies.
Recently, large-scale HVDC system has been introduced in NTT Group.

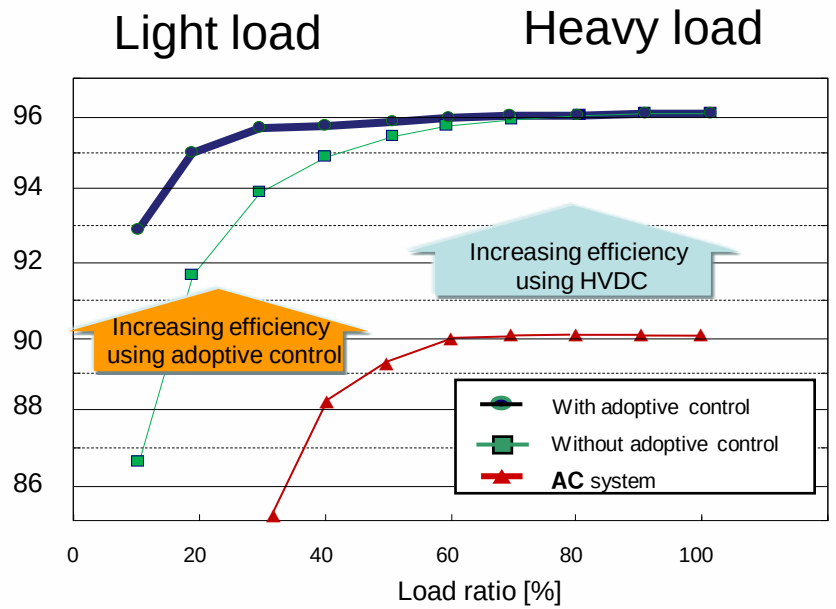


Large-scale rectifier: 500-kW system (NTT Facilities)
Total power: 4 MW (500 kW x 8 systems)
Reduce power loss ⇒ Lower power consumption by 20%
Initial cost of this HVDC system was less than that of conventional system

Development of further savings (Adaptive control)

NTT group has been developing adaptive control technique for reducing power consumption for data centers.
In adaptive control technology, we control number of working power modules according to ICT load.





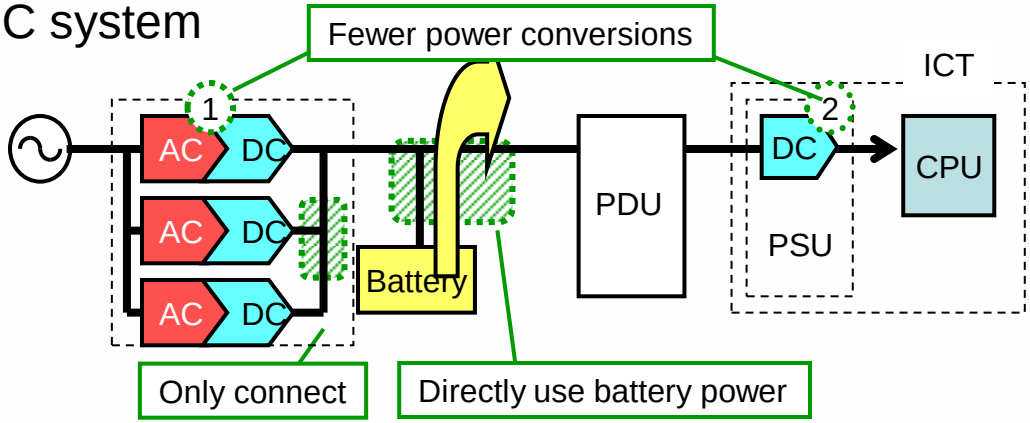
NTT Facilities activity in NEDO green IT project

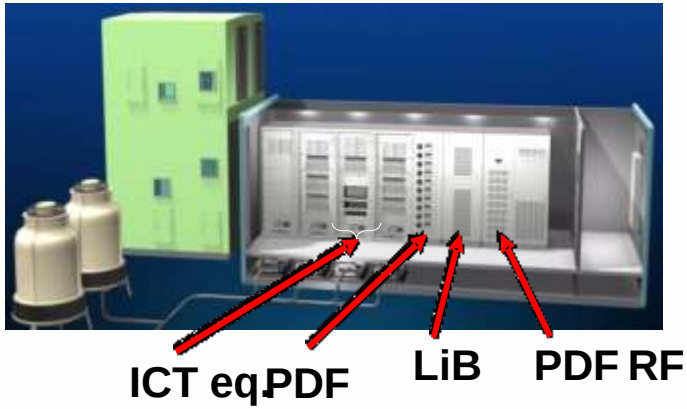
NEDO: New Energy and Industrial Technology Development Organization

Ease of controlling DC power supply unit

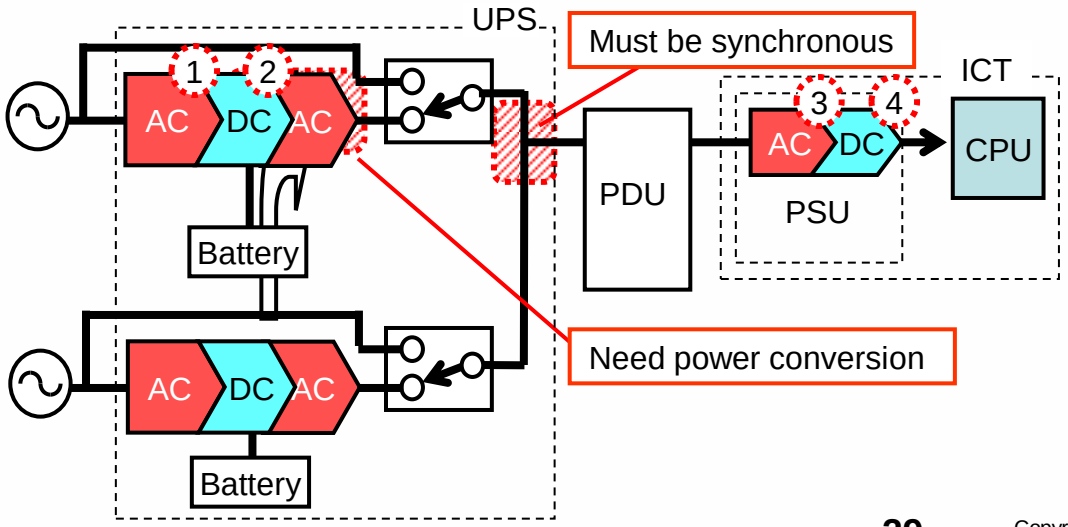
It is easy to control power supply unit of DC system.
⇒We do not have to control synchronous and bypass circuits like AC in system

DC system



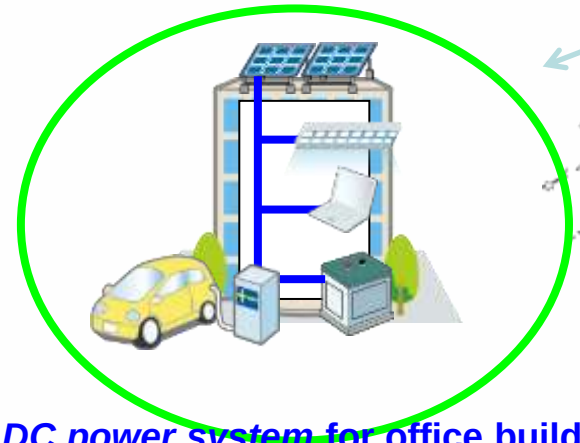


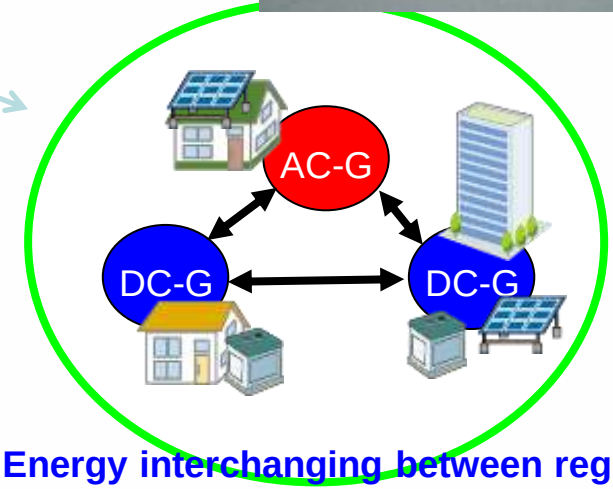
AC system



Application of HVDC (NTT Facilities)

**NTT group has been developing system using HVDC and renewable energy.
Verification tests at two sites for independent distributed-energy society.**





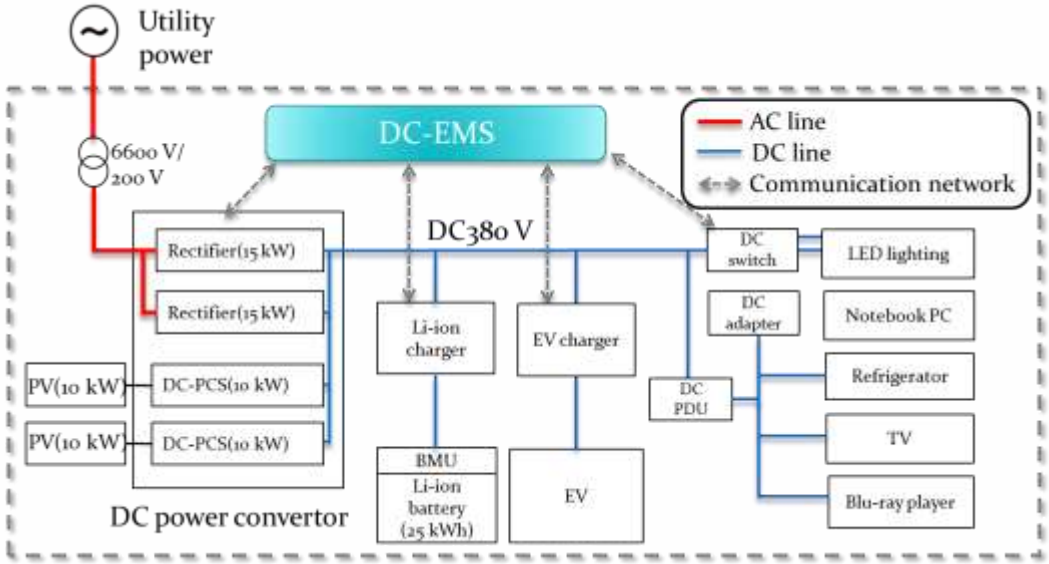
***DC power system* for office buildings (Obihiro system)**

Energy interchanging between regions (Yamagata site)

These projects were supported by Ministry of Environment, Japan from 2012 to 2015

Obihiro Project

HVDC system was introduced in office-type building at Obihiro site.
DC-EMS control power modules such as rectifier, battery, and PSU of application side.



System Configuration

DC-EMS monitoring image

Left: Li-ion charger
Right: DC power convertor (Rectifier & DC-PCS)

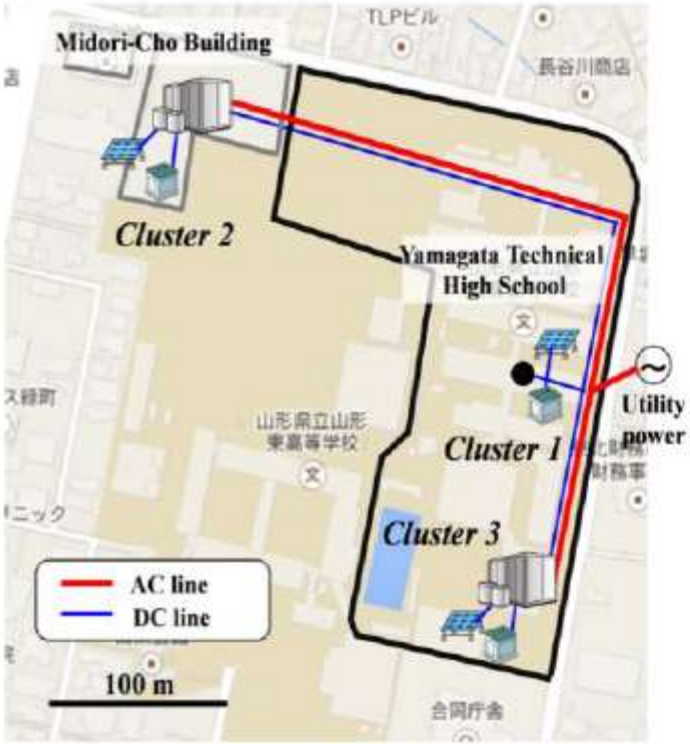
Flame-retardant Li-ion Battery (23 kWh)

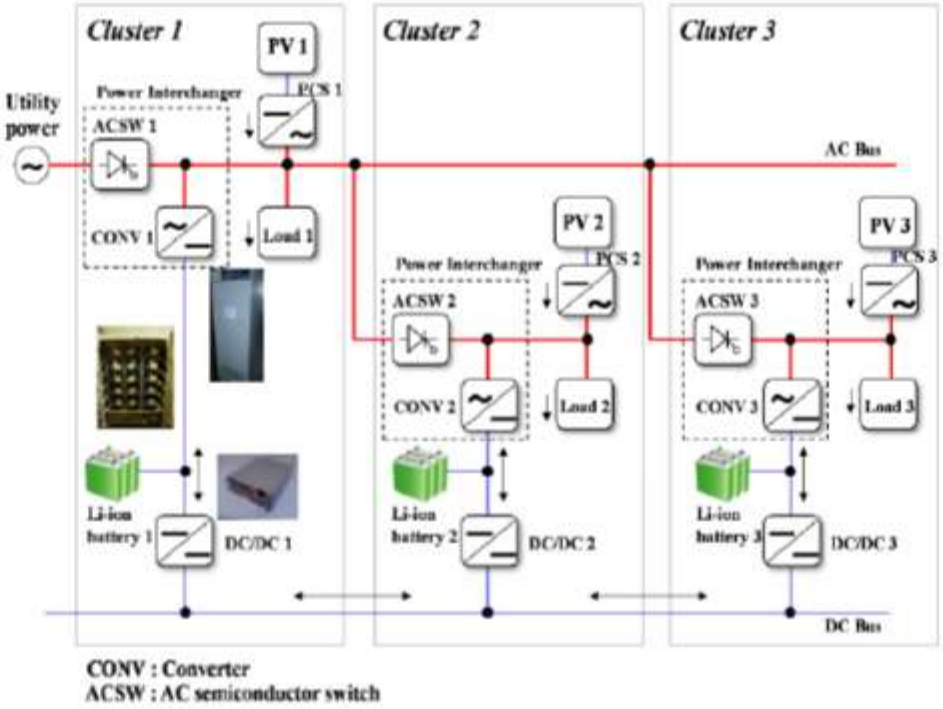
Refrigerator

TV & Blu-ray player

Yamagata Project

HVDC system and renewable energies are introduced at Yamagata site.
HVDC DC bus is connected between building and houses.
DC power is supplied from building to houses.





Outline

HVDC power supply system

1. Introduction
2. Advantage of HVDC
3. NTT group's strategy and technical requirement
4. Application of HVDC

Next generation power supply system

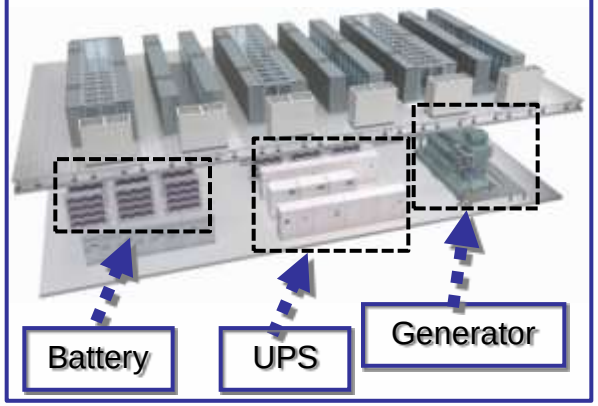
1. System topology
2. Study of voltage levels

Summary

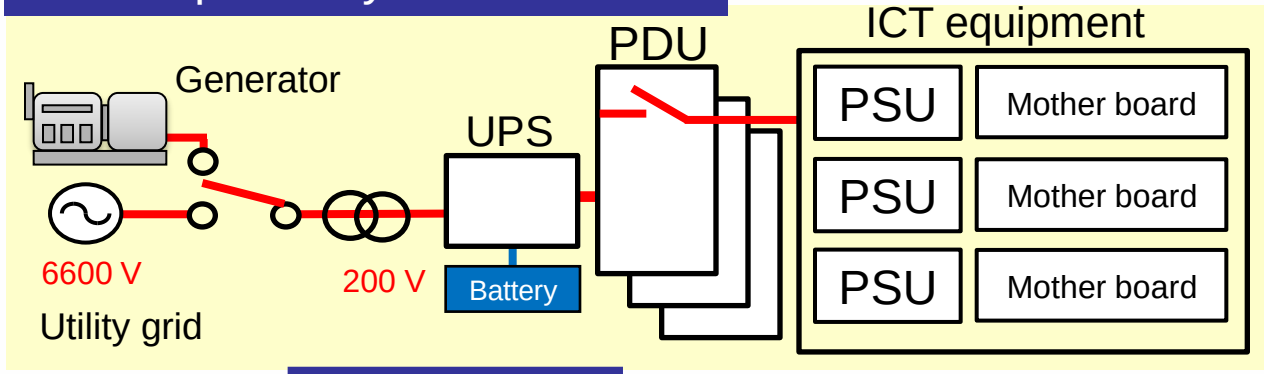
Outline of power supply system in data centers

There is much power loss when we consider entire power supply system from input port of building to input port of CPU. To reduce power conversion loss, we have to particularly consider power topology of ICT rack.

Data center



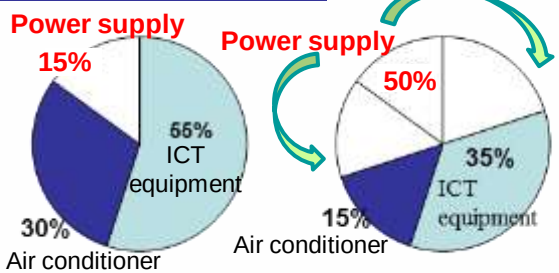
Electric power system outline



Circuit model

Power rating

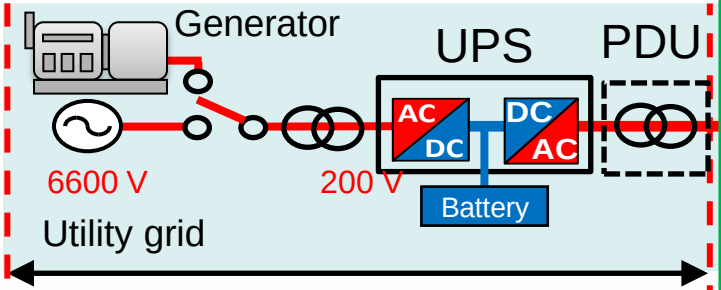
Increase power supply rate



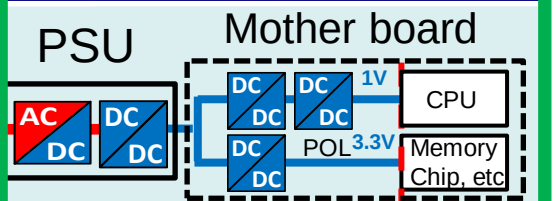
Power supply is defined from Infrastructures only

Power supply is defined from Utility grid to CPU

Infrastructures side



ICT equipment side



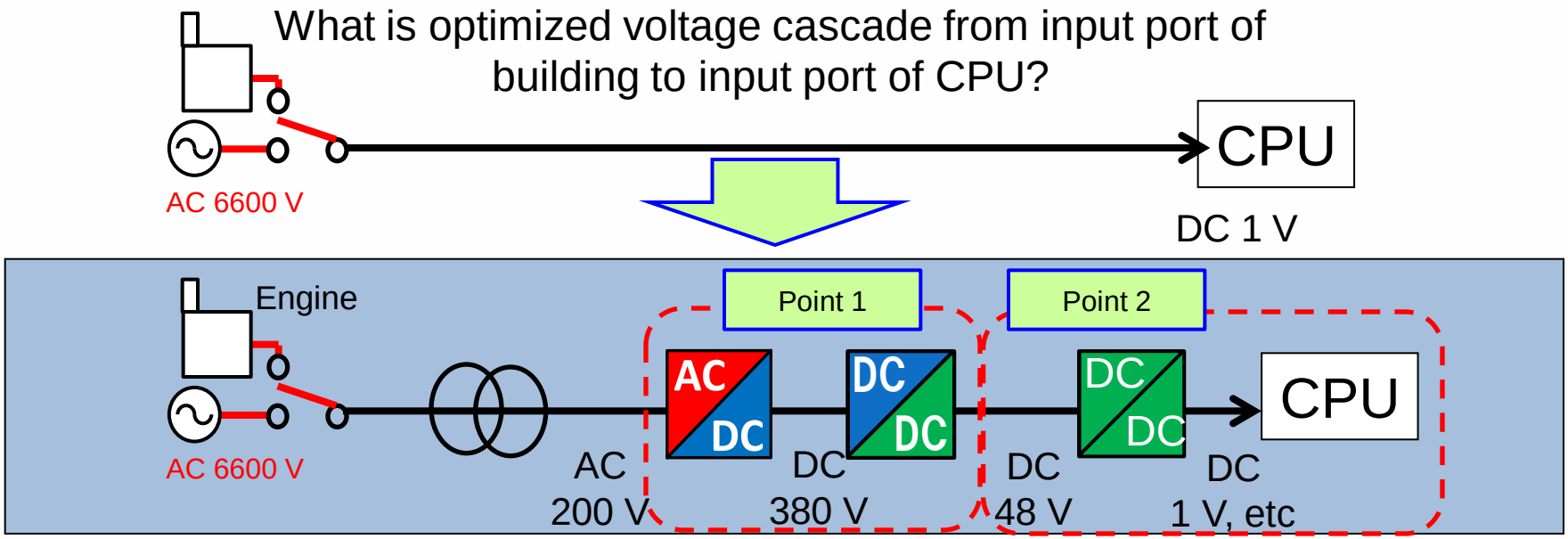
Efficiency in conventional verification range: 95~98%

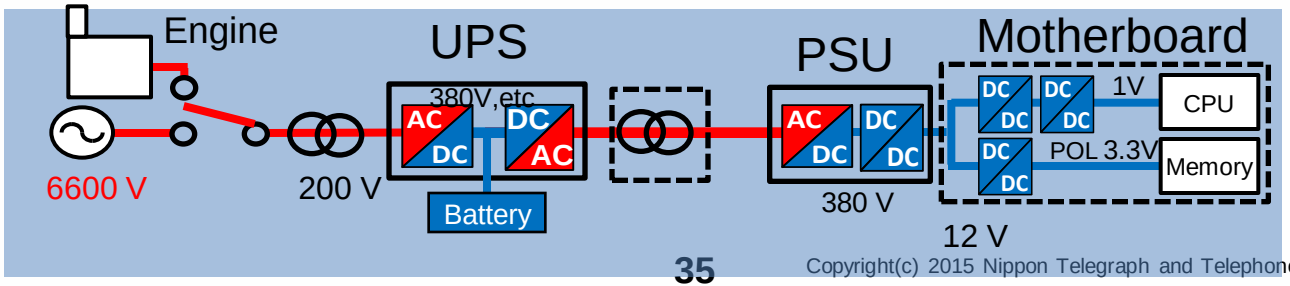
Efficiency of power translation to CPU: about 78%

Review of ICT rack is necessary

Optimized voltage cascade in telecom buildings and data centers

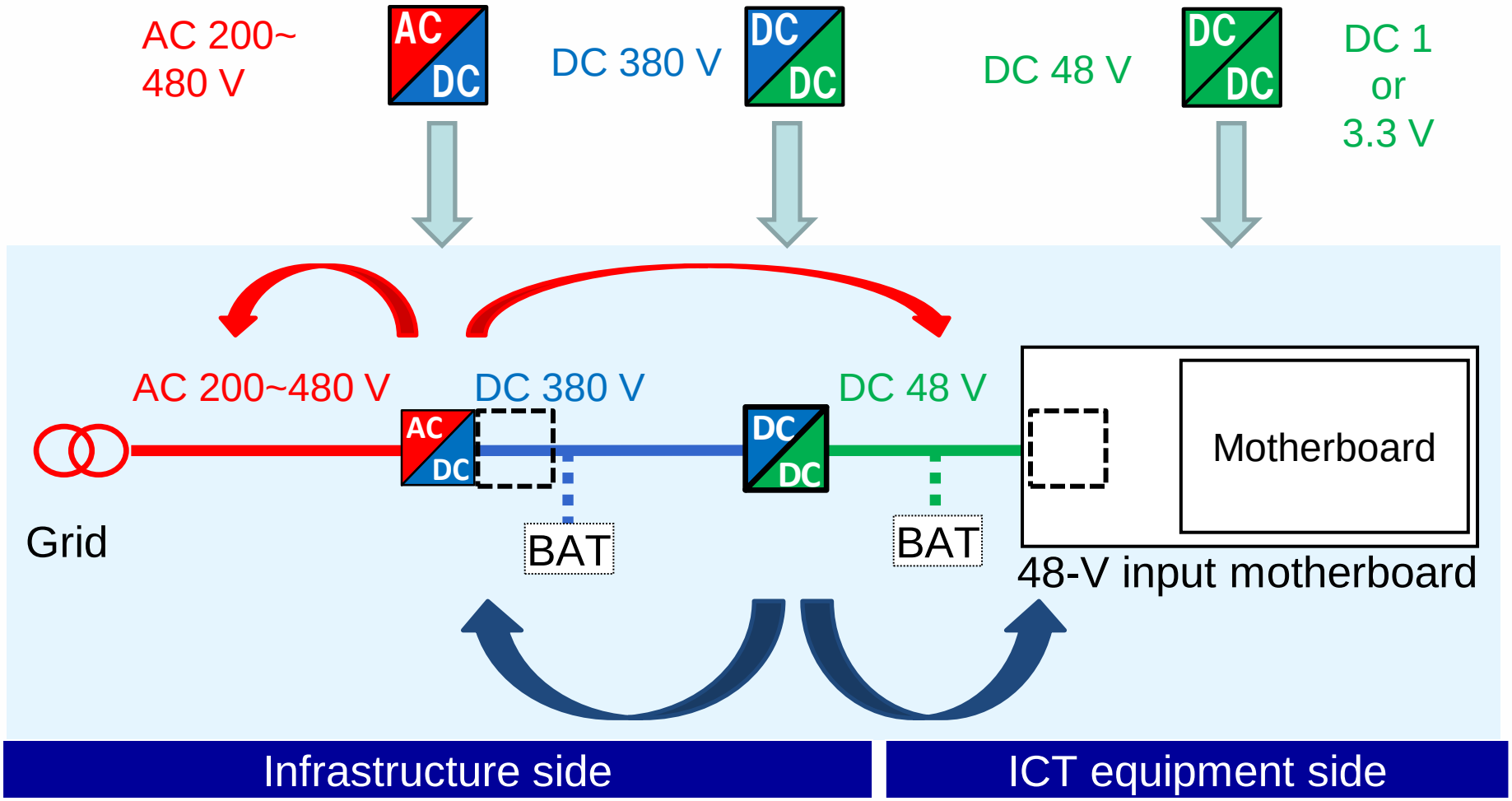
Considering trend that power consumption of CPU is increasing and line distance between grid and CPU, optimized voltage cascade is DC 380 and 48 V.





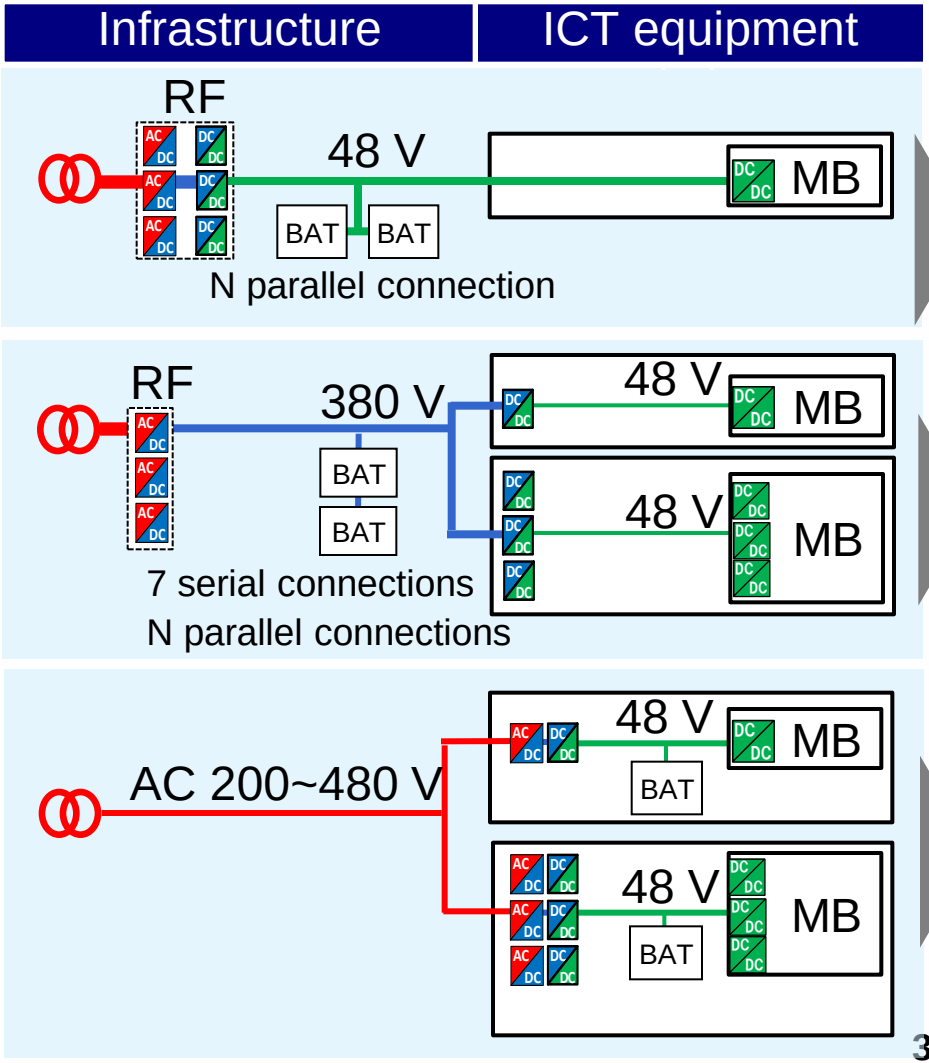
Power block system of power supply

When we use AC/DC and DC/DC converters as power blocks, we can move power blocks according to building conditions.



Configuration of power block system

**Power block system can be used to construct various reliable and capacity power supply systems by adjusting number of batteries and number of converters.
Using this topology, we can construct flexible system.**

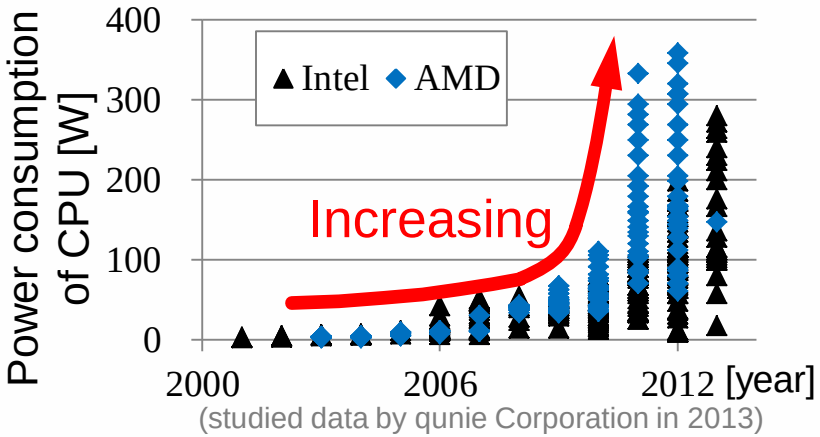


Power feeding system	Applicable building	Backup time	Renewal time
DC 48 V system	Small-scale telecommunication buildings (under 100 kW)	telecommunication buildings: About 3 h	Over 5 years
HVDC system	From mid- to large-scale telecommunication buildings and data centers (100 KW and over)	telecommunication buildings: About 3 h Datacenters: About 10 min	Over 5 years
AC direct shipment system	Data centers that do not require reliability	Several minutes	About 3 years

Issues of 12 V on mother board

Power consumption and current slew rate of CPU are increasing

Size of line and converters inside motherboard using DC 12 V of input voltage is increasing.

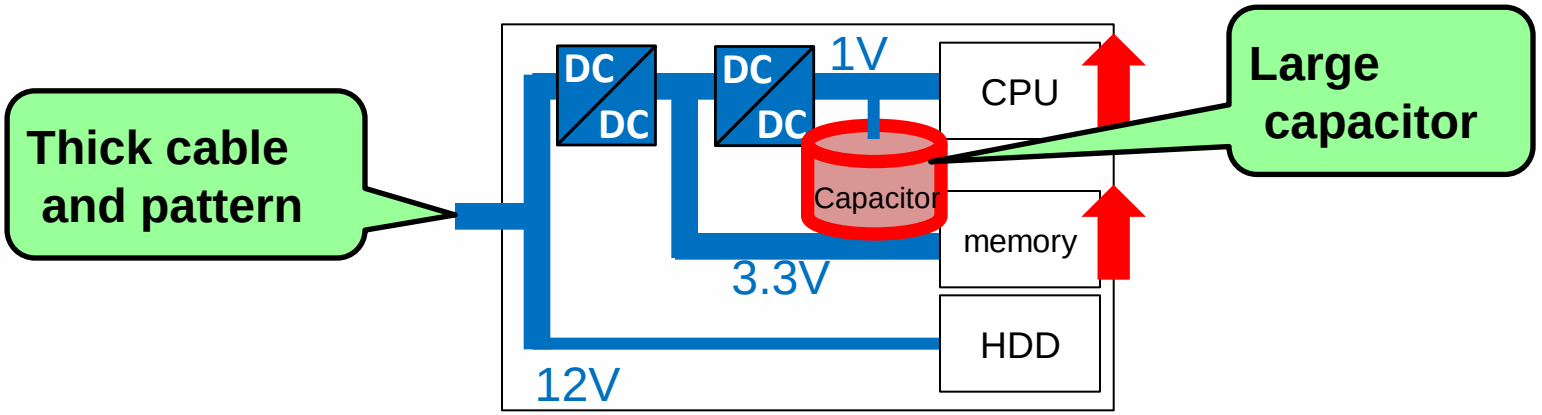


(studied data by qunie Corporation in 2013)

Power consumption is increasing

Driving voltage: 5 V ⇒ 1 V
Current range: 20 A ⇒ 100A
(CPU power consumption is 100 W)

Current slew rate of CPU is increasing with decreasing Input voltage.



Point 2

Advantages of 48 V compared to 12 V

Reducing Cross-sectional area of cable

Space saving

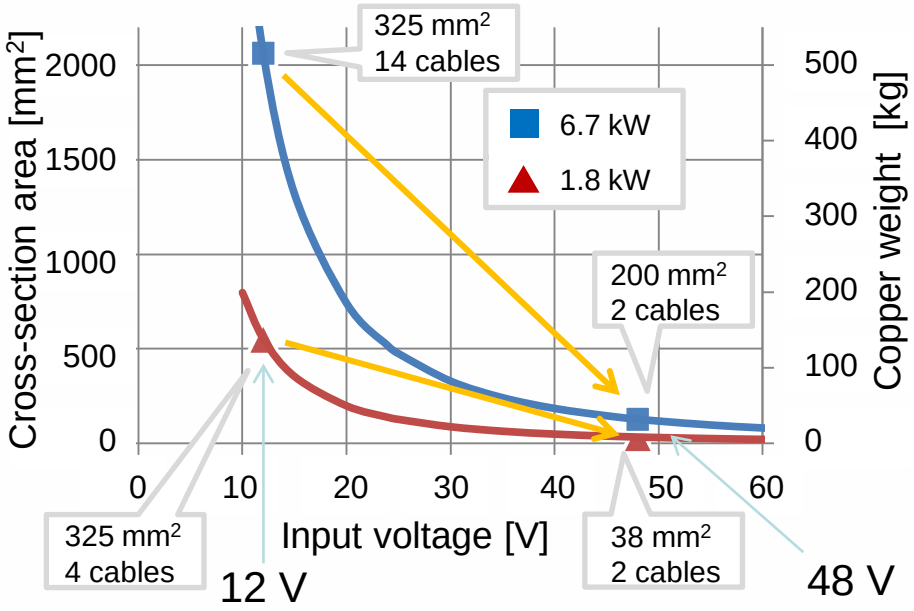
Equality of efficiency for converter

Equality of safety

Advantage of 48 V compared to 12 V (①)

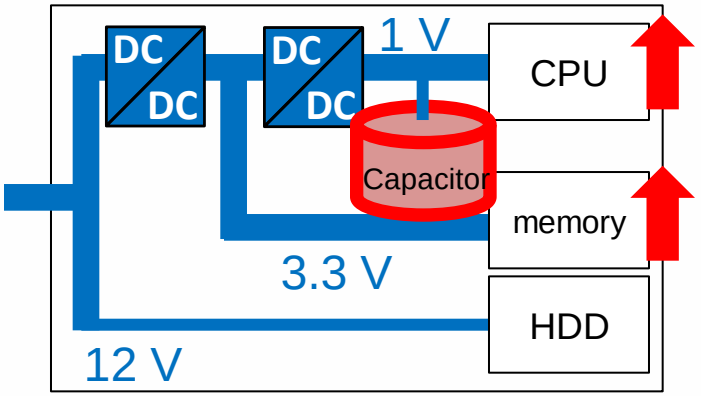
When we use 48 V, we can reduce cable diameter and power component space (POL and capacitor)

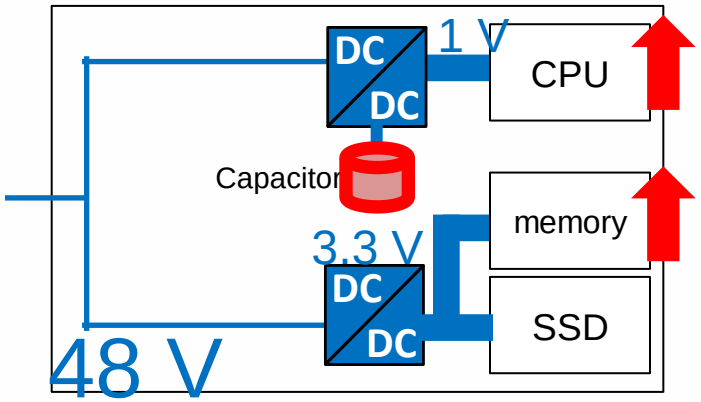
Relationship between cable cross-sectional area and input voltage



48-V system can reduce cable diameter.
⇒48 V is excellent with system

Condition: 30 m (guideline for electric power system)





Capacitor energy
$U=1/2 \cdot C \cdot V^2$

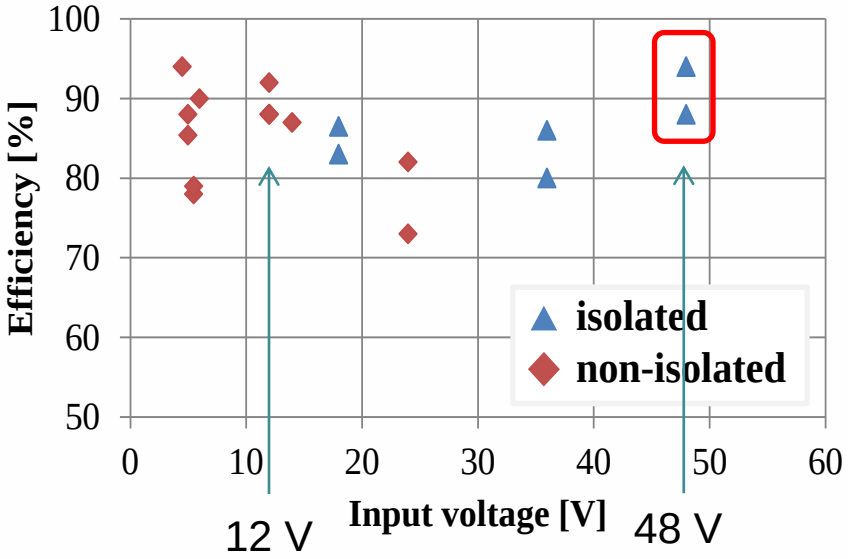
Capacitance of capacitor can be reduced to about $1/50^2 = 1/2500$

Advantage of 48 V compared to 12 V (②)

Recently, efficiency of 48-V input converter has not been lower than 12-V input converter.

Safety measure is same level as 12 V because 48 V is SELV (up to 60 V).

Relationship between converter efficiency and input voltage (marketing research)



IEC 60950
Information technology equipment – Safety –
Part 1: General requirements

SELV: safety extra low voltage

SELV CIRCUITS shall exhibit voltages that are safe to touch both under normal operating conditions and after a single fault.

Voltages under normal conditions:
Under 42.4V peak or **60 V DC**

Efficiency of 48-V converter is high

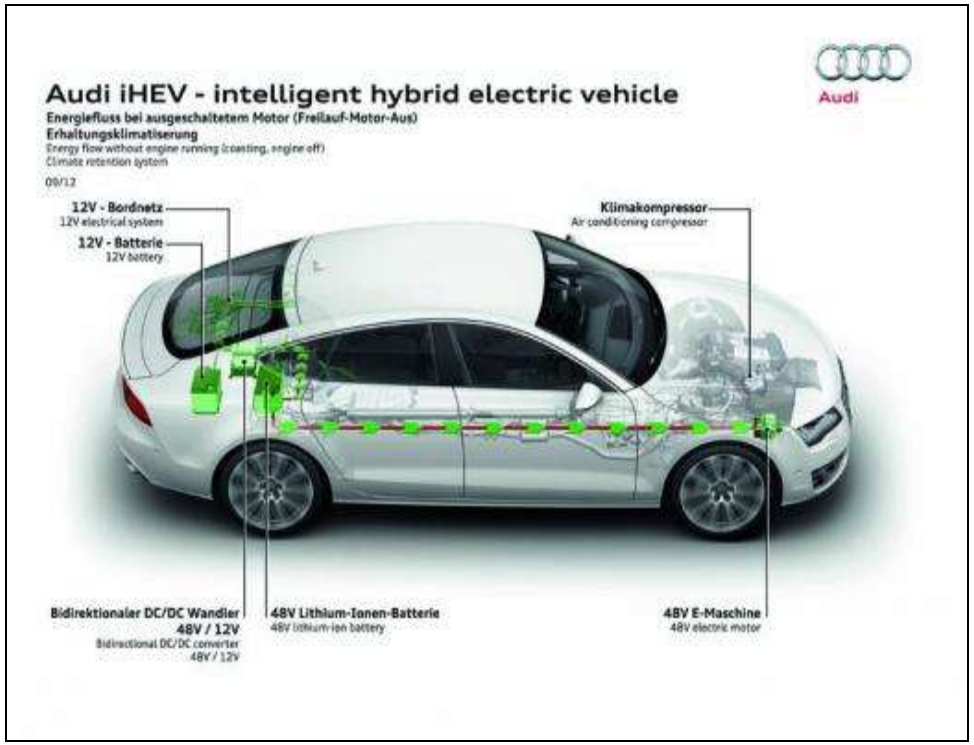
⇒ No longer disadvantage

Safety measure is same level as 12 V because 48 V is SELV (up to 60 V)*.

*IEC60950

48-V trend in other industries

◆In 2011, German auto makers (Volkswagen, Audi, Porsche, Daimler, BMW) announced that they will use 48-V power supply units in vehicles.
◆Audi disclosed concept car “iHEV” in 2012, which uses 48-V technology.
◆Standardization of 48 V is proceeding. LV148, which concisely describes 48-V system, has already been published by VDA.



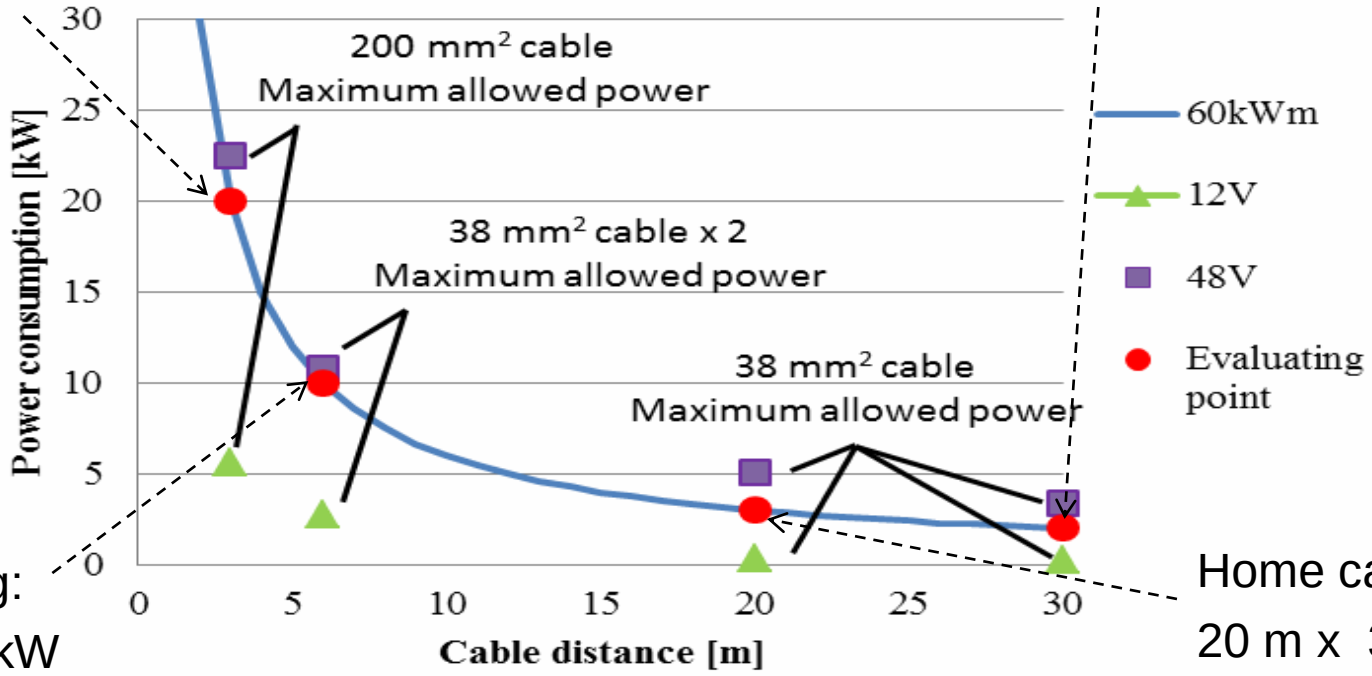
http://techon.nikkeibp.co.jp/article/HONSHI/20131122/318108/?rt=nocnt

Application area of 48-V system

60 kWm, unit multiplied by power consumption and distance, is application area of 48-V system. Thus, 48-V system can be applied in not only ICT industry but also in wide range of industries, such as automotive, and home.

19-inch rack:
3 m x 20 kW
= 60 kWm

Air plane (control unit):
30 m x 2 kW
= 60 kWm



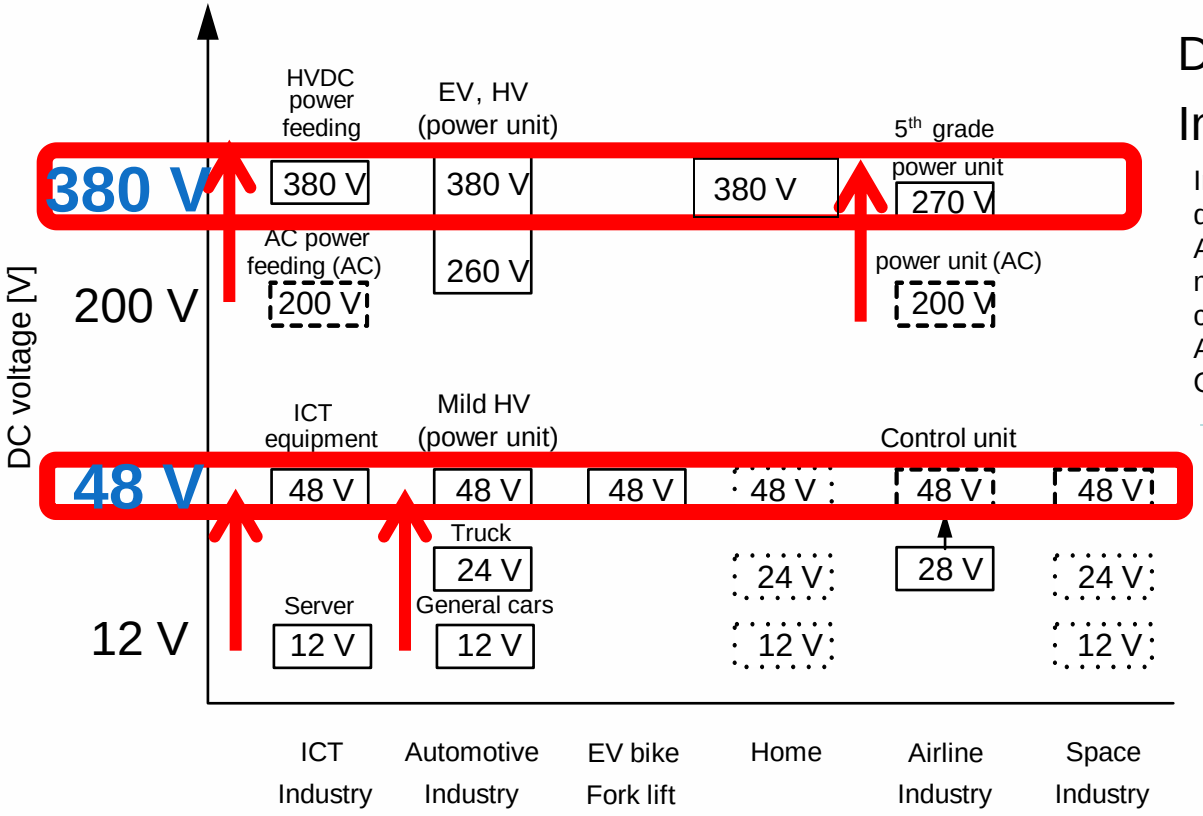
Car cabling:
6 m x 10 kW
= 60 kWm

Home cabling:
20 m x 3 kW
= 60 kWm

Relationship between cable distance and maximum allowed power

Aggregate of DC voltage (48 and 380 V)

Voltages will be aggregated to DC 48 and 380 V in future. Particularly, ICT industry and automotive industry markets are very large and are expected to grow significantly. Significant cost reduction in equipment and parts to use common voltage is expected.



DC 380 V

Infrastructure side or large motor

Infrastructure of telecommunication buildings and data centers
Automotive motors
main home infrastructure (PV, fuel cell, refrigerator, air conditioning)
Aircraft power systems
On-site power (Smart Community)

DC 48 V

Rack side or user side

Summary

- We designed HVDC system topology and developed many power components and introduced many HVDC systems.
- Moreover, we have worked on international standardization (ITU-T L.1200 and ITU-T L.1201.)
- We have established HVDC strategies for introducing HVDC systems in telecom buildings and data centers of NTT Group. Against this background, we have described technical requirement.
- We also described new power supply system concept to further reduce power consumption and cost.
- We will promote DC systems worldwide.

【Reference】Limit of 12-V system in rack

Recently, each component, such as CPU, memory and storage, is put in each chassis, and power supply is centralized in rack.

Therefore, current is increasing and bus bar become thick using 12-V bus.

■ Power supply topology in rack