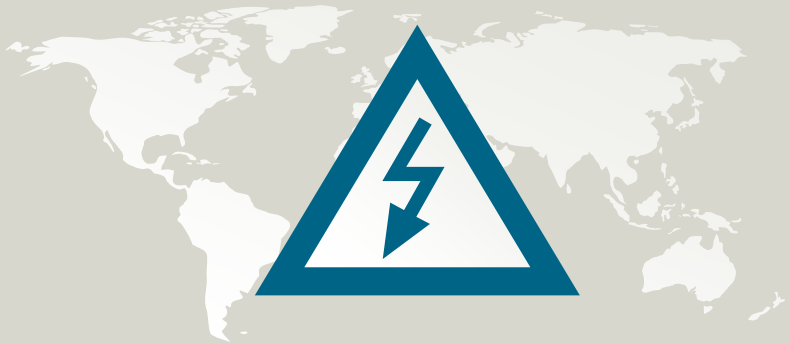
Electrical Design, Equipment and Case Study

Data Centers

George Roscoe, P.E.

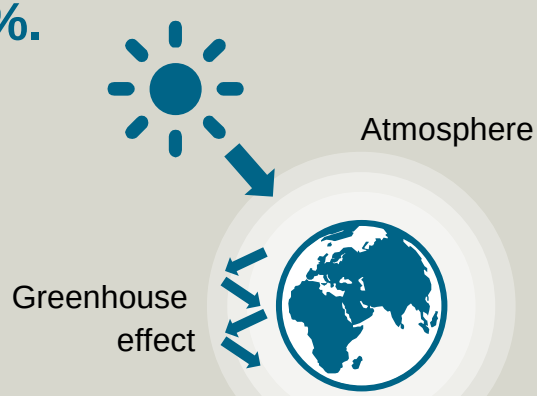
Data center market facts (1/6)

Data centers are among the world's largest users of electricity!
(approximately 2%)



Source: http://www.koomey.com/post/8323374335

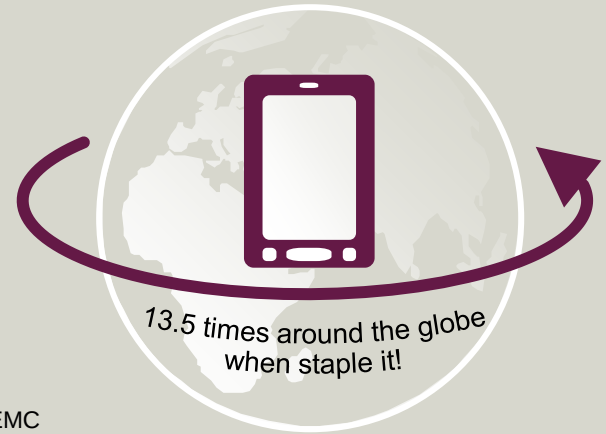
Researchers have estimated that information and communication technologies (ICT) are responsible for at least 2% of global greenhouse gas emissions, with data centers accounting for about 1.3%.



Source: http://www.computerweekly.com/news/2240164589/Datacentre-power-demand-grew-63-in-2012-global-datacentre-census

Data center market facts (2/6)

More than 1.8 Zettabytes of information was created and stored in 2011!
Enough to fill 57.5 billion 23 gigabytes Apple iPads.



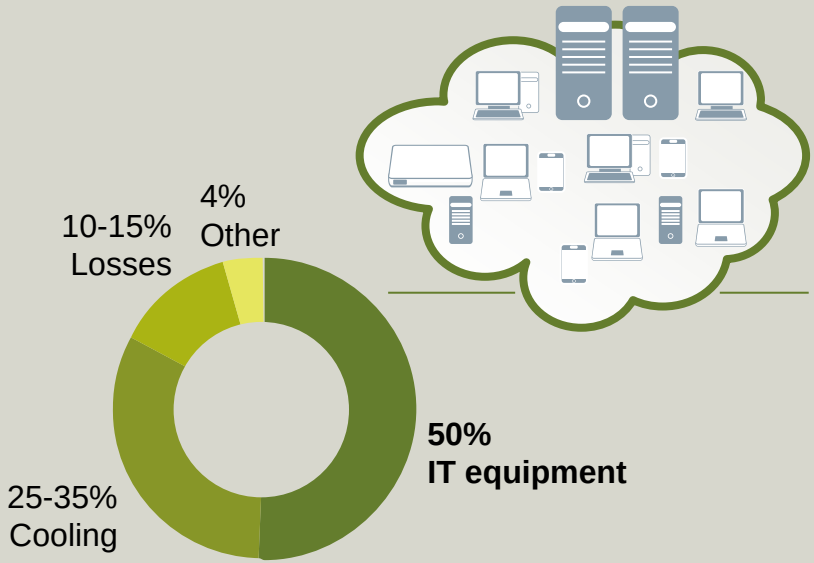
Source: IDC, EMC

Data storage demand doubles approximately every 18 months!

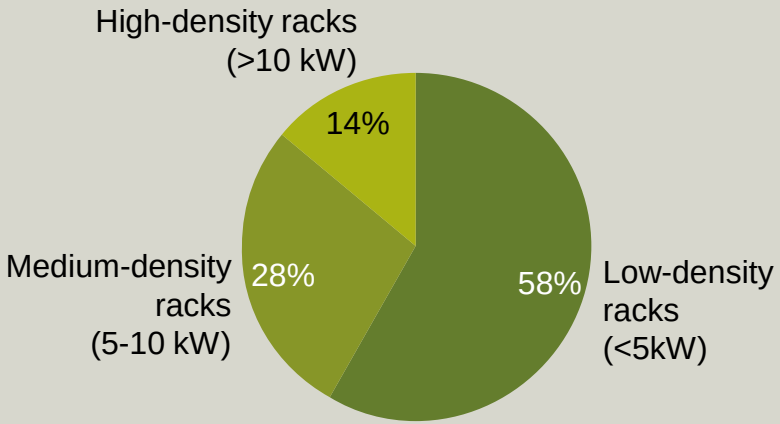
Source: Moore's Law & Intel

Data center market facts (3/6)

Only approximately 50% of data center energy consumption is used for direct IT operation, traditionally!



Rack density in 2011.

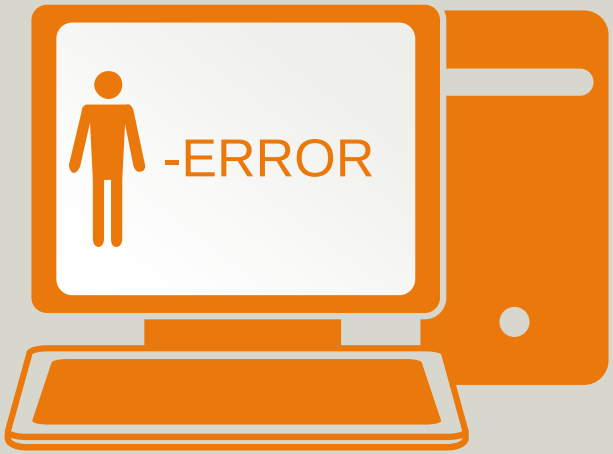


→ Average overall is at around 4.05 kW

Source: http://www.computerweekly.com/news/2240164589/Datacentre-power-demand-grew-63-in-2012-global-datacentre-census

Data center market facts (4/6)

"Human error is responsible for 70% of data center outages."



Source: Uptime Institute – AIRs Abnormal Incident Reports database, 2012

Energy costs are the key OPEX factor for data center!

Data center market facts (5/6)

205 billion e-mails were sent daily in 2015

Source: Worldwide daily e-mail traffic, 2012-2016

We are all contributing to global growth with our day-to-day behavior!

Data center market facts (6/6)

91% of data centers have experienced an unplanned data center outage in the past 24 months.

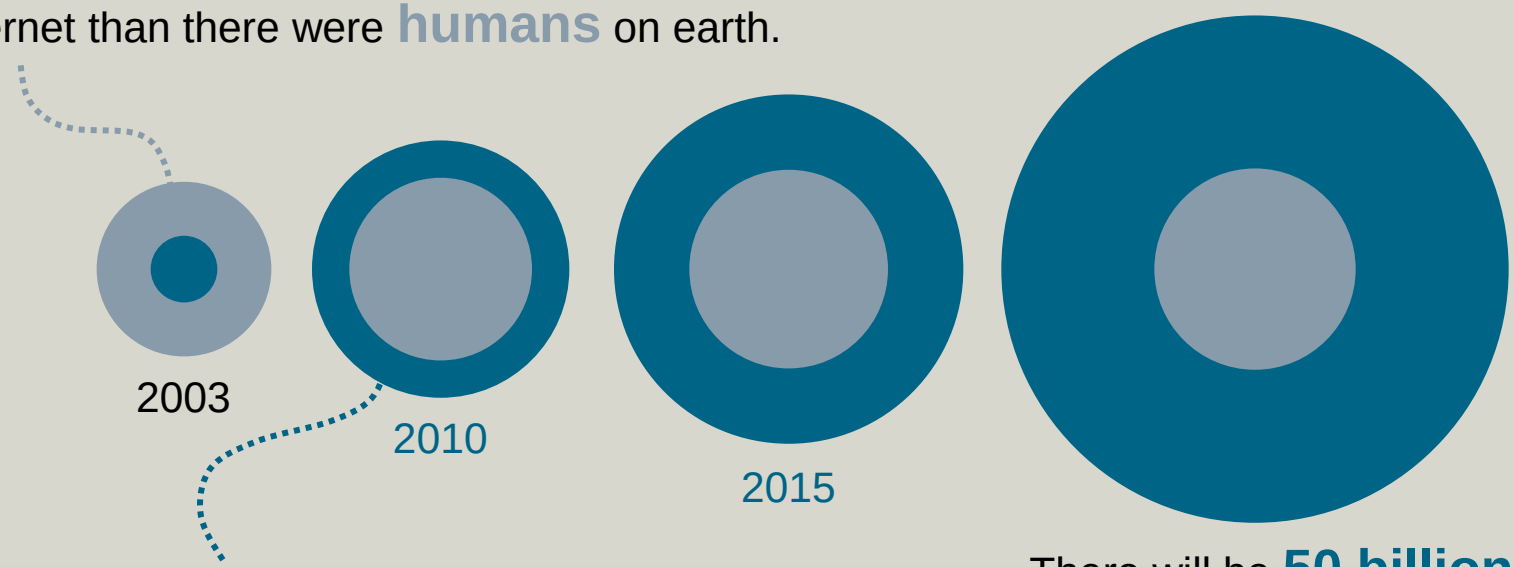
Source: Ponemon Institute

The average cost per minute of data center downtime has increased 41% from $5,614 in 2010 to $7,908 in 2013.

Source: Ponemon Institute

Internet of things (IOT)

The year 2008 marked the first time in history that more **devices** were connected to the Internet than there were **humans** on earth.



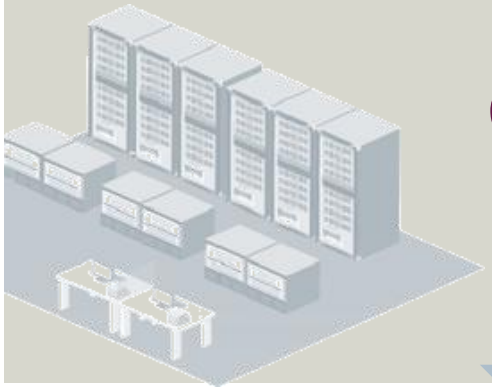
There are **many more devices** connected to the Internet than just smart phones and tablets.

There will be **50 billion** devices by **2020**.

→ http://www.faz.net/aktuell/feuilleton/debatten/auf-dem-weg-zur-totalen-ueberwachung-wir-muessen-jetzt-handeln-12285395.html

Data center challenges

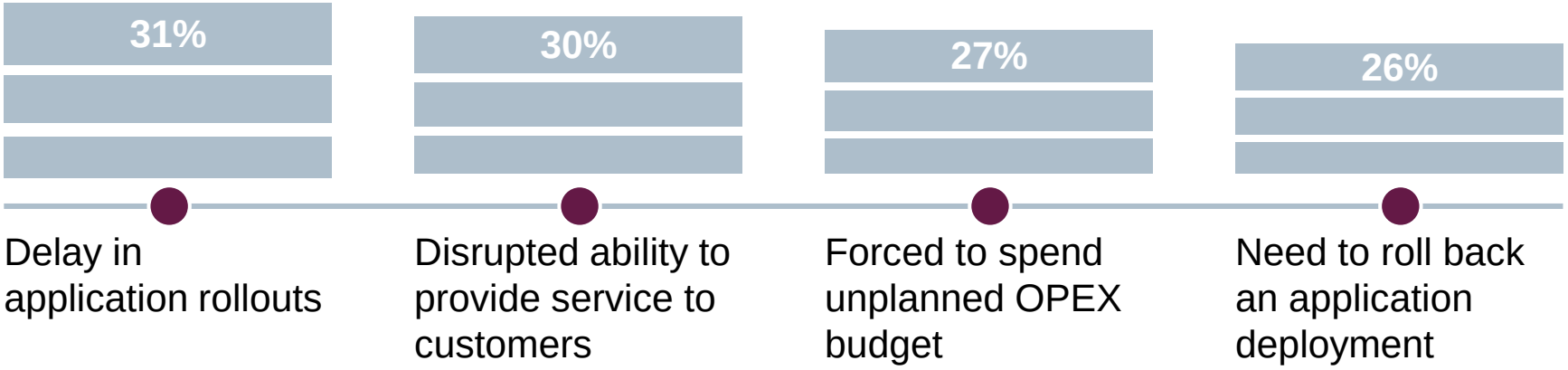
Issues of power, space, cooling and uptime impede innovation



84%

of data centers had issues with power, space and cooling capacity, assets and uptime that negatively impacted business operations

…consequences for the business



Content adopted from: IDC Global DCIM Survey, 2012

Data center challenges

Three commonly cited reasons why things go wrong in the data center

1

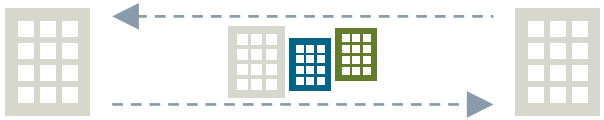
Inconsistent data center information

63% of data centers do not have a standard set of management tools

2

Divided data center operations

Responsibility for a wide range of operations is split between IT, facilities and other groups

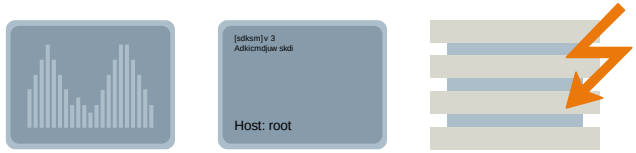


58% of enterprises have IT and facilities in separate organizations

3

Inconsistent data center maturity

Businesses have data centers with varying maturity levels

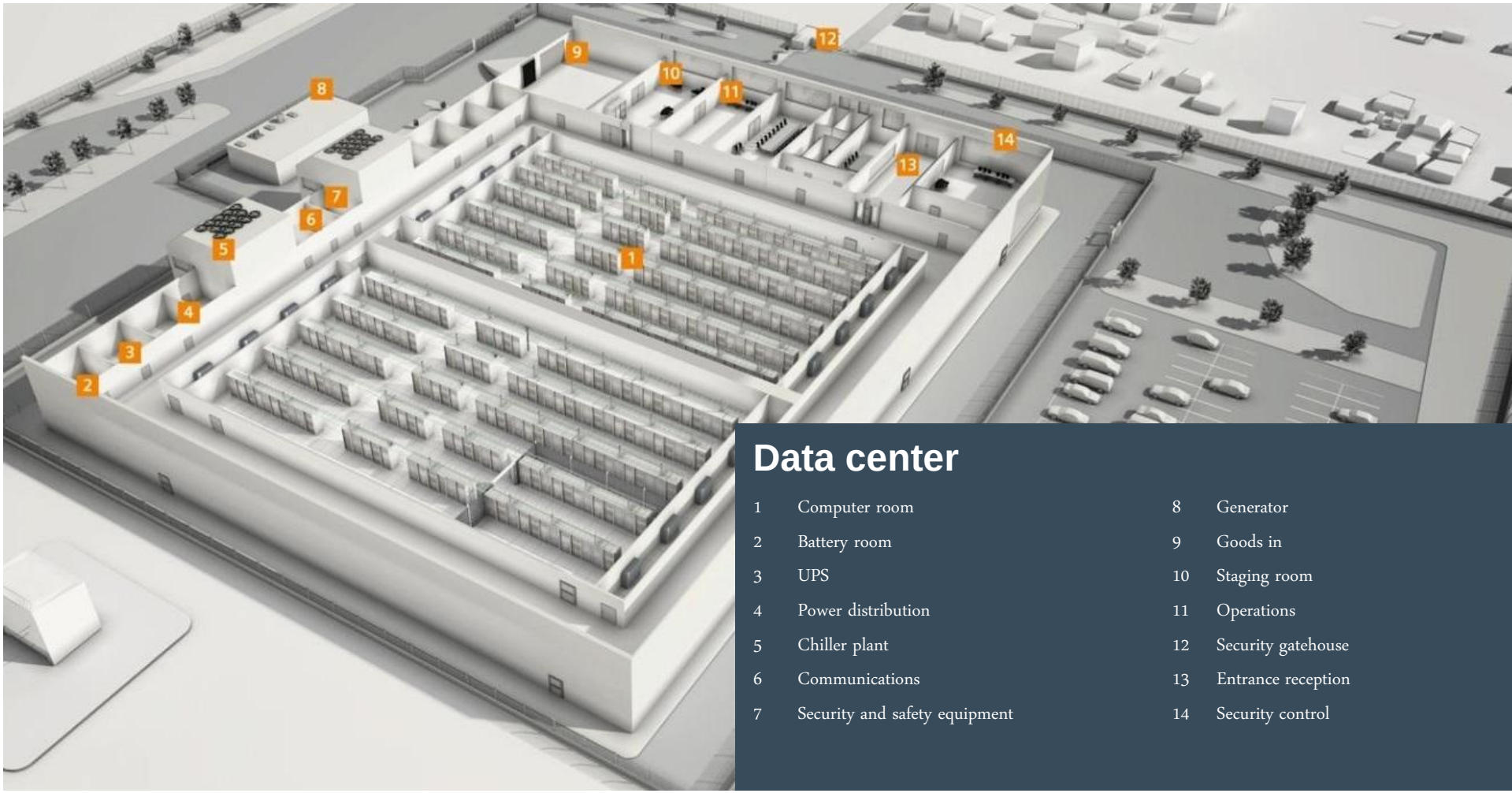


57% of data center managers consider their data centers to be inefficient or only moderately efficient

Content adopted from: IDC Global DCIM Survey, 2012

Data centers – the factories of the 21st century

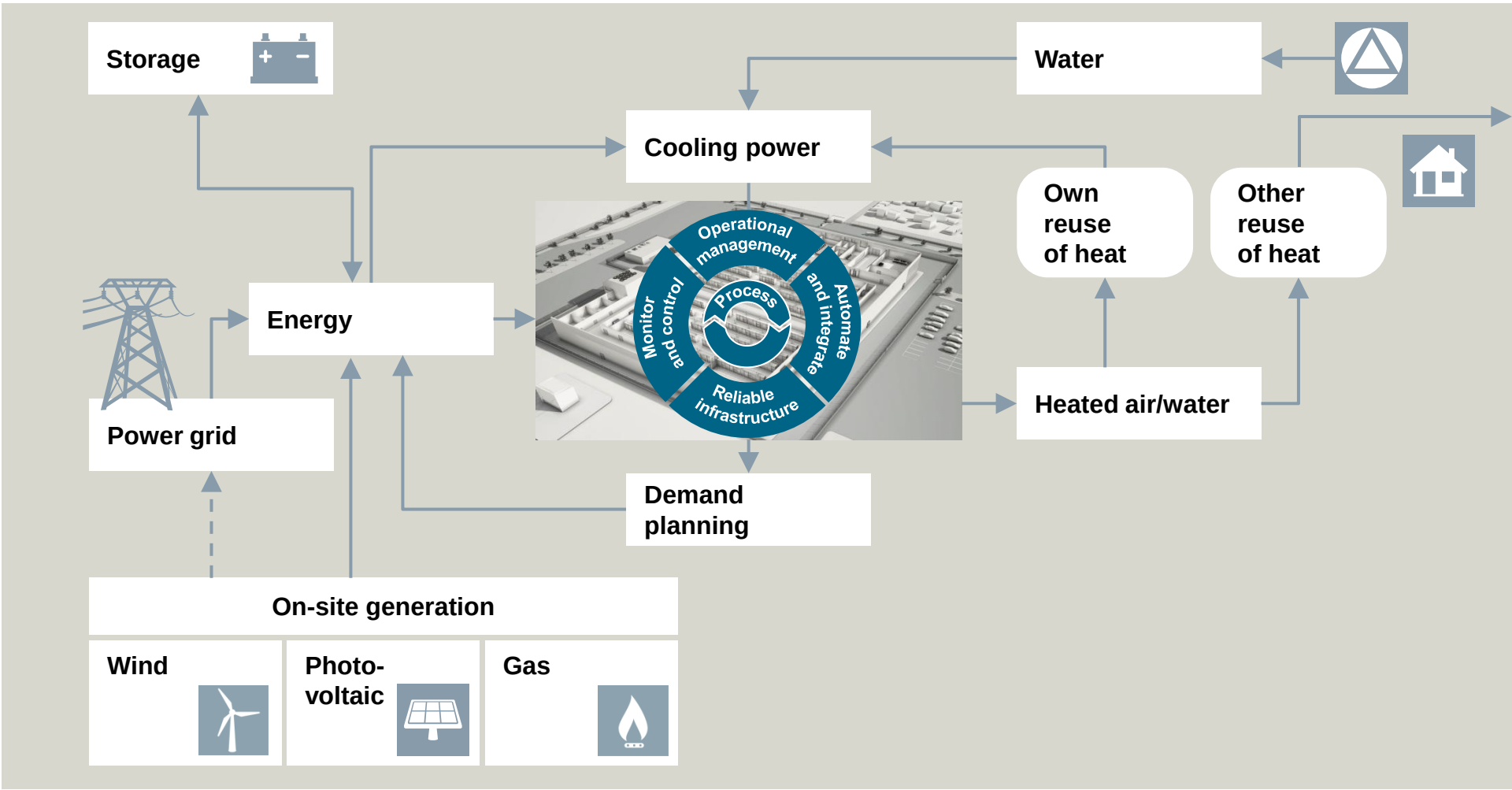
Data Center Layout



Data center

1	Computer room	8	Generator
2	Battery room	9	Goods in
3	UPS	10	Staging room
4	Power distribution	11	Operations
5	Chiller plant	12	Security gatehouse
6	Communications	13	Entrance reception
7	Security and safety equipment	14	Security control

Data center ecosystem
Outside-in perspective

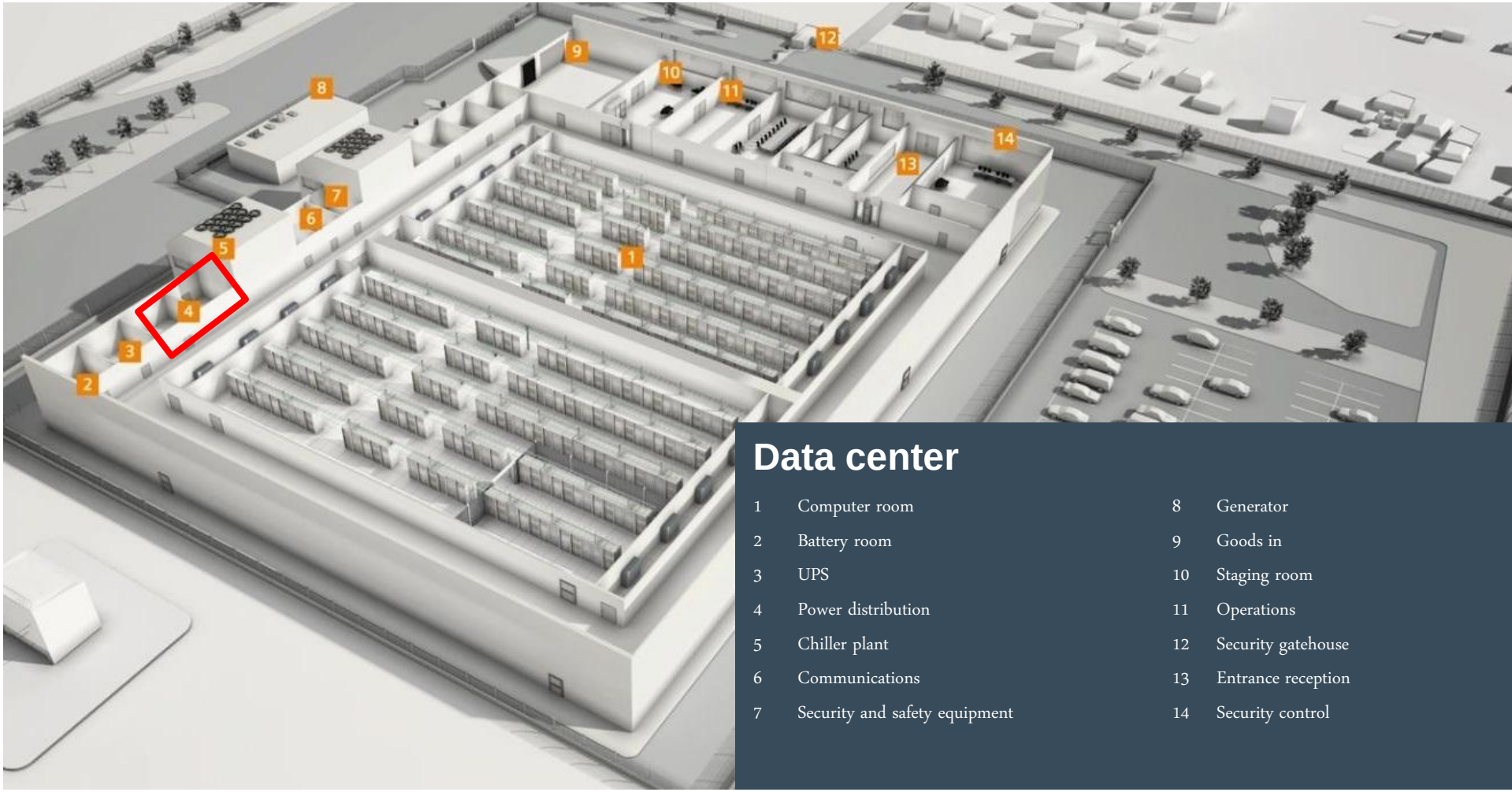


Data center market segmentation
Types of data center customers

Corporate/ enterprise data centers	Data center service providers Companies that operate data center to sell their services		Hyperscale data centers
From small enterprise to corporate data centers Companies that operate their own data center for their own use	**Colocation (Colo)** Data center infrastructure is sold as a service, IT equipment, like application servers, owned and operated by end user	**Dedicated/managed hosting** Complete IT is sold as a service, IT equipment is operated by data center. This also includes also cloud services	**Internet service providers data centers** Companies that provide Internet services like search engines, e-mail, social media, etc.

Data centers support the business – horizontal market → **Data centers and IT services are core businesses – vertical market**

Data Center Layout – Power Distribution



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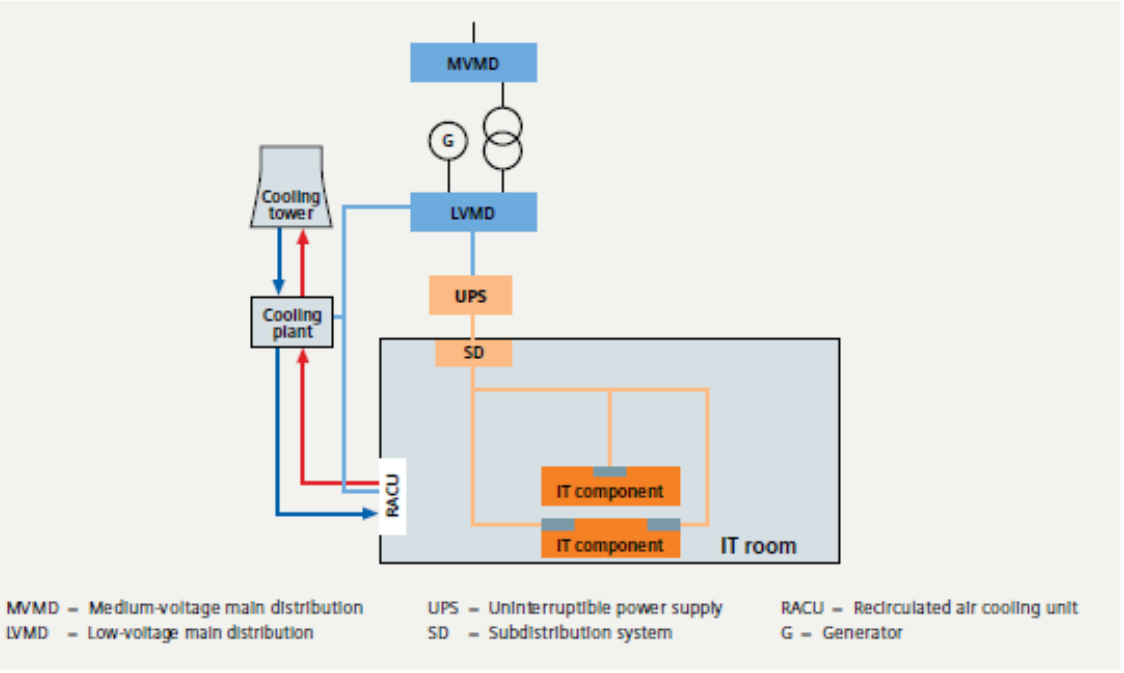
Simple Supply Grid (Tier 1)



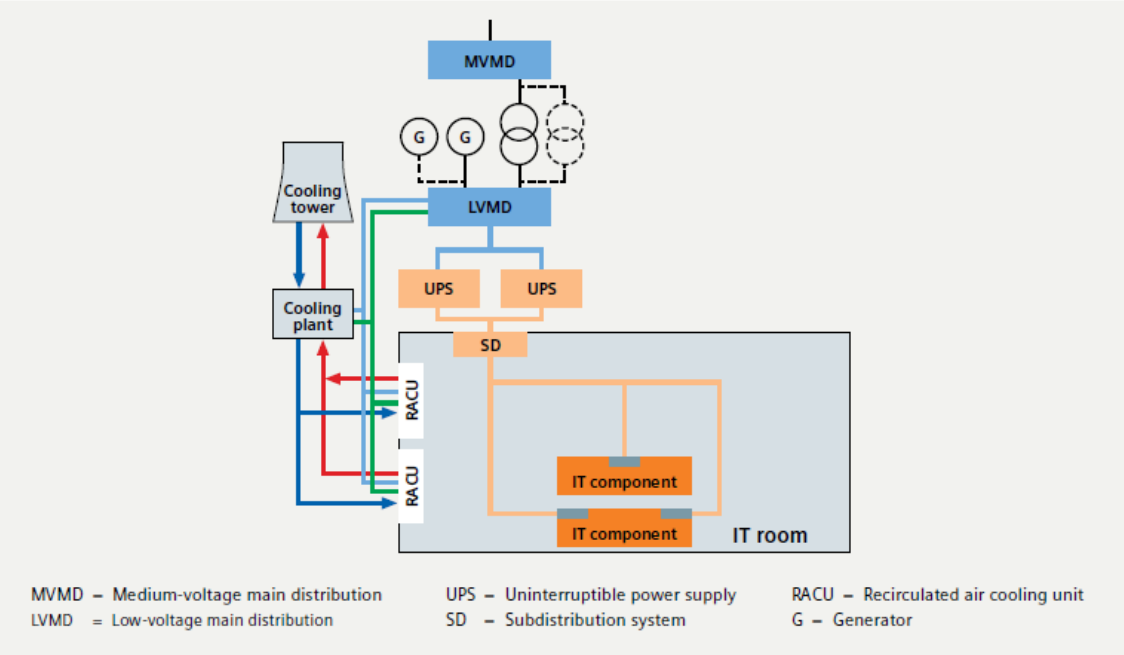
Applications

- Smaller businesses using IT technology to cope with internal processes
- Businesses regarding their web presence mainly as a passive marketing tool
- Start-up businesses without the need of computer based customer care

Main features

- No redundant feed-in components and supply lines
- Faults in the supply system may cause an interruption in the IT components
- The system is susceptible to interruptions as a result of scheduled and non-scheduled events
- Complete shutdown for maintenance work at the supply system is necessary
- **Availability: 99.67 %**

Supply grid with redundant feed-in components (Tier 2)



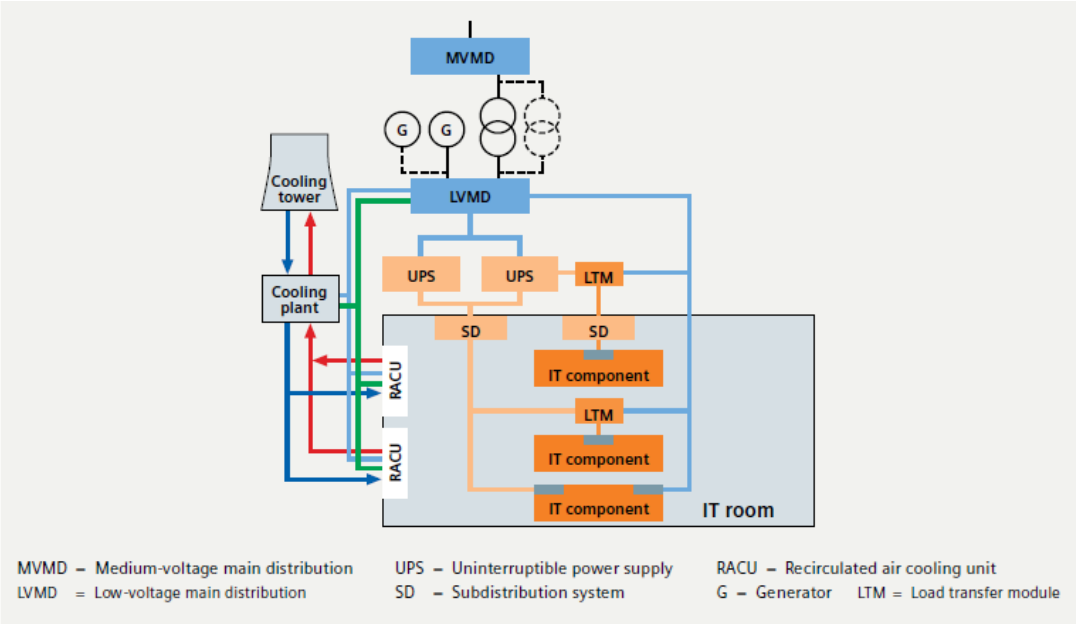
Applications

• Smaller businesses mainly using the IT during normal business hours so that shutdown after work is possible without any problems
• Computer systems for software developers (taking account of night runs), CAD firms
• Businesses which, though using their Internet connection for business purposes, “merely“ risk delays and data loss in case of IT non-availability but no business-critical delays

Main features

• Redundant UPS installations and generators are required
• No redundancy of the supply lines
• Faults in the supply system may cause an interruption in the IT components
• The system is susceptible to interruptions as a result of scheduled and non-scheduled events
• Shutdown for maintenance work on the system is necessary
• **Availability: 99.75 %**

Supply grid maintained during normal operation (Tier 3)



Applications

• Businesses or service providers that have to be ready for operation for their internal and/or external customers around the clock, such as service centers or emergency facilities which can however be accessed or are capable of working in another way if computers are off-duty during short periods of time (e.g. during maintenance)

• Businesses whose IT facilities are used for electronic business processes, but where service for customers is not impaired during maintenance or shutdown times

• Businesses operating in different time zones, but in such a way that different regional business hours do not result in any drawbacks

Main features

• Redundant UPS systems, transformers and generators are required
• Redundant supply lines to the IT components are required
• Every component of the feeder and the supply line can be switched to a non-operating state in a defined mode for the purpose of scheduled maintenance without shutdown, continuous supply is ensured by the redundant components or supply lines.
• The system is susceptible to interruptions as a result of non-scheduled events
• Dual power packs in the IT components or load transfer modules (LTM) in the grid between UPS and IT component required for continuous operation during maintenance work
• The risk of interruption increases during maintenance
• Faults in the supply grid may cause an interruption in the IT components
• Availability: 99.98 %

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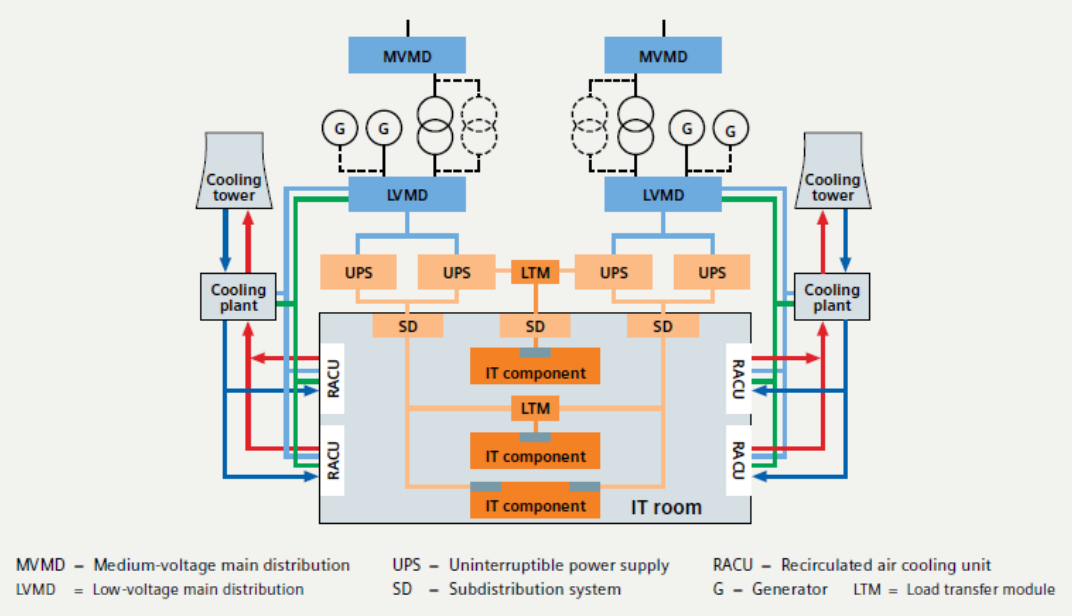
Fault Tolerant Supply Grid (Tier 4)



Applications

• Businesses with an international market presence having to reliably provide a service during 24h, 365 days throughout the year to remain competitive
• Businesses based on e-commerce, electronic market transactions or financial services
• Globally operating businesses active in different time zones so that employees can access important resources and their customers can use the most up-to date applications at any time

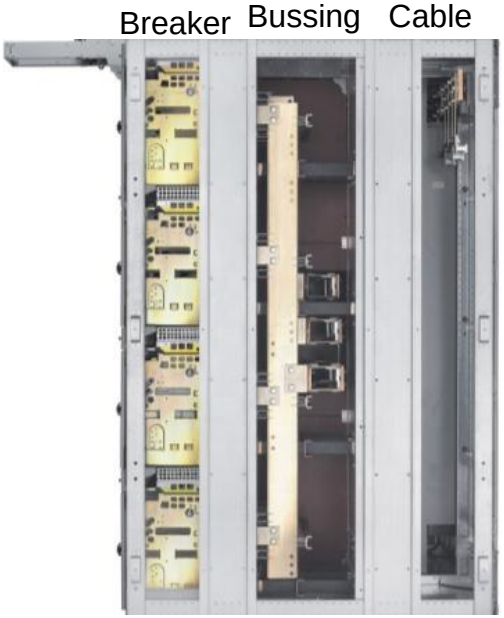
Main features

Main features
• Redundant UPS systems, transformers and generators are required
• Redundant supply lines to the IT components are required
• Every IT component has a dual power pack
• A single worst-case fault somewhere in the supply grid must not affect the IT component
• Every component of the feeder and the supply line can be switched to a non-operating state in a defined mode for the purpose of scheduled maintenance without shutdown, while supply is continued via the redundant components or supply lines
• Dual power packs in the IT components or load transfer modules (LTM) in the grid between UPS and IT component required for continuous operation during maintenance work or in the event of a fault
• Complementary systems and supply lines must be physically separated (barriers), so that single faults will not affect both systems
• The supply system is not susceptible to interruption as a result of a single scheduled or non-scheduled event
• The risk of interruption could increase during Maintenance
• Fire alarm, fire suppression, or “Emergency Power Off” (EPO) function may cause an interruption of the IT components
• Availability: 99.99 %

Electrical Equipment Discussion

- Switchgear
- Switchboards
- Panelboards

Equipment Classifications - ANSI Switchgear



LV Metal-Enclosed (ANSI C37.20.1)/ UL 1558

All circuits are enclosed in one enclosure. Examples include load break switches, low voltage switchgear and switchboards.

- Drawout or stationary power breaker (manually or electrically operated)
- Each circuit breaker is enclosed in a grounded metal compartment … but other isolation is not required (e.g., between buses and cable connections)
- Shutters are not required
- Bare bus can be used

Low Voltage Switchgear

- Each vertical section consists of up to four individually enclosed breaker or auxiliary compartments – WL breakers for Siemens

- Included in each compartment are components such as:
  - circuit breakers
  - meters
  - transformers
  - relays
  - three phase bus work
  - all internal wiring, connectors & other supporting equipment

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Siemens SB Switchboards

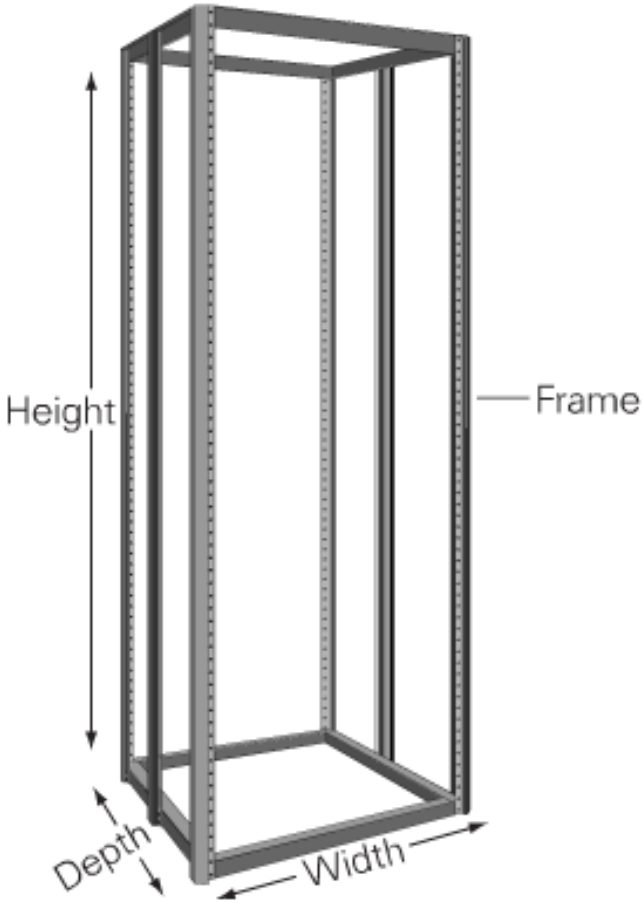
- UL 891 rated
- Mostly uses UL 489 breakesr
  - Front connected
  - Cable connections available in front
  - Consists of breakers, fused switches etc.
  - Typical ampacities 800A-6000A
  - Anchored to floor
  - Multi-section
  - Datacenter market ~ 80% switchboard

Switchboard Overview - Frame

Standard:

- Height: around 90” (option 70”)
- Width: 20’’-46’’
- Depth: 20’’-60’’

- Other sizes available, depending on customer requirements

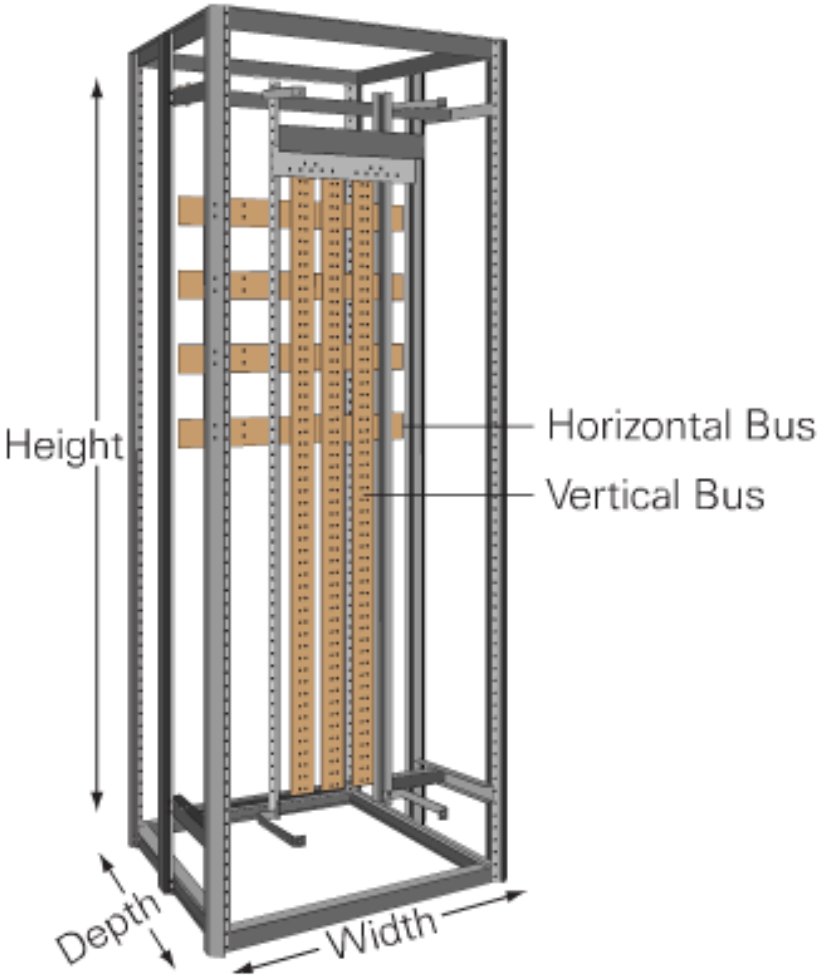


Switchboard Overview - Bussing

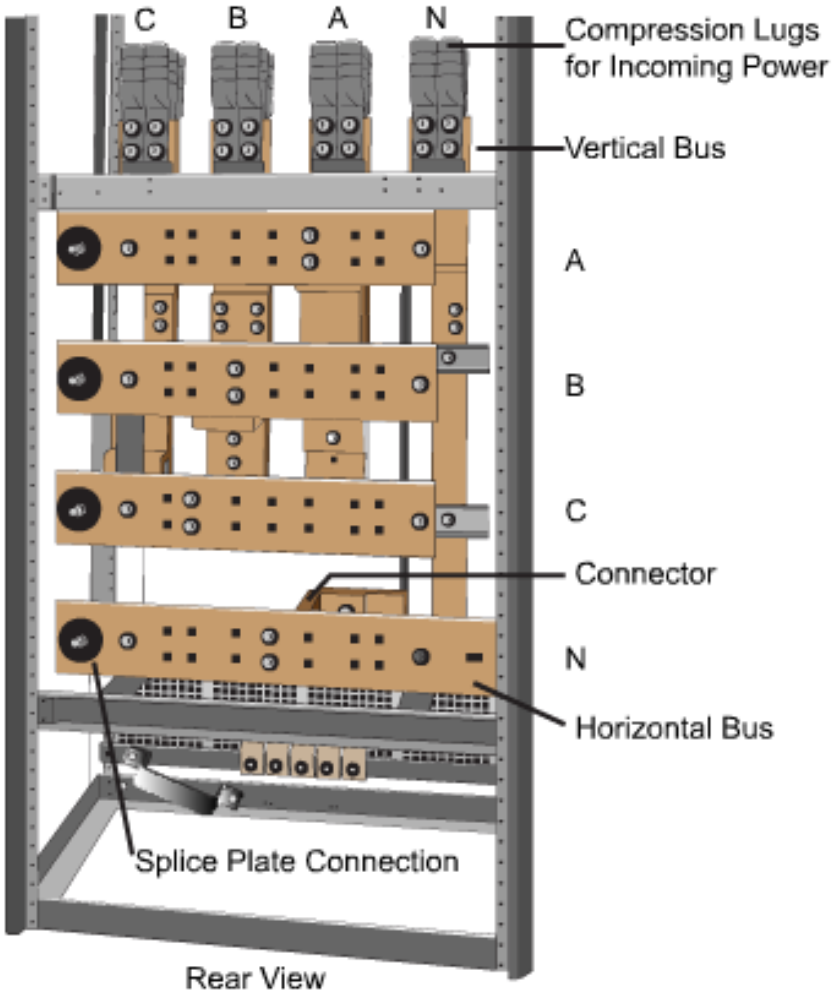
Horizontal (Through) Bus
- Typically from 400 – 6000A
- Tapered and non-tapered

Vertical (Section) Bus
- Typically from 400 – 3000A

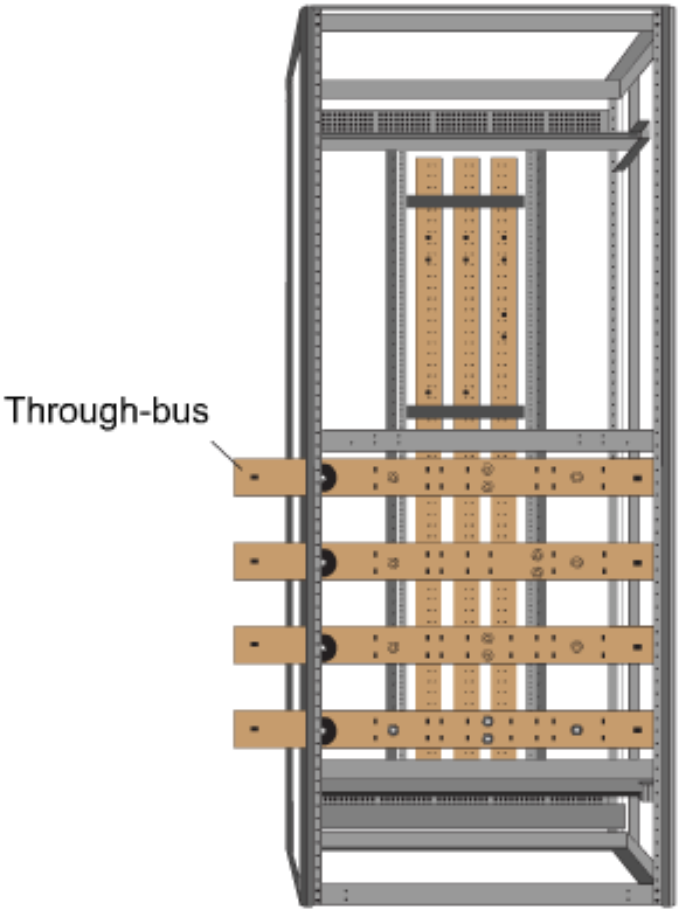
Bussing Material
- Standard: 65C tapered Aluminum
- Options
  - 65C Aluminum
  - 65C Copper
  - A/in^2 Copper & Aluminum
  - Others may be available



Rear View of Switchboard



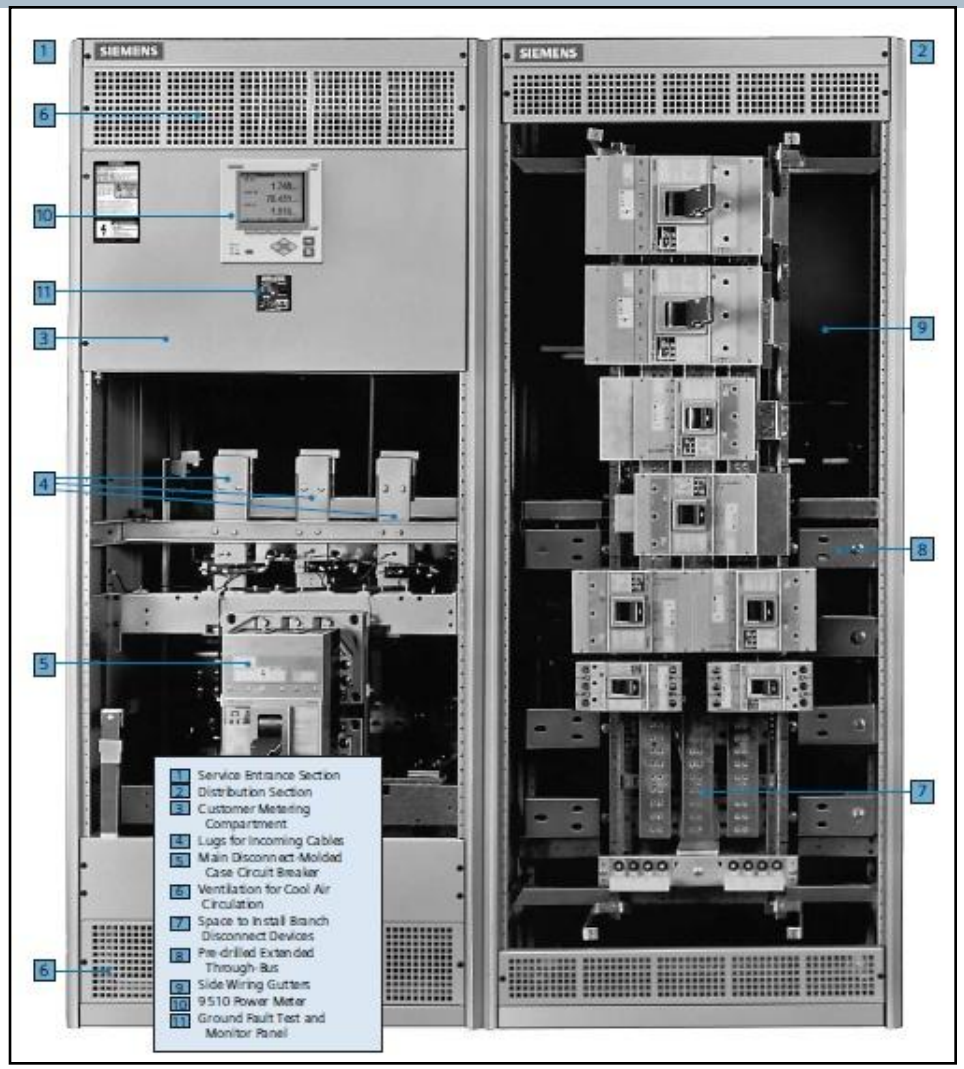
Rear View



Rear View

Typical Switchboard: Front View

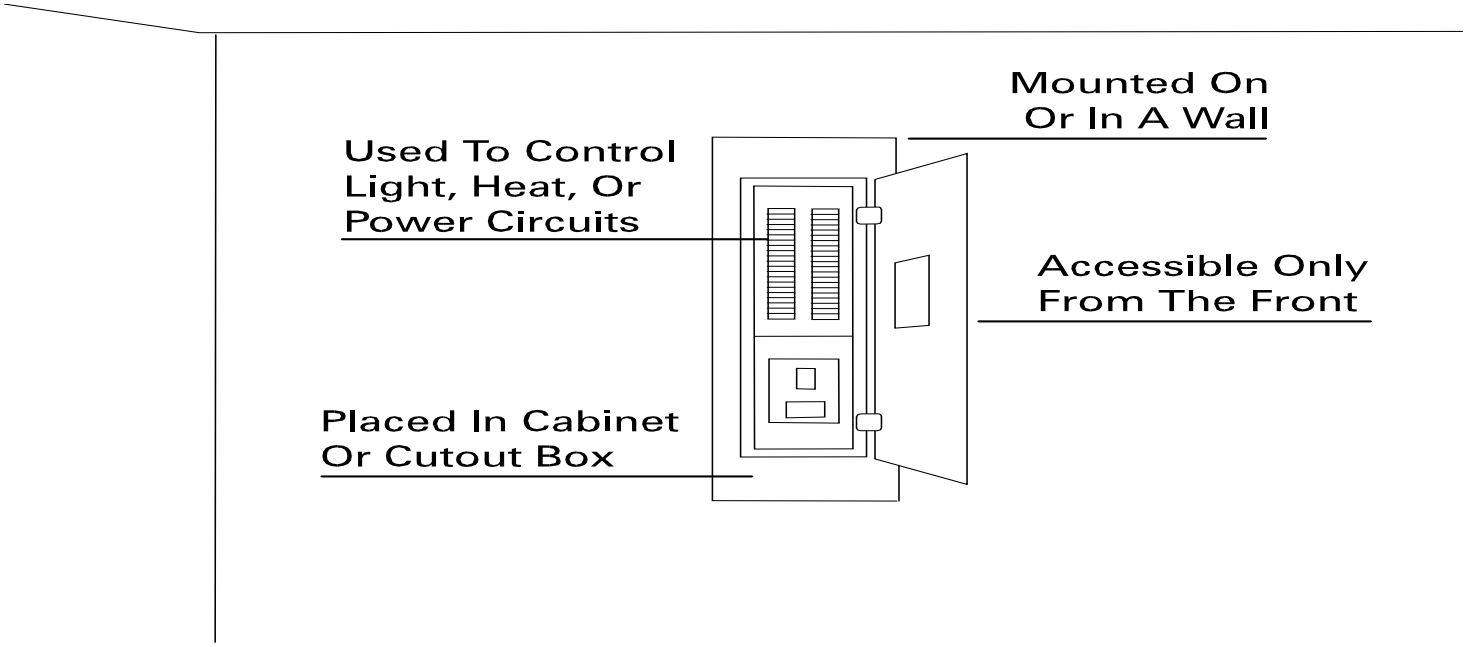
1. Service Entrance Section
2. Distribution Section
3. Customer Metering Compartment
4. Lugs for Incoming Cables
5. Main Disconnect-Molded Case Circuit Breaker
6. Ventilation for Cool Air Circulation
7. Space to Install Branch Disconnect Devices
8. Pre-drilled Extended Through-Bus
9. Side Wiring Gutters
10. Power Meter
11. Ground Fault Test and Monitor Panel



Definition of a Panelboard

According to the NEC (NFPA 70), panelboards are:

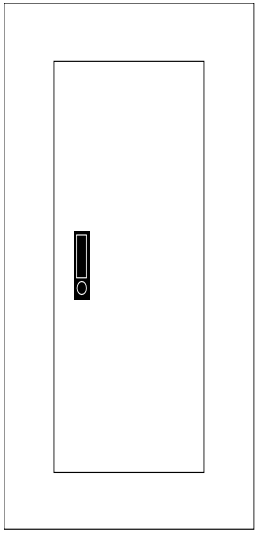
- **Used to control light, heat, or power circuits**
- **Placed in a cabinet or cutout box**
- **Mounted in or against a wall**
- **Accessible only from the front**

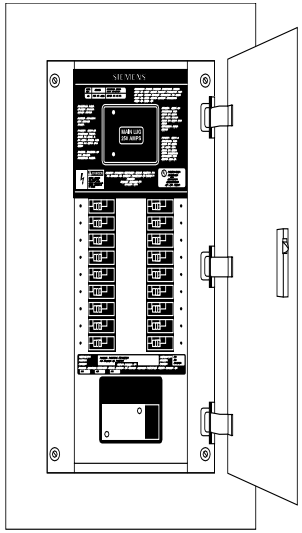


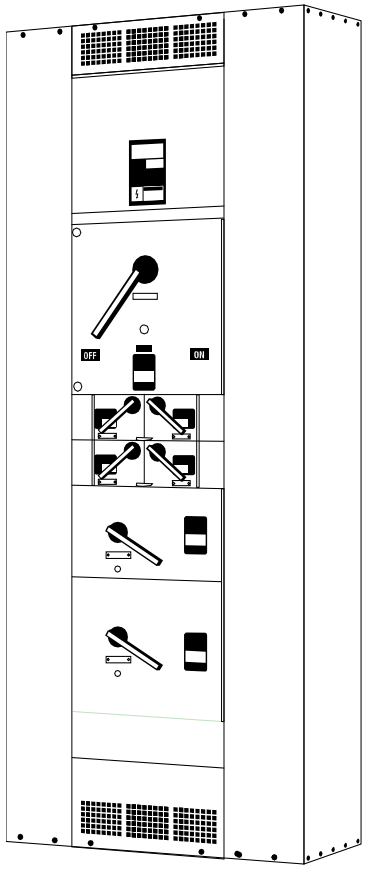
Panelboard Types

Panelboards basically fall into two categories:

- **Lighting and appliance**
- **Power and distribution**







Switchgear vs. Switchboards

Switchgear

- UL 1558/IEEE C37.20.1
- 5000A+ thru bus
- Voltage up to 635V
- Copper bussing only
- Drawout Power breakers
- Requires front and rear access
- 60 cycle withstand test

Switchboards

- UL 891
- 5000A+ thru bus
- Voltage up to 600V
- Copper and aluminum bussing
- ICCB fixed, drawout, MCCB, fused switches, etc.
- Typically front access
- 3 cycle short circuit test

Switchboards vs. Panelboards

Switchboards

- UL 891 rated
- 6000A-400A bus range
- Multisection
- 100s of different designs

Panelboards

- UL 67 rated
- Typically 100A-1200A
- Single section – cable between
- MCCB breakers only
- Available in wide range of sizes

Data Center Macro Trends

Switchgear usage has gone down to about 20% of the market

Switchboards have overtaken the market up to 80% of the market

Key features driving trends:

- Similarities between UL 1066 breakers and UL 489 breakers for larger frame sizes
- Electronic trip molded case breakers feature set
- Cost
- Footprint

Power CB vs.ICCB

Drawout Circuit Breaker

Fixed Circuit Breaker

• UL 1066 or UL 489
Similar feature set
• Electronic trip units
• Electrically operated (open/close)
• 800A-5000A Frames
• Power metering
• Modbus, + others communications
• Maintenance mode
• Rack in/out
Difference
• UL 1066 has serviceable parts (arc chutes, etc.)

• Almost exclusively UL 489
Similar feature set to draw out
• Electronic trip units
• Electrically operated (open/close)
• 800A-5000A Frames
• Power metering
• Modbus, + others communications
• Maintenance mode
• Non-removeable

UL 489 Molded Case Circuit breakers (MCCB)

Thermal Magnetic

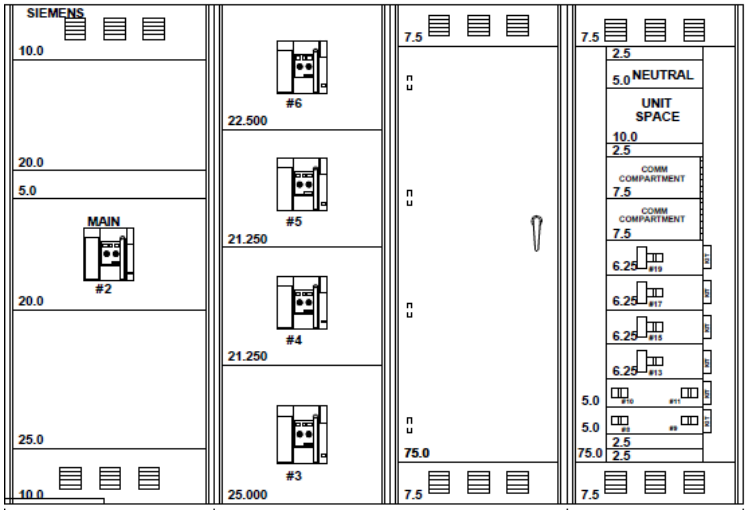
Electronic trip units

- Thermal Magnetic CB
  - UL 489 MCCB
  - Typically legacy
  - 150A-2000A typical range
  - 400A-1600A electronic trip
  - Basic electronic trip including GF
- Electronic Trip CB
  - UL 489 MCCB
  - Modernized last 15-20 years
  - 800A-1600A thermal magnetic
  - 150A-1600A electronic trip
  - Advanced communications including Modbus + others
  - Maintenance mode

Cost

- Datacenter life vs. equipment life
- Molded case breakers versus Power circuit breakers
- Energy consumption in data centers causing future re-designs/placements

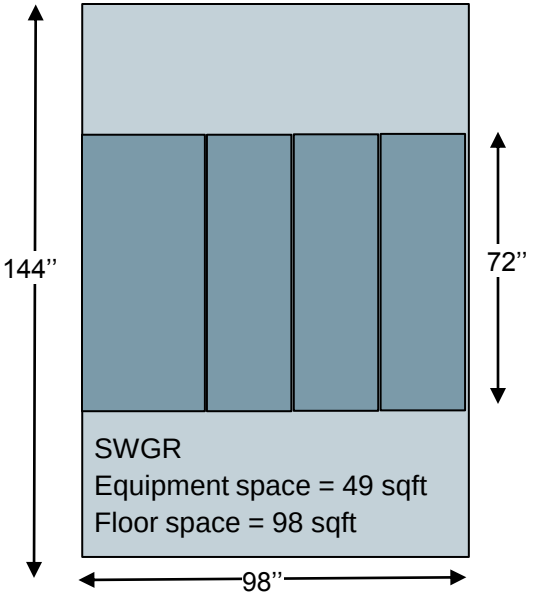
Footprint Switchgear vs. Switchboards space savings

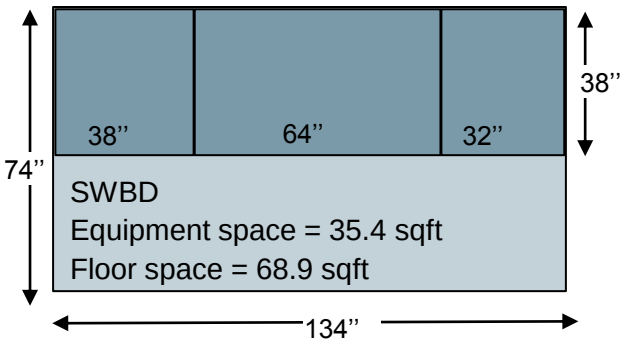


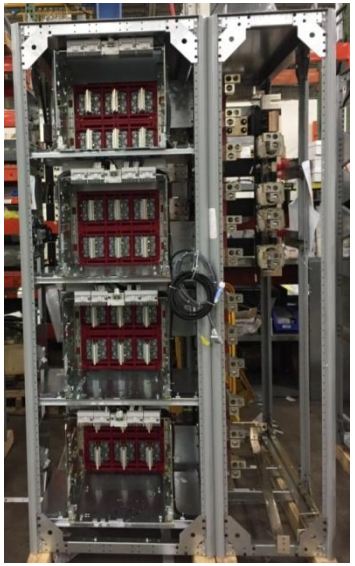
Space savings vs. conventional switch gear/rear connected switchboards >30% floorspace savings

Example: 3000A main with 2x1600A frame, 2x1200A frame, 4x400A, 4x250A frames

No rear access needed, saving additional floor space by allowing it to be against or nearly against the wall







SIEMENS

Code and design considerations

Datacenters

What is an arcing fault?

Source: EHS Today

- Current flowing through air
- Typically arcing current is 35-50% of bolted fault current
- Risks include
  - Heat
  - Sound
  - Flying Objects

2017 NEC clause 240.87

New code requires any circuit breaker with a 1200A frame or higher to have some level of arc flash energy reduction by reducing clearing time.

There are 7 methods proposed to reduce clearing time:

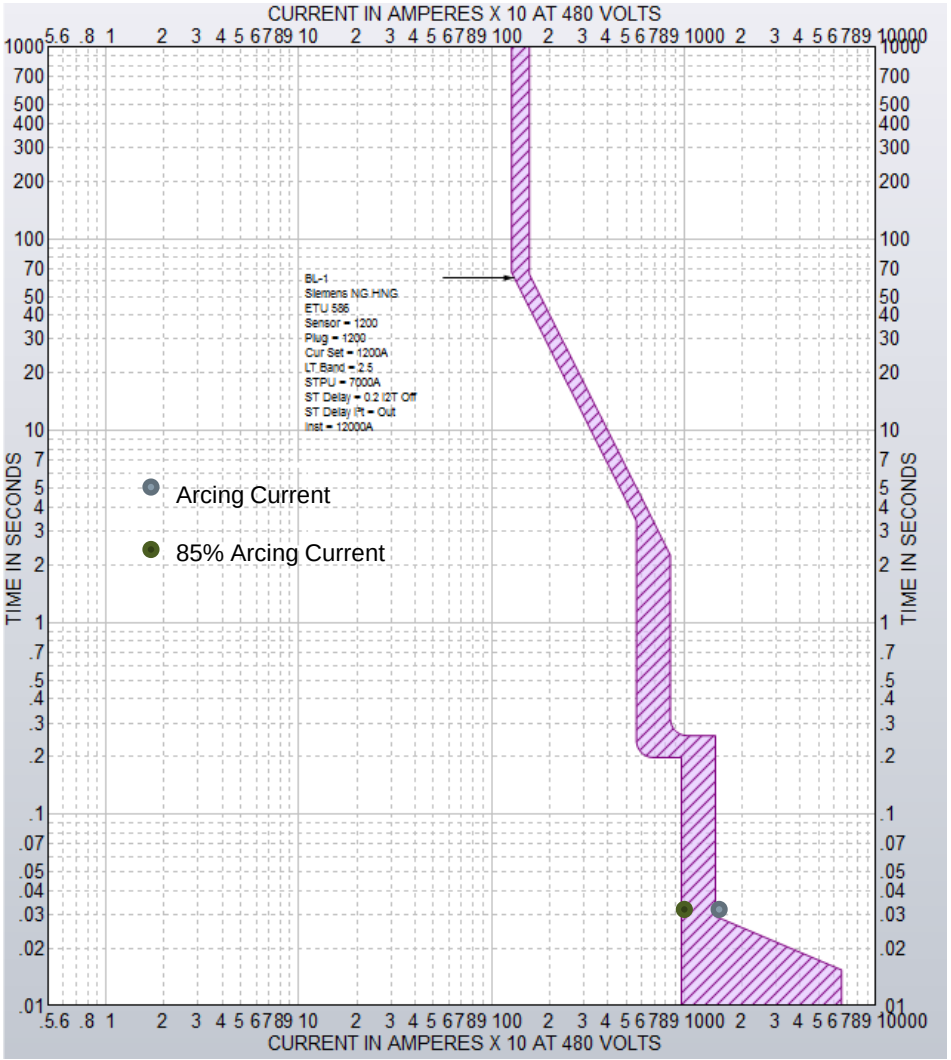
1) Zone Selective Interlocking
2) Differential relaying
3) **Energy-reducing maintenance switch with local status indicator**
4) Energy-reducing active arc flash mitigation system
5) *An instantaneous trip setting that is less than the available arcing current*
6) *An instantaneous trip override that is less than the available arcing current*
7) An approved equivalent means

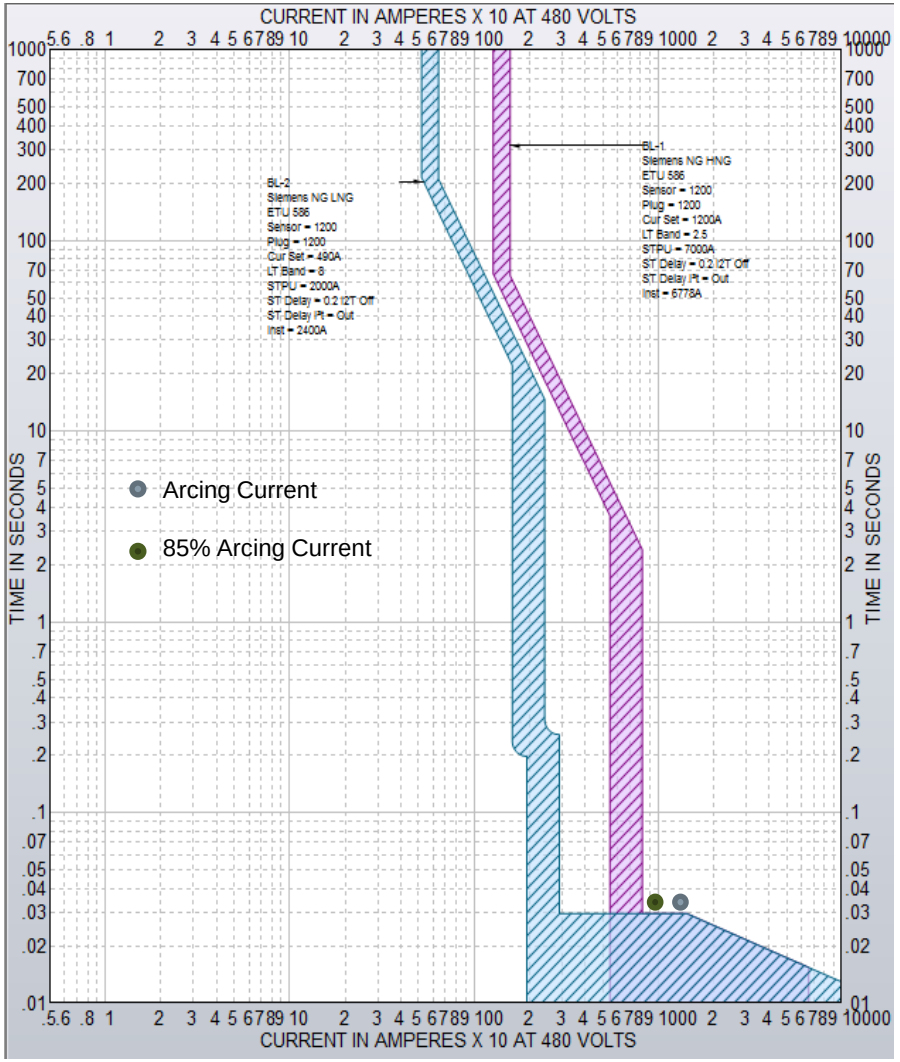
Maintenance switch has become one of the most common ways to meet requirement

Italics are 2017 additional options

What is maintenance mode?

- Alternate set of trip parameters
- Often instantaneous hard set to minimum -2X
- Typically activated by a switch with a light confirming change to maintenance mode state
- Additionally some systems can adjust long time, short time, instantaneous and/or ground fault settings in maintenance mode


CURRENT IN AMPERES X 10 AT 480 VOLTS
TIME IN SECONDS
BL-1
Siemens NG HNG
ETU 586
Sensor = 1200
Plug = 1200
Cur Set = 1200A
LT Band = 2.5
STPU = 7000A
ST Delay = 0.2 I2T Off
ST Delay I²t = Out
Inst = 12000A
Arcing Current
85% Arcing Current


CURRENT IN AMPERES X 10 AT 480 VOLTS
TIME IN SECONDS
BL-2
Siemens NG LNG
ETU 586
Sensor = 1200
Plug = 1200
Cur Set = 490A
LT Band = 8
STPU = 2000A
ST Delay = 0.2 I2T Off
ST Delay I²t = Out
Inst = 2400A
BL-1
Siemens NG HNG
ETU 586
Sensor = 1200
Plug = 1200
Cur Set = 1200A
LT Band = 2.5
STPU = 7000A
ST Delay = 0.2 I2T Off
ST Delay I²t = Out
Inst = 6778A
Arcing Current
85% Arcing Current

Breaker Settings

- Beware most if not all manufacturers set breaker to min shipping from factory

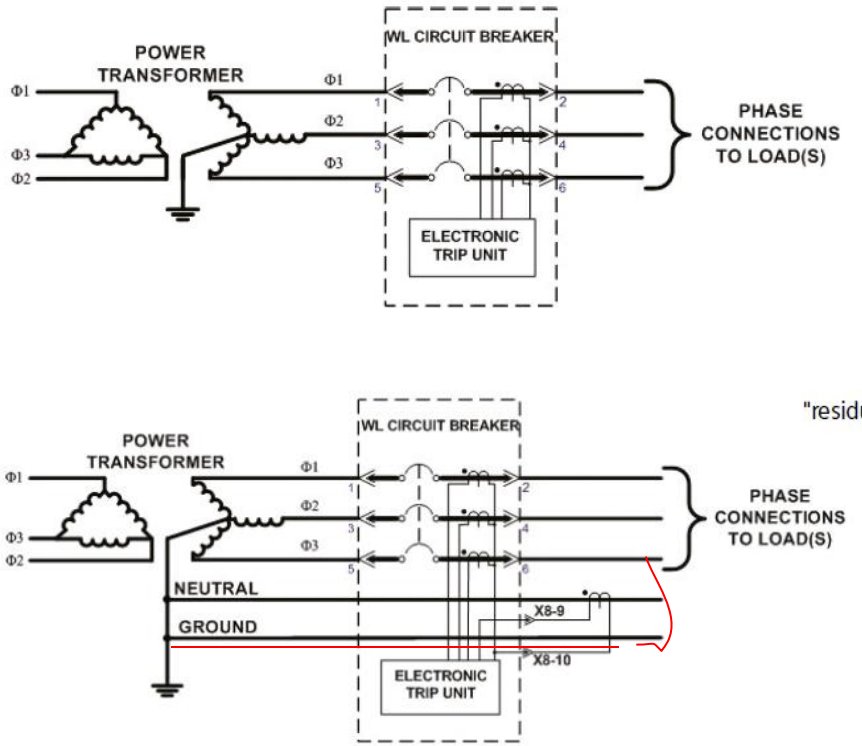
- This is an example of one of the ways to avoid nuisance tripping

- Make sure settings on breakers match settings done in load flow studies etc.

Ground Fault Applications

SB Switchboards

What is ground fault and residual ground fault detection?



A ground fault is when phase makes a connection to ground causing current to flow

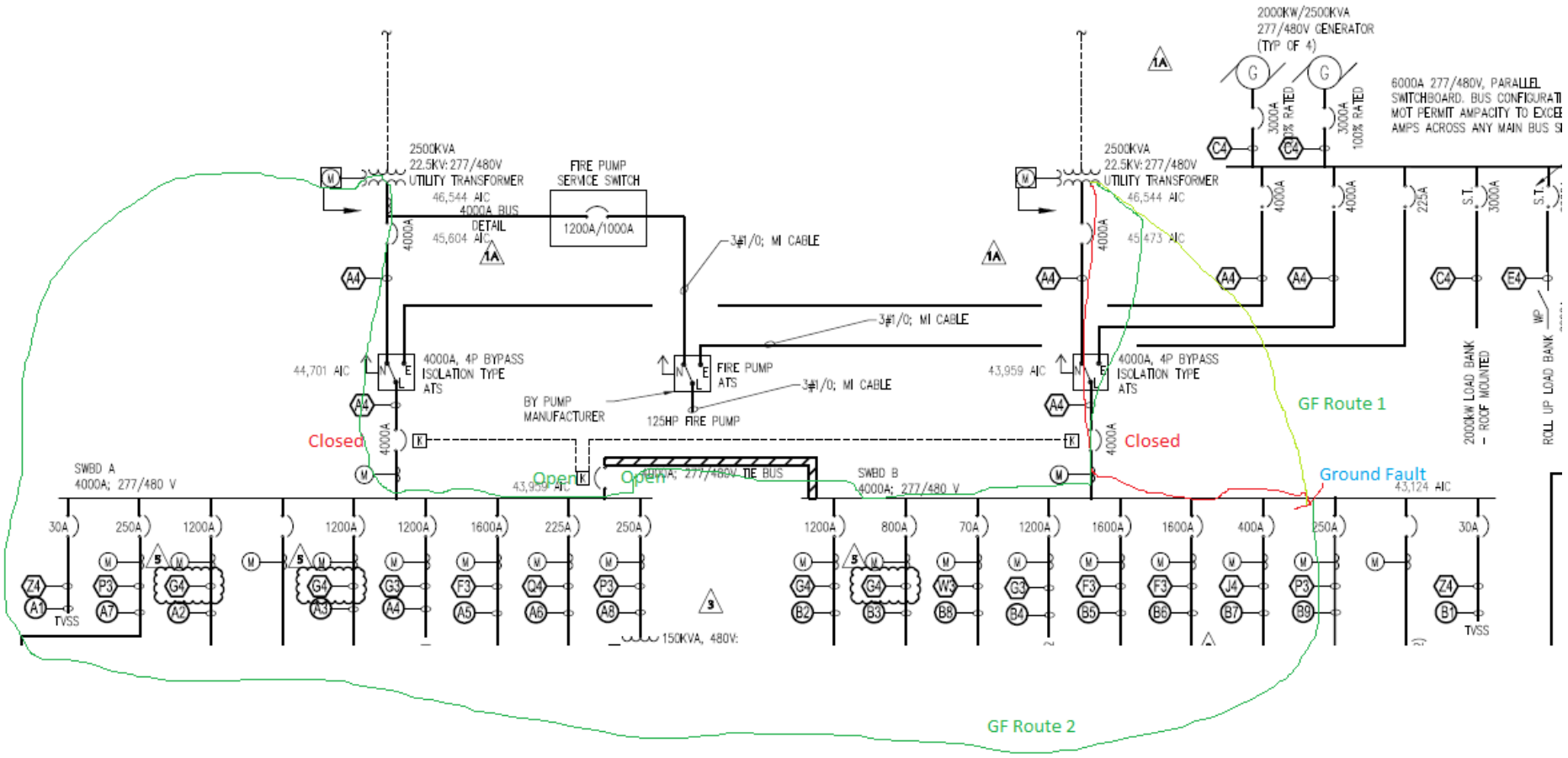
In solidly grounded systems this could be up to 87% of available fault current

In resistance grounded systems (HRG) it is typically designed to be limited to 5A

To the left are two typical ground schemes

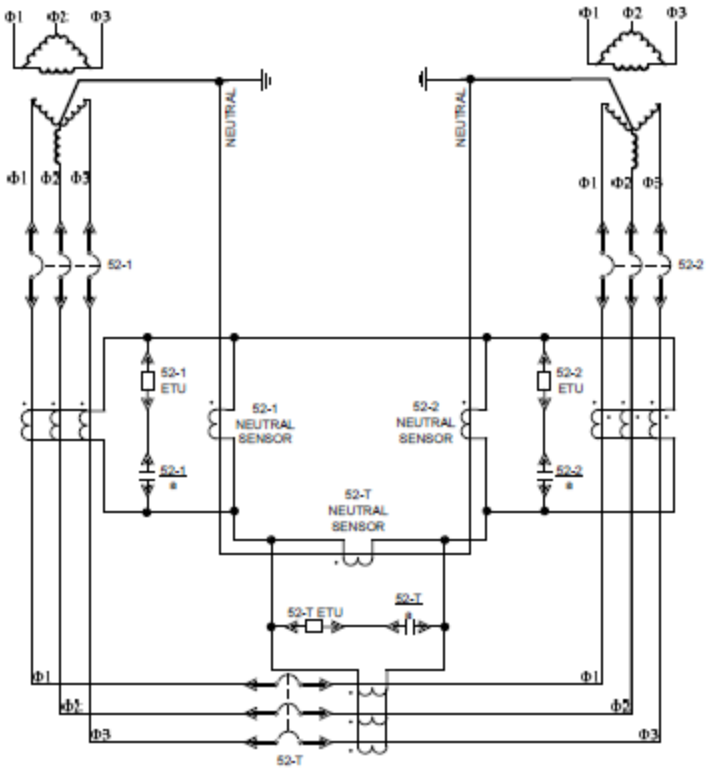
In order to trip the sum of the phases must be greater than a determined threshold

When does residual ground fault not work?



Example: Multiple path to ground. This can cause a residual ground fault scheme not to work

What is MDGF (Modified Differential Ground Fault) and when is it needed?



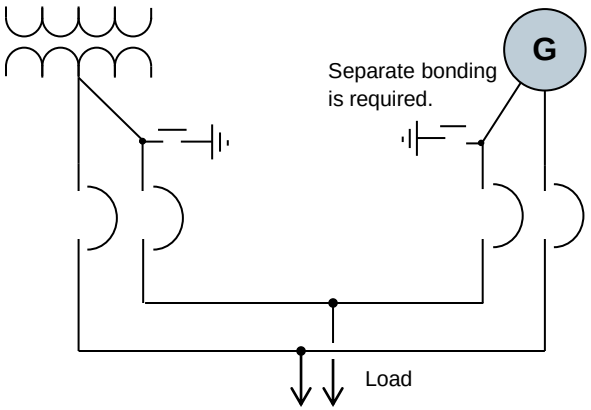
- A scheme using inter connected CT's to be able to detect ground faults and determine which breaker to trip

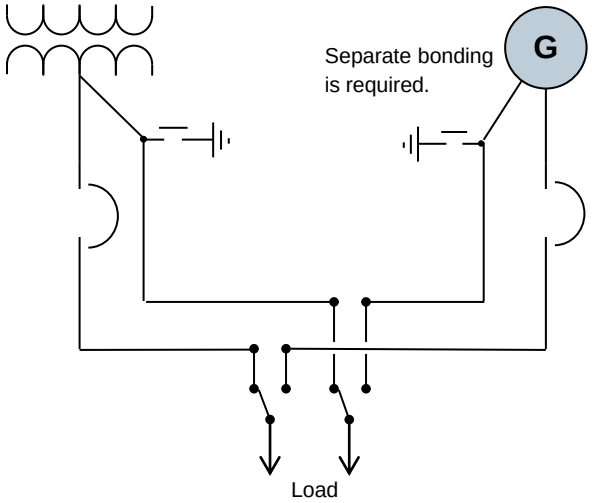
- Note: This type of scheme maybe be needed across SWBDs if multiple grounds are interconnected (like previous page)

- An alternate method can be a ground fault relay

- MDGF is mostly commonly needed on these systems:
  - M-T-M or M-M
  - M-G
  - Main switchboard inside with Generator boards outside

When is MDGF not needed





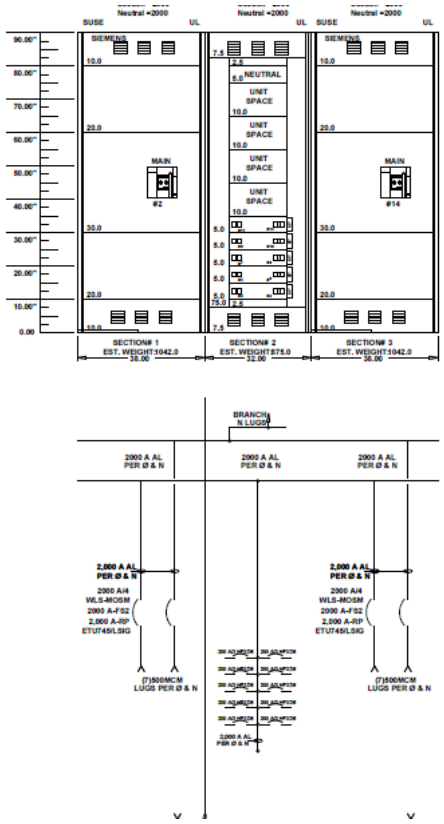
MDGF is not needed when the grounds are disconnected from each other typically with a 4 pole ATS or 4 pole breakers in non-parallel applications

In image one you can see the four pole breaks the neutral preventing a round loop

In image 2 you can see can see how a four pole ATS switches the neutral and prevents paralleling

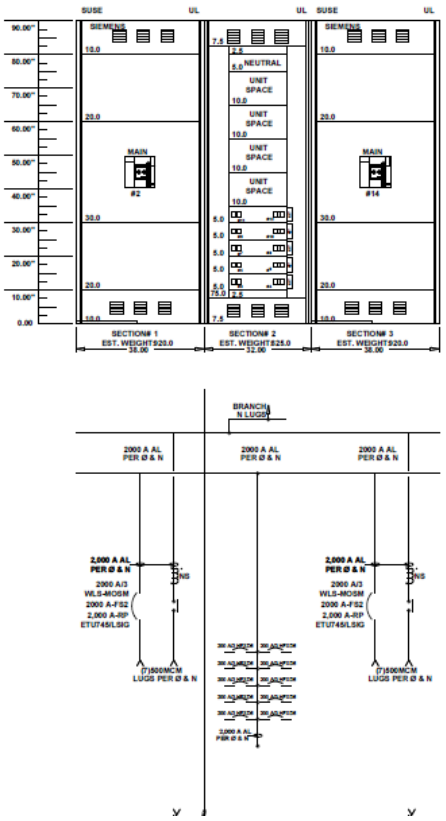
If you have M-T-M the tie would not need to be a four pole unless the user wanted to be if the mains

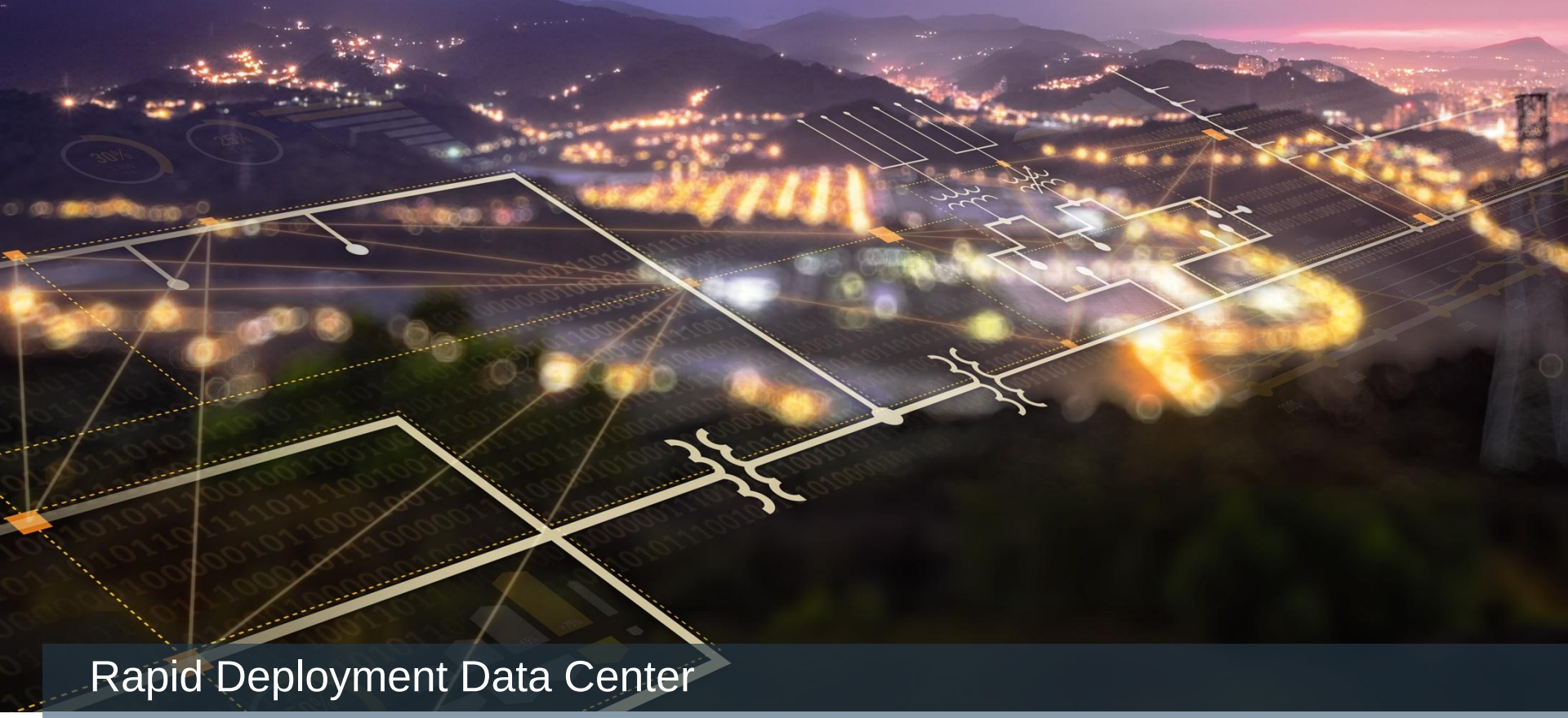
Difference 4 Pole vs. MDGF



Reasons to use 4P

- Possible add on generator or on site power
- Simpler wiring in the field
- Only needed at source level





Rapid Deployment Data Center

Case Study

From 179 to 80 Days – The Reality of Rapid Deployment Data Centers

- Growing Data Center Demands
- Challenge: Solution to rapidly deploy data center infrastructure
- Solution: Pre-fabricated, modular architecture
- Quality Solutions
- Innovative Solutions
- Results: Masters of Rapid Deployment
- Shared Vision for the Future
- Contacts

Challenge:
Solution to rapidly deploy electrical equipment to DC facilities

- Data Centers are constantly looking for ways to bring new capacity online faster while ensuring
  - energy efficiency,
  - reliability
  - flexibility and
  - industry-leading uptime.

- Traditionally, data centers are custom-built using different equipment and with all production done at the construction site.
  - This system is prone to delays and inefficiencies.

„We needed to develop products faster. We needed to get customers into data centers more quickly. And we needed to do it in a way that didn't compromise the quality of the product they

Solution: Pre-fabricated, modular architecture

Through pre-fabricated, modular Construction of one of the most critical components — the data center's electrical system — is completed away from the building site. Equipment for the Electrical rooms is assembled in a controlled, factory environment and shipped to the construction site on a flatbed truck. The equipment is built on a standard metal frame and pre-wired for easy installation.

- Pre-fabricated, modular Construction streamlines the process of building the electrical infrastructure.
- Electrical equipment is consistent from project-to-project.
- Assembly takes place concurrently with site construction.
- Final product is delivered when needed.

Innovative Solutions: Flexibility

To create new Manufacturing and Field Installation Standards for rapid deployment of the pre-fabricated, modular architecture:

- Flexibility for Field Modifications to Standard

Innovative Solutions: Plug and Play

To create new Manufacturing and Field Installation Standards for rapid deployment of the POD Design.

- One-to One Wiring
- Pull apart Terminal Blocks
- Plug and Play Wiring

Results: Masters of Rapid Deployment

- Using the pre-fabricated, modular electrical system design this customer has cut production time of its rapid projects by over 30%.
- A typical deployment for the company is now around 80 days.
- Delivered over 100 pre-fabricated electrical room solutions to date.
- Saved over 1,600 days of construction.