Data Center Expert Day, December 1st, 2016, New York City

Data Center Expert Day
Intelligent data needs intelligent power

Power and productivity for a better world™

Data Center Expert Day
Agenda

10:00 – 10:20 AM – Welcome and introduction

Brian Davis, Data Center Industry Segment Leader, North America

10:20 – 10:40 AM - Technology advances for the future of Data Centers

Dave Sterlace, Global Head of Data Center Technology

10:40 – 11:30 AM - Saving time and money with data center automation

Rich Ungar, Business Manager, Data Center Automation

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11:30 – 11:45 AM – Break

11:45 – 12:15 AM – Transformer design considerations for safety & reliability

James Ritter, Channel Manager, OEM Sales, Transformers

12:15 – 1:15 – Lunch

1:15 – 1:40 - Benefits of the modular UPS to a data center

Joergen Madsen, Director Business Development, Power Protection

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1:40 – 2:05 PM – Data Center availability optimization through static switch transfer schemes

David Dupuis, Product Manager, Enterprise Power Protection

Adil Oudrhiri, Systems Engineer, Power Protection

2:05 – 2:45 PM – MV digital swithgear & IEC 61850 enabled innovations

Don Elliott, Product Manager, Medium Voltage

2:45 – 3:00 PM – Break

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3:00 – 3:45 PM – Substation design & renewable integration

Matthew Vaughn, Business Development Manager, Substations

Pat Ervin, Compact Substation Business Development Manager

3:45 – 4:15 PM – Modular Systems: E-houses and Product Packaging Solutions

Sarah C. Butz, ABB Packaging, Marketing Engineer

4:15 – Reception with refreshments

ABB – A global technology pioneer
Leading market positions in power & automation

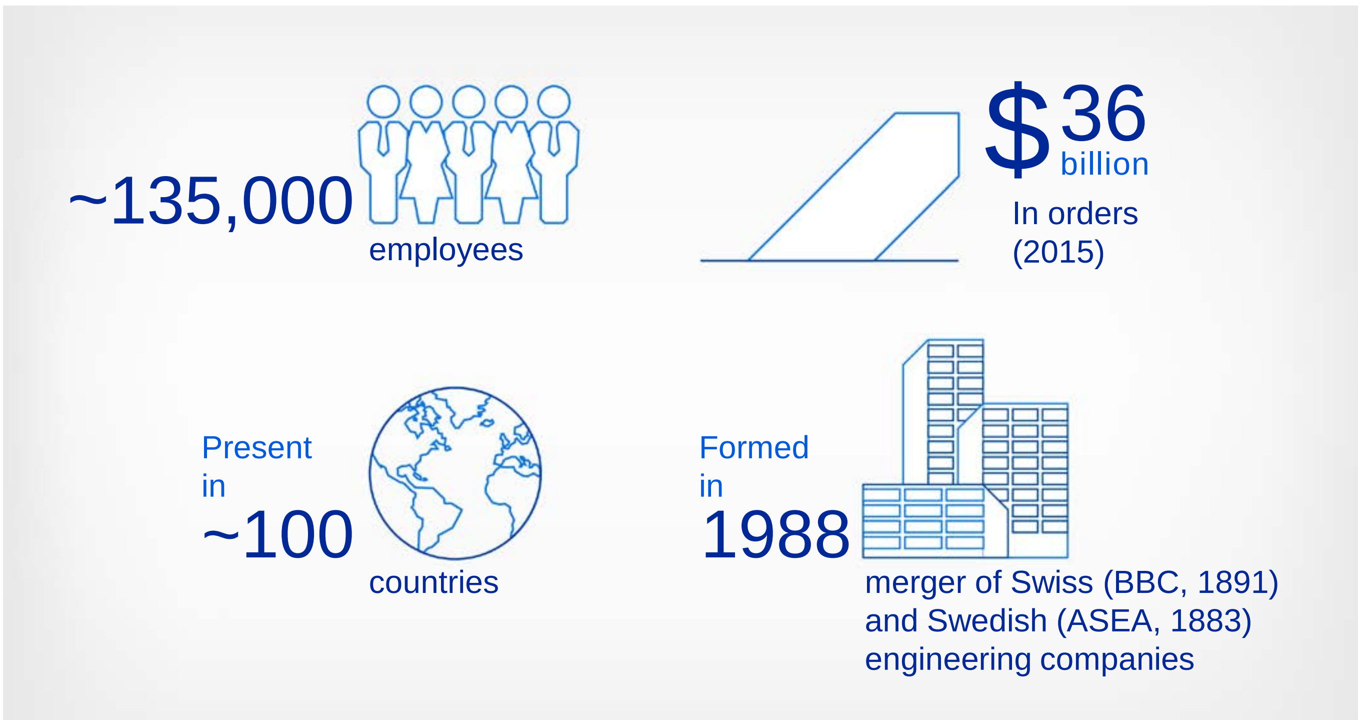
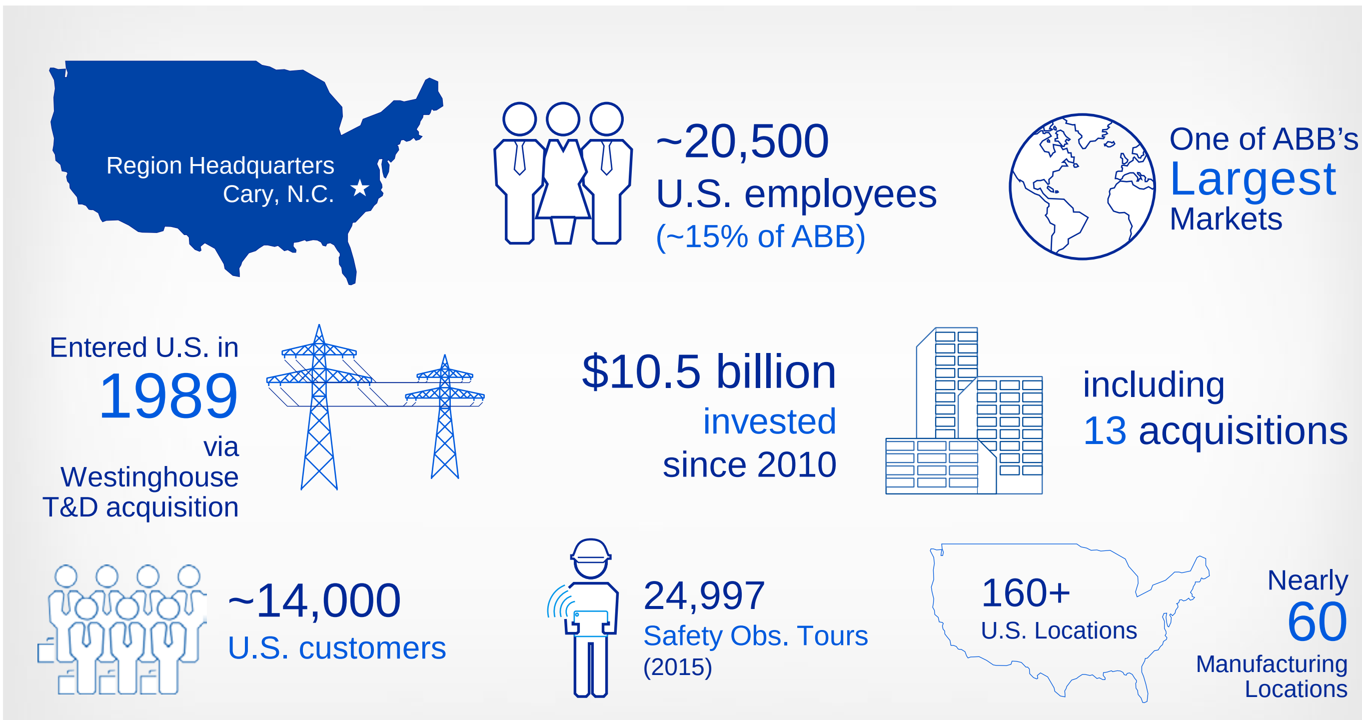
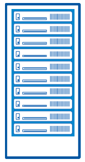


ABB in the United States
Investment and growth



How ABB is organized
Four divisions



Electrification Products

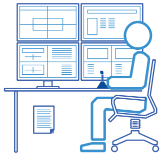
5,374
U.S. employees

Electrification Products delivers products and systems designed to connect, protect and control electrical systems, ensuring reliability, efficiency and safety for your equipment and personnel.

Discrete Automation and Motion

7,590
U.S. employees

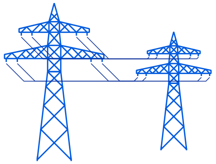
Discrete Automation and Motion products, systems and services help improve efficiency and reliability throughout the energy value chain.



Process Automation

2,266
U.S. employees

Process Automation products, systems and services help optimize operations and processes across the energy value chain.



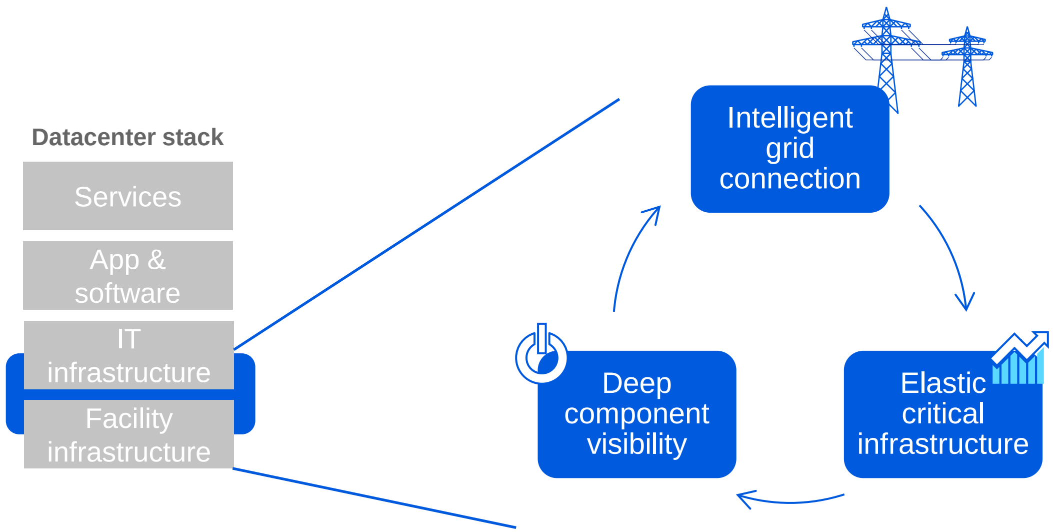
Power Grids

4,439
U.S. employees

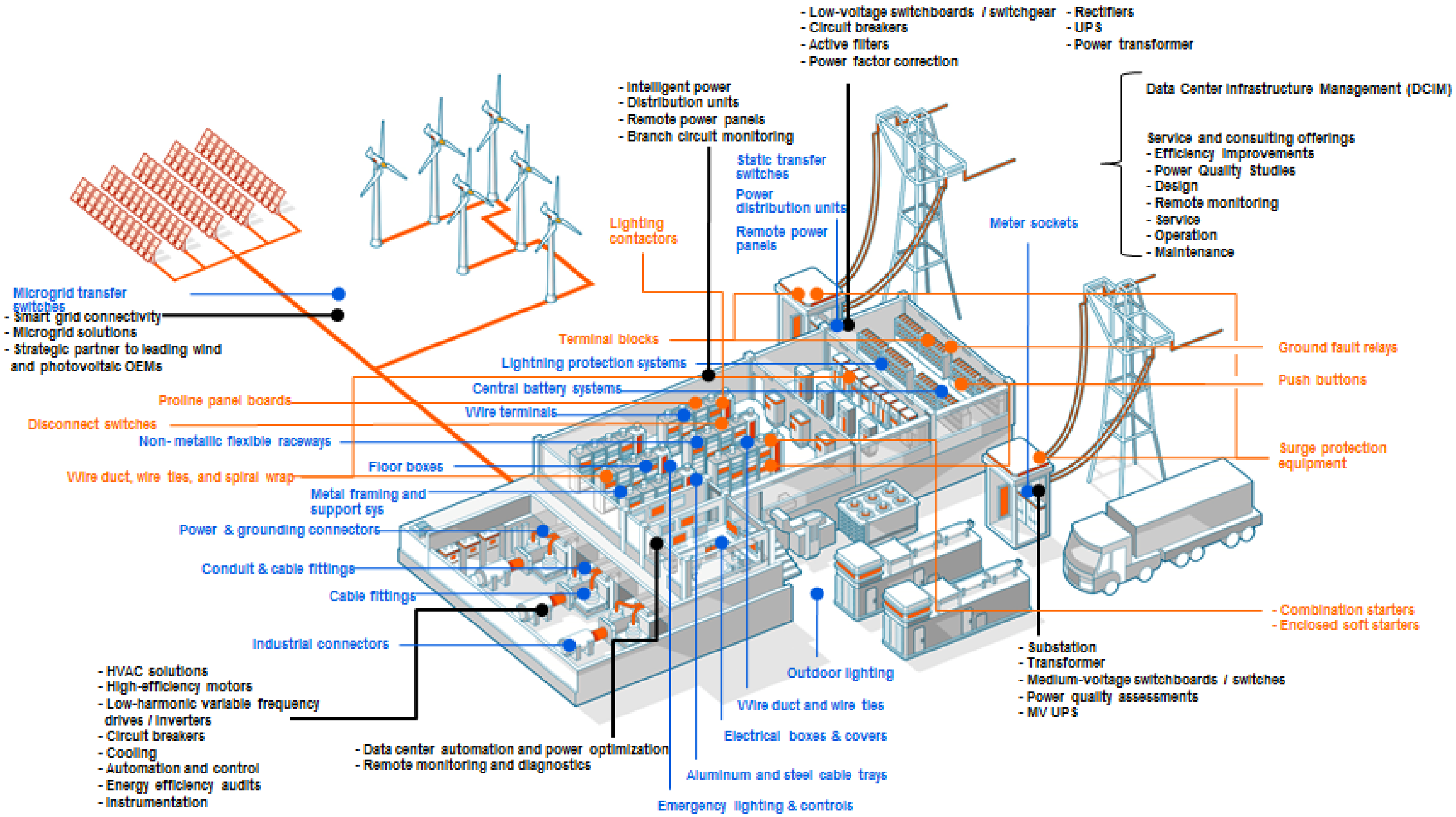
Power Grids helps improve efficiency and reliability throughout the power value chain from generation to transmission and distribution.

The ABB vision for the datacenter
Born out of 100 years for industrial experience

Smarter infrastructure for the industrial datacenter



Technology update
A rich portfolio…



Dave Sterlace, Global Head of Technology, ABB

Internet of things and its impact
An ABB perspective

What do you need to know about IoT?
Unprecedented Scale

20B connected devices by 2025 per Gartner 50B per Cisco!

What do you need to know about IoT?
Wireless

100k cell sites in NYC in 2025 vs 3000 today

What do you need to know about IoT?
Latency

…will drive Edge

What do you need to know about IoT?
Security

…Target's breach went in through HVAC "back door" in '12

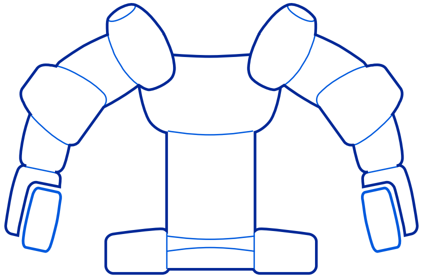
What do you need to know about IoT?
Flexibility

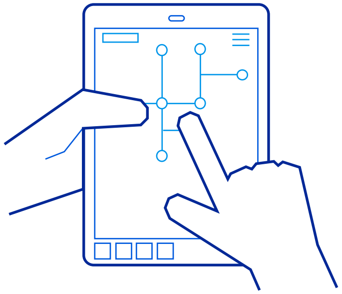
…infrastructure must scale with IT loads

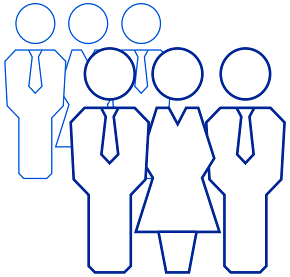
What do you need to know about IoT?
Visibility

…infrastructure must scale with IT loads

ABB
impact of the Internet of Things







Things

Devices and machines communicate with each other, deliver data for Big Data.

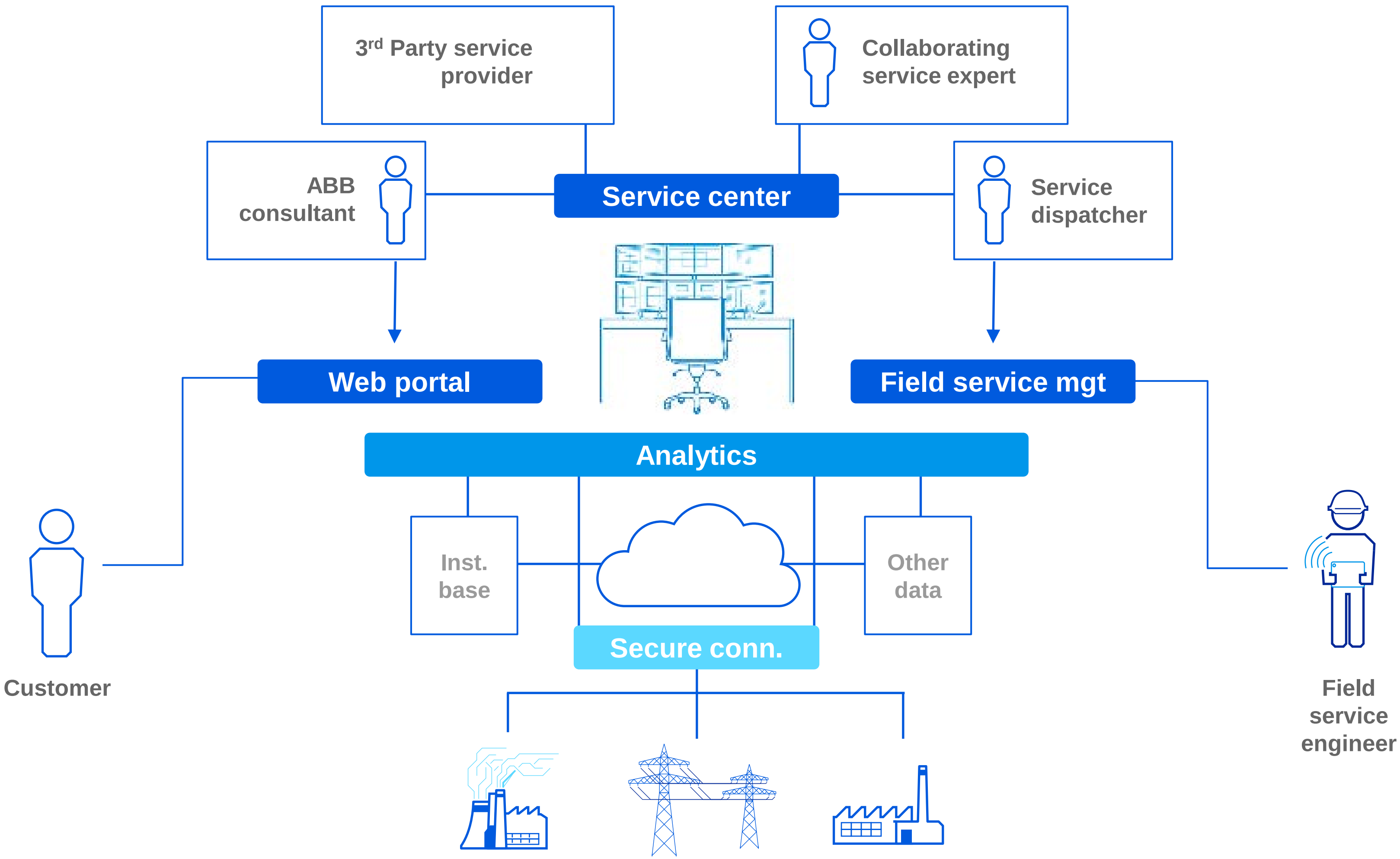
Services

How the data will be analyzed and used is crucial, new business models emerge.

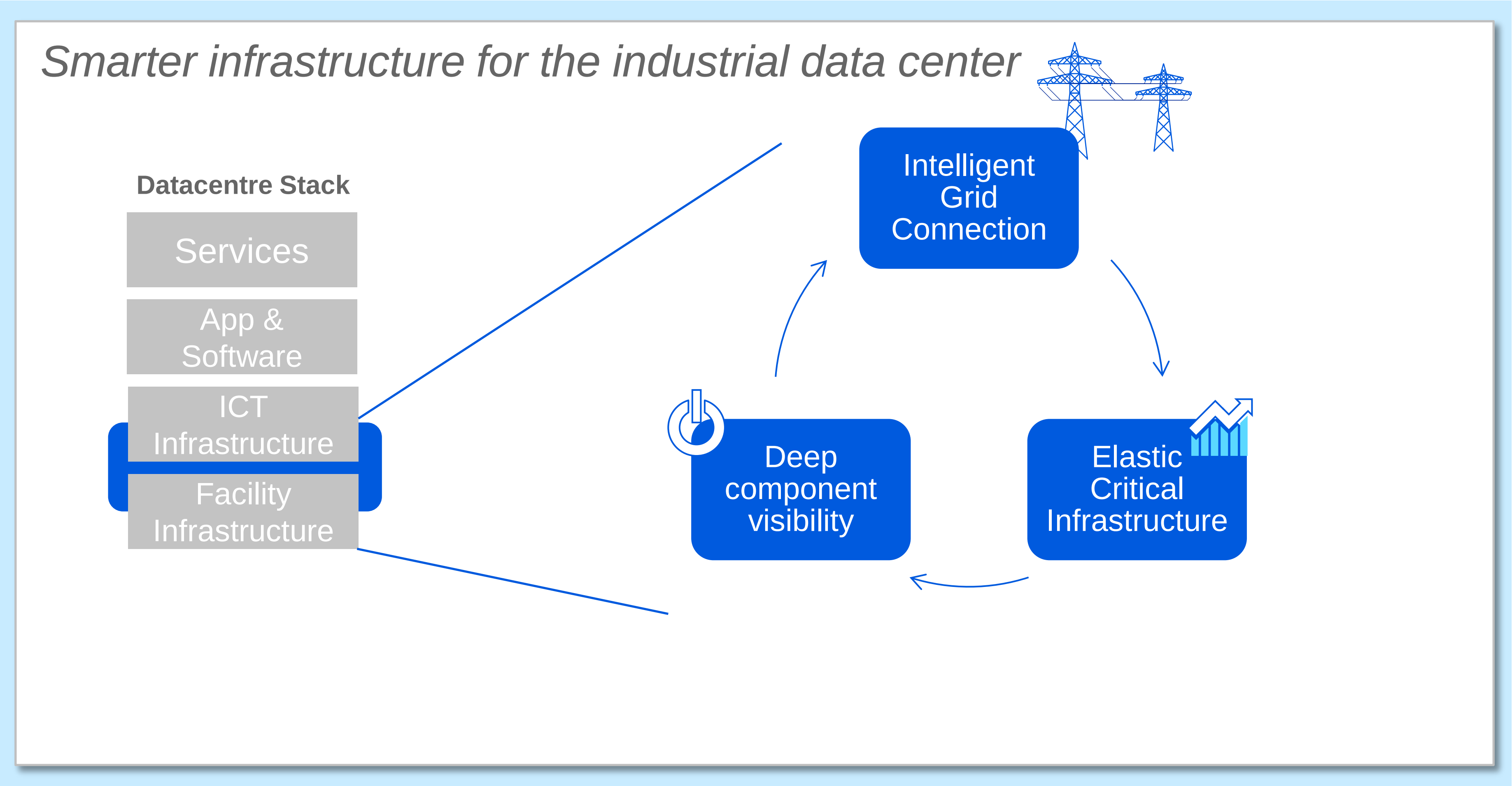
People

Humans remain in charge, program and control the activities of things.

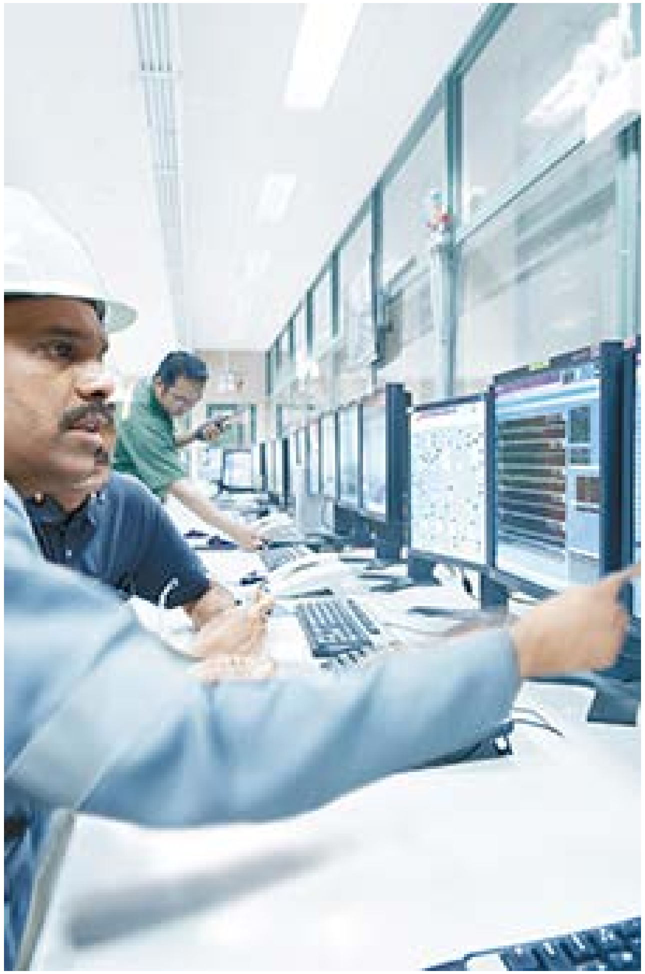
Internet of Things
Improves productivity, efficiency and reliability



Characteristics of Future Data Centers



Prepared for the internet of things?
Absolutely



Intranet of Things – Internet of Things

- Intelligent devices with sensors are providing large amounts of data
- Essential requirements remain (safety, reliability), cyber security and data privacy become more important

People

People will remain in control of the production process. People will be the decision makers

Services

- Services becomes more advanced through data analytics.
- Opportunities for new service models that build on collaboration.

Rich Ungar

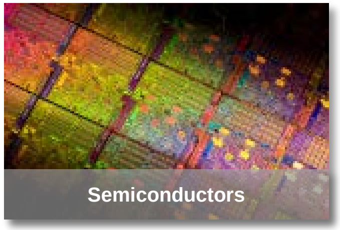
Saving time and money with Data Center Automation

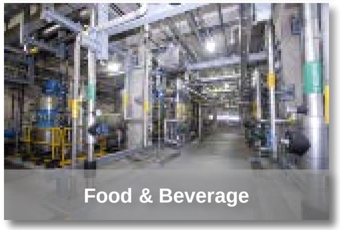
Power and productivity for a better world™ ABB

Learning from other industries is an opportunity

Data center industrialization is inevitable

Data Center Automation takes industrial technologies and applies them to the data center





Highly *available* infrastructure

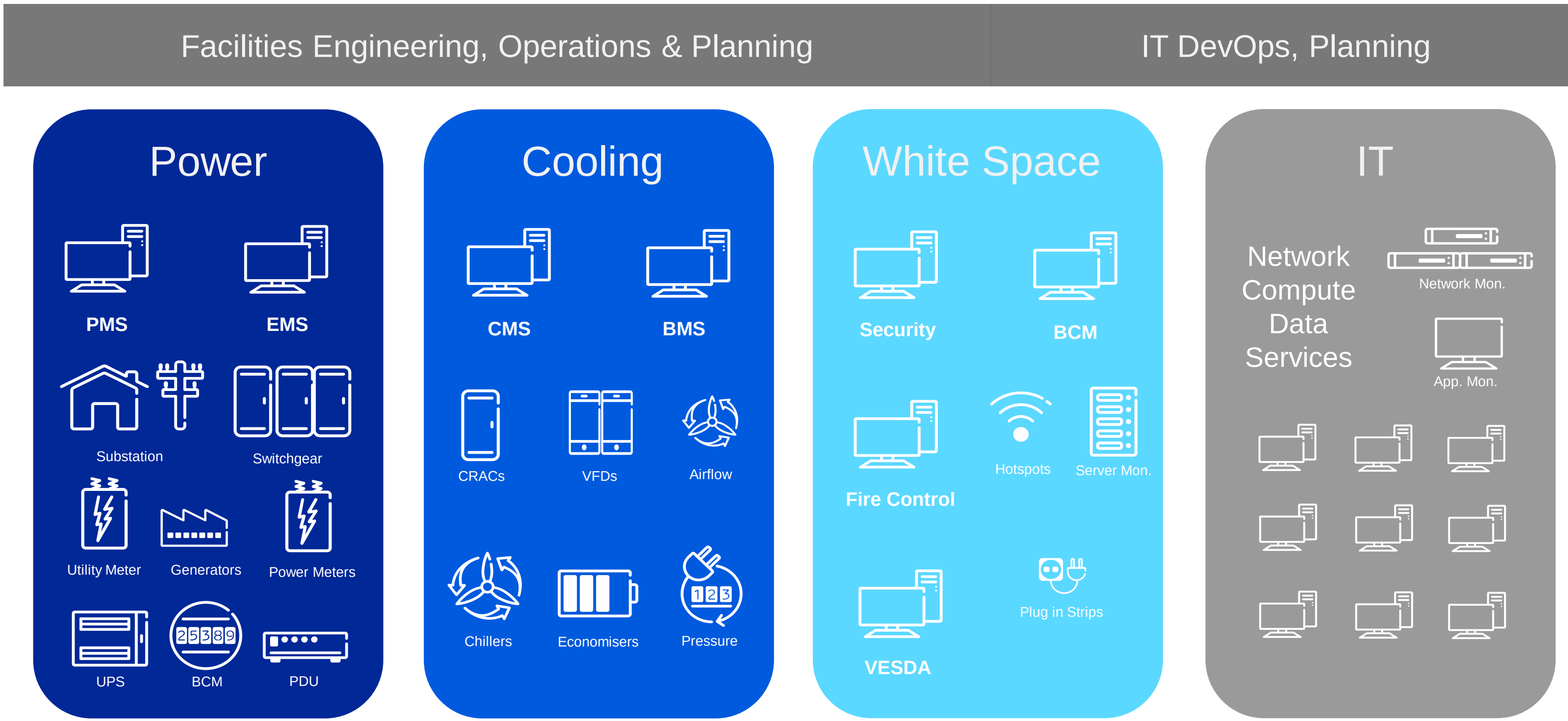
Super efficient industrial operations

Automated workload management

Data Center Automation

“Data center automation merges industrial monitoring, control systems and predictive analytics to optimize networked asset utilization, including virtual assets and services like the cloud, technology refresh, environmental conditions and even human workflow. At a functional level, controls deliver a highly reliable and secure machine-driven sequence of operations and repeatable processes. Thus, a data center infrastructure management system with controls provides intelligent, flexible, adaptable and ultimately autonomous control of the entire data center or fleet of data centers.”

Silos

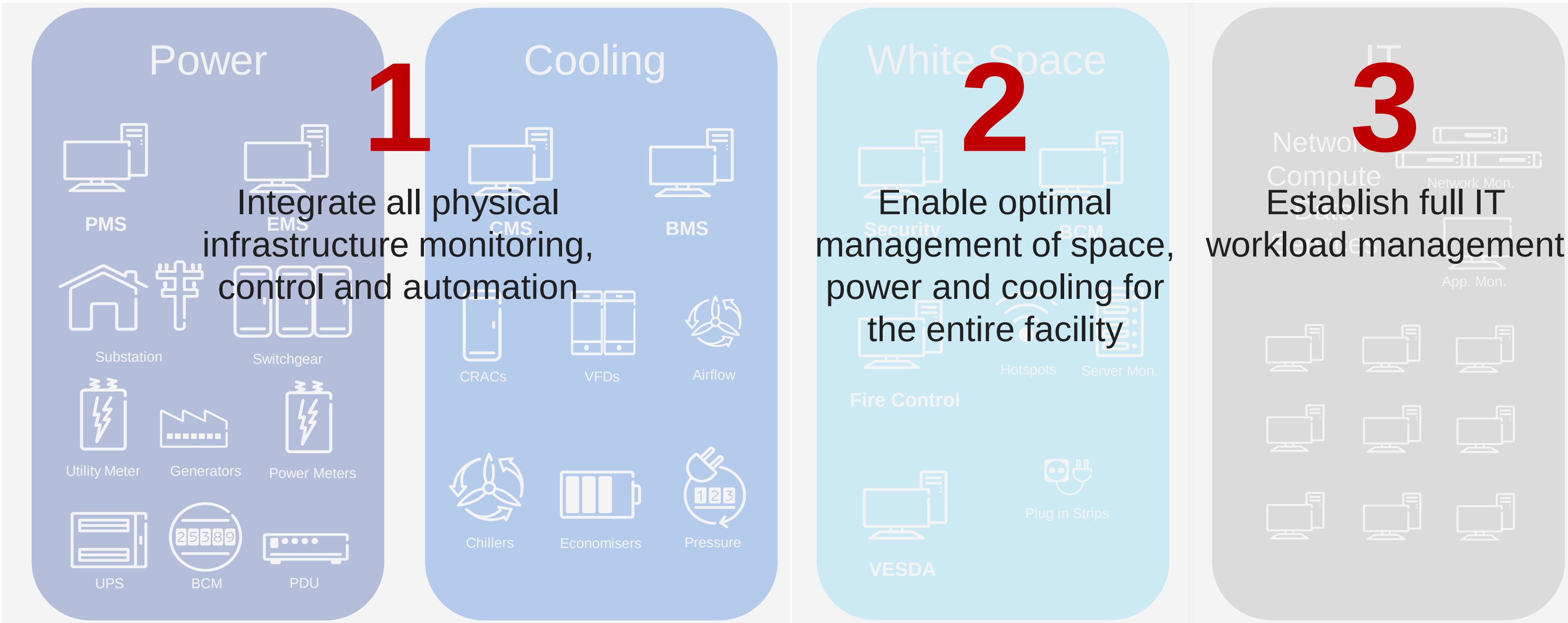


‘Islands of automation’ increase risk, cost, inefficiency

Eliminate the silos

Converged DevOps and Management

All physical and virtual infrastructure as one



1
Integrate all physical infrastructure monitoring, control and automation

2
Enable optimal management of space, power and cooling for the entire facility

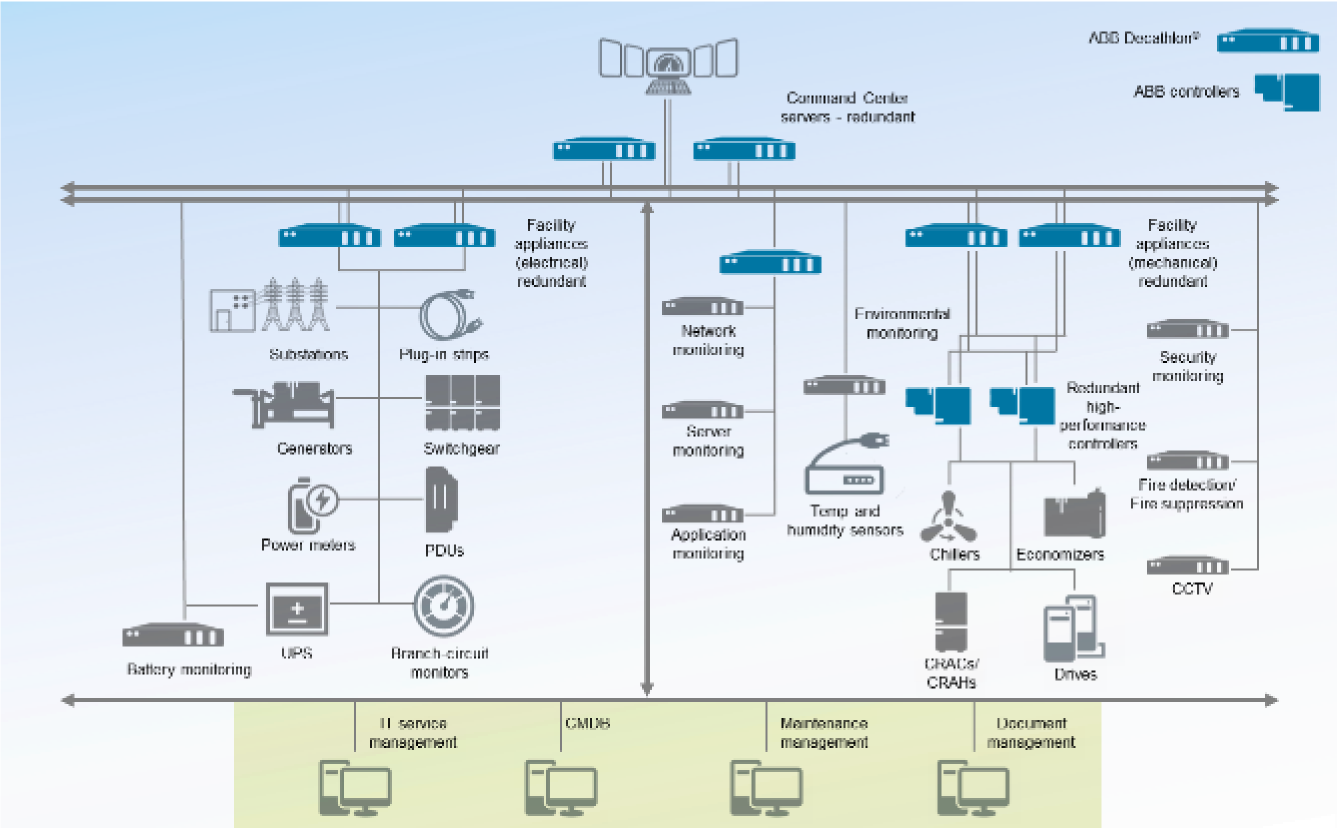
3
Establish full IT workload management

Comprehensive management of the 3 Cs in your data center:

Cost Capacity Control

Step 1 - Integrate all physical infrastructure monitoring, control and automation

What does an integrated Data Center Automation system look like?



- Common user interface
- Open architecture with standardized integration
- Use of high-availability design and redundancy
- Segmented networks and servers
- Common API for integration with 3rd-party applications

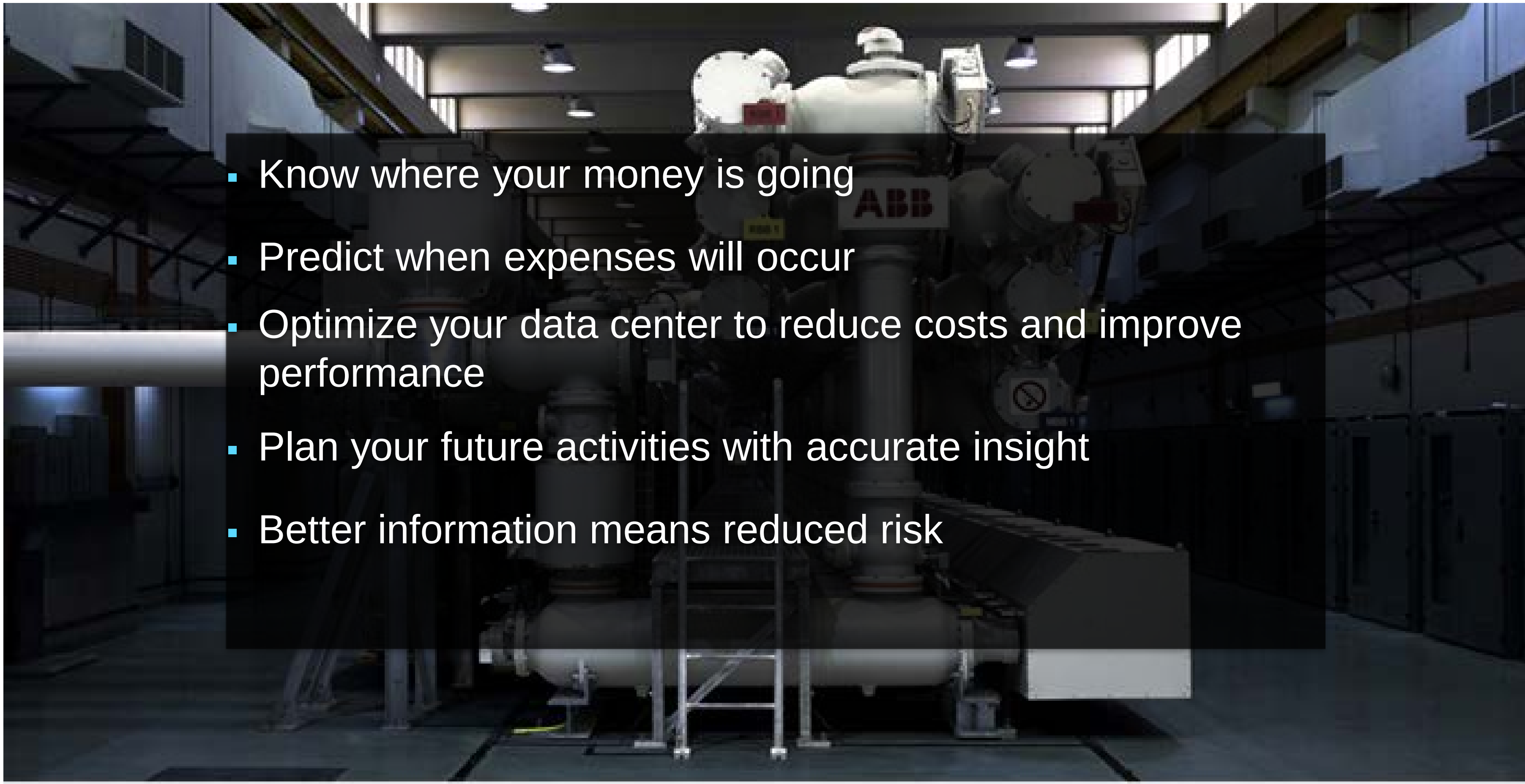
CAPEX benefits of one system

- One control technology
- One HMI to commission
- No system integrations
- No finger-pointing between controls vendors

- Reduce troubleshooting and rework delays
- Speed up commissioning time
- Less training required
- Fewer spares parts needed

- Cost reductions through lower overhead & coordinated construction activities
- One contract
- One site team, one project manager
- One support contract

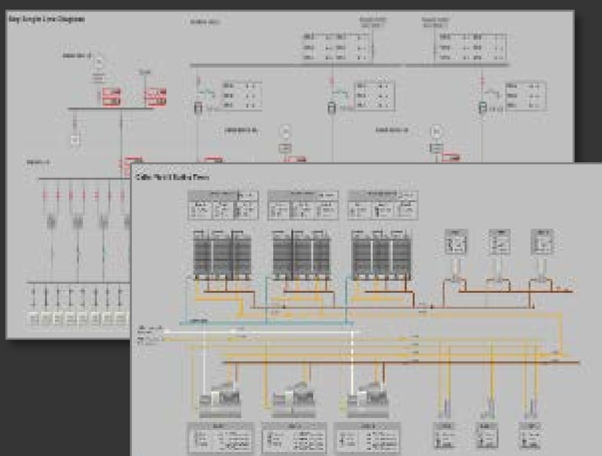
OPEX benefits of a Data Center Automation solution



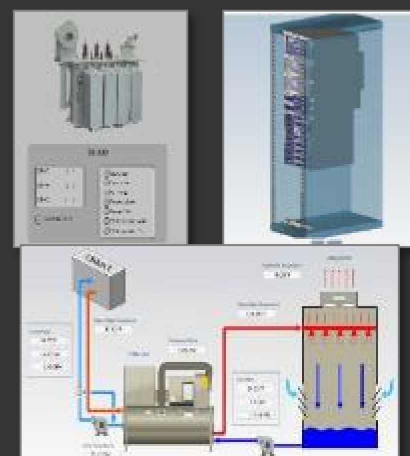
- Know where your money is going
- Predict when expenses will occur
- Optimize your data center to reduce costs and improve performance
- Plan your future activities with accurate insight
- Better information means reduced risk

Know everything about your data center - NOW

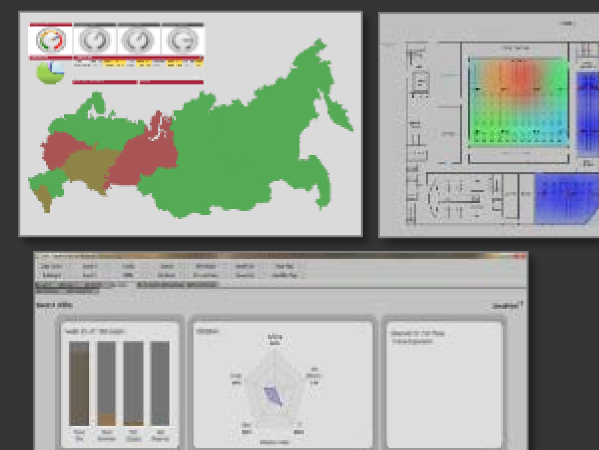
Reduced risk, cost and inefficiencies for data center operations and management teams by creating an Operational Management platform that provides real-time, high-reliability monitoring, control & automation.



Schematic based approach



Connect to everything

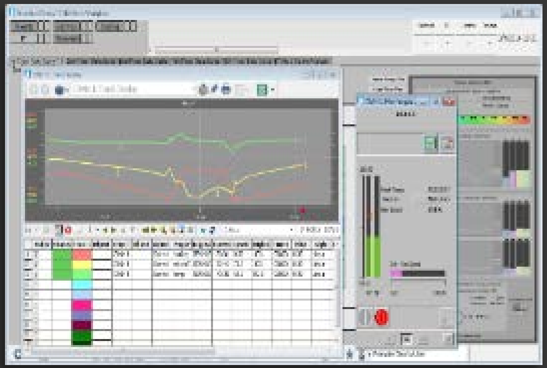


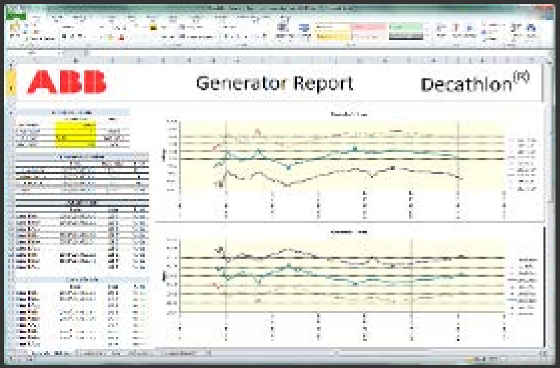
Rich visualisation & dashboards

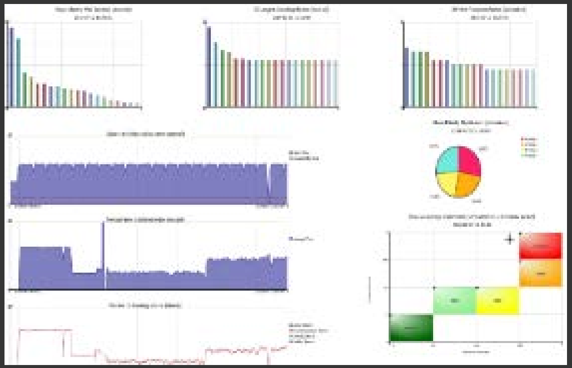
Seeing the truth behind the data

Advanced alarming and alarm diagnostic capabilities, for fast troubleshooting

Sophisticated reporting and analytics environment

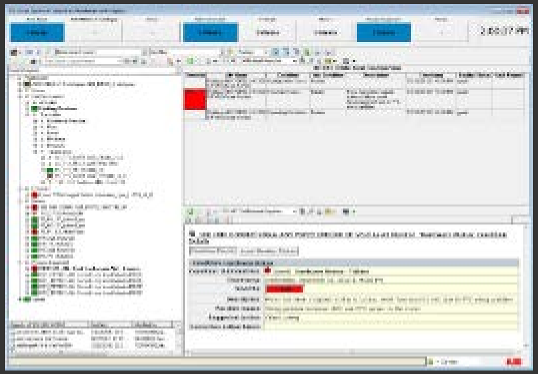


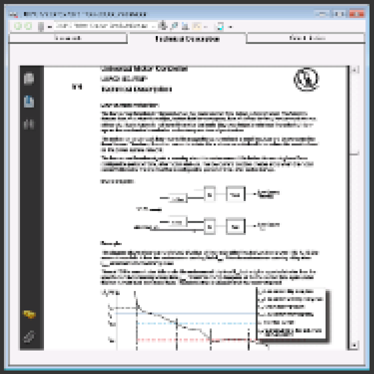


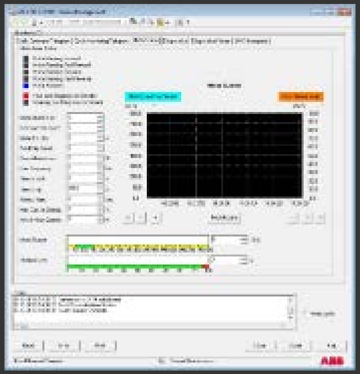


Looking into the future

Condition-based monitoring and prognostics integrated with maintenance management tools



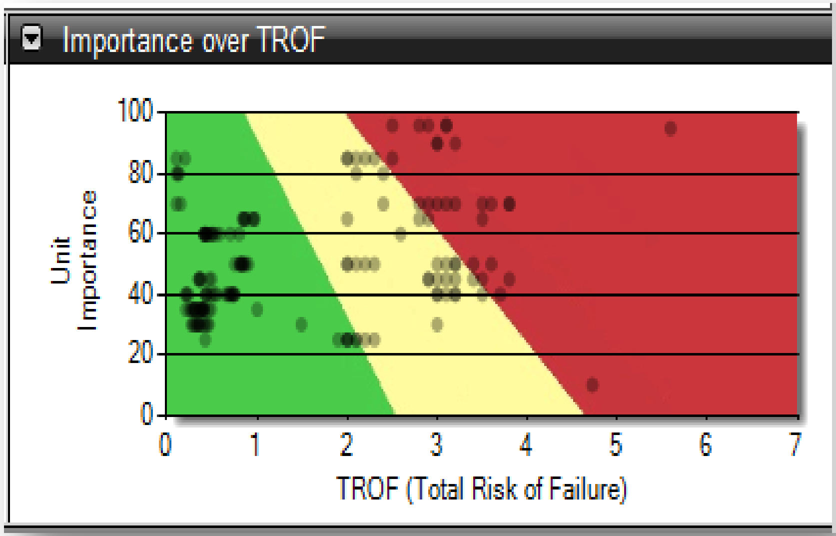




ABB

Asset Condition Monitoring

- Maintain aging assets while under increasing pressure to hold or reduce operations and maintenance spend while increasing uptime and reliability.
- Asset Health (ACM) is a method for Data Centers to assess critical assets based on the combination of the criticality and risk of failure.
- Asset Condition Monitoring Systems combine operational and information technologies, along with product and diagnostic expertise.



Asset Health Solution

1 Data Acquisition; Data from a variety of sources ranging from

- **Real time data *(condition, EMS-SCADA, monitors and sensors, DCIM)***
- **Near real time data *(GIS, mobility, Historian, EAM)***
- **Enterprise Data (EAM *data warehouse, market databases, ERP etc)***

2 Data Aggregation and Analytics; Leveraging ABB Experts , Statistics, and Condition Assessments

Analytics, Algorithms and Engineering best practices determine total risk

- **Mechanical risk**
- **Thermal risk**
- **Dielectric Risk**
- **Accessory risk**
- **Miscellaneous risk**

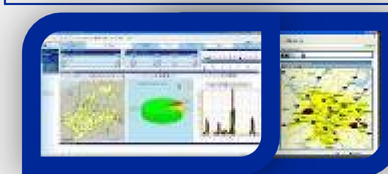
3 Decision Support; KPIs and Workflows to Prioritize Investment and Maintenance Work

KPIs That Matter

- **KPI Dashboards**
- **Packaged Analytics**
- **Notifications & Reports**
- **Adhoc capabilities**

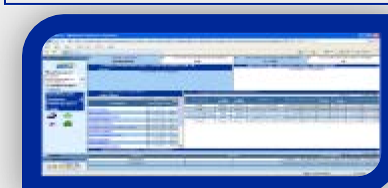
4 Results and Communications; Actionable; Integrated into Work and Asset Management

Digital Dashboards



Field Inspections/ Communications & Work Notifications

Work and Asset Management – Work Orders



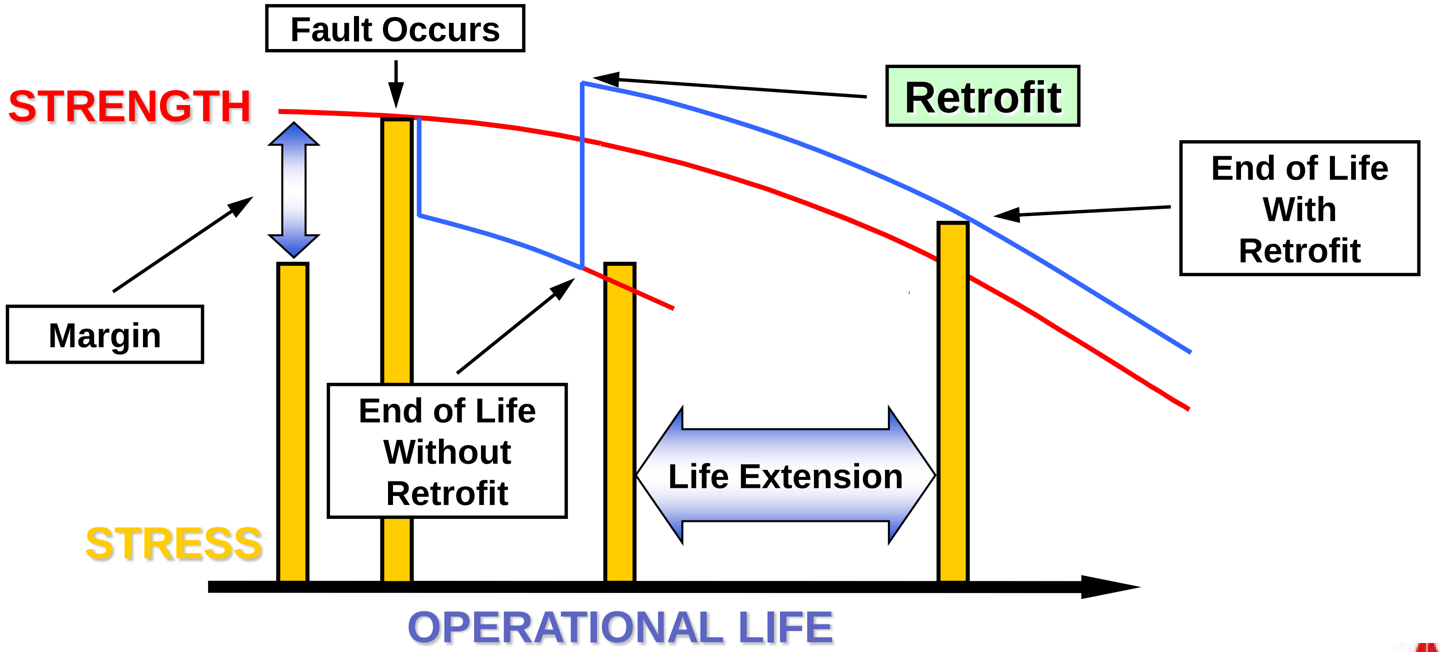
Transformer Aging & Failure Model

Overview

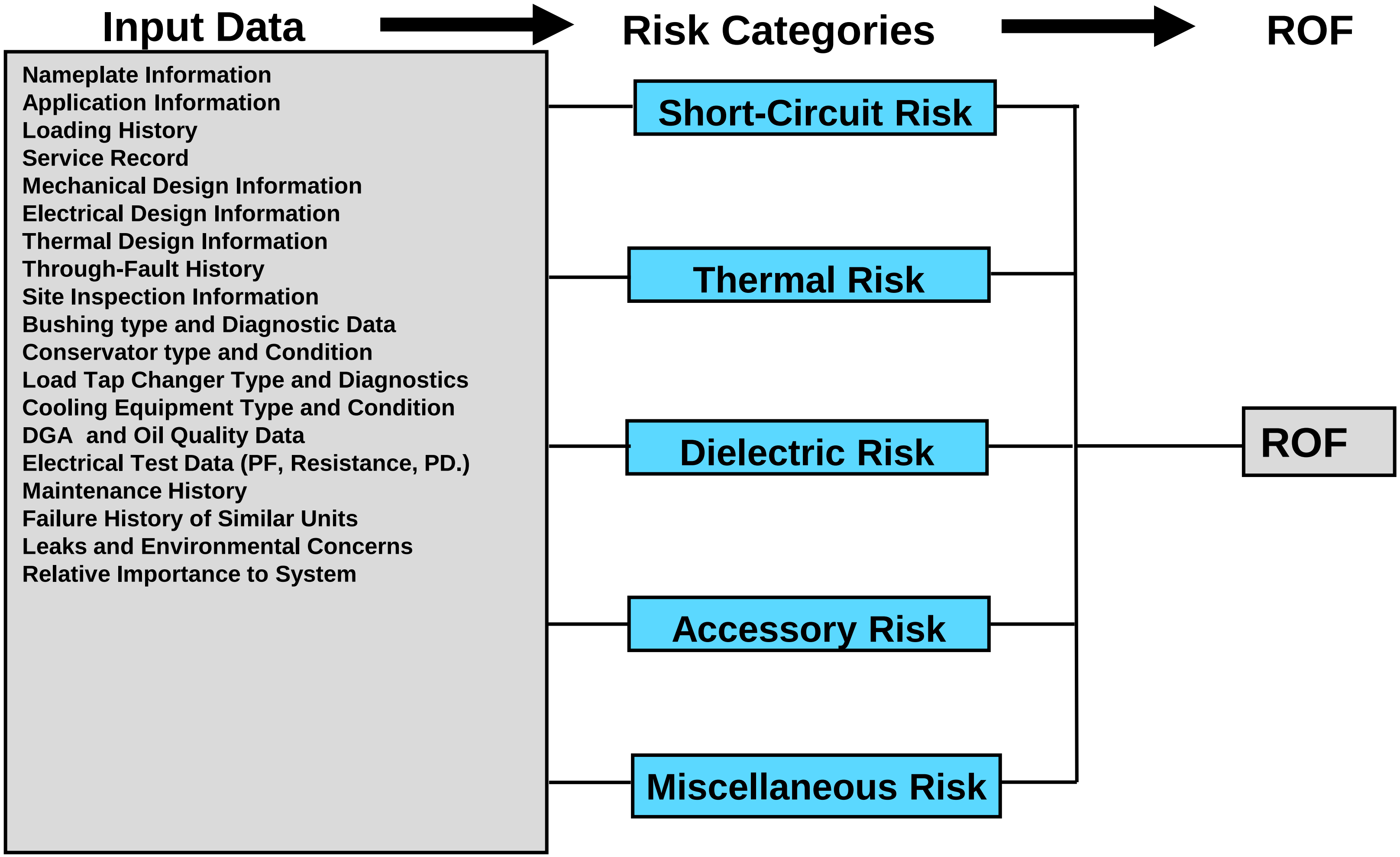
Thermal aging
Temperature
Chemical aging
Moisture
Oxygen
Acids

Mechanical aging
Overstress
Vibration / Nr. of operation

Electrical aging
Overvoltage
Overcurrent
Harmonics



Transformers Life Extension Options & Considerations
Risk Of Failure Determination



Battery Monitoring and Alarms
Float Current Monitoring

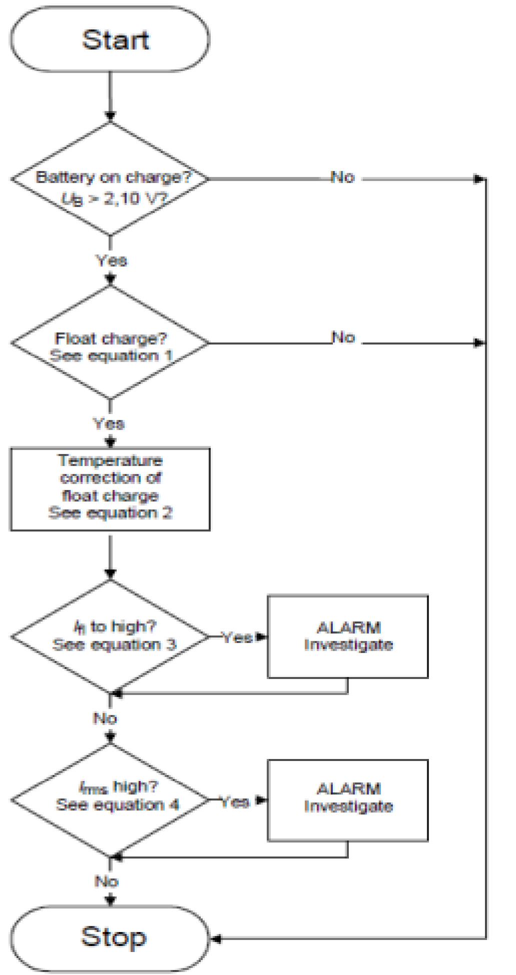
Input

- AC and DC floating current measurements
- Thresholds presetting
- Ambient temperature

Output

- Battery condition level based on AC/DC floating current measurement

Note: Float current measurement needs correction based on temperature



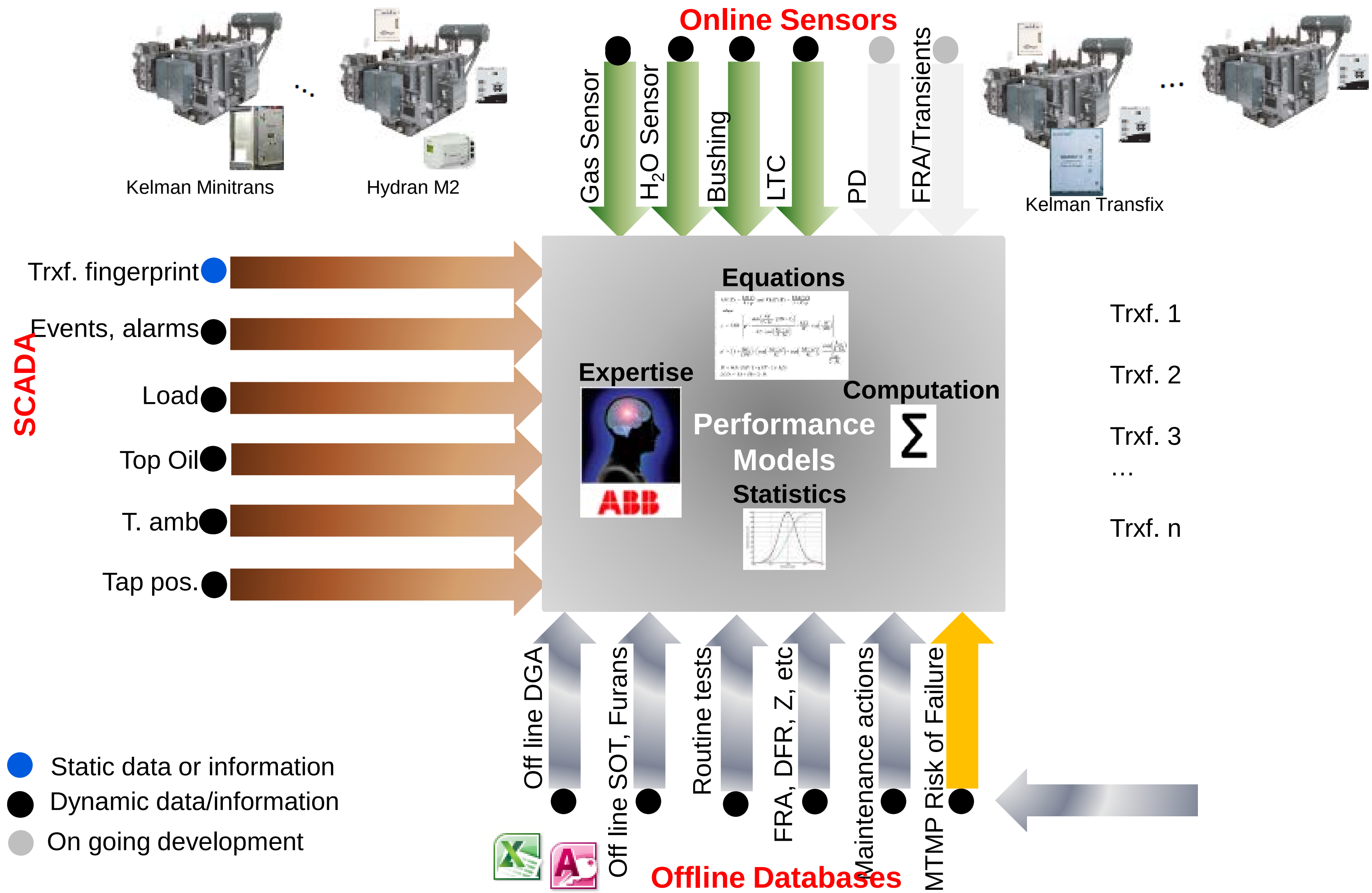
Battery condition evaluation and alarm with following parameters

- Float current
- Float voltage
- Temperature
- AC/DC resistance or conductance
- Electrolyte level (where available)

Battery Risk of Failure calculation

Reference: IEC TR62060

Asset Health Center – Information Flow & Analysis



Basic Asset Monitor Library

- Limit Check Asset Monitor – limit condition for analog vibration measurement
- Flow Delta Asset Monitor – monitors allowed difference between e.g. steam flow and feed water flow
- Counter Check Asset Monitor – monitors number of valve strokes, motor starts, breaker activations etc.
- Runtime Asset Monitor – monitors any equipment runtimes
- X-Y Profile Deviation Asset Monitor – monitors feed pump capacity (flow vs current)
- Compressor/Pump Curves Asset Monitors - Imports pump curves and compares actual and expected performance

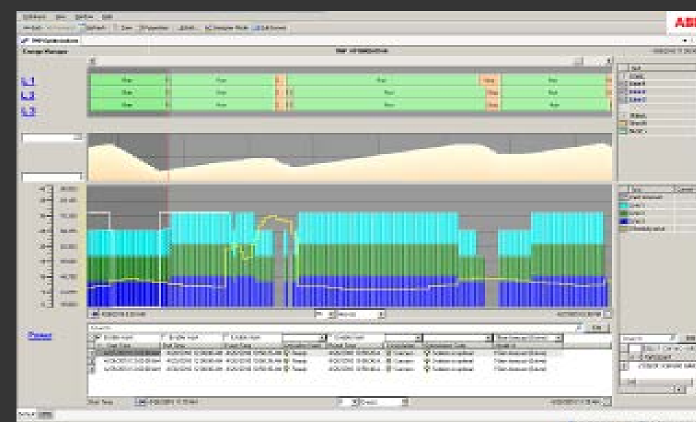
Expected Benefits

- Consolidated data on asset condition available to stakeholders in a timely fashion
  - Providing situational awareness
  - Support for making maintenance and capital replacement decisions
- Decreased reliance on specific local knowledge
  - Deployment of advanced decision support tools
- Early warning signals of potential failures
  - Make operational decisions with actionable intelligence
- Improved asset utilization
  - major maintenance is performed less frequently on healthy assets
- Workforce efficiencies
  - Specific tasks at the right time
- Clear path to Condition Based Maintenance

Step 2 - Enable optimal management of space, power and cooling for the entire facility

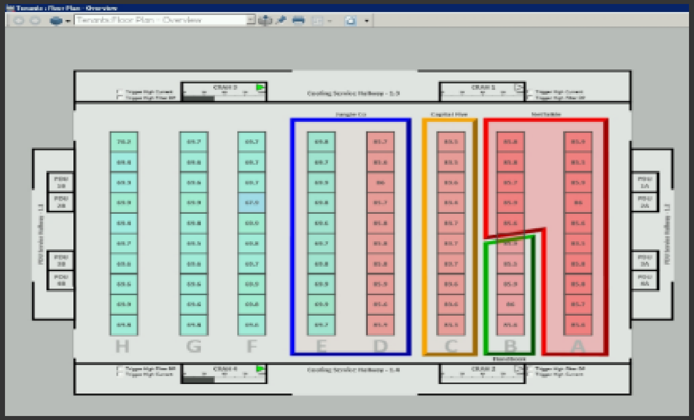
Energy optimization

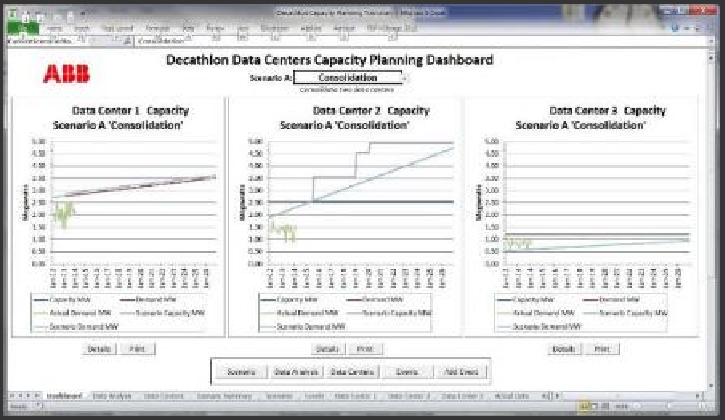
Monitoring, reporting and analytics of energy utilization including the optimization of the use of supply resources to meet the predicted consumption at minimum total cost.



Capacity Management

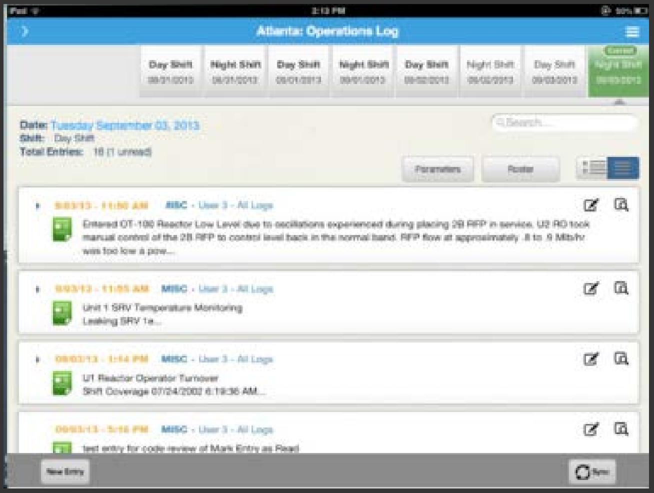
Optimize space, power and cooling capacity through intelligent placement of IT assets. Perform modeling and "what-if" analyses and automate and manage workflow processes.



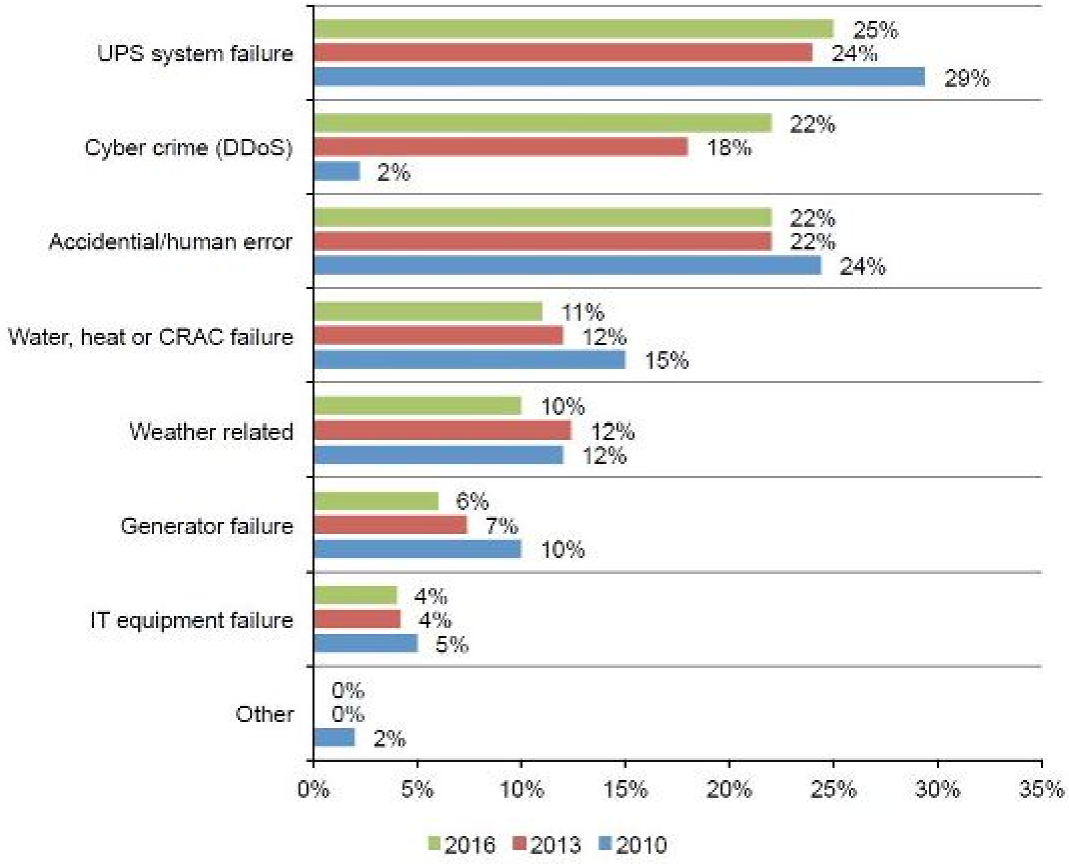


Operations Management

Provide a consistent, organized, and integrated approach to those activities that affect equipment configuration, system status, and data center operation.



Root Causes of Unplanned Outages



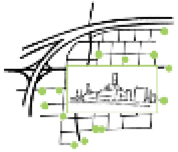
Poneman Institute Study January 2016

The Impact of Inefficient Work Execution

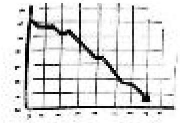
Managing complex operations,
there is no room for
compromises or short cuts

Work crew safety

Compliance, Audit Reporting



Company reputation

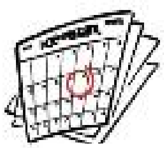


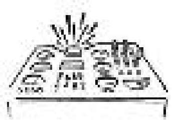
Overall system reliability

When Operations Management processes are weak …

Rely on human experts to pull everything together in high pressure work environment

Supporting Data Cente
activities online
and during outages



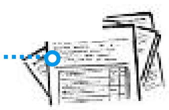


Equipment
configuration
control for
worker safety

Gathering field
information for
timely
Decision
making

Needed
data in
multiple
systems &
formats

Tracking
operations
status to
regulatory
requirements



Logging
operation
activities

The Value of an Operations Management Solution

Improve worker safety, equipment performance, work effectiveness, and regulatory compliance

Know that worker safety is not compromised while increasing plant efficiency

Know that the work is done right with quality and safety

Know that your plant is operating at peak performance

Operations Management
Features and Benefits

Key Features

- **Clearance** – assists in implementing, controlling, and executing a plant's lockout procedure
- **Operator Rounds** – automates the tasks of collecting, storing, and analyzing equipment operating data
- **Narrative Logs** – records and qualifies events which occur during an individual's shift watch
- Notice of Change (NoC) – manages the complete life-cycle of an organization's NoC process
- **Mobile Logbook** – allows desktop log entries and associated plant data to be transferred to, and accessed on an operator's mobile device, along with providing more timely access of plant activities to enterprise level decision makers

Key Benefits

- Worker Safety - meet safety standards for the workers, plant and environment
- Plant Reliability - extend asset life, preserving plant integrity and configuration
- Productivity - do things once, do things right – the first time
- Communications and efficiency - Improves decision making with ease of access to information across all key plant personnel - and not only subject matter experts
- Governance / Compliance - ensure public and stakeholder confidence, ensure regulatory compliance and create an environment of continuous improvement
- Costs – reduce costs through effective issue prioritization and leverage performance improvements to processes and equipment

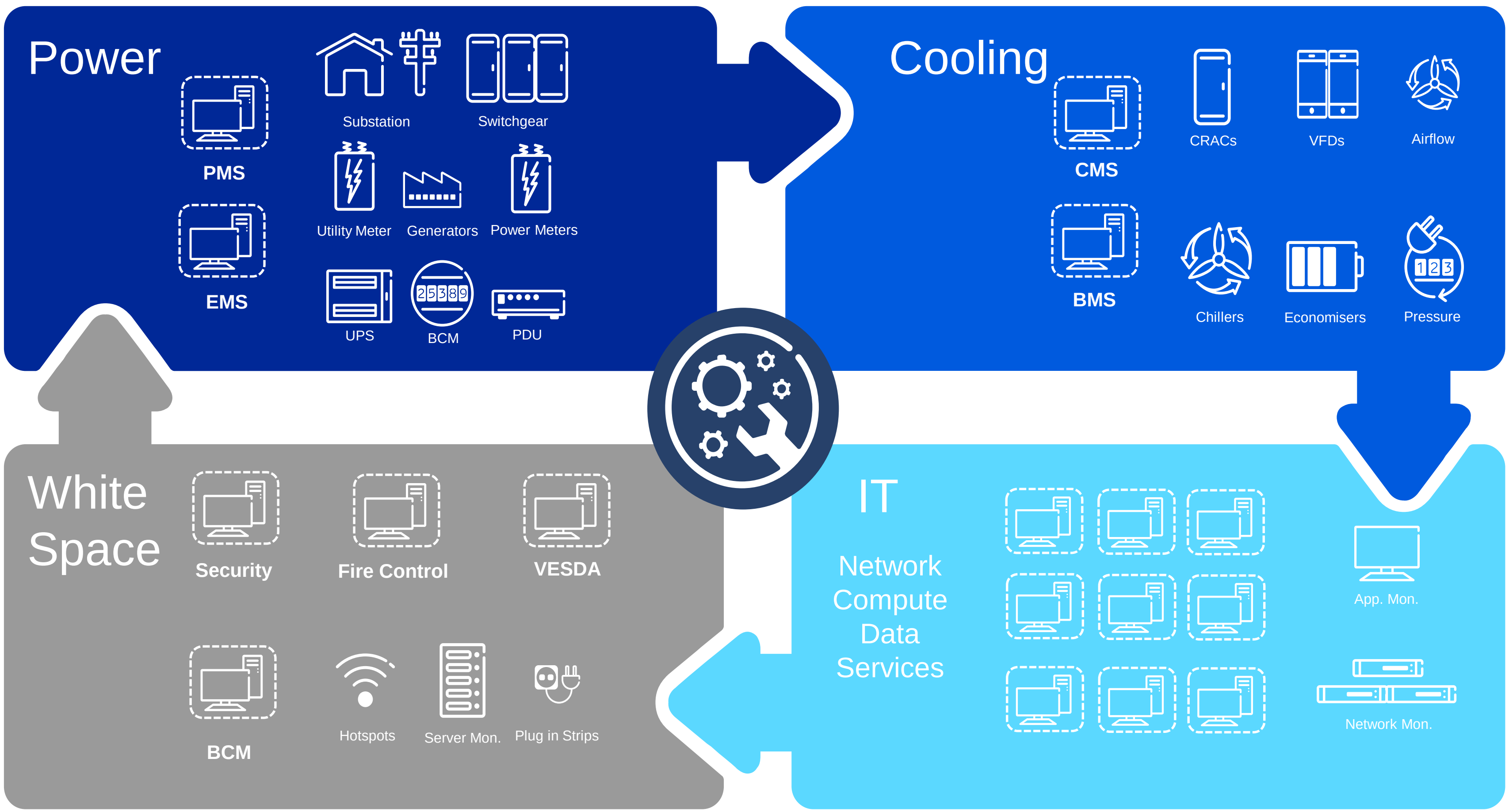
Key Benefits: Operations Management

Improve worker safety, equipment performance, work effectiveness, and regulatory compliance with comprehensive Operations Management

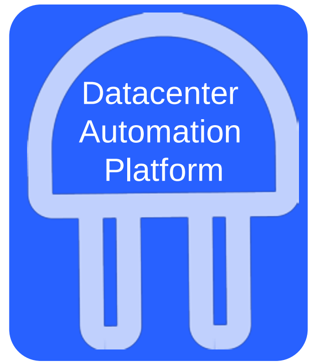
Top benefits	How Operations Management helps
Improved workforce safety	Automate Permits to Work. Ensure safety checks actually performed and consider the conditions.
Reduce shutdown duration	Efficient turnarounds with optimized tagging to eliminate overruns and minimize downtime
Empower your workforce to make better decisions	Availability and visibility of key plant data, functional logs, shift turn-over information and regulatory requirements
Improve consistency of work	Operations processes are being followed consistently while providing tools and templates which adjust to suit work conditions.
Improve process efficiency	Information system integration for plant data management and correlation of plant activities
Improve equipment Performance	Higher quality information and trends showing equipment status and operational history

Step 3 - Establish full IT workload management

The industrialized data center
Fully integrated facility and IT



The industrialized data center
Fully integrated facility and IT



Aggregate. Analyze. Hypothesize. Automate.

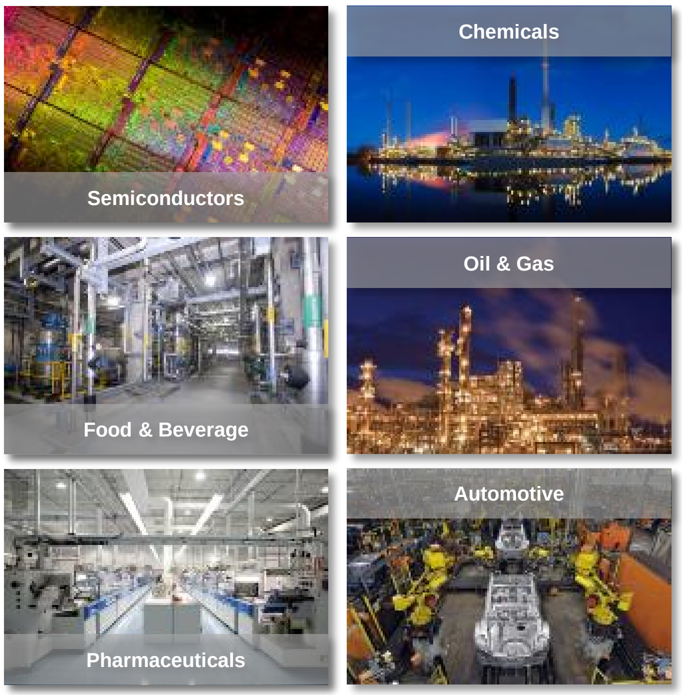
Automate.
End-to-end intelligence.

Collect data into one place.	Get end-to-end insight.	Simulate possibilities.	Put into action.
Aggregate for full spectrum of machine knowledge. Full transparency.	Analyze. Real-time KPIs and benchmarks. Data visualization.	Ask what-ifs. Create business cases. Capacity planning.	Decouple data and infrastructure. Optimal utilization. Repeatable. Auto-scaling.

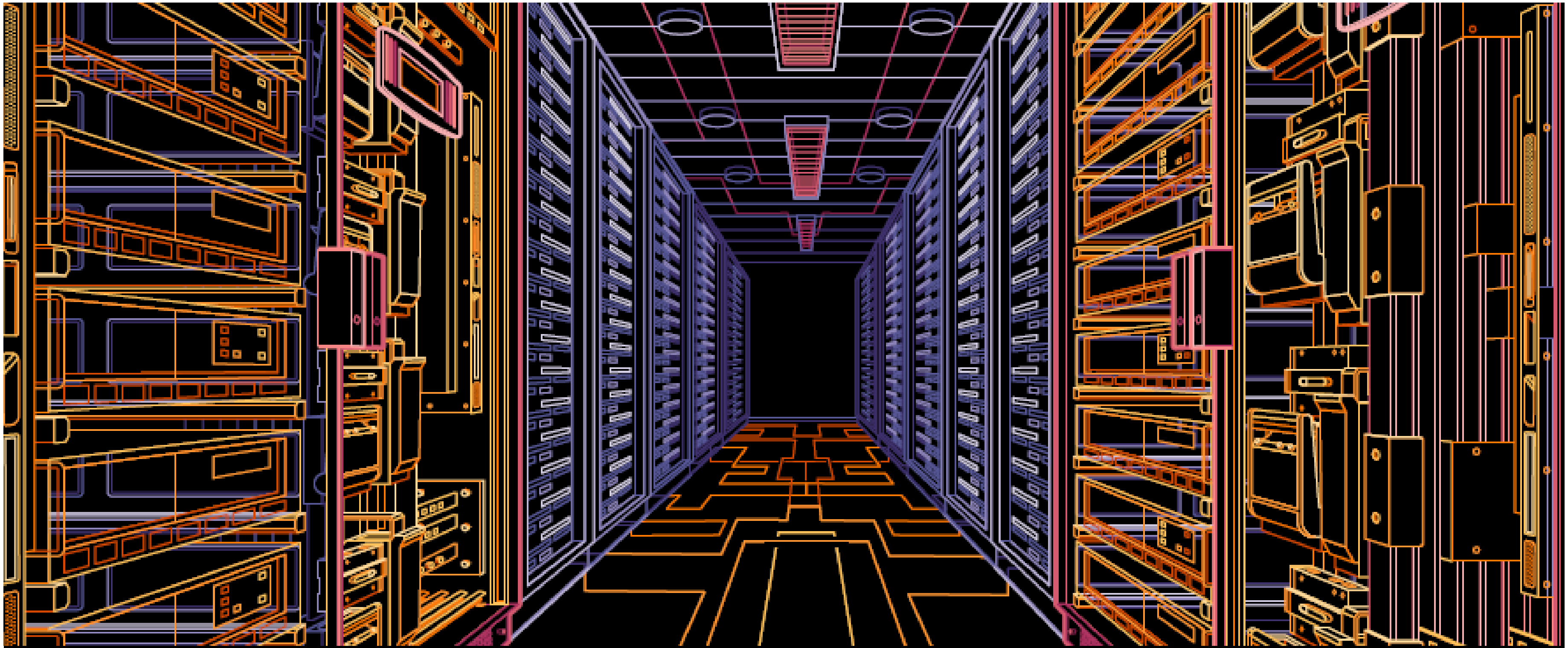
Speed of business goes from weeks/months to minutes/hours – with total governance.

ABB

Conclusion:
Learning from other industries is essential



"This really is an innovative approach, but I'm afraid we can't consider it. It's never been done before."



Jamie Ritter, ABB Power Grids, Channel Manager, Dry-type Transformers

Transformer design enhancements

Transformer considerations for data centers
Keys to proper transformer selection

- What is the installation environment
  - Will the transformers be located indoors or outdoors
  - Are there environmental concerns, sensitive areas – close to water
- What is the application
  - Transmission or Distribution step down
  - Secondary unit substation
  - VFD / VSD isolation transformer
  - Rectifier input transformer
  - General purpose distribution
- Are there loss evaluations (A&B Factors)
  - What is load profile
  - What is cost of energy
- Are there dimensional or weight restrictions
- Are there any other considerations

Transformer considerations for data centers
Typical locations of transformers in data centers

1

- Substation
- Transformers
- Medium-voltage switchgear
- Generators
- Power quality assessments
- HV UPS
- Low-voltage switchgear

2

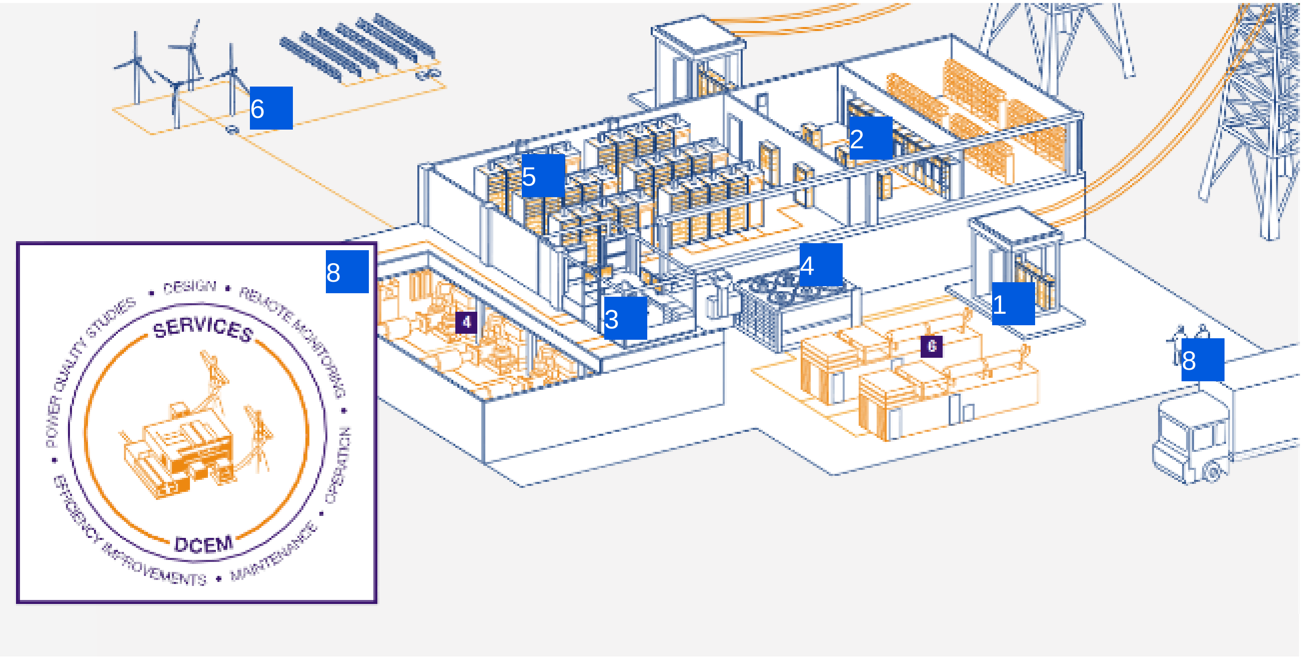
- Isolation transformers
- Input transformers
- Rectifiers
- UPS

3

- Internal distribution transformers

4

- HVAC solutions
- High-efficiency motors
- Low-harmonic variable frequency drives / inverters



5

- General Purpose
- UPS
- Intelligent power distribution units
- Remote power panels

6

- Power generation
- Step up and collector transformers
- Isolation transformers

8

- Data center services
- Remote monitoring

Transformer considerations for data centers
Distribution transformers – liquid or dry?

Flammable / Non-Flammable

Environmental Considerations

Integrated Solutions

Lead-times, Product & Drawings

Complexity of Coordination's

Additional Containment

UL, FM, NEMA, ANSI, IEC, etc.

Efficiencies

Maintenance & Commissioning

ABB

Transformer considerations for data centers
The simple difference

Oil-filled Transformer

Uses **OIL** for main dielectric and cooling media

Dry-type Transformer

Uses solid insulation materials for main dielectrics and natural **AIR** for cooling

Transformer considerations for data centers
Key feature advantages

Oil-filled	Feature	Dry-type
✓	Size & Weight	
✓	Initial Cost	
✓	Losses/Efficiency	
✓	Noise	
✓	Overload capability	

Transformer considerations for data centers
Location considerations

- Typical convention
  - Dry type inside
  - Liquid filled outside
- Reality is that dry type are used outdoors and liquid filled are used indoors
- High temperature dielectric fluids are classified less flammable
  - Additional fire suppression systems may be required
- Liquid filled units sometimes leak
  - Additional fluid containment may be required

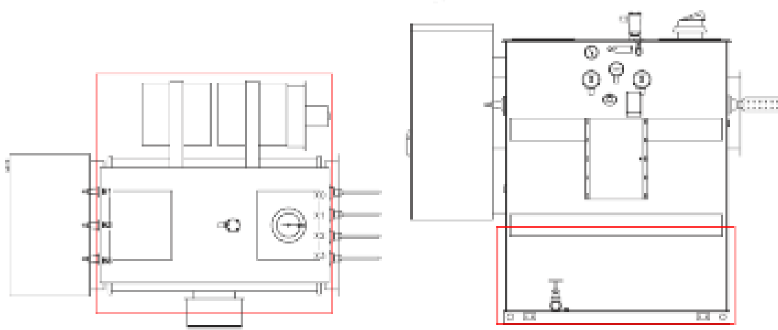
Transformer considerations for data centers
Location considerations

- Dry-type aren't restricted to indoors and liquid filled aren't just outdoors
- Advantages for locating units outside
  - Reduce HVAC costs
  - Reduce floor space
  - Reduce utility bills
- Disadvantages for locating units outside
  - Adds cost of bus duct
  - Can create voltage regulation issues for sensitive equipment, across the line motor starters
  - Increased security for MV outside

Transformer considerations for data centers
Location – costs of containment

Primary Containment

- NEC® requires containment for all indoor liquid-filled transformer applications



Secondary Containment

- The EPA mandates that secondary containment is needed for oil storage of transformers in a combined volume of 1,320 gallons
- A 2000 KVA liquid filled indoor transformer has roughly 550 gallons of Natural Ester Fluid

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Transformer considerations for data centers
Transformer oils

Mineral Oil

- Non-flammable, but combustible
- Flash point of 170°C
- Lowest cost transformer technology
- Long history of being safe

Ester Oils

- Non-flammable, but still combustible
- Flash point of 330-360°C
- 98% biodegradable seed oil (when unused)
- Not suggested for indoors

Dry

- Non-flammable AND non combustible
- No flash point (nothing to ignite)
- Only technology suited for indoor applications

Increased safety

Transformer considerations for data centers
Transformer oils continued

- Burnable materials for 1000 kVA oil and dry distribution transformers

Material Type	Oil	Dry
Solid Burnable	160 lbs	500 lbs
Liquid Burnable	**3,300 lbs**	**N/A**
Total Weight	**3,460 lbs**	**500 lbs**

- In case of external fire:
  - Heat released: Oil transformer = 7 x Dry transformer
  - Dry Benefits:
    - Minimal combustible fuels
    - Self extinguishing / does not burn easily
    - Increases safety for people and property

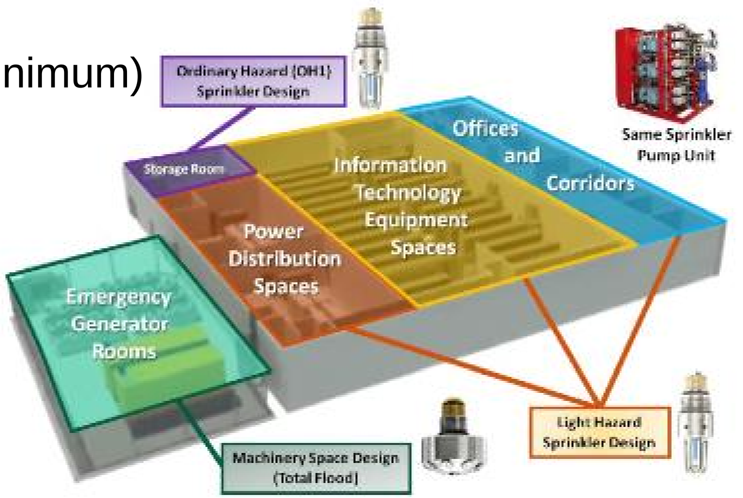
Transformer considerations for data centers
NEC insulation exceptions for installations

- Per NEC, dry-type transformers are exempt from fire rated vaults due to their insulation class of $\geq$ 155ºC and lack of combustible material
- Oil immersed units are subject to vaults reinforced by 4in thick concrete, minimum total kVA within electrical rooms, extended space separations of equipment, fire resistant barriers and automatic fire suppression systems
- Per NEC, for outdoor applications, liquid filled substations must comply with Type 1 & 2 fire rated building construction (1-4 hour fire resistance) and meet confinement distances either by construction code or by the listing of the liquid

ABB

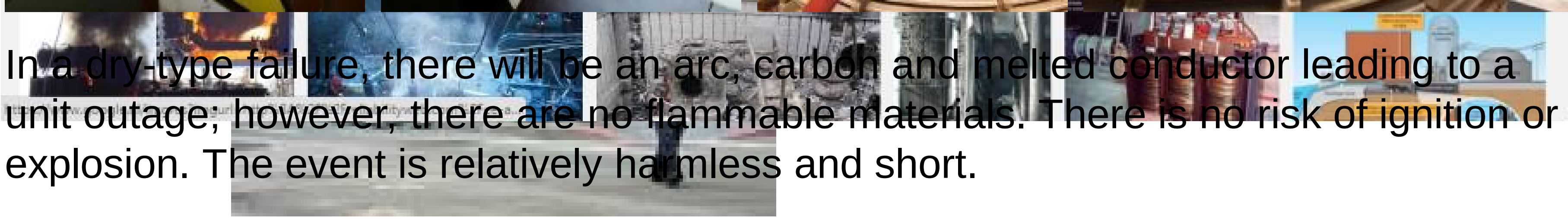
Transformer considerations for data centers
Location – infrastructure costs for indoor

- Wet pipe systems (code minimum)
- Dry pipe systems
- Pre-action systems
- Water mist systems
- Raised floors
- Complex smoke detection



- Combustible liquids require extensive & costly fire suppression systems
- The power distribution rooms in Datacenters are considered Tier II hazards and require extensive containment
- Determined by the impact, special fire walls and vaults may be required

Why the growing popularity for dry-type technologies?
Failure modes



In a dry-type failure, there will be an arc, carbon and melted conductor leading to a unit outage; however, there are no flammable materials. There is no risk of ignition or explosion. The event is relatively harmless and short.

Why the growing popularity for dry-type technologies?

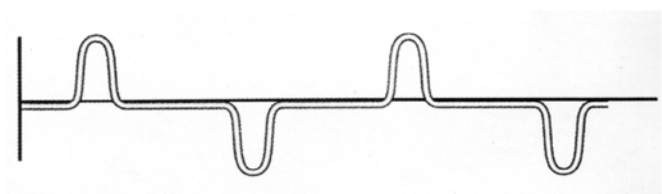
Oil leaks, spills and theft

Transformer design considerations in datacenter applications

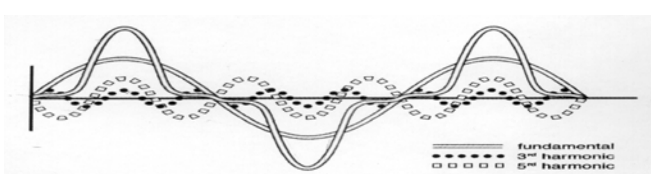
Transformer considerations for data centers
Application considerations - Harmonics

Voltage or Current Waveform for linear loads
(Sine Wave)

Current Waveform of Switching Power Supply

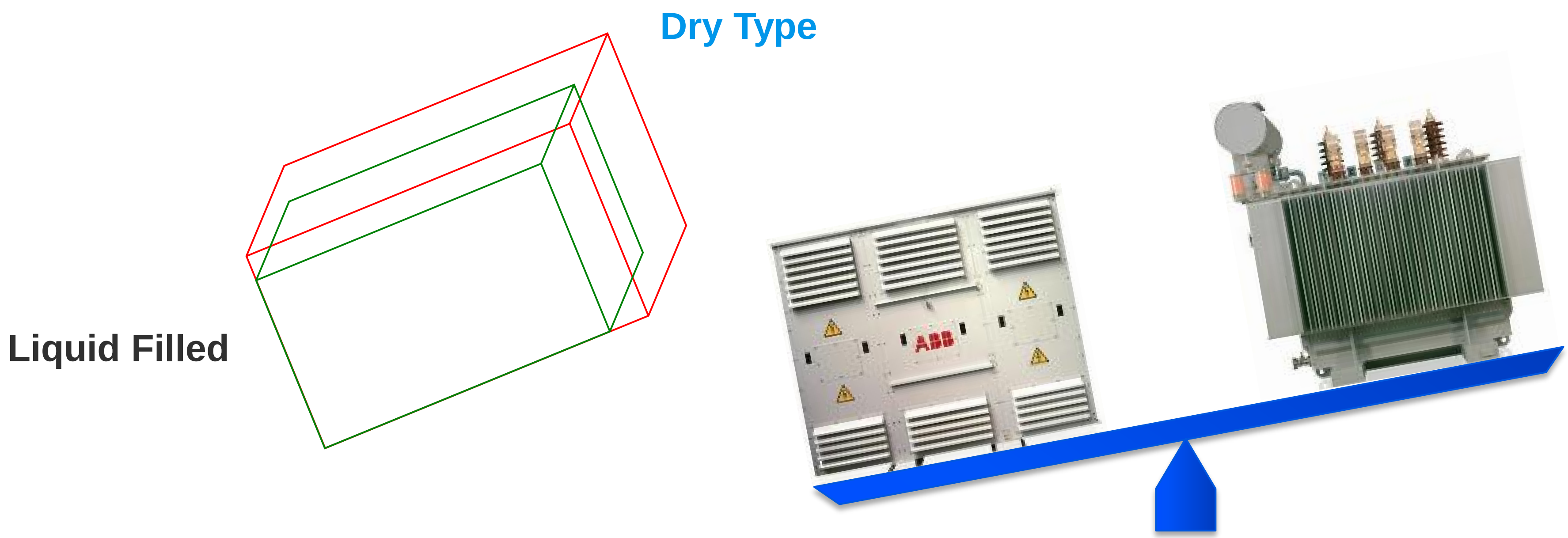


Non-linear Current and its fundamental plus 3rd and 5th harmonic component



- Static rectification devices - AC to DC power conversion devices - current is drawn only during a controlled portion of the waveform.
- Single phase sources include computers and lighting ballasts.
- Three phase sources include motor drives and uninterruptible power supplies.
- Harmonics are fed back into the power system from these loads.
- Harmonic can drive higher K factor ratings
- Harmonics can create neutral grounding issues

Transformer considerations for data centers
Size and weight considerations



Dry-types are generally larger and 15% - 20% heavier than liquid-filled units

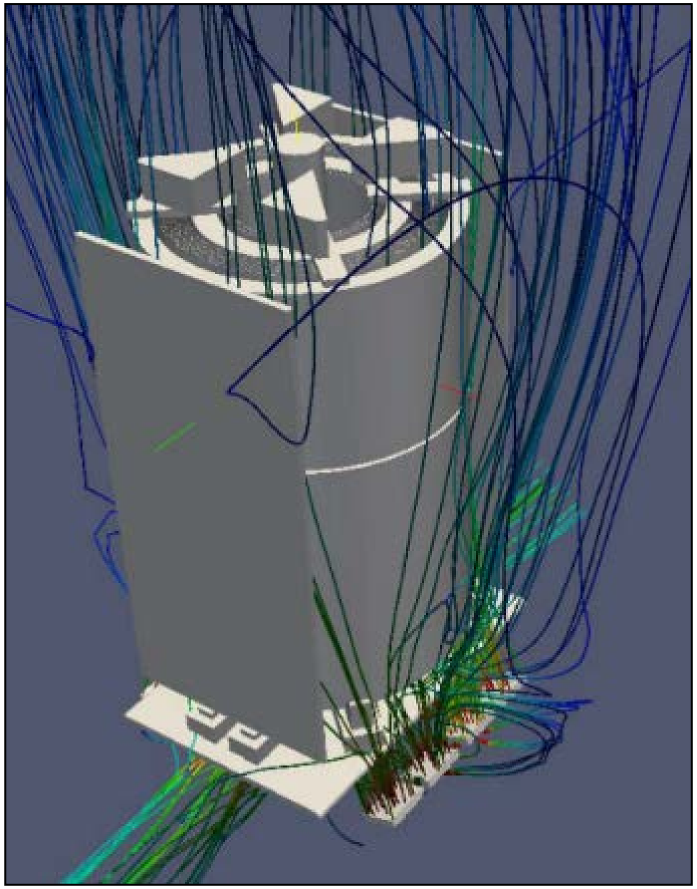
Transformer considerations for data centers
Sound levels

3P Power (kVA)	Dry-Type AA Sound Level	Liquid OA Sound Level
1000	64 dB	58 dB
2500	68 dB	62 dB
5000	71 dB	65 dB
7500	75 dB	67 dB
10000	79 dB	68 dB
15000	82 dB	70 dB

All of these are below industry standards

Newer technologies and materials can be used to lower sound levels for both types of transformers

Transformer considerations for data centers
Overloading



- Loading beyond the limitations of either liquid or dry units can shorten the insulation life of either type of transformer, but can be made possible under certain conditions
- Forced air (FA) cooling is a common accessory that can increase the loading of both types of transformers.
  - 25% max for liquids, 50% max for dry medium size transformers

100% 125% 133% 150%

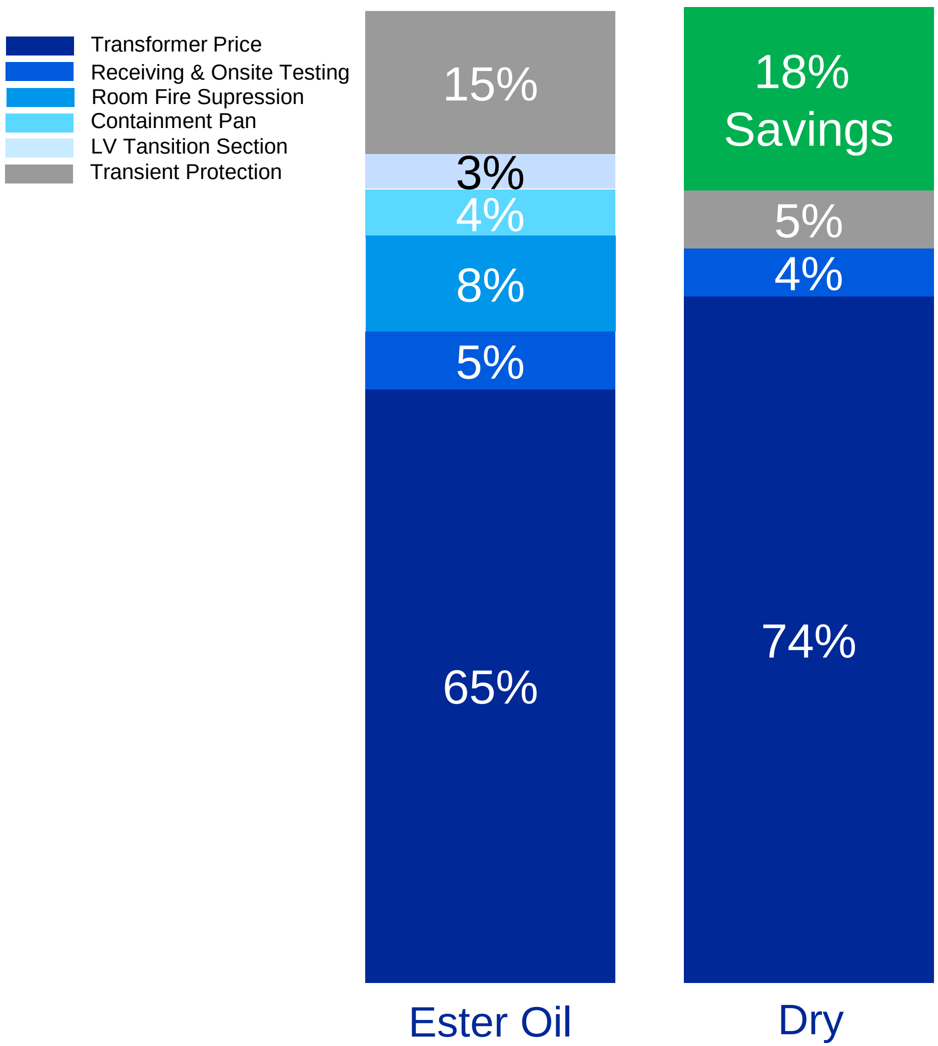
Transformer considerations for data centers
Transformer maintenance

MAINTENANCE	FREQUENCY	OIL	DRY
Oil Level	**monthly**	YES	NO
Porcelain Insulator Cleaning	annually	YES	NO
Surface Cleaning	annually	YES	YES
Connections (Tighten)	annually	YES	YES
Painting State	annually	YES	NO
Oil Analysis (Dielectric Test)	annually	YES	NO
SILICAGEL (Verify and Replace)	annually	YES	NO
Accessories to Check			
Pressure Guage/Relief	Monthly	YES	NO
Buzcholz	annually	YES	NO
Over-Pressure Relay	annually	YES	NO
Oil Level	annually	YES	NO
WTI	annually	YES	YES

Transformer considerations for data centers
Commissioning

- Dry-type transformers are less complicated to commission. They are shipped and stored fully assembled and have no major pre-commission test requirements
- Liquid immersed units require consideration for the liquids whether it is in the lifting, or in onsite filling, oil testing, or pre-commission testing
- Additional assembly may be required with liquid filled units due to disassembled radiators and / or containment pans. However, if needed, dry-types can be disassembled in place and moved as component parts

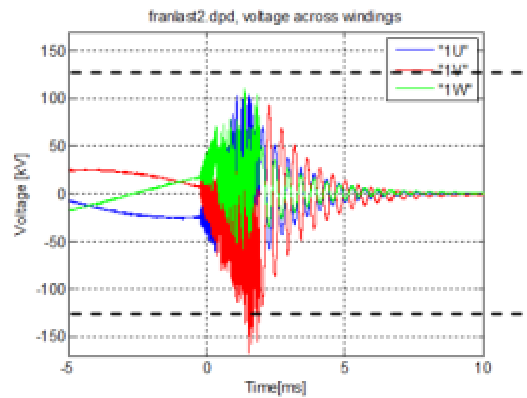
Why the growing popularity for dry-type technologies?
Total ownership costs; case study



- Tier One Data Center
  - 42, 1.8 MVA, 13.8 kV transformers, indoor & modular/skidded application
  - Required transient protection because of load switching with VCB’s

Design / product considerations for contending with VCB's

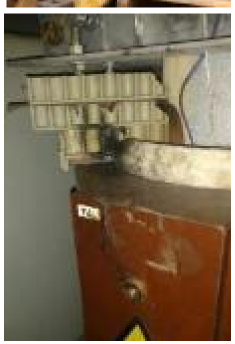
Transformer considerations for data centers
Vacuum circuit breakers – switching & bypass



- Vacuum circuit breakers can create over voltages on inductive equipment
- This is a system issue that needs to be analyzed taking the breaker device, cable, distance between devices and transformer into consideration
- Factor into design up front
- Results are breaker manufacture specific
- Add protection only when and where needed

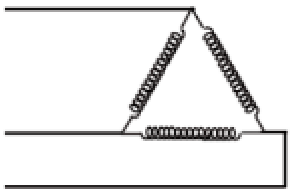
Transformer considerations for data centers
Switching transients - Pperceptions of what's happening



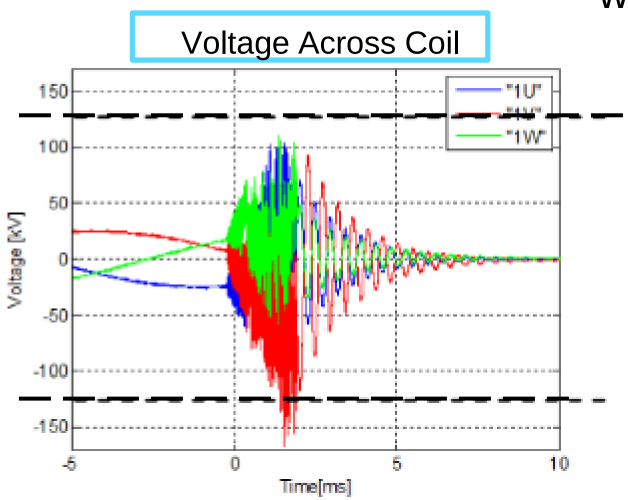
- When a breaker is switched…
- The transient recovery voltage (TRV) may cause a re-strike in the breaker and send fast transients into the transformer
- OR, the opening of the breaker traps currents causing voltage amplification due to ferroresonance
- OR, the wide frequency sweep of switching transients matches the natural frequency of the transformer windings causing voltage amplification due to harmonic resonance (IEEE Std C57.142-2010)
- OR, the fast frequencies themselves prematurely age the transformer insulation materials

Transformer considerations for data centers
Understanding the problem (worst test case)

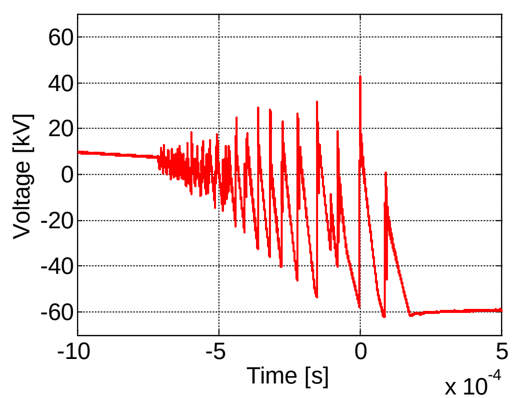


No protection

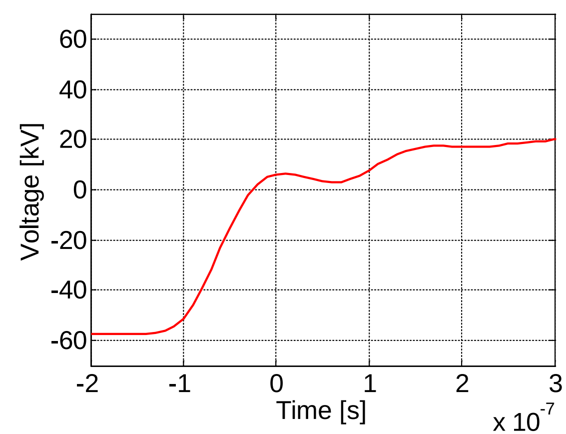
- The rise time (Δt) is less than 0.1 μs and the rate of rise is about 600kV/μs
- 10x faster than impulse wave and occurs 30+ times in ~ 0.5 ms
- Overvoltages also stress the *middle* of the winding; opposed to a lightning impulse that stresses the external and ends of the winding



168 kV peak terminal voltage on 125 kV BIL design

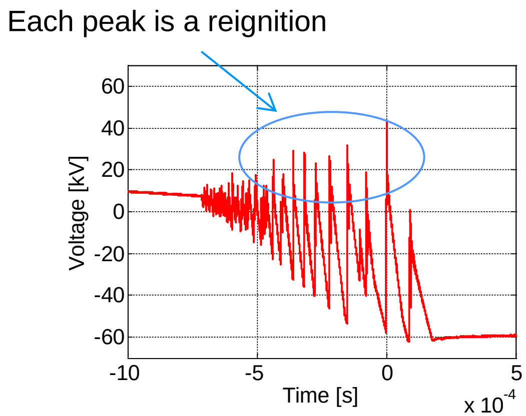


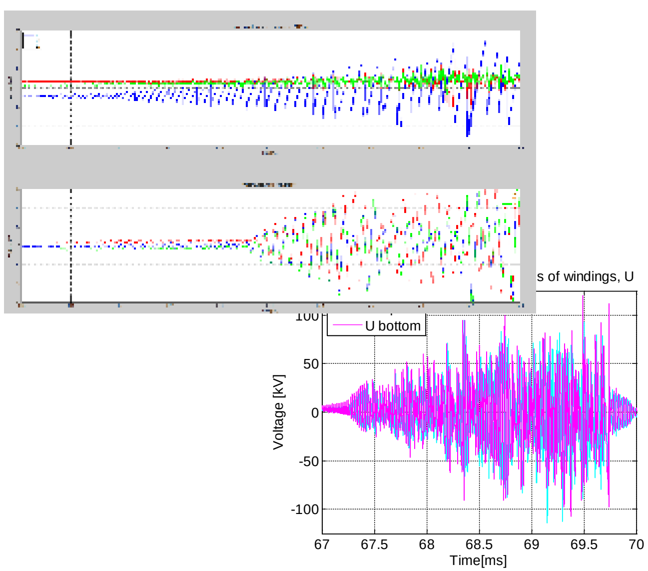
Zoom in (10^{-4})



Zoom in (10^{-7})

Transformer considerations for data centers
Two types of winding stress; must protect from both

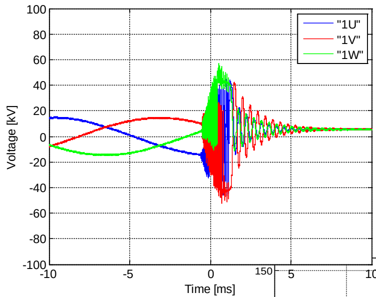




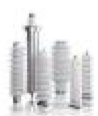
- Voltages spikes due to reignitions
  - Occurs when the voltage potential across the poles of the circuit breaker are still high enough to cause a spark across the terminals
  - Chance to occur during every switching event at load (seen on previous slide)
- Voltage amplification due to resonance
  - Occurs when input voltage matches one of the natural frequencies of the transformer windings
  - Caused by a resonance between the transformer's short circuit inductance and cable capacitances on the load side of the breaker
  - Rare event but needs to be protected from for a total solution

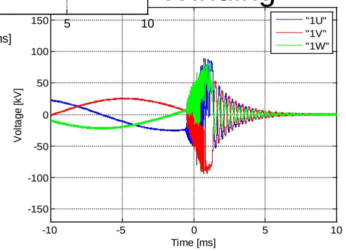
Transformer considerations for data centers
Current market solutions

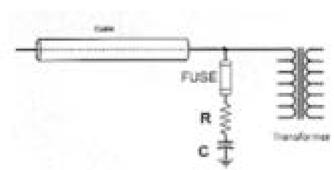
Voltage to Ground



Voltage Across Winding







Line surge arresters

Not enough protection

- Reduces peak overvoltages to ground, but overvoltages inside winding can still be very high

Field recorded failure cases

RC snubber circuit

+$20 kUSD to total price

+2' box extension in any direction placed

Does not limit overvoltages to controlled levels

Monitoring/maintenance required

However, <u>no</u> field recorded failure cases

Liquid hardened transformers

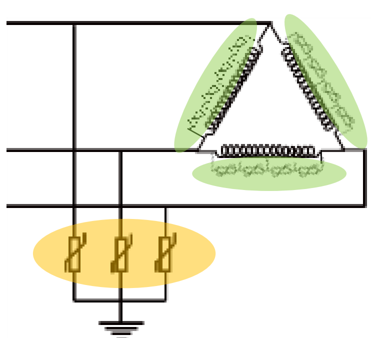
Higher line-end capacitance and BIL resistance

Survival not guaranteed in all system configurations

Arcing may still occur, creating gas

Recorded field failure cases due to VCB switching

Transformer considerations for data centers
Current market solutions – ABB's TVRT™



- The TVRT™ uses strategic, proprietary arrangements of varistors to enhance ABB's vacuum cast coil technology
  - The varistors act as a surge limiter, preventing overvoltages inside the coil from growing beyond known levels
- With the peak voltage known, the internal windings are designed to withstand the transient
- This solution works in ALL system configurations because it prevents voltage rise

Coil varistors – limit internal voltage peaks to below winding insulation levels

Line surge arresters – limit voltage to ground stress

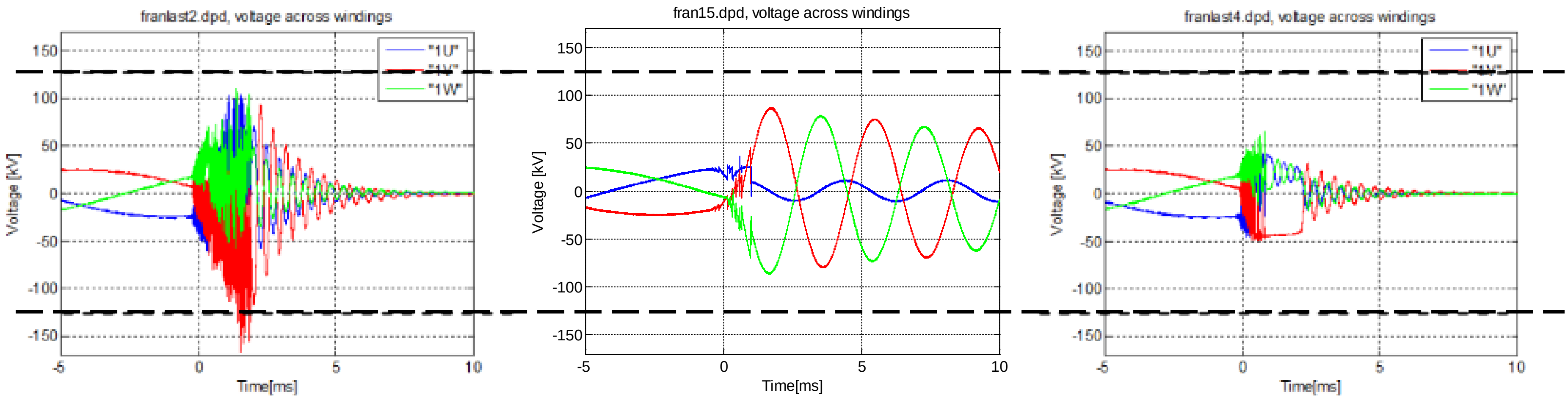
Transformer considerations for data centers
The ultimate solution – TVRT™

BIL of test transformer

No protection

RC snubber circuit (with internal resistors)

TVRT™



168 kV peak

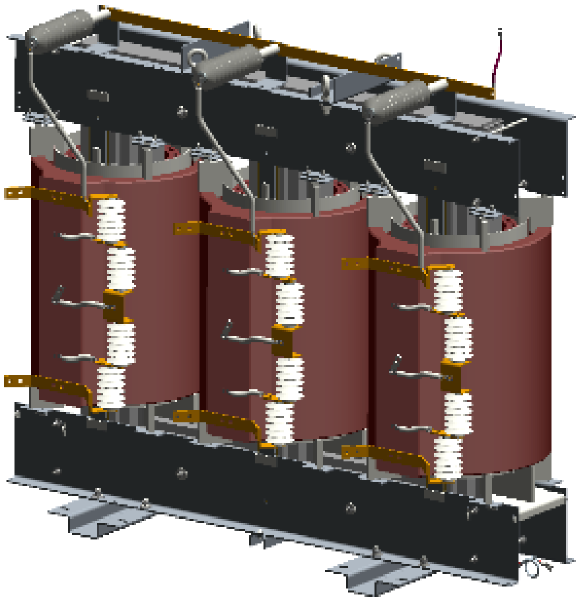
250 Hz oscillation,
85 kV peak amplitude

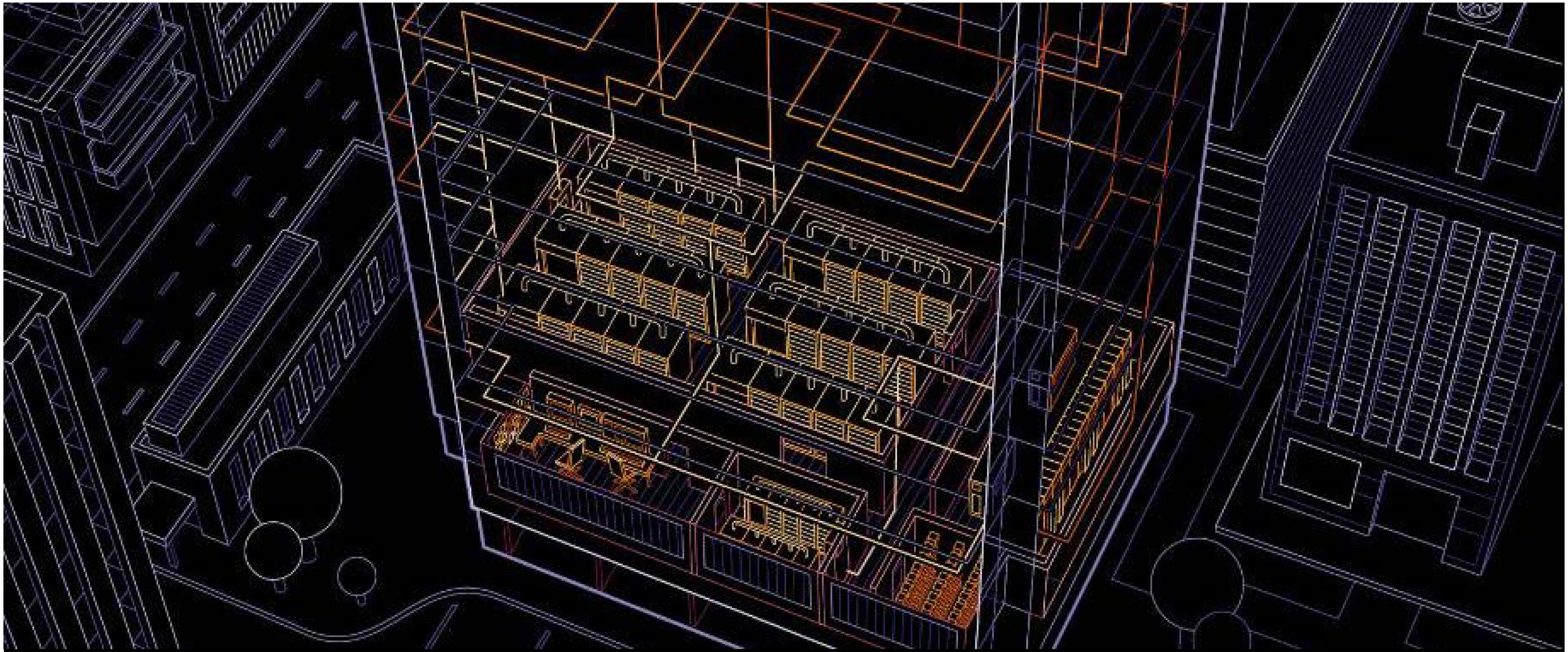
40 – 45 kV (hf transients up to ≈ 65 kV)

Worst case system switching results. All other variables held constant

Transformer considerations for data centers
TVRT™ in Summary

- **Benefits include:**
  - Fully Dry-type solution
  - Same enclosure sizes to unprotected SUS
  - Simpler and more robust than traditional “snubber” circuits (does not require the use of resistors or capacitors)
  - Solution requires no maintenance or monitoring and carries the same life expectancy as the transformer
  - Damage due to VCB interaction covered under standard warranty
  - Works in all system configurations; eliminates the need for system studies





Joergen Madsen

Benefits of the modular UPS to a data center

Data centers and UPSs
Why UPS?

Critical load requiring constant uninterrupted power
Mission critical applications require high power availability

Availability ⟷ TCO

Agenda

- UPS History
- Current UPS Topologies
- Market Drivers
- Technology Trends
- UPS Configurations & Architecture
- Application Trends/Future

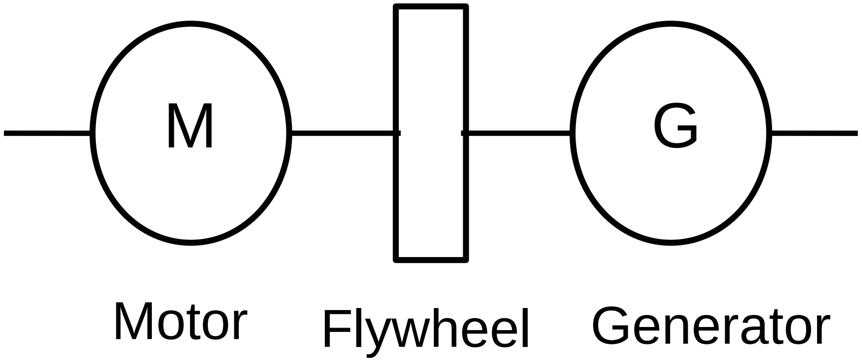
Data centers and UPSs
First UPS systems

Motor/generator set ~1950's

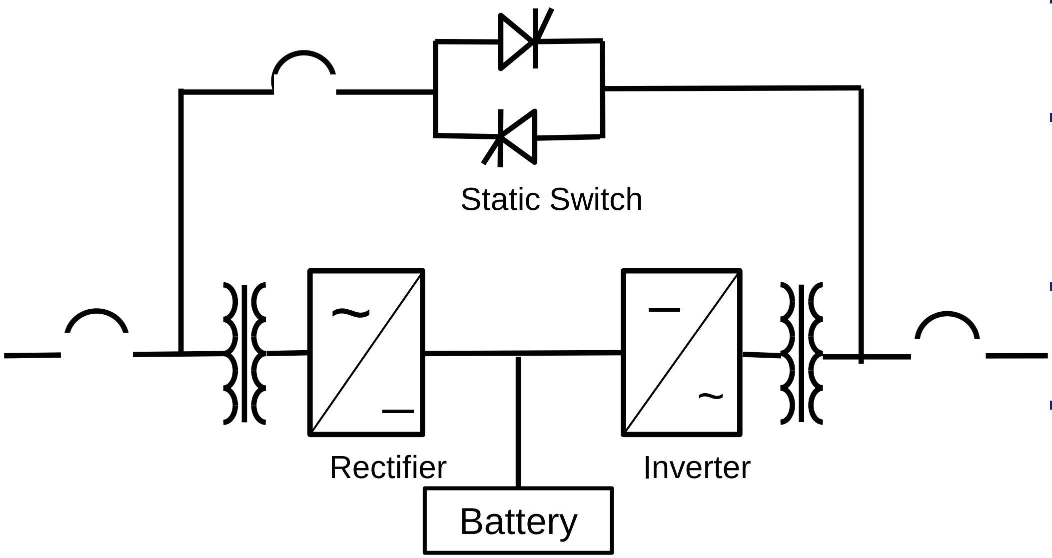
- Motor (DC or synchronous AC)
- Flywheel
- Generator

Electrical ▶ mechanical ▶ electrical

- Simple
- Reliable
- Inefficient
- Limited ride through times
- Still available today



Data centers and UPSs
Traditional North American UPS system



Transformer based double conversion UPS

Transformer based static UPS

- SCR rectifier converting AC to DC feeding inverter and charging Battery
- Inverter converting DC to AC generating clean AC power for critical load
- Energy storage, traditionally lead acid batter
- Static switch to support critical load with direct utility power in case of high overload or UPS failure (lately also utilized for economy mode operation)
- Transformers to ensure safe operating voltage for semiconductors (and provides galvanic isolation)

Market Drivers
Total cost of ownership (TCO) – drivers

U.S. Green
Building Council
(USGBC)

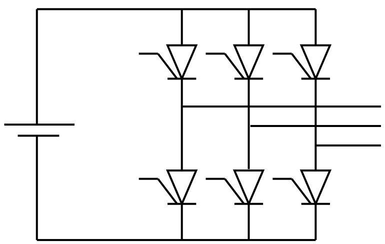
LEED
- **Platinum**
- **Silver**
- **Gold**

PUE..
WUE..
CUE...

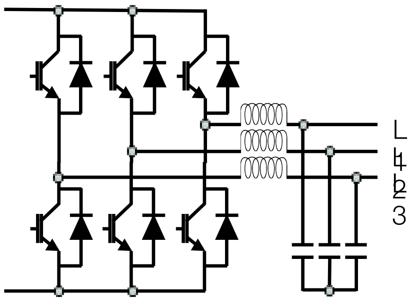
TCO drivers

- $$... bottom line
- Cost savings – eliminate losses
- Financial incentives
- Political
- Green profile
- Lobbying
- Legislation

Technology trends
Inverter - SCR -> IGBT topology



SCR based Inverter



IGBT based Inverter

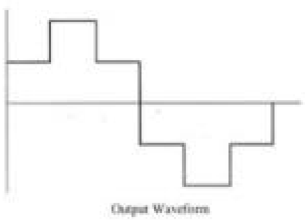
Static UPS SCR -> IGBT

- Higher voltage rating eliminates need for transformer
- Higher switching frequency allows reduction of filter size
- High efficiency
- PWM control -> excellent dynamic performance

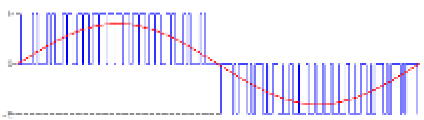
SCR

IGBT

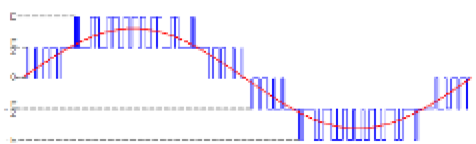
Step wave



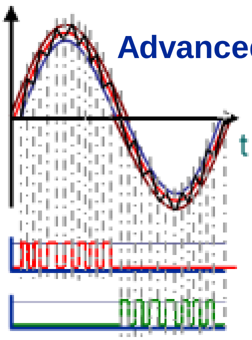
2-Level PWM



3-Level PWM



Advanced PWM

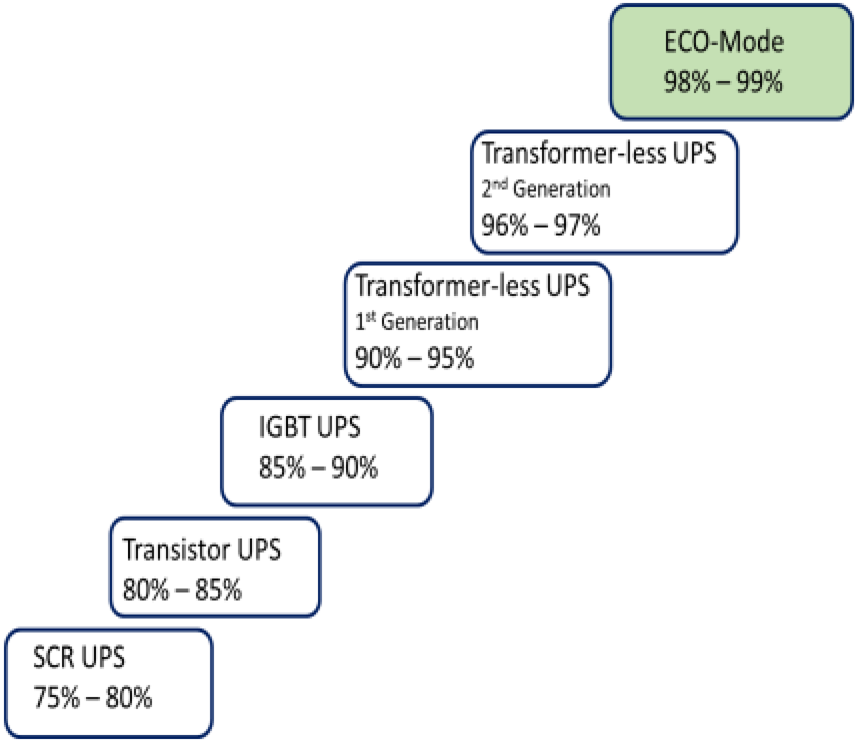


Technology trends
TCO – technology drivers

Technology drivers – history

- IGBT based inverter and rectifier
- Reduced switching and filter losses
- Online efficiency > 96%
- Efficiency optimized at typical load level
- Eco-mode efficiency up 99%

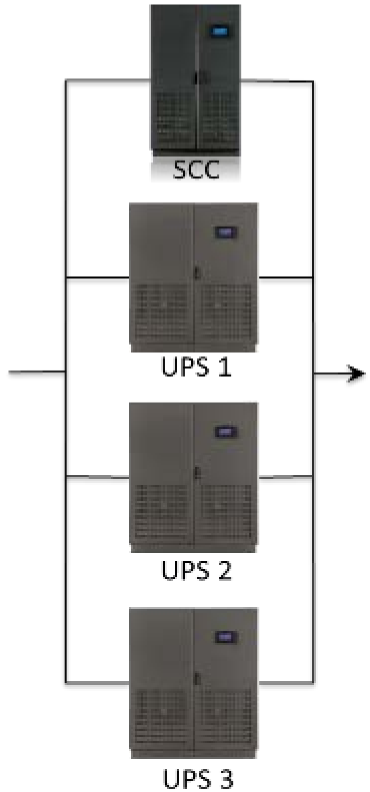
UPS efficiency – Eco-mode



UPS configurations and architecture

Availability is King!
No downtime requirement – parallel /redundant UPSs

UPS



Parallel UPS

Need for higher availability

- Continuous uptime
- Single → parallel configuration
- Parallel for redundancy or capacity
- N+1, N+2 …..
- 2(N+1) w/ STS or dual corded load
- Tier level classification

New modular UPS designs
Monolithic vs. modular – addressing CapEx

Monolithic (traditional) UPS Design

400kW UPS　　400kW UPS

400kW + 400kW = 400kW N+1

Modular UPS Design

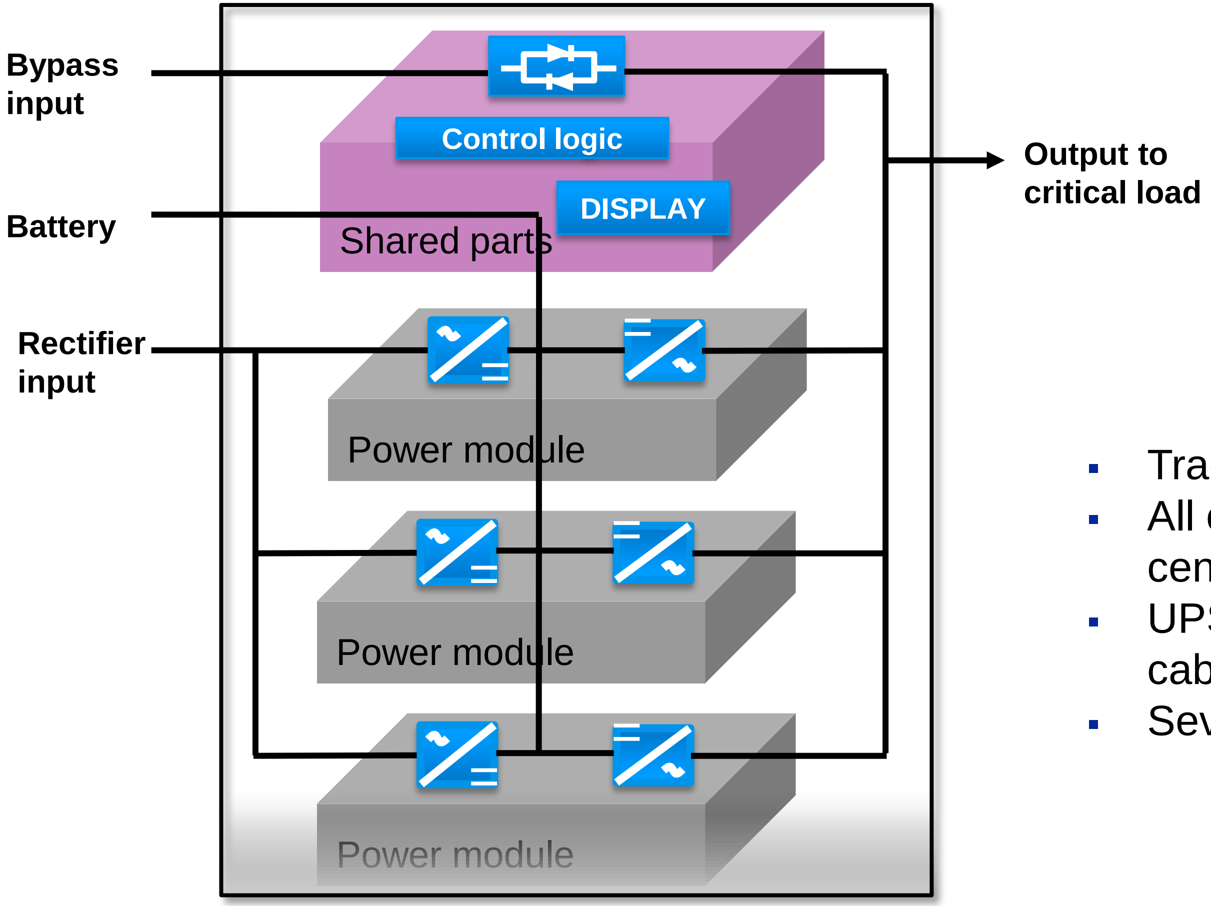
400kW N+1

Modular 5x100kW = 400kW N+1

Modular UPS designs

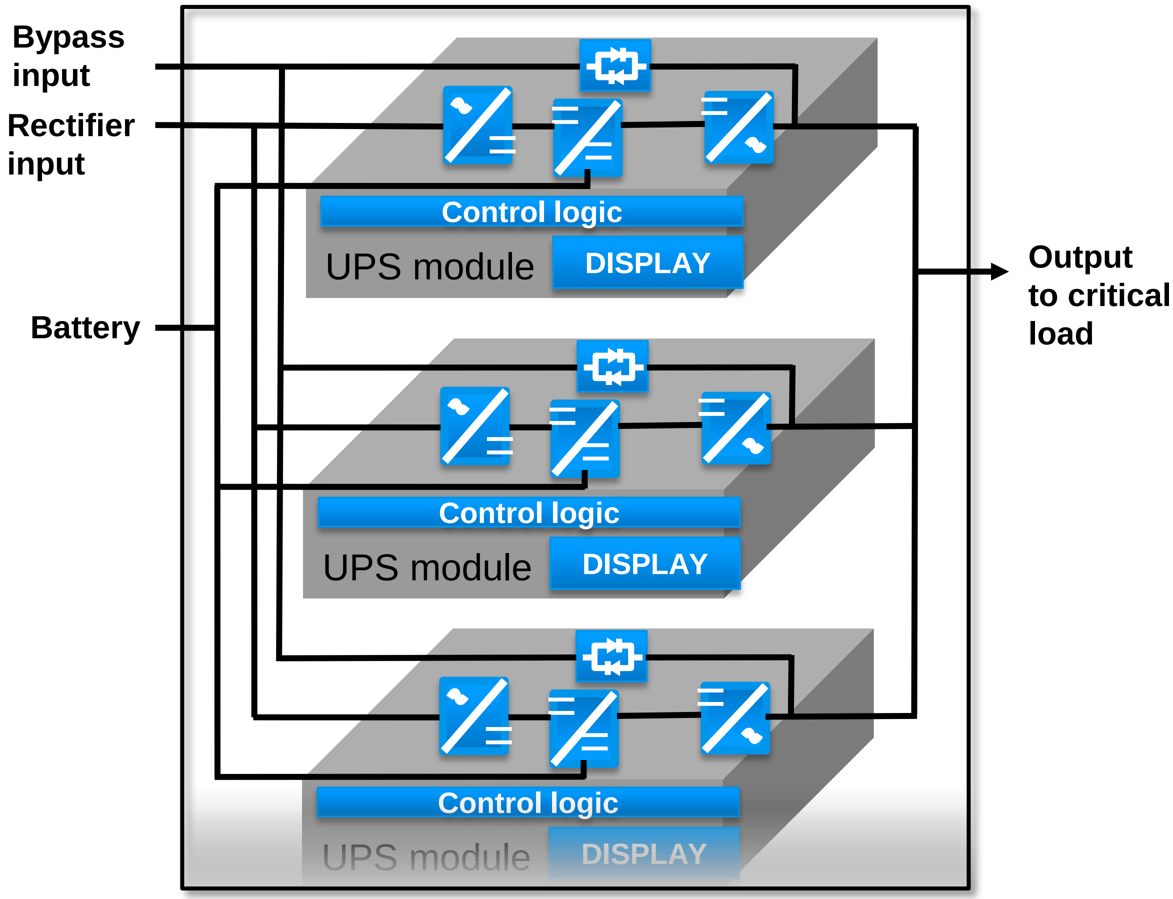
- Scalable – pay as you grow
- Rightsizing
- Eliminate stranded capacity
- Availability – integrated redundancy
- Serviceability – low MTTR
- Flexibility – easily scalable to fit current power/redundancy need

Modular UPS – centralized design
Centralized modular UPS



- Traditional modular UPS design
- All control logic, static switch etc., centralized in UPS frame
- UPS frame is system control cabinet (SCC)
- Several single points of failure

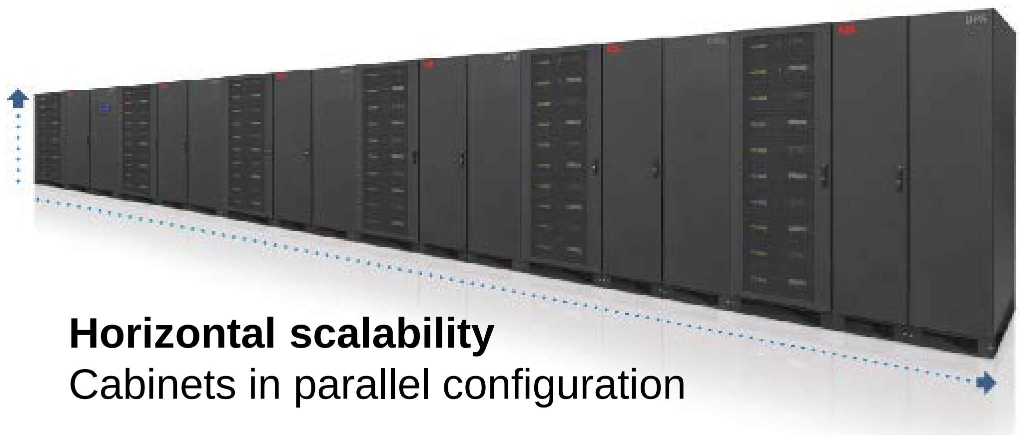
Modular UPS – decentralized design
Decentralized parallel architecture (DPA)



- All control logic, static switch etc., in each power module
- Active power module is a complete UPS
- Passive frame design
- High availability
- Eliminates single points of failure
- Perfect load sharing
- Any UPS can be the logic leader (multimaster system)

Modular UPS – decentralized design
Conceptpower DPA UPS

Vertical scalability
1 – 5 modules in one single cabinet



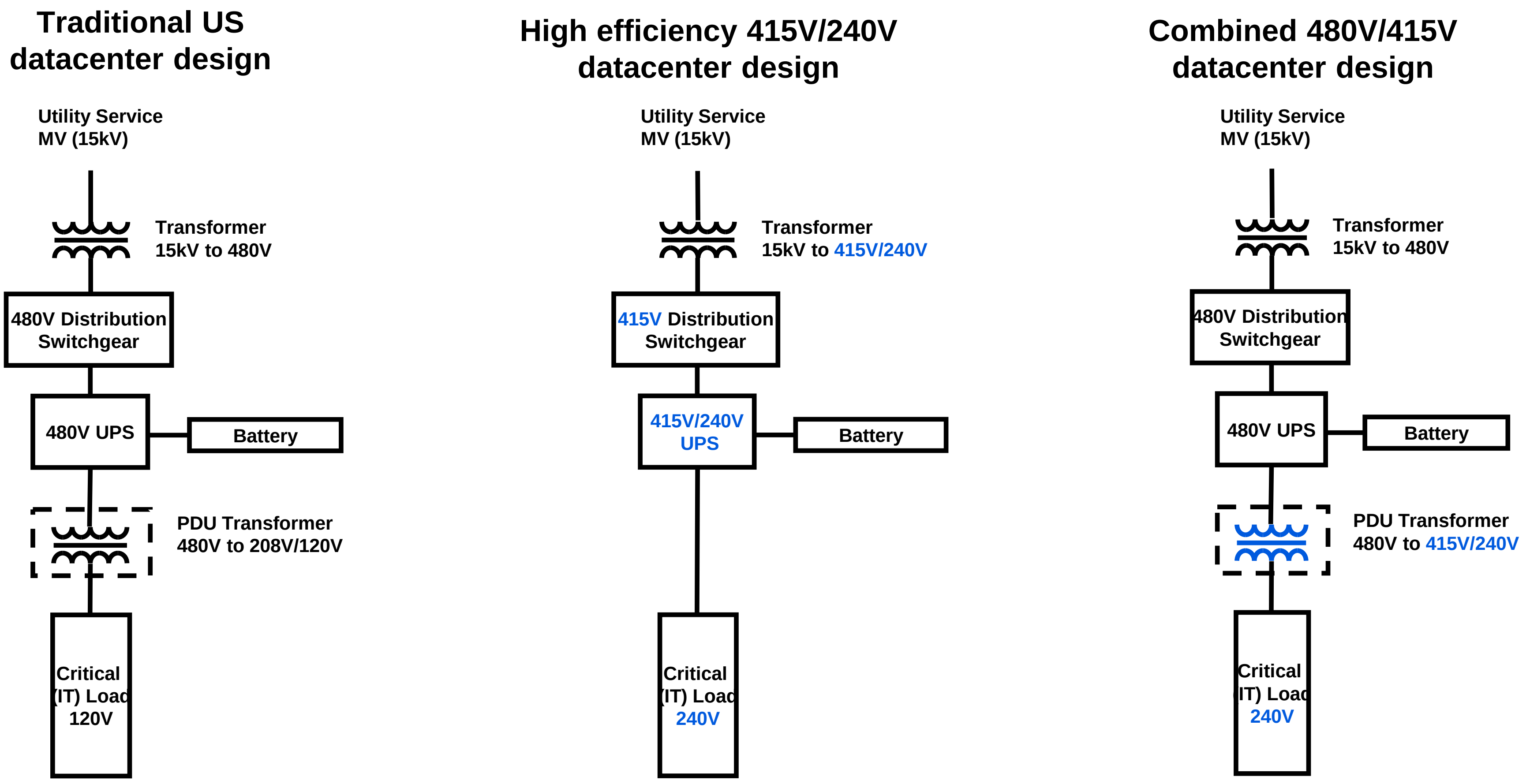
Horizontal scalability
Cabinets in parallel configuration

Parallel configurations

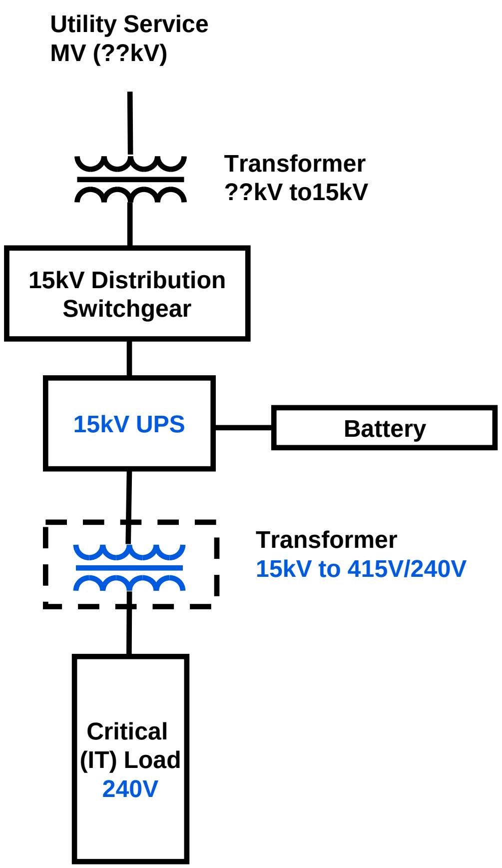
- Scalable – vertically and horizontally
- 100kW to 3MW, 480V
- Online-swap modularity (OSM)
- Serviceability – low MTTR

Applications trends/future

480V with 208V/120V distribution vs. 415V/240V



Medium Voltage UPS

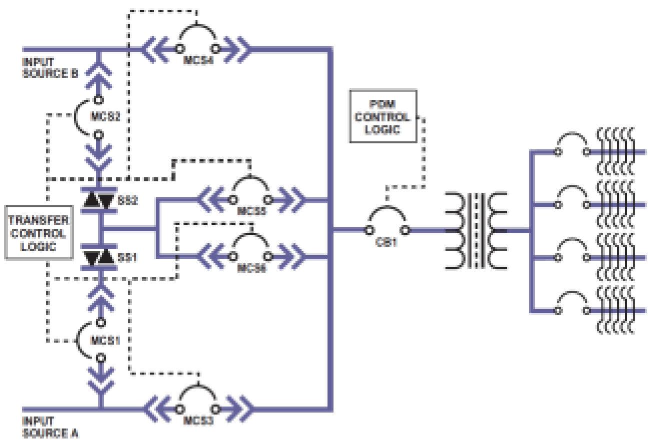


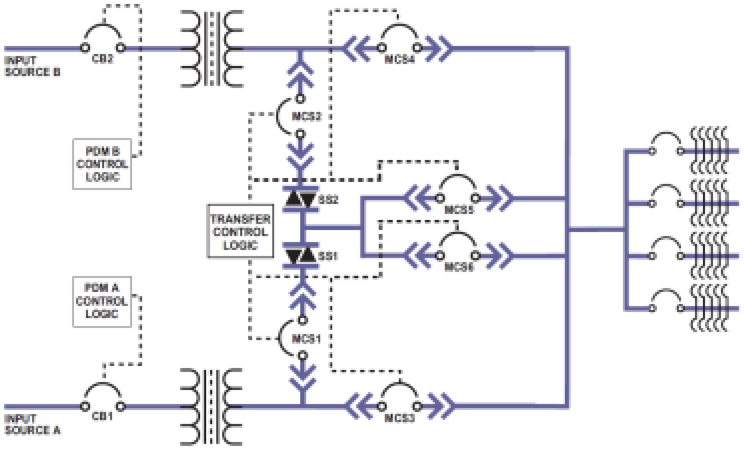
Summary

- Online double conversion with full VFI operation is still the dominating UPS design – primarily transformerless design, due to higher efficiency.
- After several years of efforts to increase efficiency, now up to 98% online efficiency with SiC based semiconductors, very little room for further improvement.
- Economy mode – the market has been very reluctant to adapt, and with very high online efficiency – limited gains.
- “Exotic” voltages and configurations not likely to gain significant traction – do not offer significant benefit over current solutions (code, hardware availability, and safety issues).
- Future (and current) focus on “Rightsizing” – solutions that can eliminate/limit stranded capacity – to lower Cap-Ex and maintenance cost – need for scalable solution that easily adapt to ever changing load conditions – flexibility is key.
- Trend towards increased use of MV UPS in hyper scale data centers, due to savings on installation cost.

Static transfer switches
Preventing transformer saturation

STS switching architecture
Cost/benefit analysis

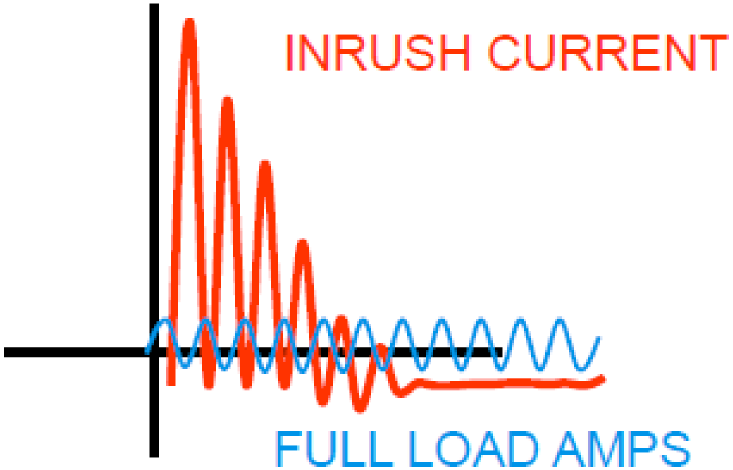




Primary side switching
Single downstream transformer
Smaller footprint
Lower initial cost
Potential downstream transformer saturation

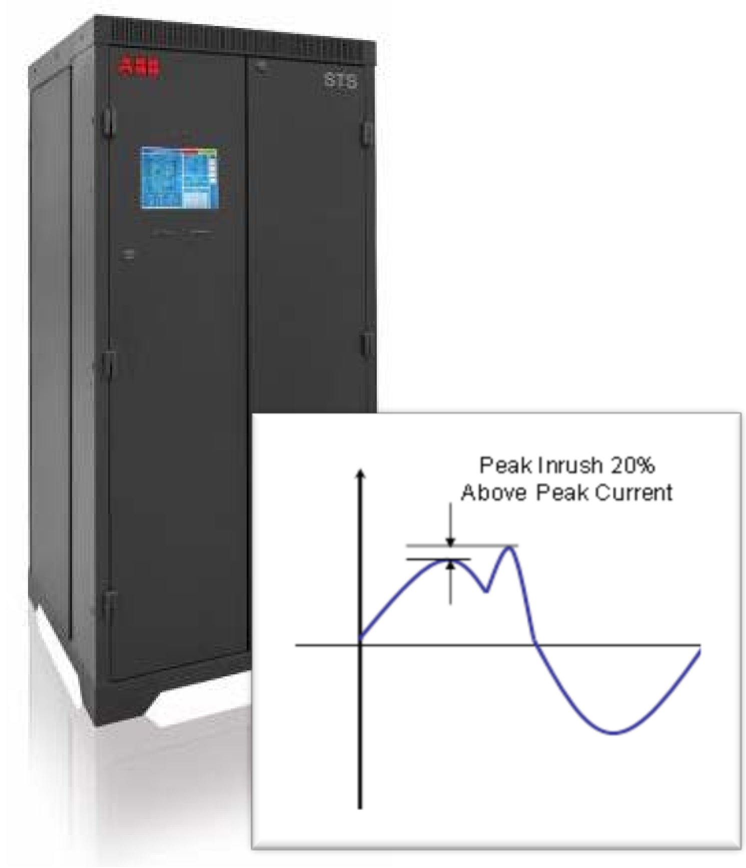
Secondary side switching
Dual upstream transformers
Larger footprint
Higher initial cost
No potential downstream transformer saturation

Primary side switching
What is flux saturation/inrush?



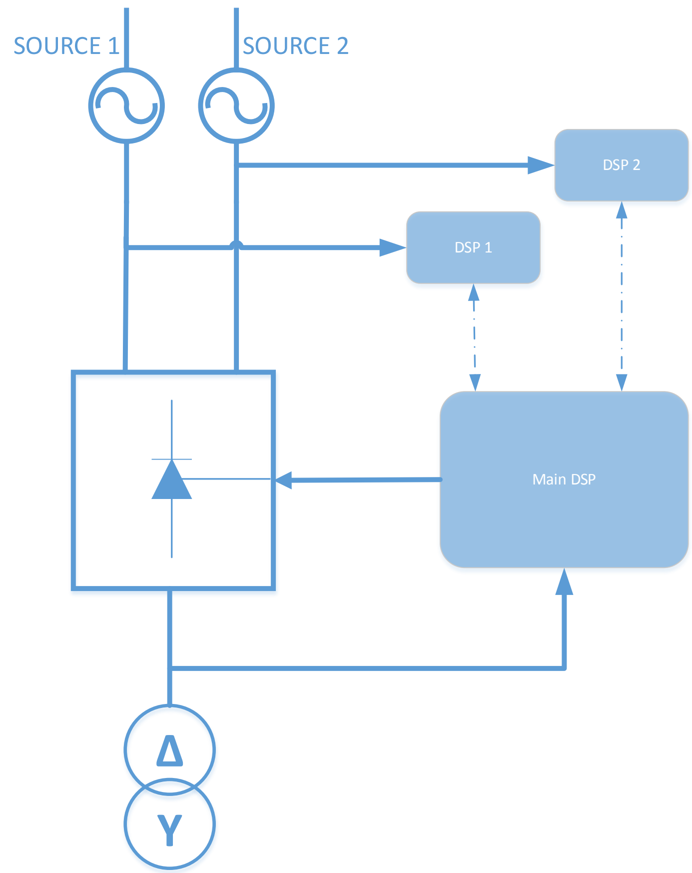
- Relationship between electric & magnetic fields (Maxwell's equations)
- Asynchronous transfers create disruption in typical AC voltage sine waveform downstream
- Magnetic flux limitation in a transformer's core (saturation point)
- Reduction in propagation of counter EMF
- Reduced impedance in primary winding results in inrush current.

Dynamic Inrush Restraint (DIR)
Inrush limiting transfer algorithm



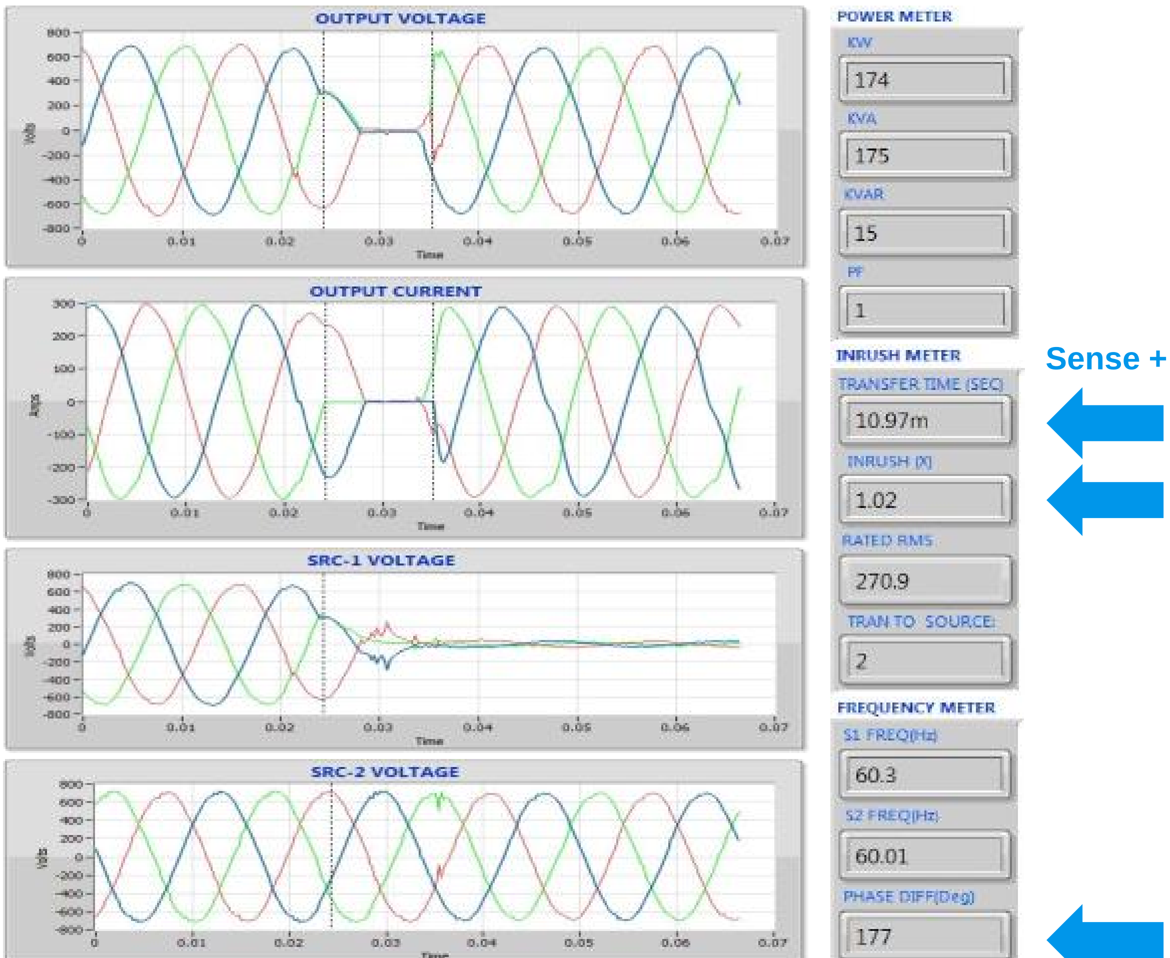
- Intelligent transfer algorithm
  - Configurable
  - Dynamically determines the optimal transfer to execute
- Ensures transfer times within CBEMA curves, even for asynchronous transfers
- Limits inrush to 1.2x nominal current
- Reduces potential stress on fuses, breakers and transformer

Dynamic Inrush Restraint (DIR)
Real Time Flux Control™



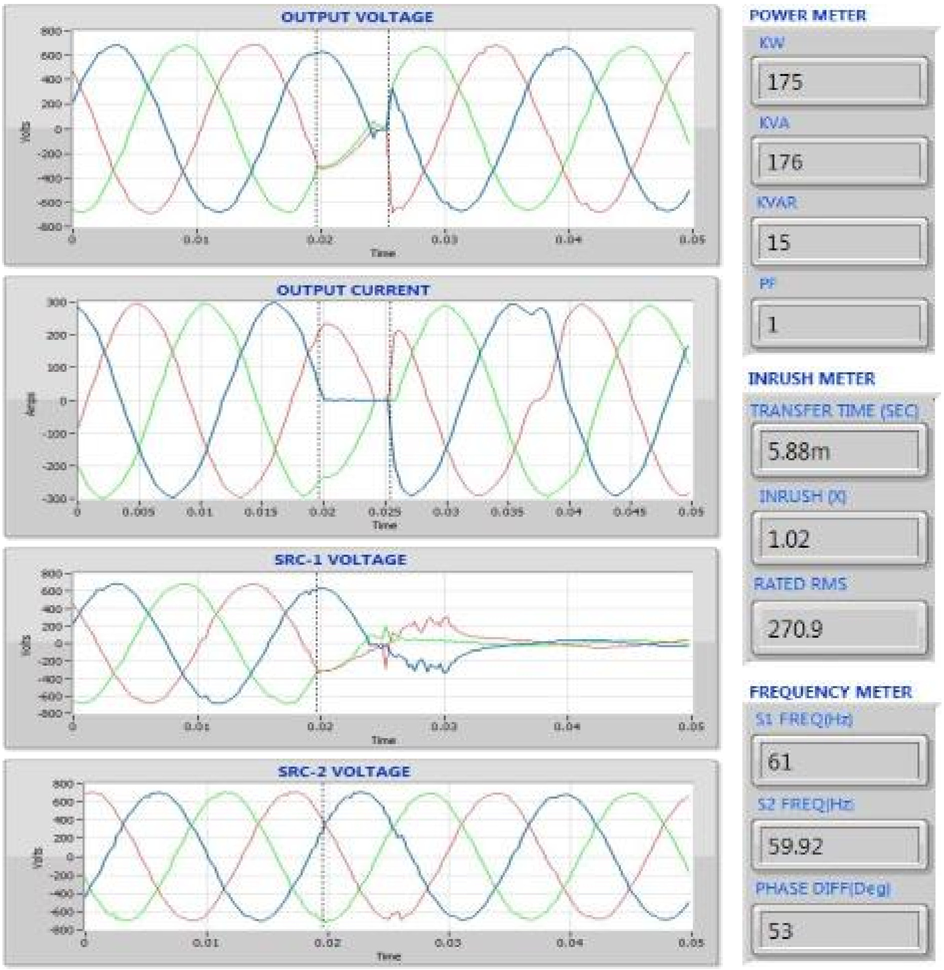
- Computes flux trapped in the transformer in real time (every 130.2usec)
- Controls the amount of flux induced in the core
- Continuously determines the optimal SCR firing angle for each phase
- Compatible with all types of transformers
- Addresses inrush in all three phases

Real Time Flux Control™ for DIR
180° loss of source transfer



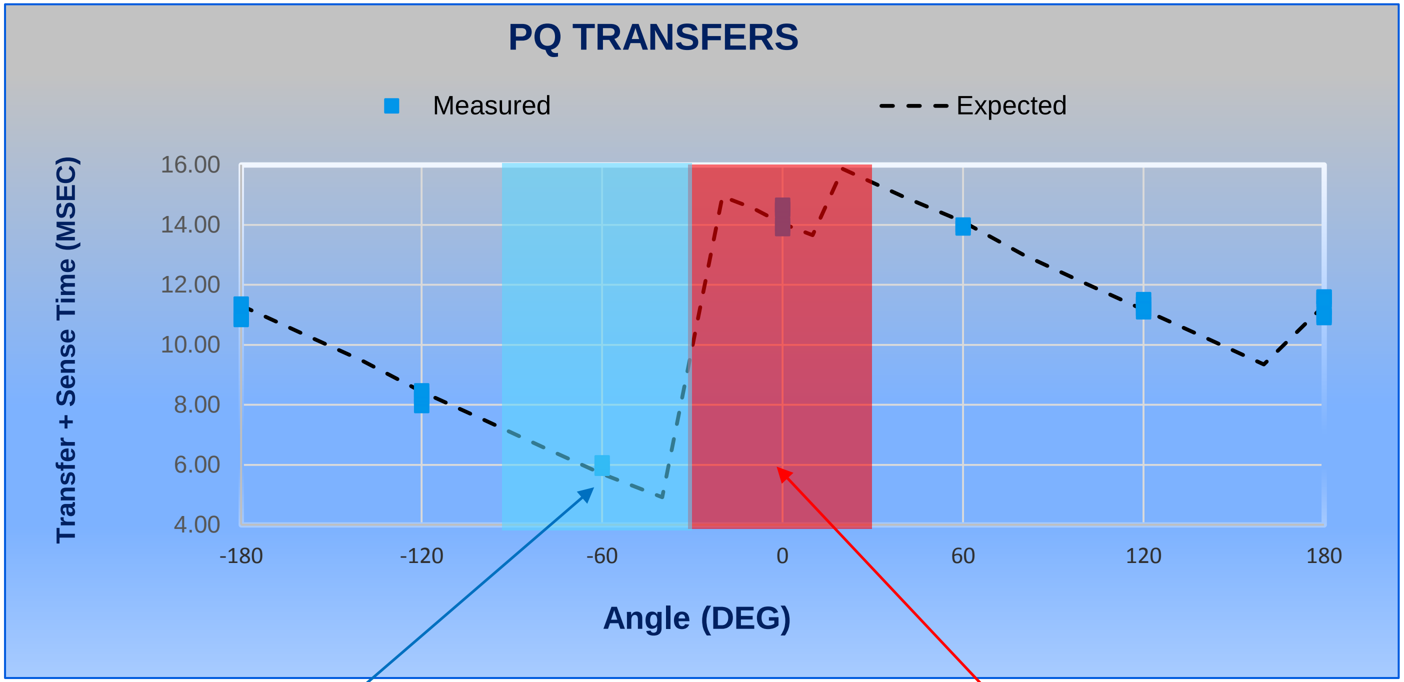
Sense + Transfer Time

Real Time Flux Control™ for DIR
60° loss of source transfer



Sense + Transfer Time

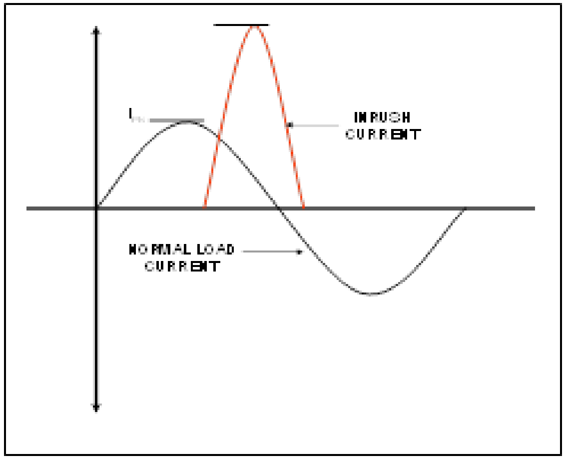
Real Time Flux Control™ for DIR Configurability

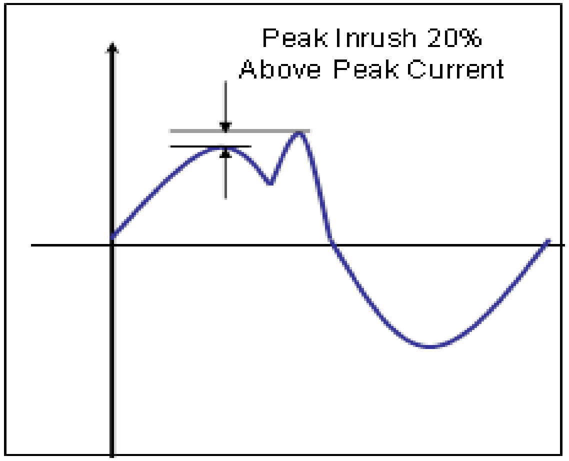


Super Transfer Area

Not used if DIR LIMITED is enabled

Best method for preventing flux saturation?
Real Time Flux Control™ for DIR





- Reduces stress on upstream infrastructure
- Sense + transfer times under 16ms, regardless of phase shift
- User configurable:
  - STS determines the optimal transfer algorithm to execute
  - On demand – no need to turn on or off
- Limits inrush to 1.2x nominal current
- Eliminates possible UPS overload or going to bypass

Don Elliott

IEC 61850 GOOSE enabled innovations

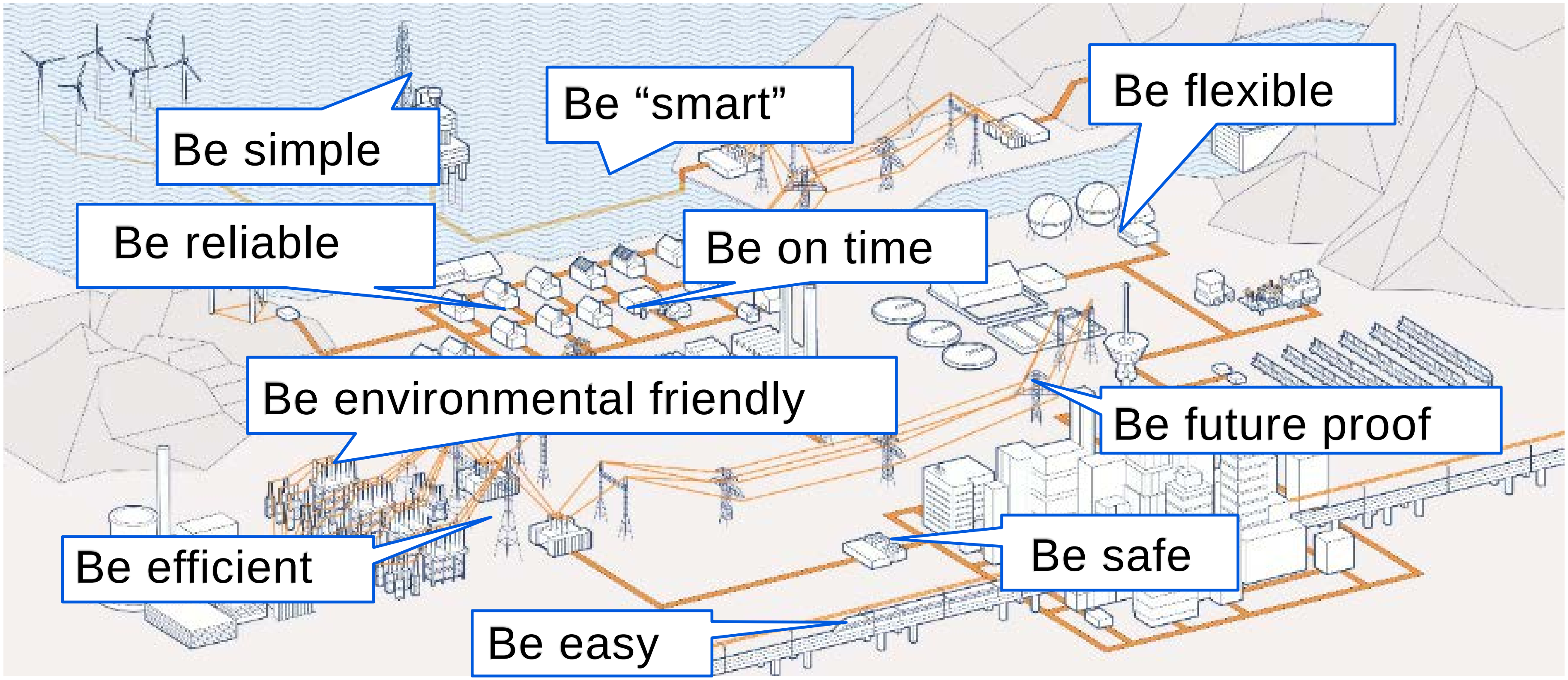
Power and productivity for a better world™

Digital switchgear and IEC 61850
Increase speed, reliability and more

Agenda

- Industry requirements
- Definition of digital switchgear
- Key digital switchgear components
- Digital switchgear benefits
- IEC 61850 with GOOSE
- Security

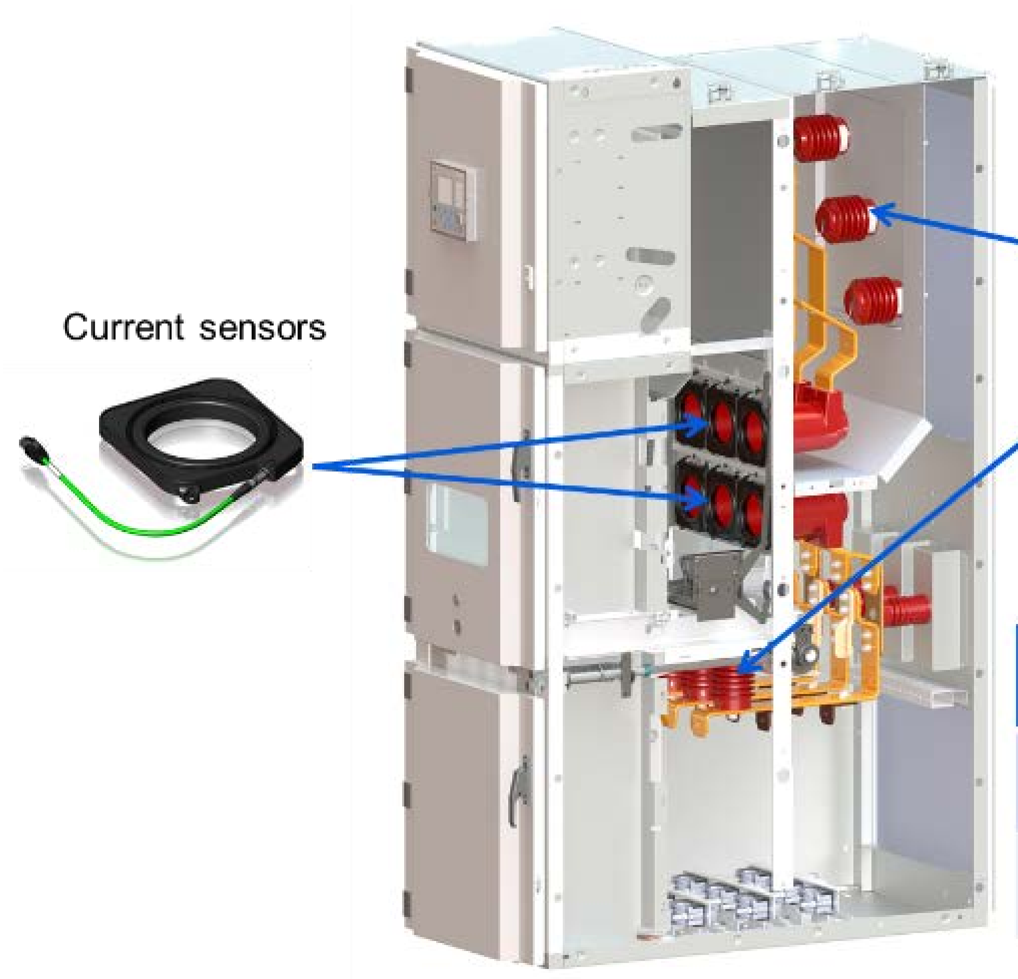
Distribution networks are getting more complex
Increasing demands on MV switchgear

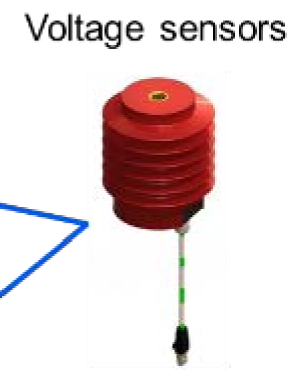


Digital Switchgear
New concept for MV switchgear

Digital switchgear is not only new products, it is a new concept in protection, control, automation

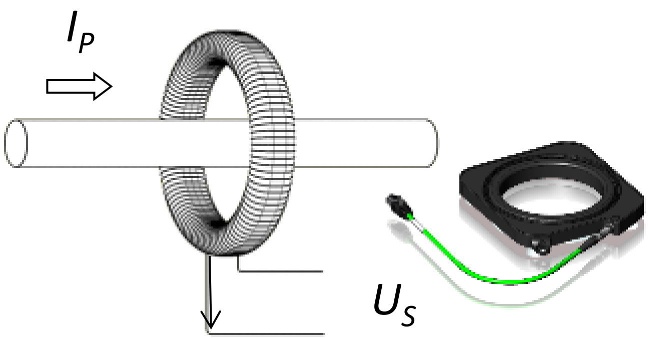
Digital switchgear
Advanced measurement solution



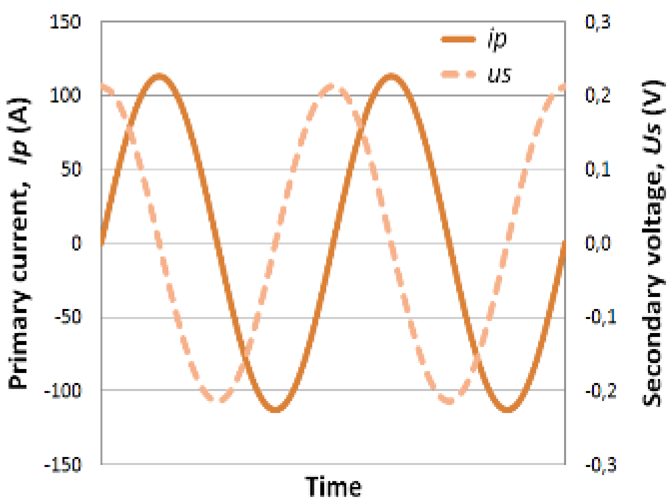


MV sensors	Standards
Current Sensor	• **IEC 60044-8 (2002)** Electronic current transformers
Voltage Sensor	• **IEC 60044-7 (1999)** Electronic voltage transformers

Digital switchgear
Current sensors



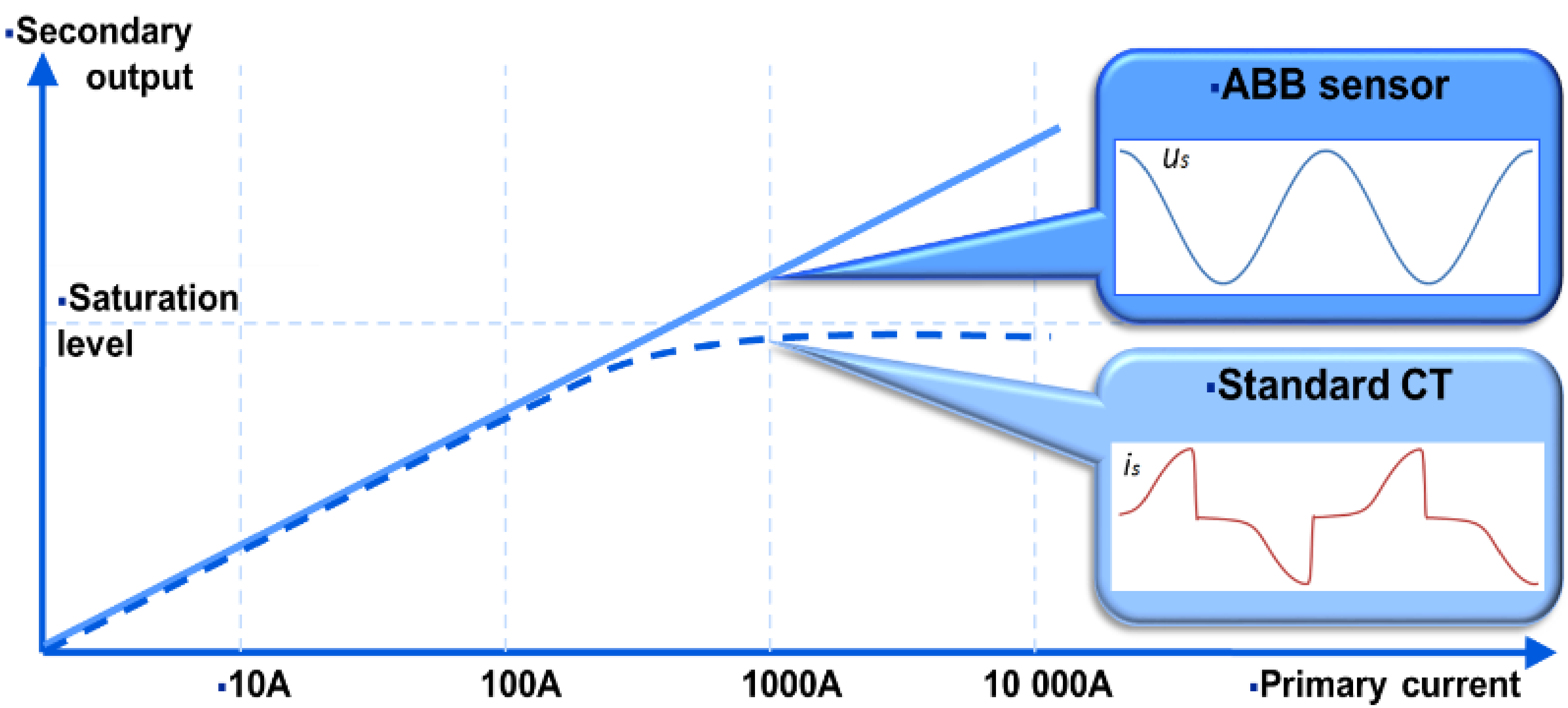
$$u_s(t) = M\frac{di_p(t)}{dt}$$



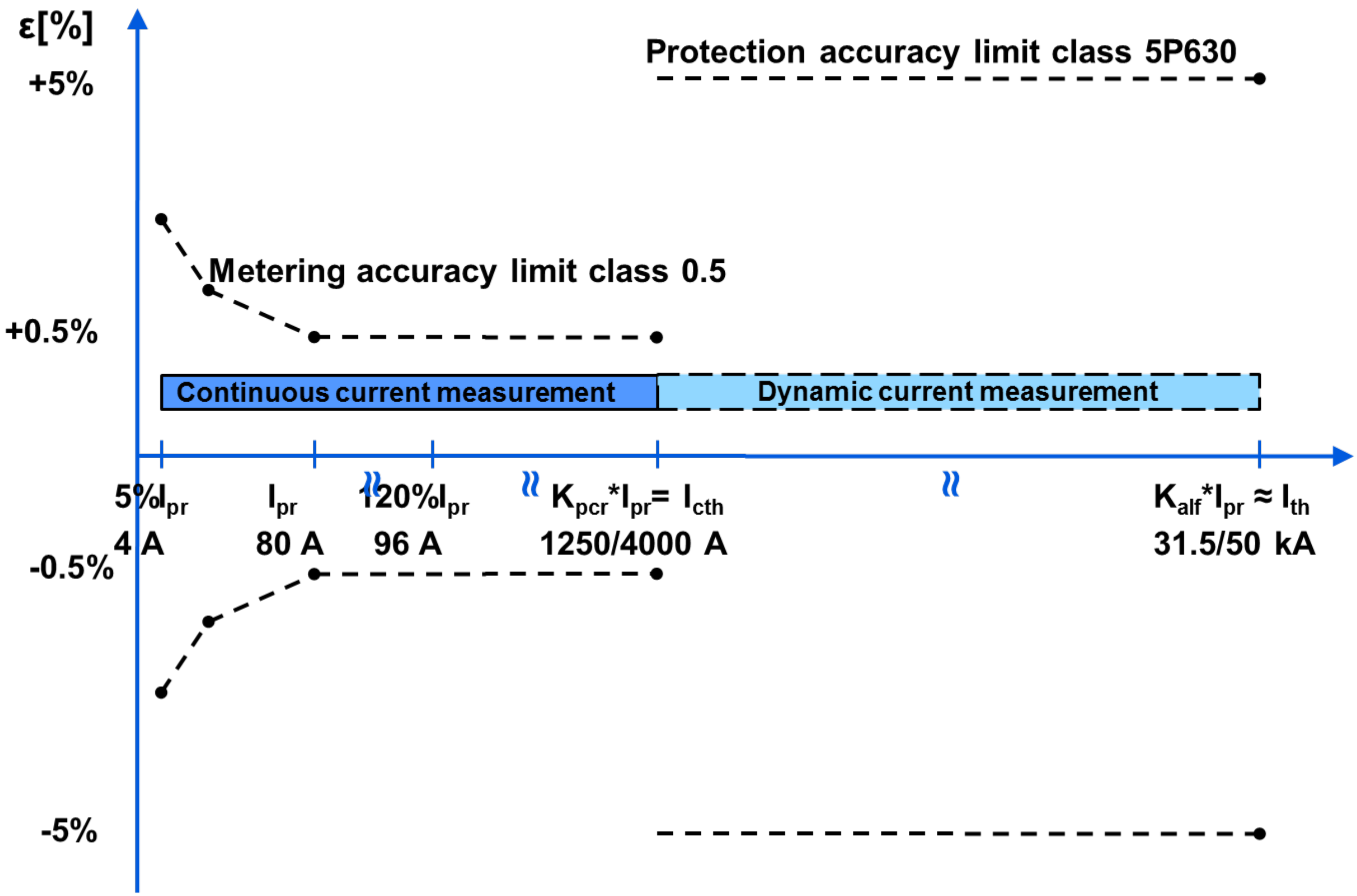
- Rogowski coil sensor
  Us=150 mV for 50 Hz
  Us=180 mV for 60 Hz
- Proven technology which brings many benefits in various applications
- Output voltage is proportional to the derivative of primary current
- Output voltage is integrated by IED
- Accuracy up to class 0.5
- Complies with IEC 60044-8

No saturation!

Digital switchgear
Current sensors



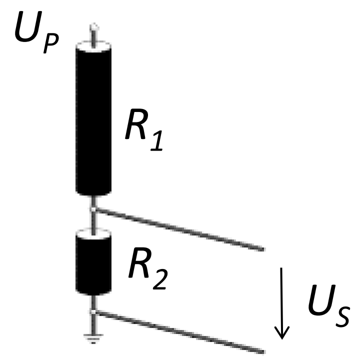
Digital switchgear
Current sensors – combined accuracy class 0.5/5P630



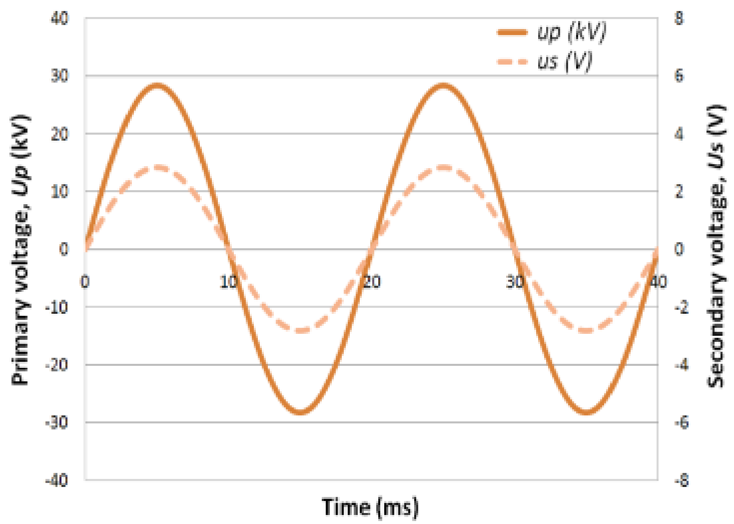
Digital switchgear
Voltage sensors

- Resistive voltage divider sensor
- 10,000:1 transformation ratio
- Accuracy up to class 0.5
- Passive element
- Complies with IEC 60044-7

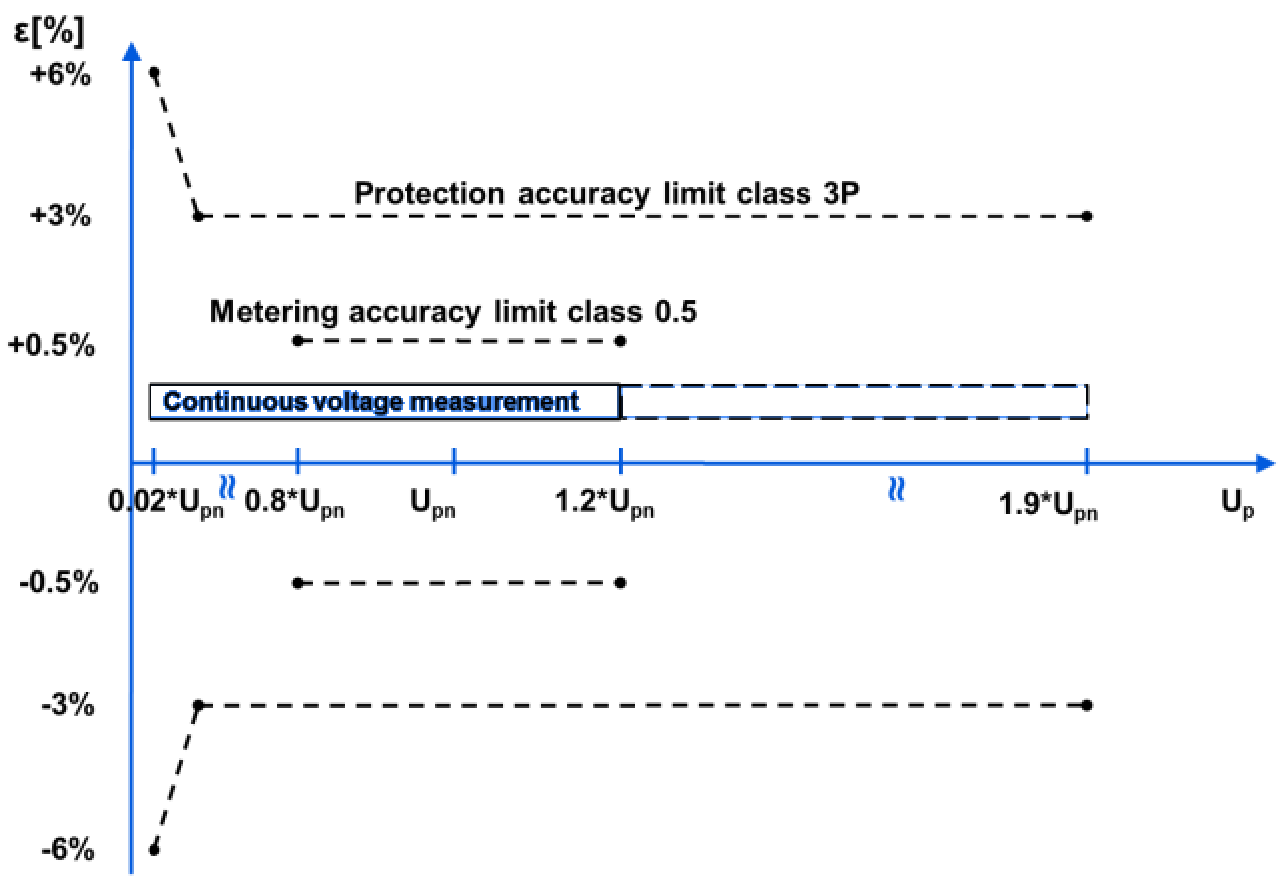
No ferroresonance!



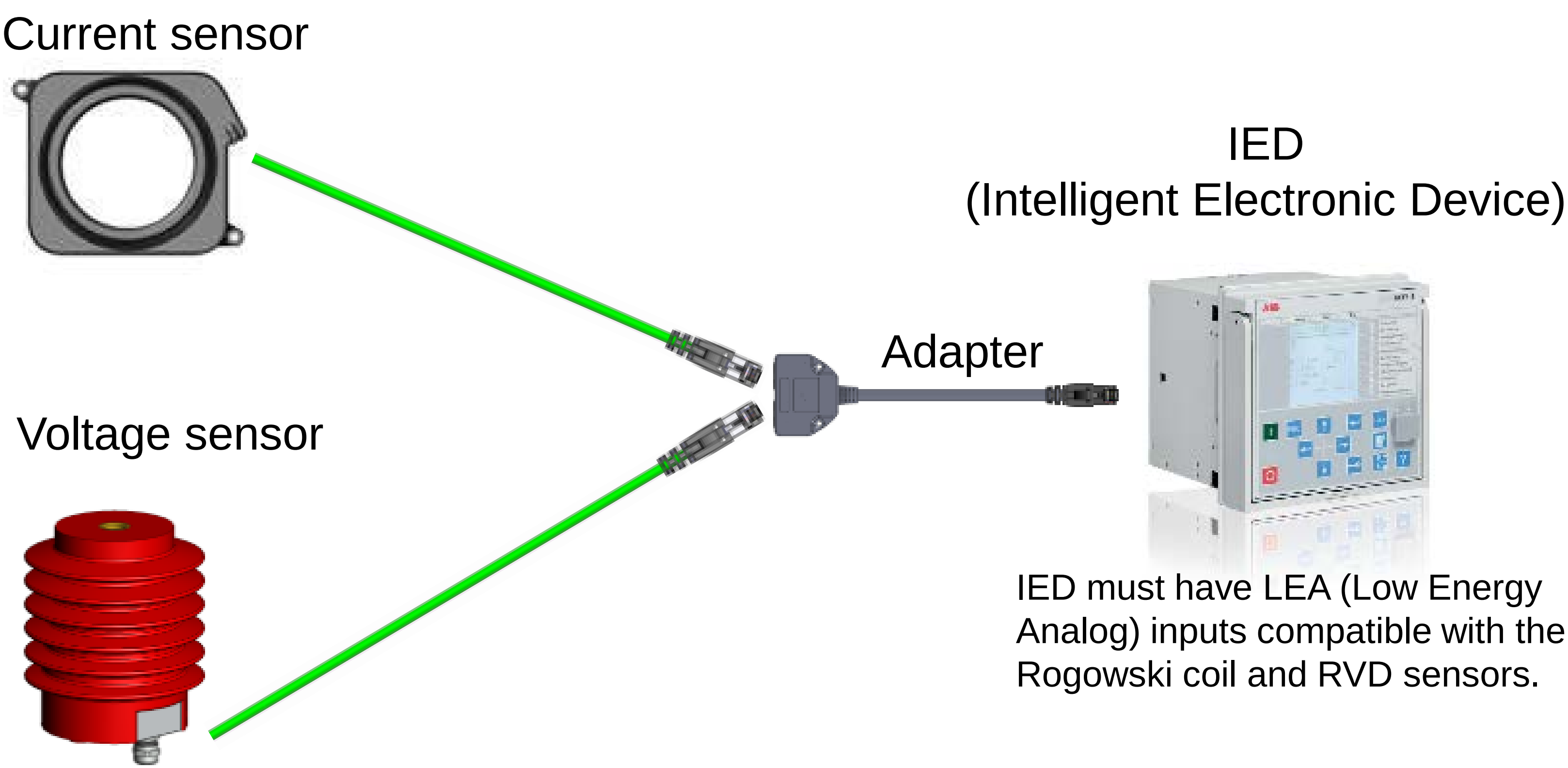
$$U_S = \frac{R_2}{R_1 + R_2} U_P$$



Digital switchgear
Voltage dividers - combined accuracy class 0.5/3P



Digital switchgear



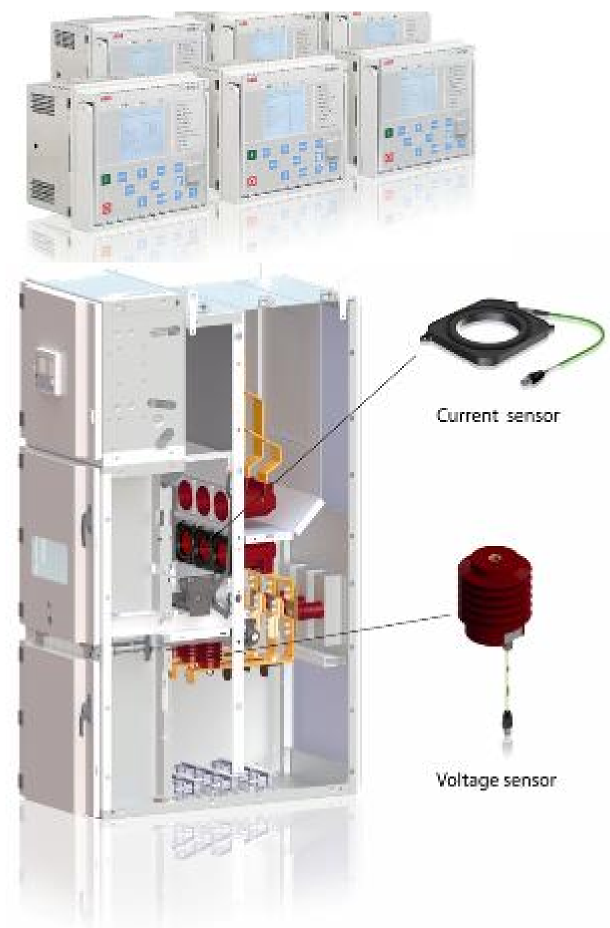
IED must have LEA (Low Energy Analog) inputs compatible with the Rogowski coil and RVD sensors.

Almost no analog wiring in the switchgear – increases reliability

Digital switchgear
Future proof solution based on IEC 61850

- Based on worldwide accepted standard ensuring long term sustainability
- Ready to be connected to remote control systems
- Available IEC 61850 features:
  - vertical communication
  - horizontal GOOSE communication
  - process bus

Digital switchgear
Technology for better switchgear



Capacity

- Integrated voltage measurement within insulator reduces space requirements
- Current sensor located in monoblock reduces space requirements

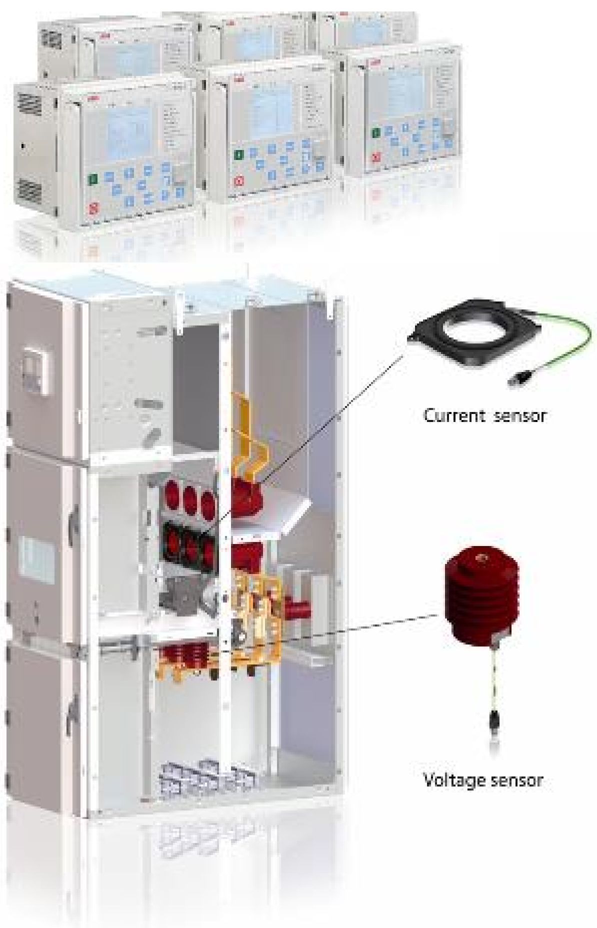
Safety

- Low energy analogue sensors
- Fewer wires to install, commission, maintain

Quality

- Better sensor accuracy and range of measurement improves protection & control

Digital switchgear
Technology for better switchgear



Efficiency

- Lower operating cost (sensors consume less power)
- Later configuration during manufacture (fewer wires to design and install)

Sustainability

- Universal standards (IEC61850) enable future system expansion
- Lower environmental impact during operation

Reliability

- Fewer parts to fail

Digital switchgear
Technology for better switchgear

Digital solution:

- Changing loads does not require changes in hardware like instrument transformers
    - Saves time and money during planning and execution
- Improved accuracy and range of current and voltage measurement for metering, protection and control
- Meets latest cybersecurity and communication performance standards
    - Manufacturer independant communication standard
    - Ready for easy SCADA integration

Digital switchgear
Technology for better switchgear

Reduced losses during operation

- Lower sensor losses
- Saving potential of up to 250 MWh over 30 years (sample switchgear with 14 frames & 42 CTs)

Improved equipment reliability

- Fewer live parts, fewer failure opportunities reducing outage potential and troubleshooting costs

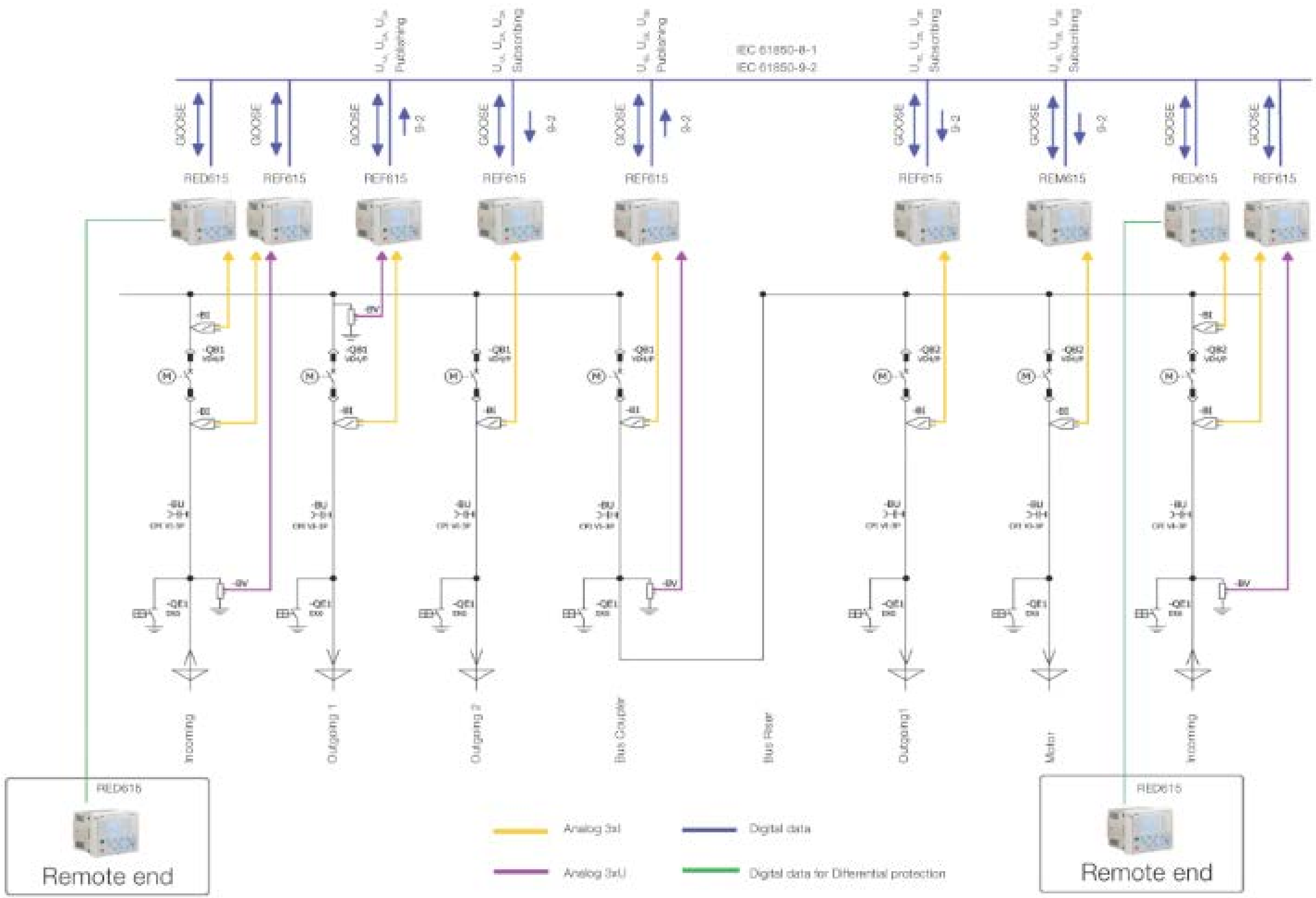
Solution that requires less space

- Complete transformer compartments eliminated
- Frame count can be reduced
- Reduced space means lower installation costs

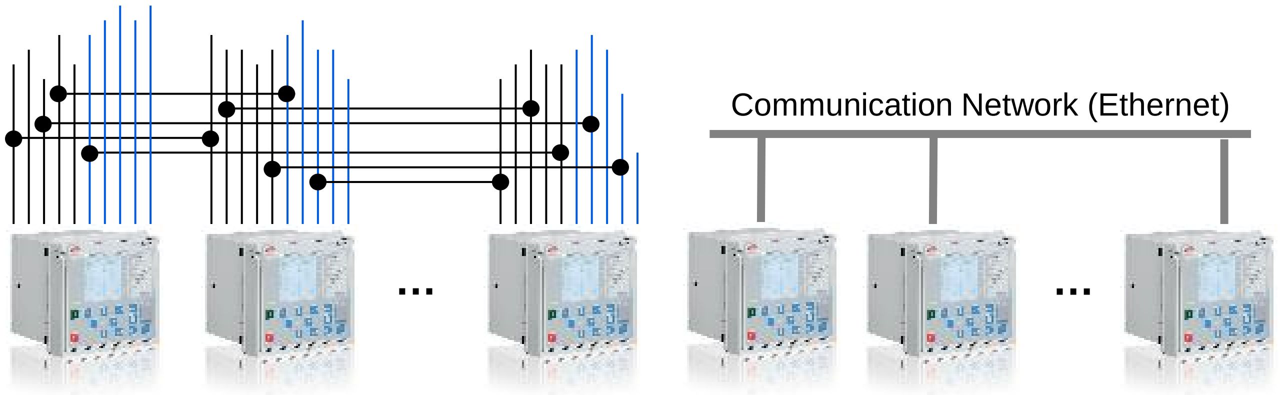
Digital Switchgear
Low Voltage Switchgear Devices

- Blue tooth configuration “Speaks” 8 industrial control networking languages including IEC61850
- Real time load management
- Available ATS control
- Reduces switchgear size and material costs by up to 25%
- Helps to prevent power failures
- Power Quality Functions
- Thermal Sensors
- Contact Wear Algorithms

Digital switchgear
Sensors and IEC 61850 communication



Digital switchgear
IEC 61850 communication and Goose

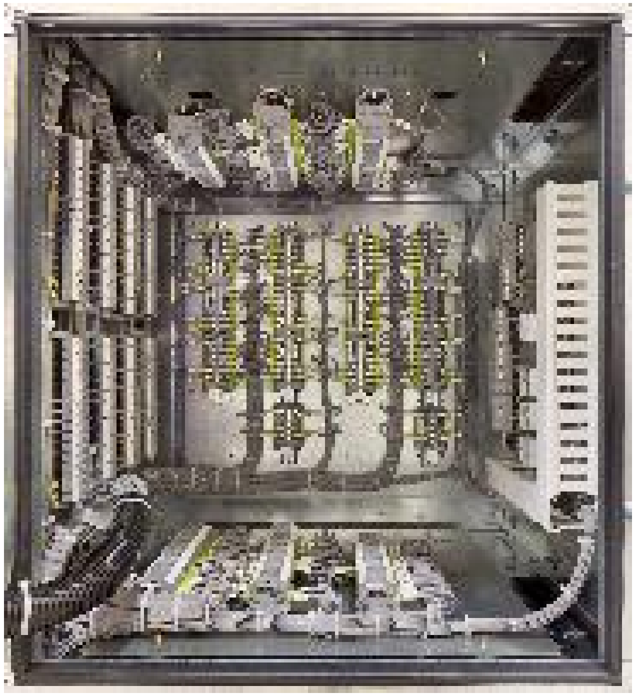


Conventional approach
Wiring between devices must be done individually per signal

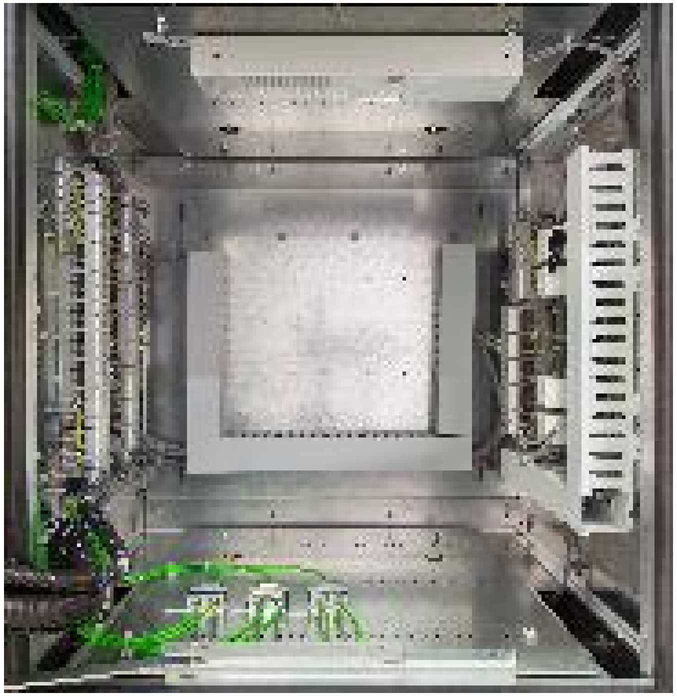
Horizontal GOOSE communication
Number of interconnections is equal to number of devices

- Solution does not require extra frames for instrumentation
- Greatly reduced wiring

Digital switchgear
IEC 61850 communication and Goose



Conventional approach



Digital approach with Goose communication

Digital switchgear
IEC 61850 Security

New innovations in automation and connectivity have generated concerns regarding cyber security

- Open IT standards such as IEC 61850 have built in cyber security mechanisms
  - Cyber security certification per IEC 624443
  - Security protocols per IEC 62351
    - Incorporating TC 57 series requirements
- HMI’s (relays and control panels)
  - 4 layers of security passwords
    - 4 levels of access/administration
  - Security zones with built-in firewalls for complete system protection

Digital Switchgear
Quick delivery time from order to operation

Digital switchgear
Quick delivery time from order to operation

This solution eliminates the trouble of defining details like CT/VT data...

- For all applications/relays?
  - No, but for nearly all of them! Reduced engineering and easier configuration selection. Reduces project administration and engineering costs

This solution supports minimized time to receive the project documentation

- CT/VT data not required
- Flexible towards last-minute changes
- Most changes are simply realizable within the IED's logic, only minor changes in wiring and schematics (if any)

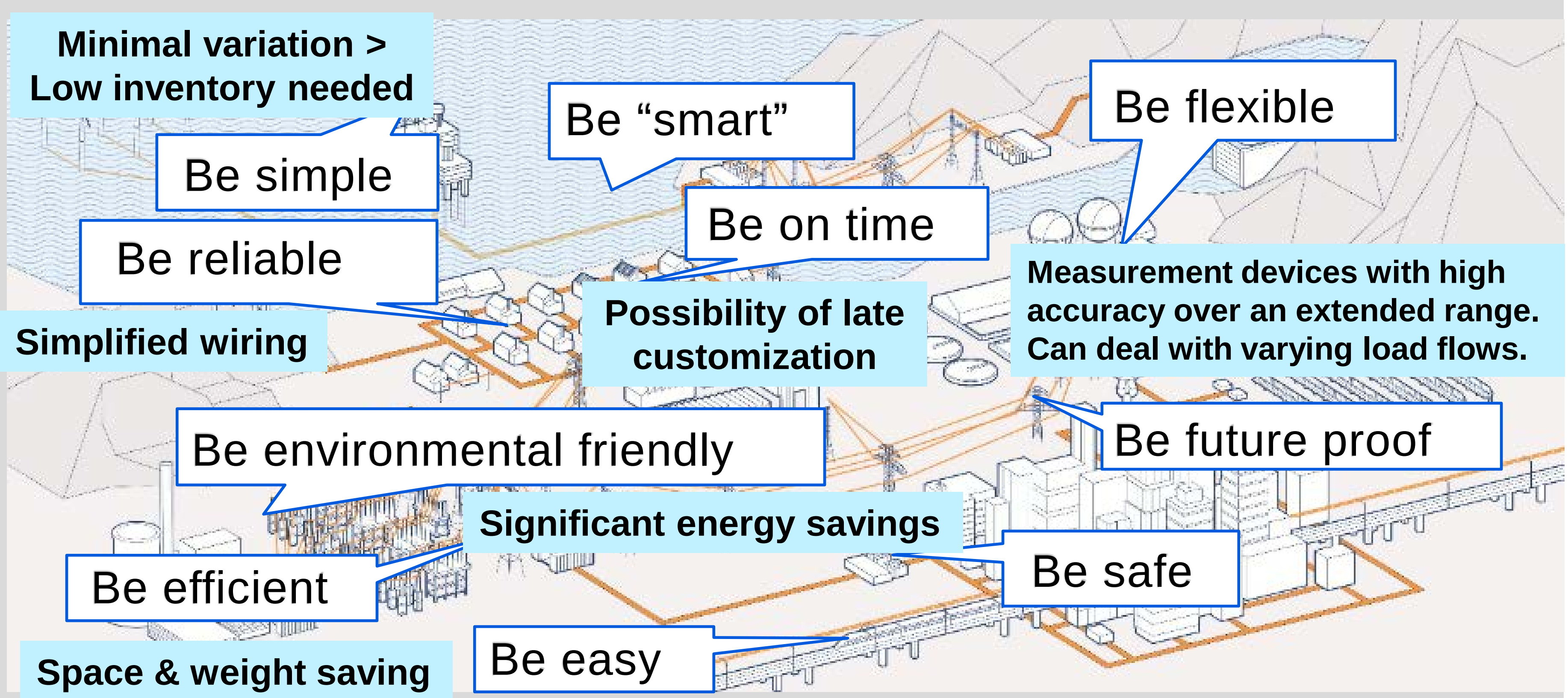
Digital switchgear
Lower environmental impact

Digital switchgear
Lower environmental impact

Digital switchgear:

- Solutions that use less material
  - Less steel, less copper, less epoxy, …
- Solutions with reduced losses
  - Lower energy required to operate the gear
- Digital switchgear can save a significant level of CO_2

Distribution networks are getting more complex
Increasing demands on MV switchgear



Digital switchgear is the solution.

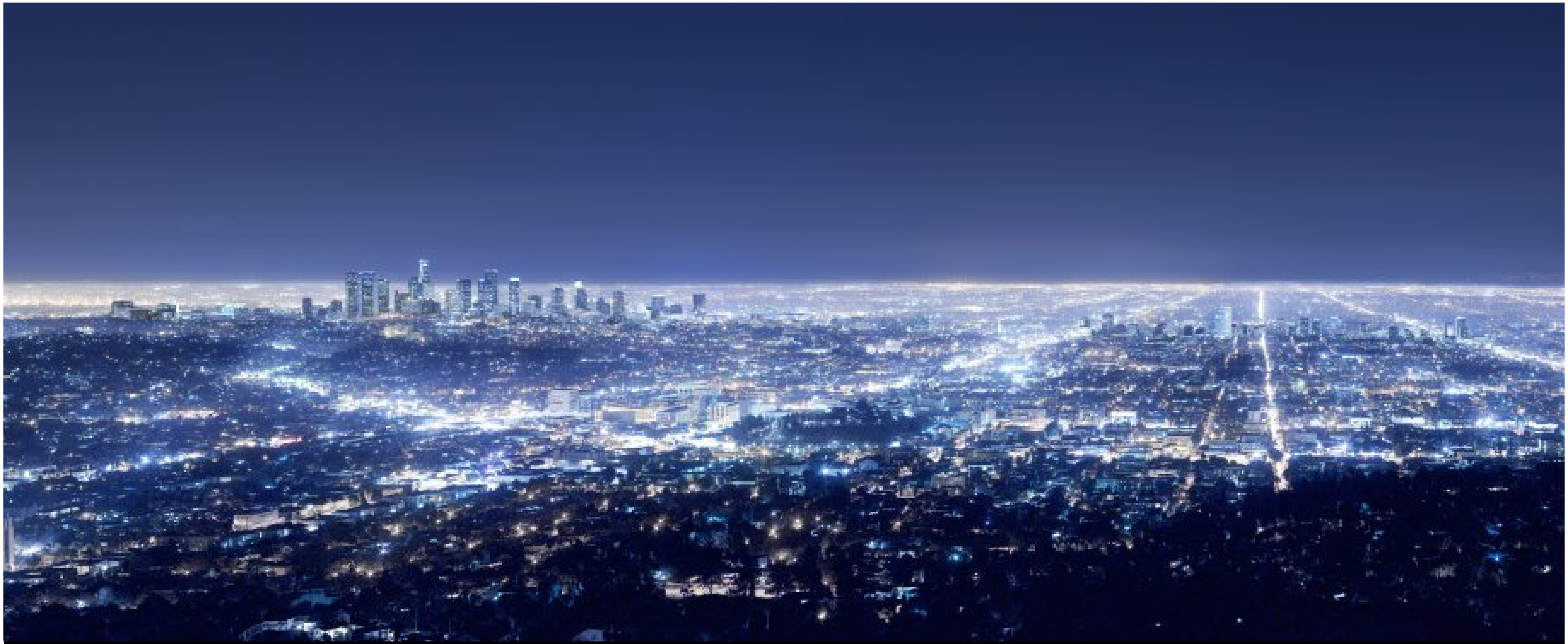
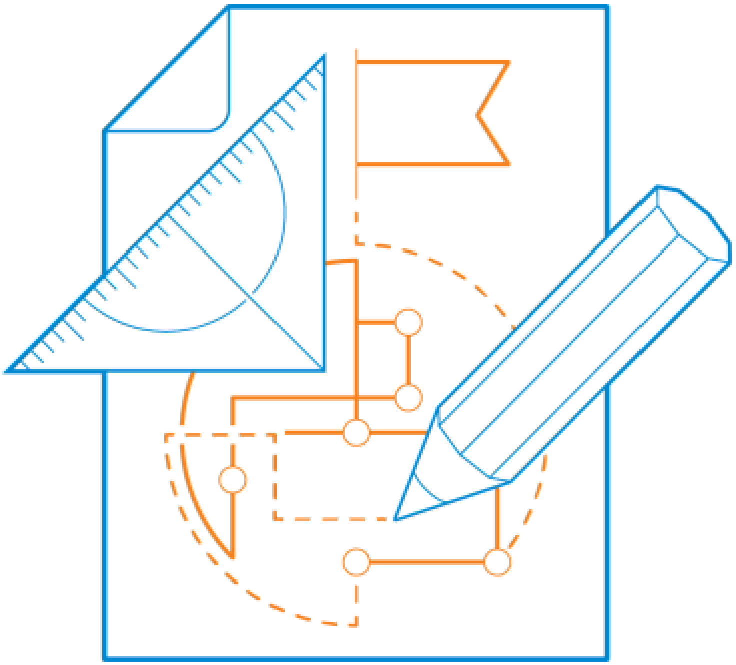


ABB Power Systems – Grid Integration

Substation Design Considerations
Data Center Expert Day

Factors to Consider in Selecting Substation Configurations

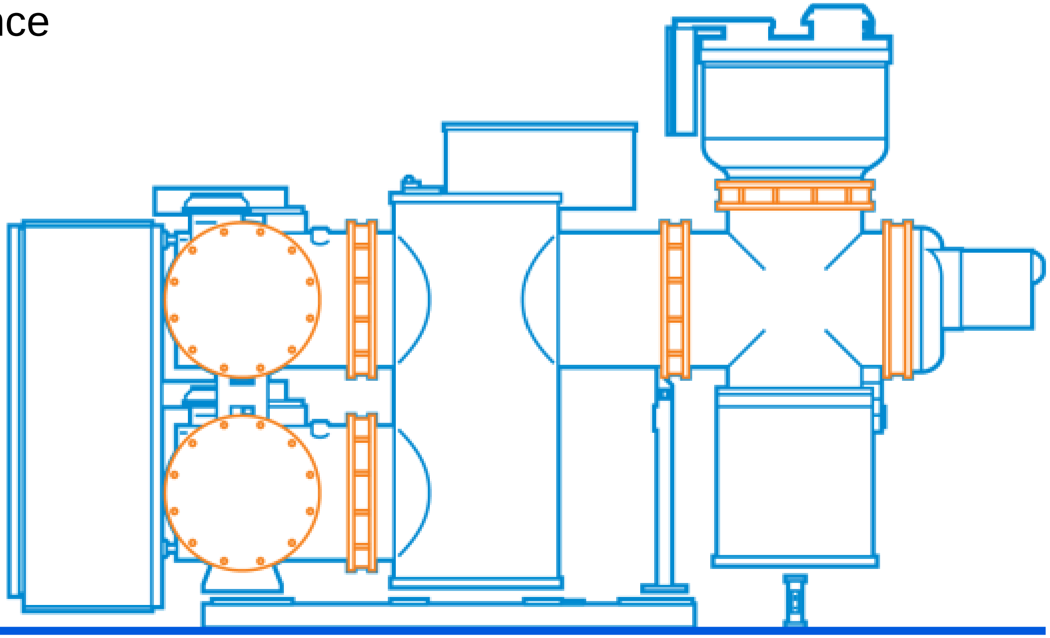
- Substation Type & Configuration (Power Generation, Transmission, or Distribution)
- First Costs vs. Cost of Power Supply Instability
- Substation Voltage & Power Rating
- Physical Size vs. Real Estate Availability & Cost
- Reliability, Future Expansion and Related Cost
- Complexity of Protection Scheme
- Technology used – AIS, GIS, hybrid
- Indoor vs. Outdoor
- Operation & Maintenance Impact



Substation Configurations

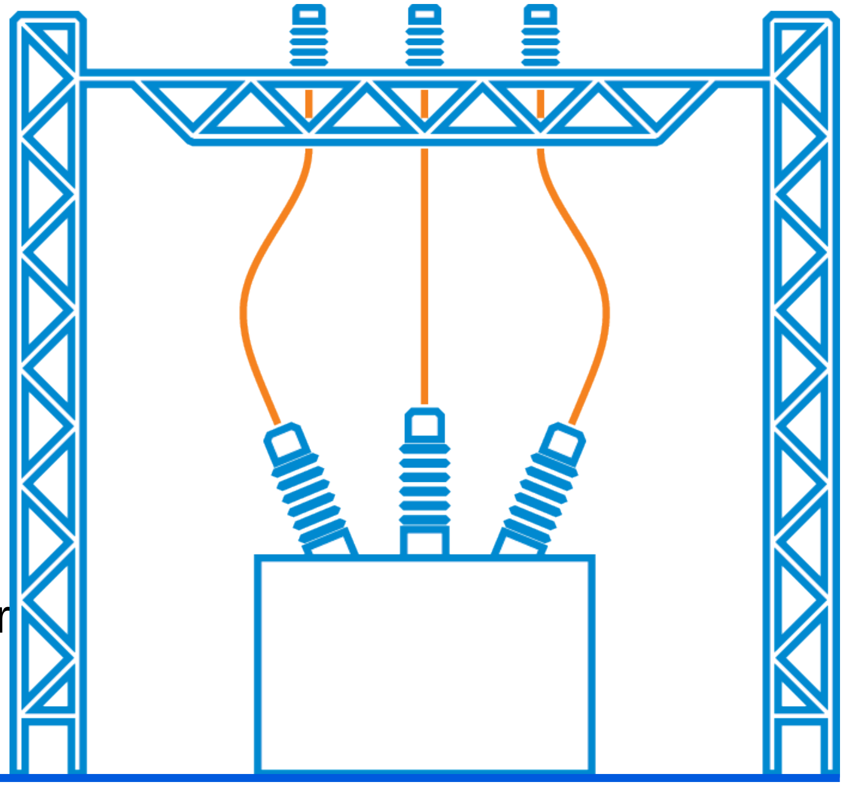
Substation configuration or Bus switching scheme is the circuit adopted for substation considering the following main criteria:

- System reliability
- Operational flexibility
- Ease of Operation & Maintenance
- Simplicity of Protection system
- Ease of Expansion
- Availability of Land
- Initial Cost
- Cost of Power Interruptions
- Others Factors…



Typical Datacenter Substation Configurations

- Collector Bus
- “H” configuration
- Main and Transfer Bus
- Double Bus, Single Breaker
- Ring Bus
- Breaker and a Half
- Double Bus, Double Breaker

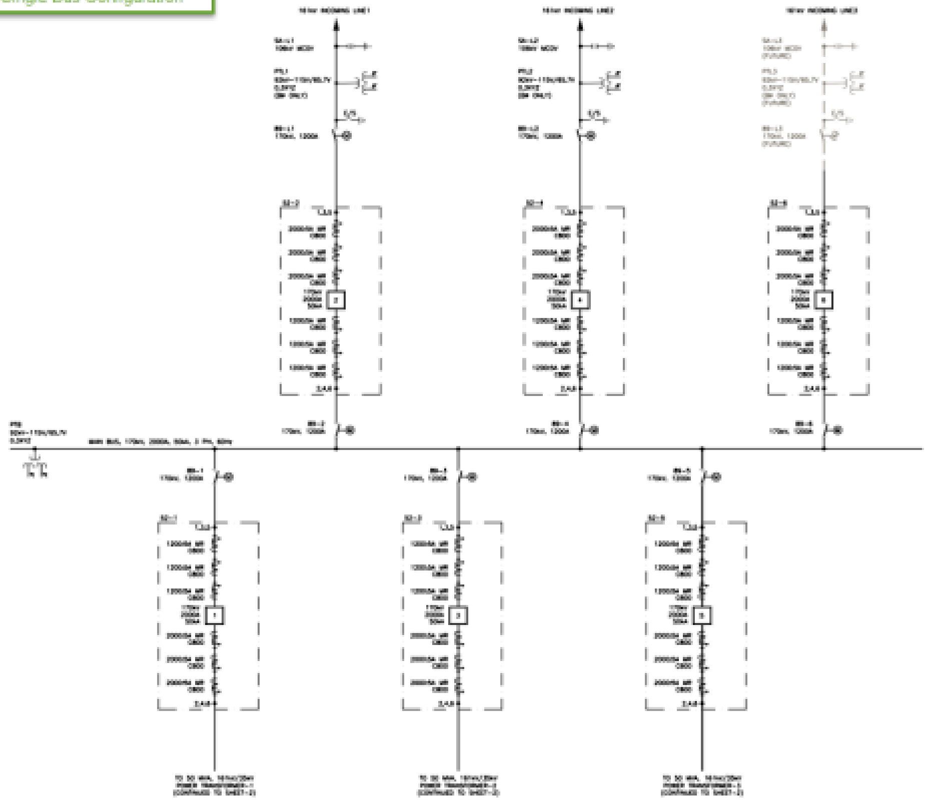


Collector Bus Configuration

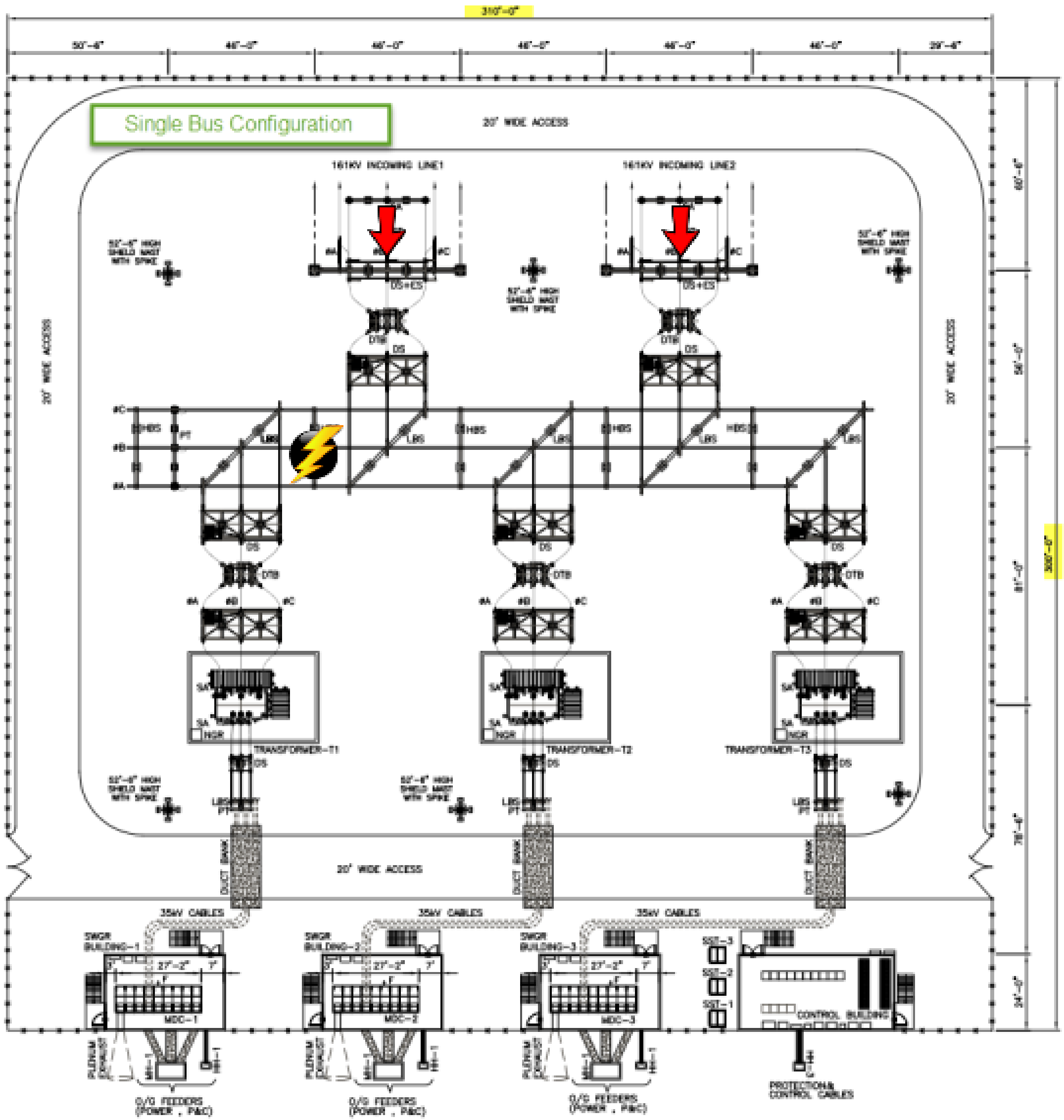
Features

- Lowest cost
- Simple operation
- Simple relaying protection scheme
- Lowest reliability
- Bus faults and breaker failures result in substation shutdown
- Difficult to maintain (outage required)
- Difficult to expand (outage required)

Single Bus Configuration



Collector Bus Configuration

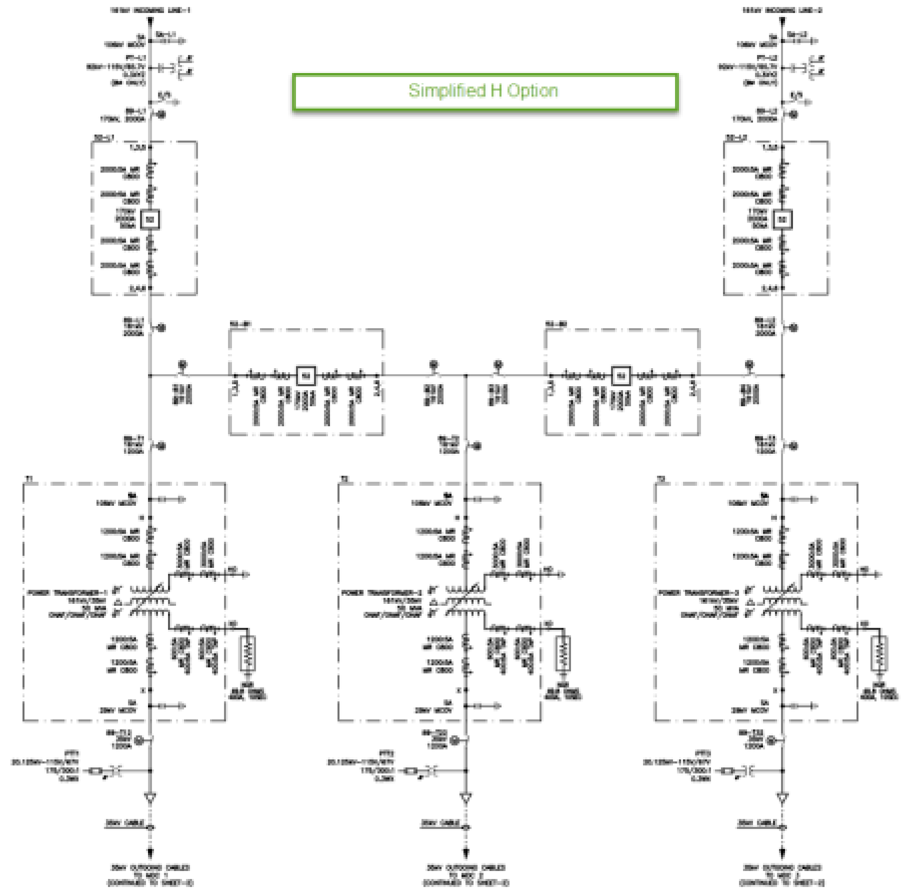


93,000 FT^2

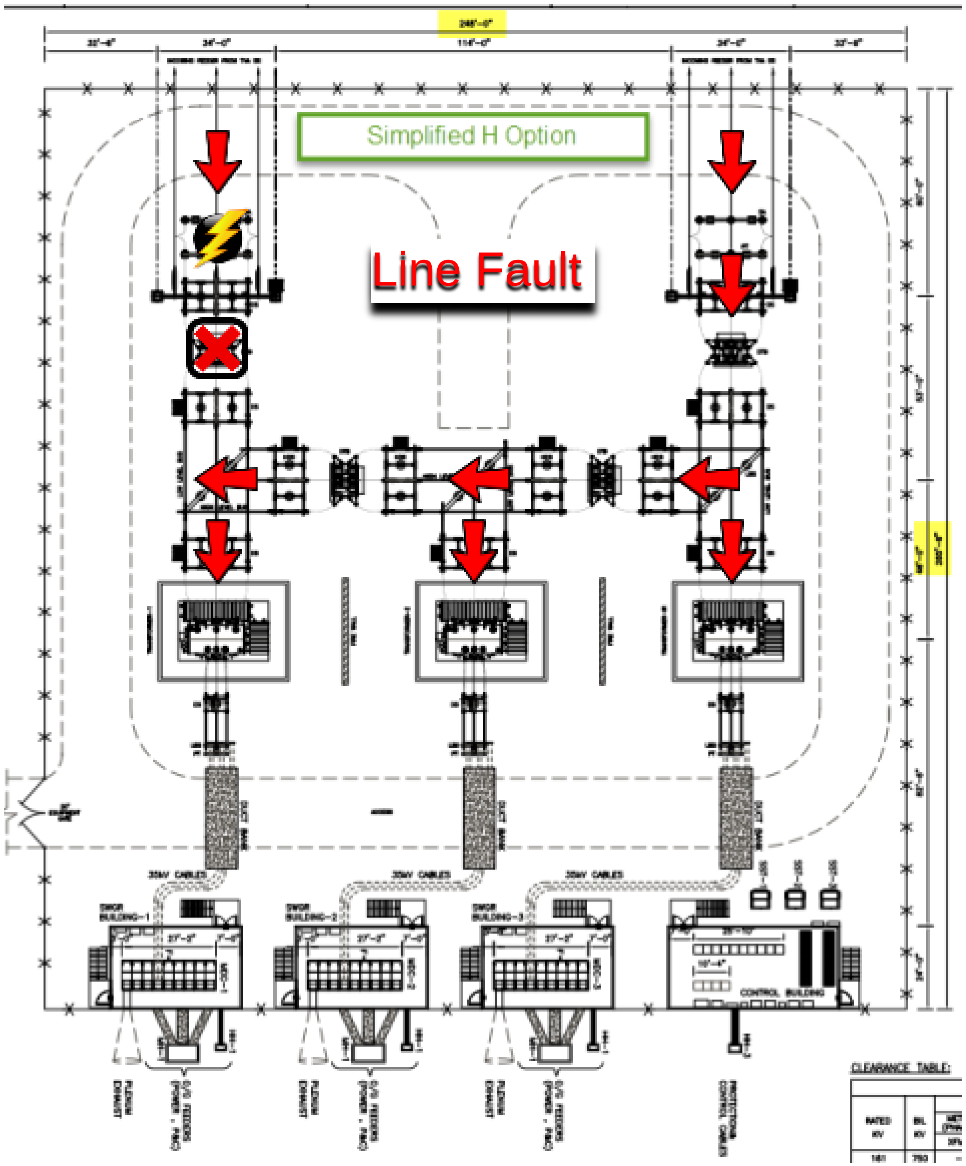
Month DD, Year

“H” Bus Configuration (simplified option)

- Simple system
  - Ease of Operation
  - Single level bus layout
- Very simple Control & Protection philosophy
- Large saving in space
- Some redundancy
- Fault on one feeder will trip two breakers.

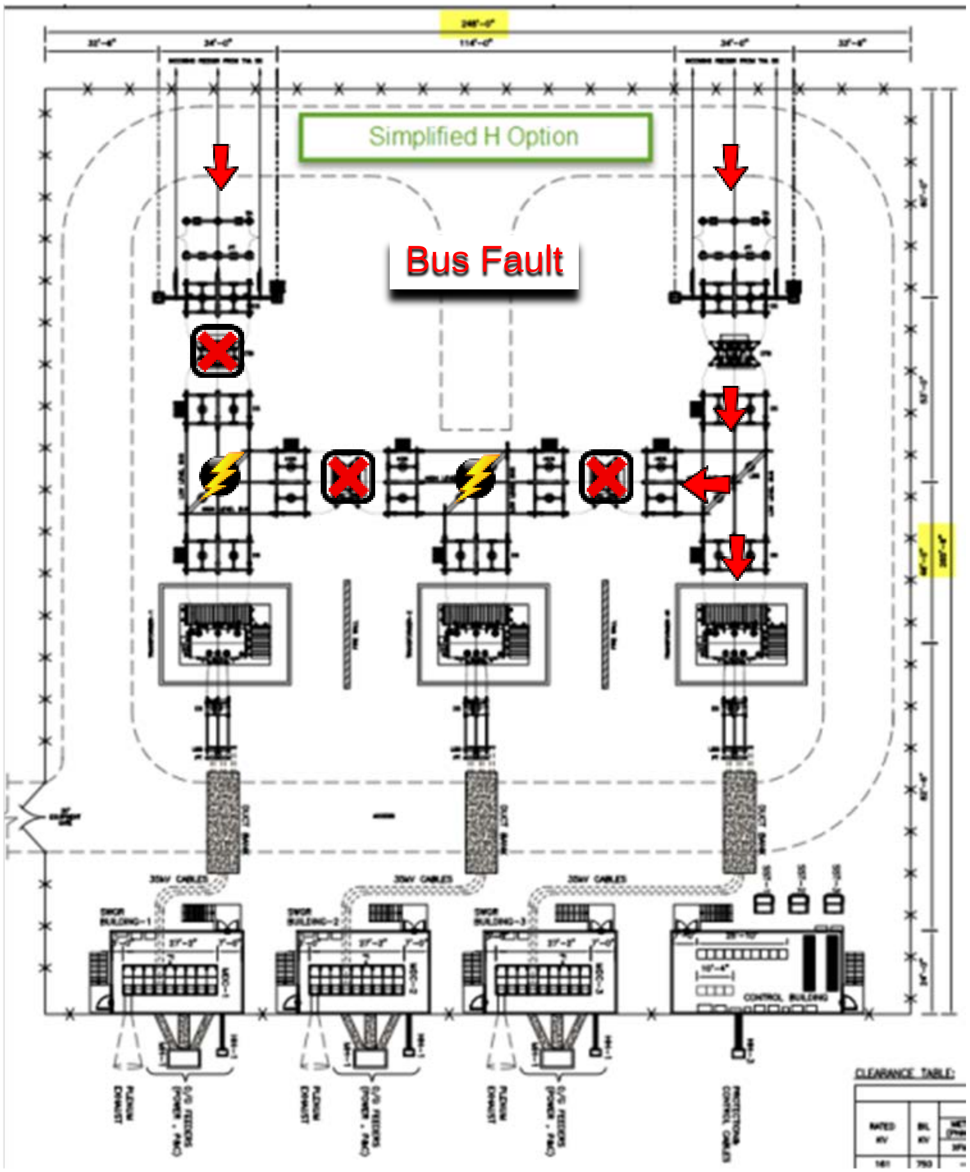


“H” Bus Configuration



81,225 FT^2

"H" Bus Configuration



81,225 FT^2

Month DD, Year

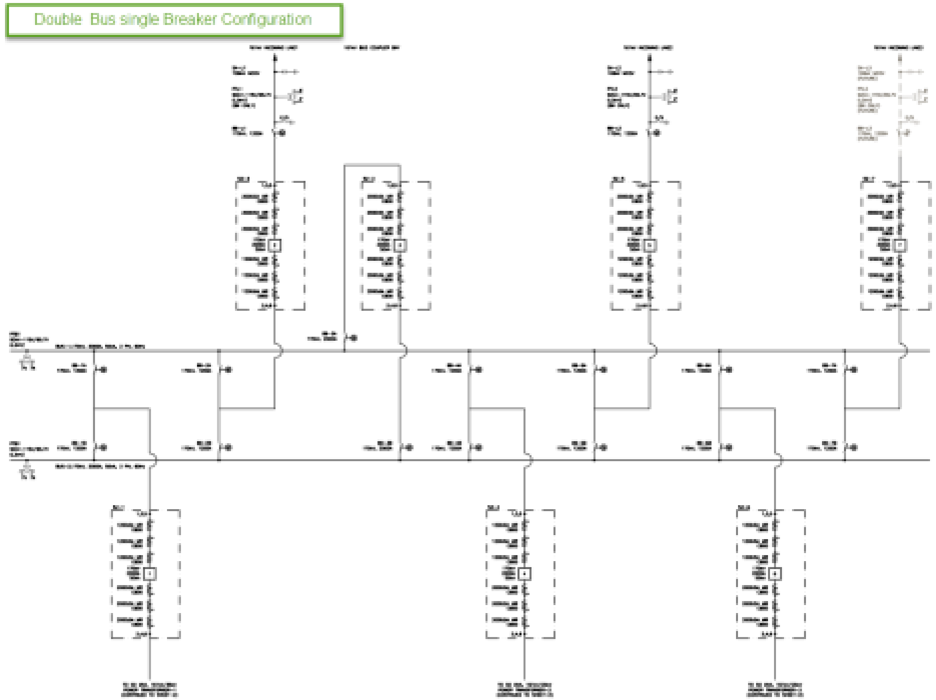
Double-Bus Single-Breaker (DBSB) Configuration

Application

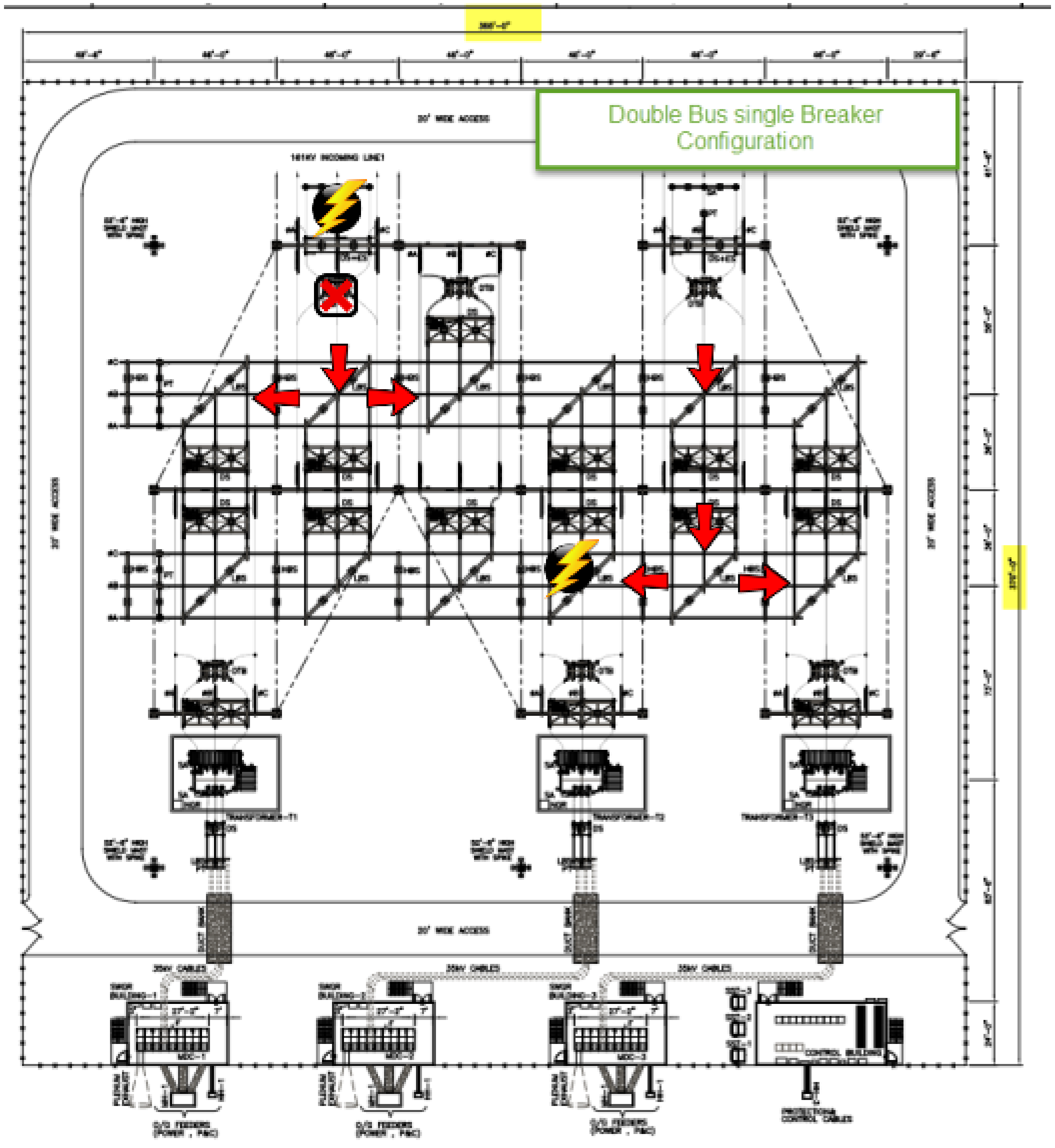
- Normally this is used for most industrial stations and some time small power evacuation system

Features

- Simpler system
- Better availability as additional bus is provided
- More reliable compare to Single Bus configuration
- Bus fault on one Bus will not effect the other Bus.



Double-Bus Single-Breaker Configuration



133,200 FT^2

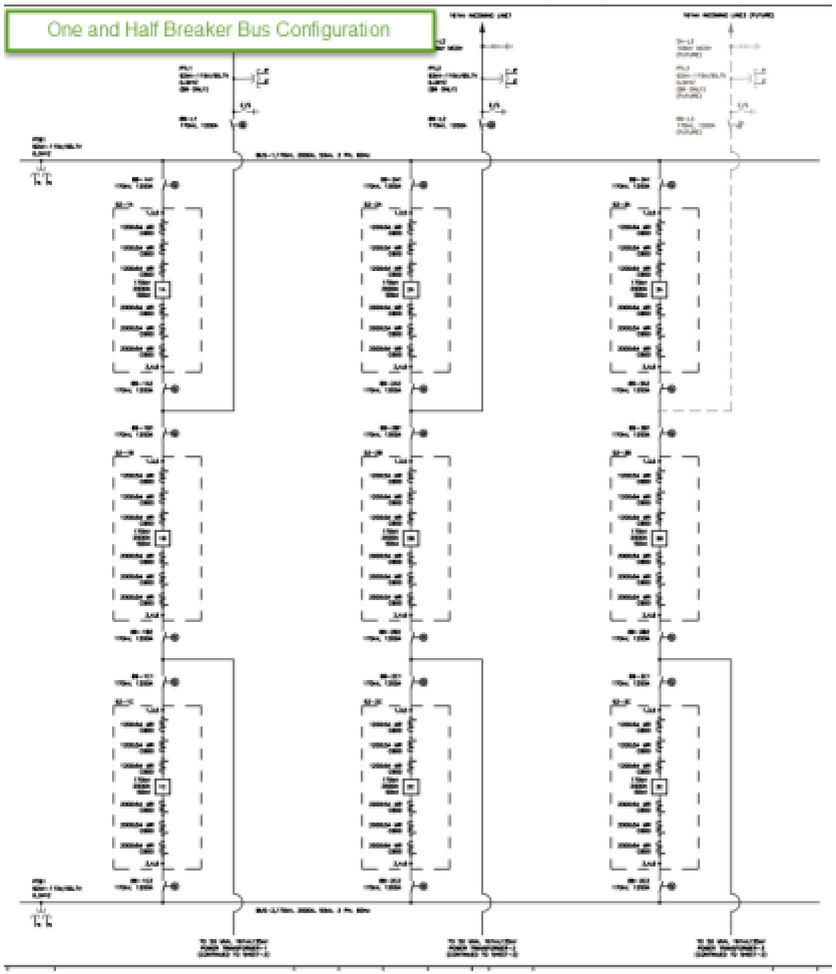
Breaker-And-A-Half (BAAH) Configuration

Application

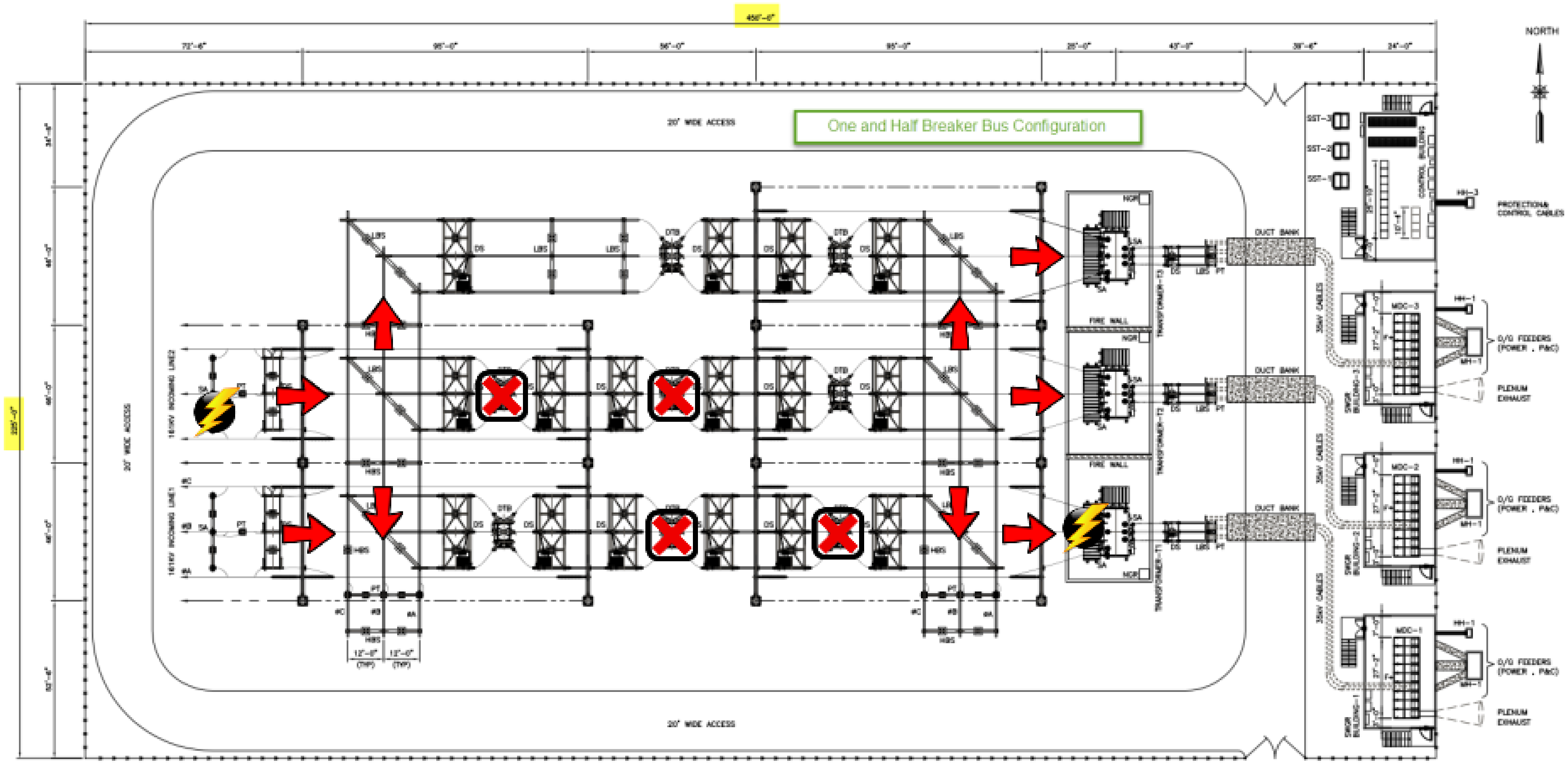
- Mostly this configuration is adopted where high reliability is required
- Power evacuation station for big power plant
- Interconnecting transmission substations with 420/245kV level

Features

- Very high reliability
- Costly because of increase number of Circuit Breaker
- Complex Control & Protection philosophy

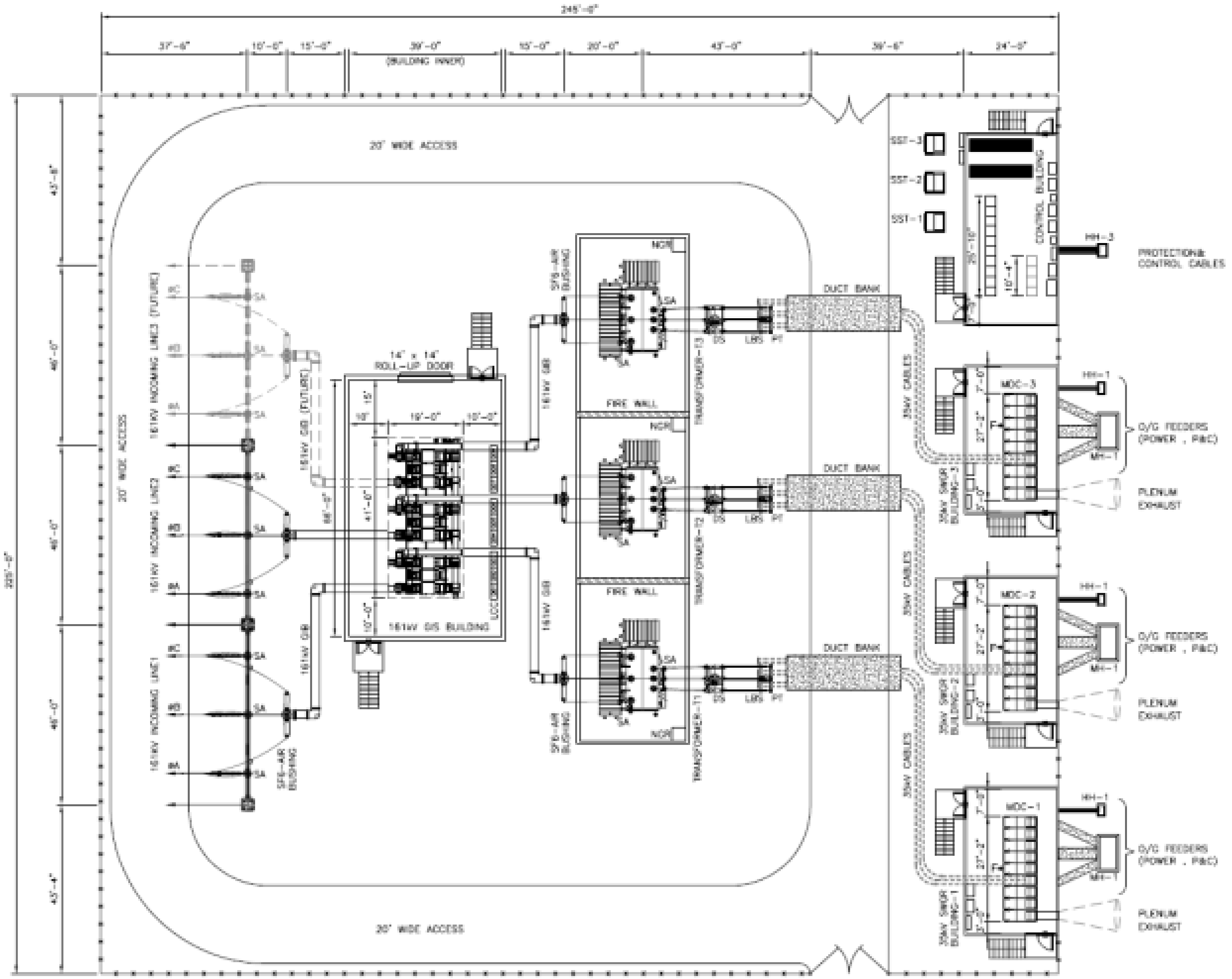


Breaker-And-A-Half Configuration – Air Insulated



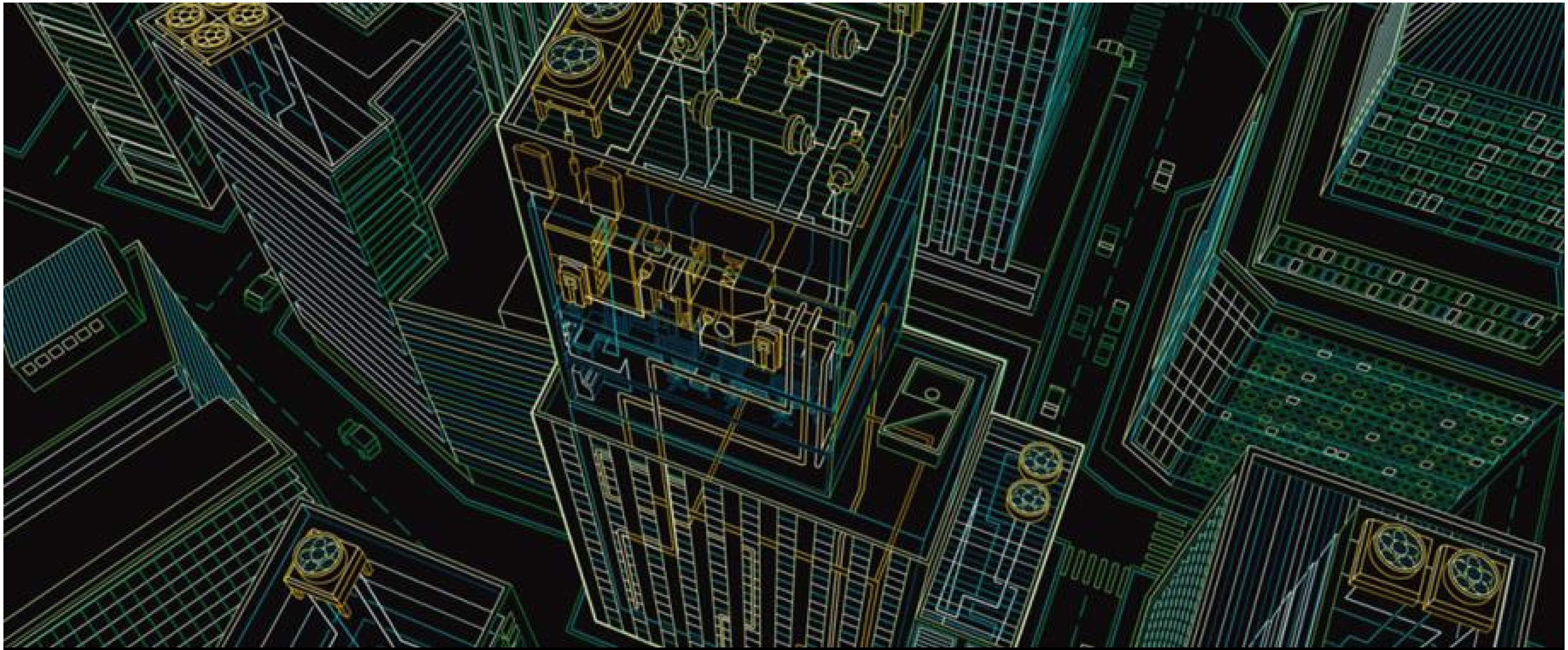
101,250 FT^2

Breaker-And-A-Half Configuration – Gas Insulated



55,125 FT^2

Month DD, Year



GL “Pat” Ervin, ABB Power Grids, Compact Substation Business Development Manager

Transmission Grid Connections
Urban, suburban & rural environments

Topics of discussion

- Compact high voltage switching technology overview
- Traditional air insulated substation (AIS) and compact gas insulated substation (GIS) comparisons
- Substation physical security: build a small energy bunker instead of a large fortress
- AIS to GIS conversion opportunities
- GIS benefits discussion- all substations are GIS candidates

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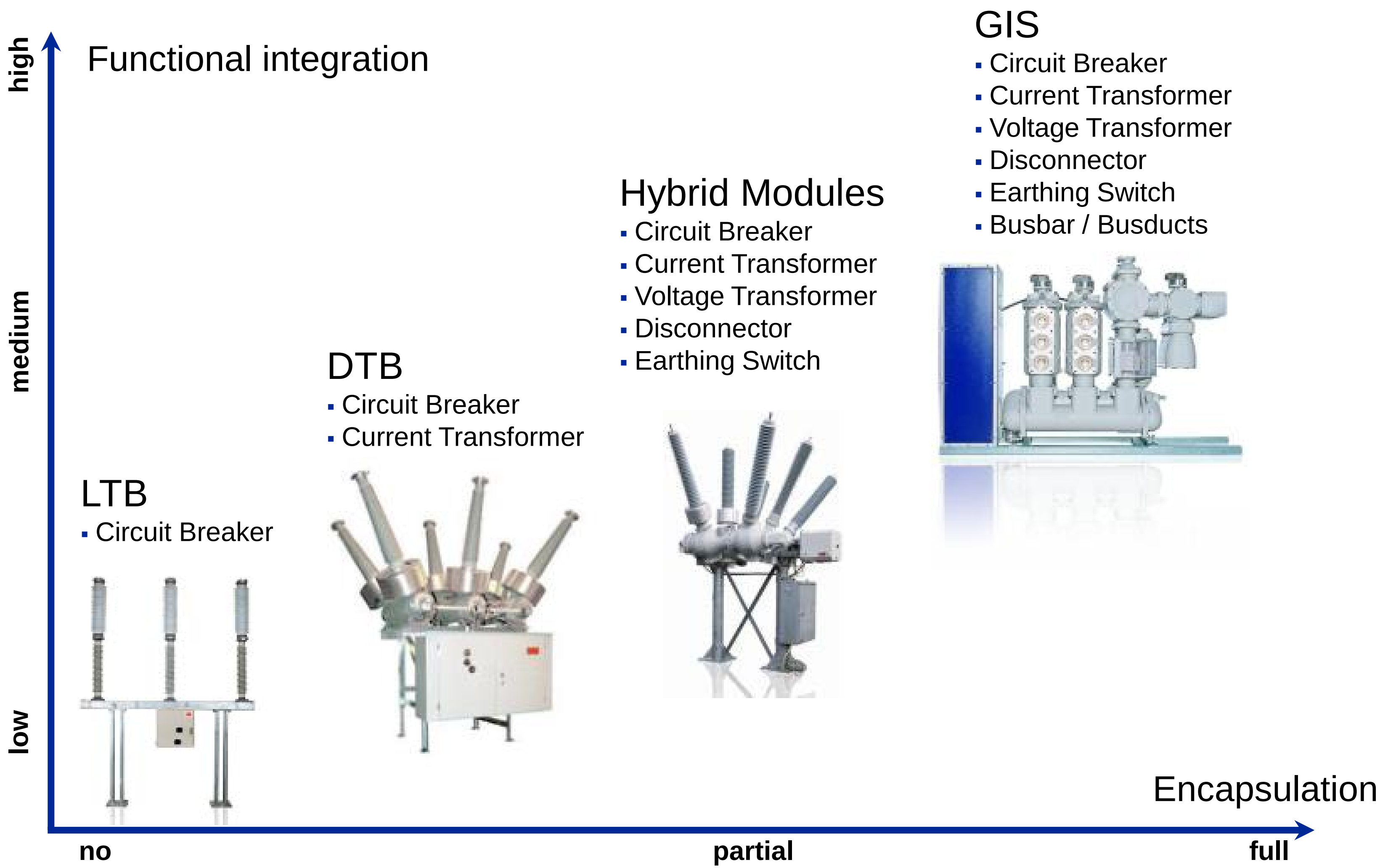
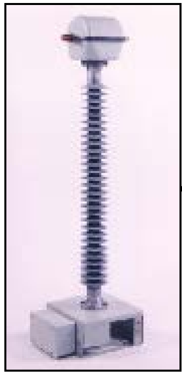
HV Switching Technology Hierarchy

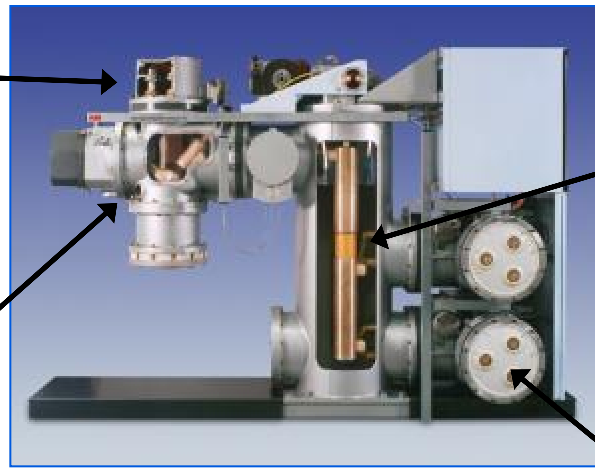


Gas Insulated Switchgear
Functional integration



Instrument Transformers

GIS



Circuit Breakers

Disconnect Switch

Busbar

Steel Structure
Insulators
Control Cabinet
Control Wiring
Supervision
On-site Test

Compact Gas Insulated Substation
Indoor or outdoor applications

- Canopies – equipment almost **independent from environment**
- **Building of all types** – prefab metal to underground
- Increased **reliability**
- Use under **difficult climatic conditions**
- **Easy planning** of outages for service and maintenance

Integrated GIS applications
A complete solution

- GIS preassembled & pretested in a container or on a skid
- Containers equipped with:
  - HVAC
  - Electrical distribution, fire alarm
- Advantages
  - Very fast on-site installation and commissioning
  - Standardisation – economical solution
  - Easy logistics
  - Limited on-site civil construction required
- Customers
  - Remote areas or areas with limited labor force
  - Smaller substations in suburban areas (aesthetics)
  - Conection to industrial applications (Oil / Gas / Mining)

High Voltage Gas Insulated Substations
Substation reliability

Increased Grid Reliability Due to GIS

- Enclosed high voltage components
- Elevated substations for flood and wetland areas, special soil conditions or in existing substations
- Seismically proofed equipment
- Use of HV power cable in combination with GIS
- Weather independent O&M

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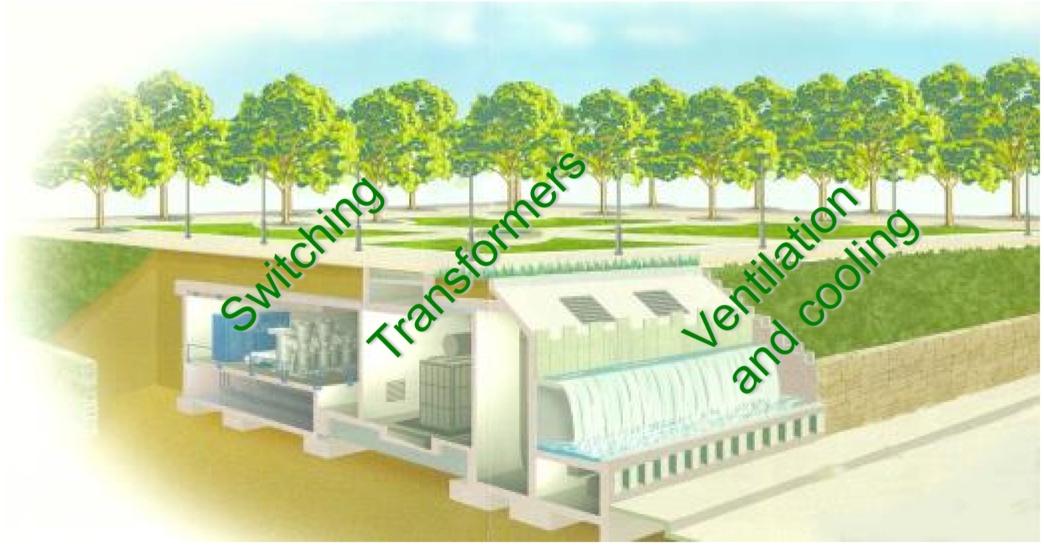
AIS- GIS Substation Comparison

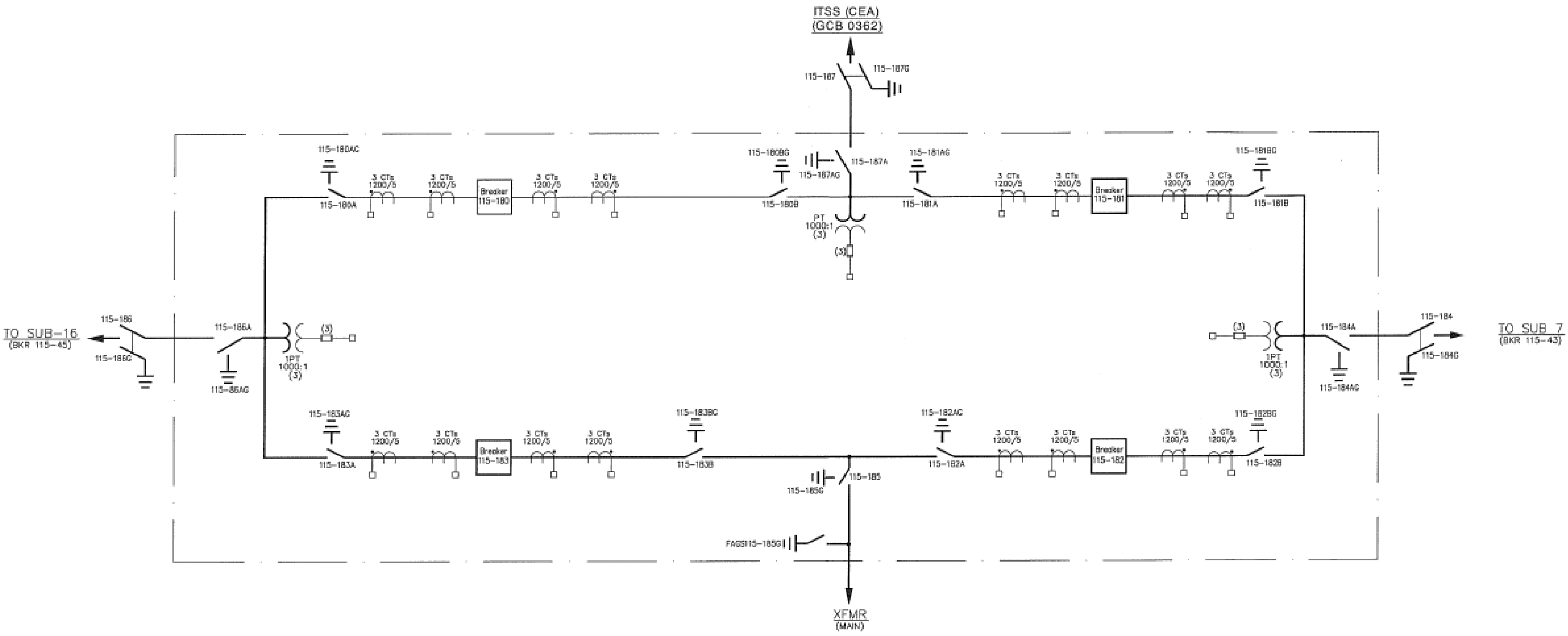
AIS

GIS



Example: 138kV 4 breaker ring configuration

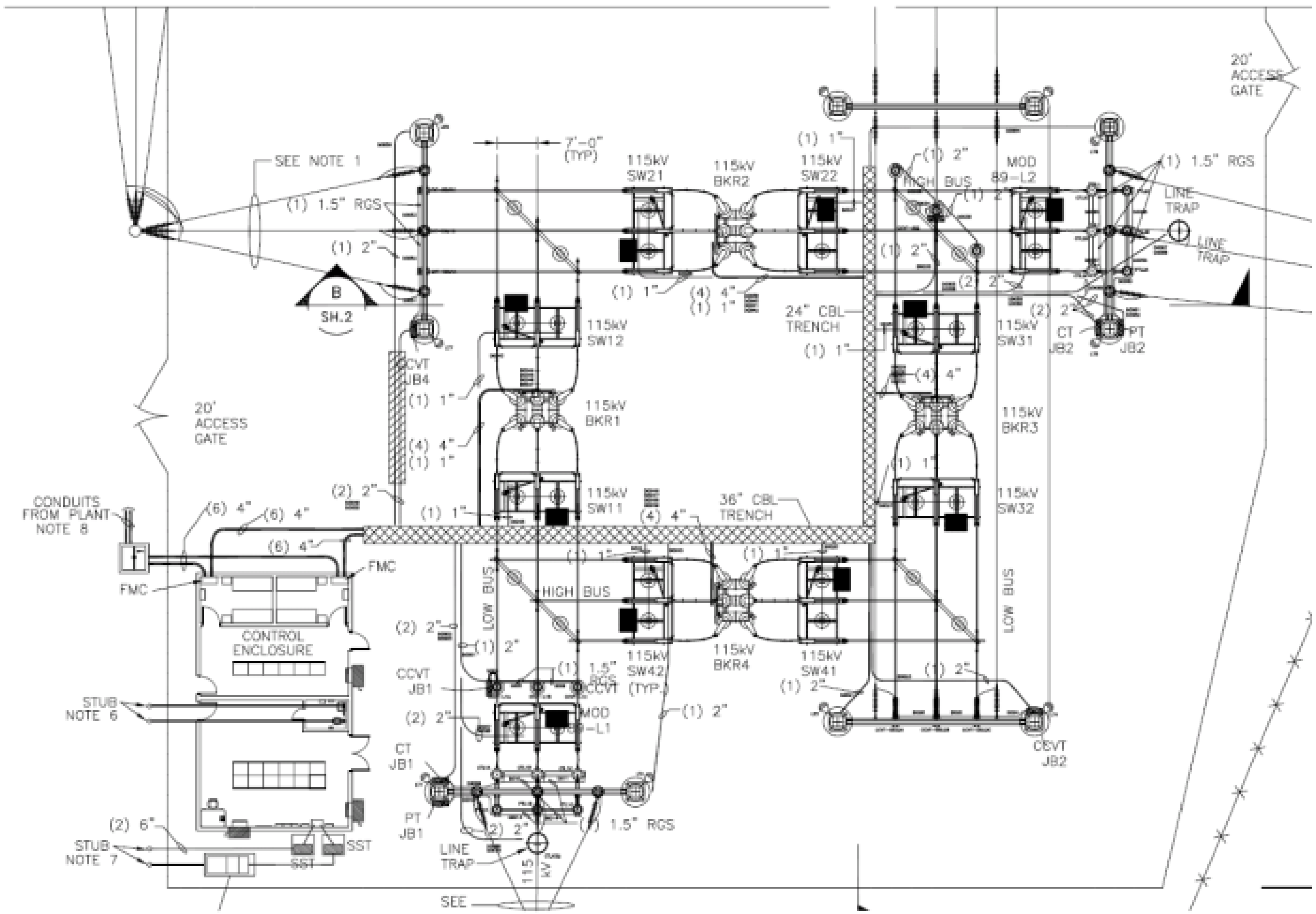
Single line diagram



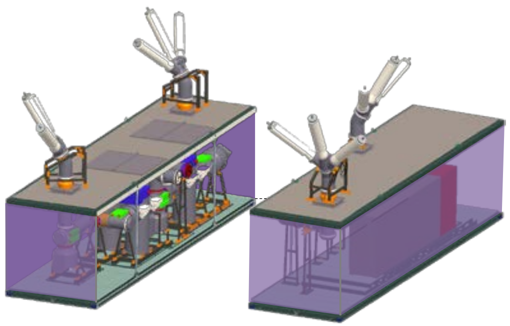
Example: 138kV 4 breaker ring configuration
Conventional AIS substation layout

AIS

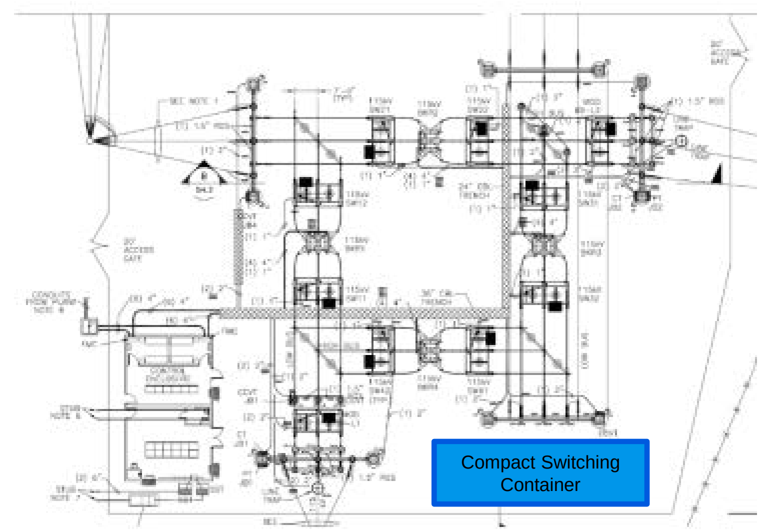
- 4 breaker ring
- 180 ft x 150 ft
- 27,000 sqft



GIS-AIS 138kV switchyard comparison



Compact 840 sq. ft. (40ft x 21ft) or
0.02 acre



Traditional 27,000 sq. ft. or 0.6 acre

ABB

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Build a small energy bunker NOT a large fortress

Large energy fortress using traditional air insulated switchgear

- Exterior & interior 8-20’ walls and gating
- Curved entry roadways
- Forward looking radar
- Anti drone capability
- Mantraps
- Extensive camera & lighting systems
- Annual first responder training
- Armed security guards
- Easily identifiable

Substation physical security
Underground GIS substation

Barbaña
Underground
Substation,
Spain

132 kV, 40 kA

Single
Busbar
Configuration
(3 CB)

Transformer
132/20 kV,
15 MVA

Substation physical security
Underground GIS substation

ABB

High Voltage Gas Insulated substations
Substation security – GIS Heidelberg / Germany

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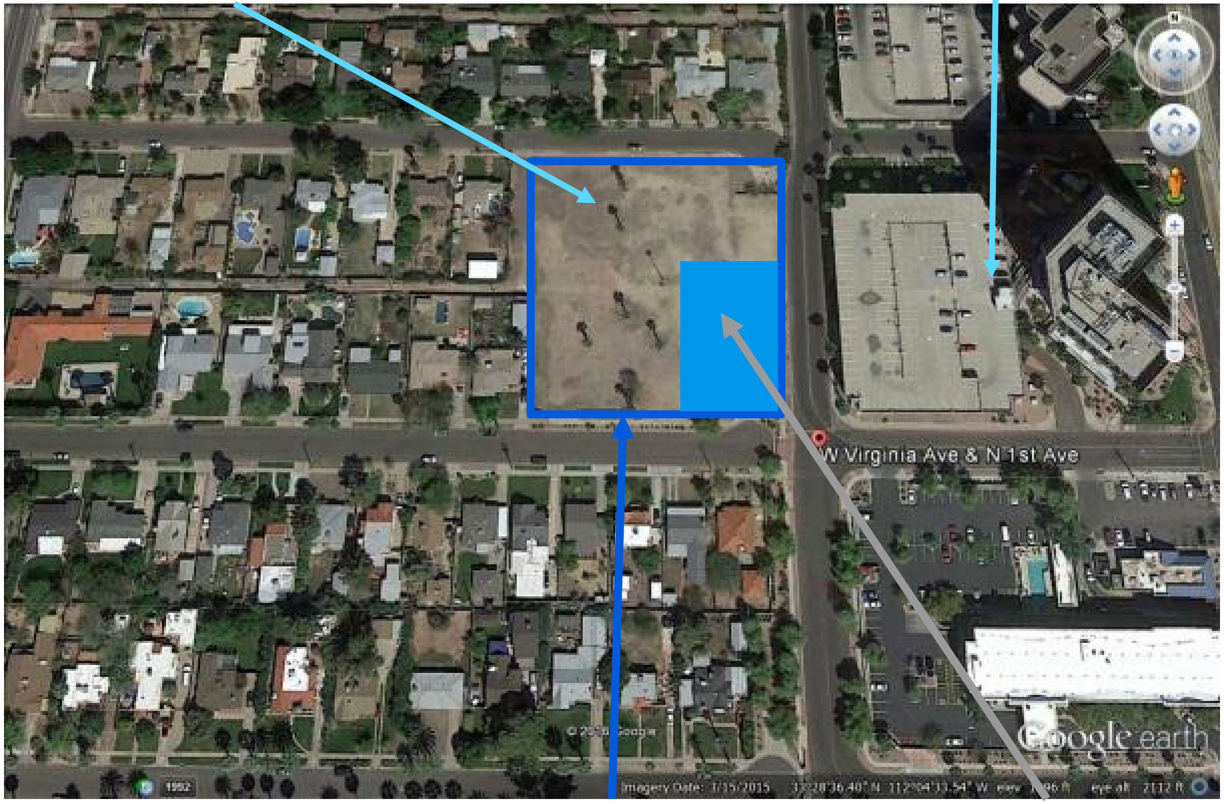
Downtown residential planned AIS substation

Utility purchased 125’ x 150’ lot (18,750 sq ft) for $2.4 million

Bank Building & Parking Garage

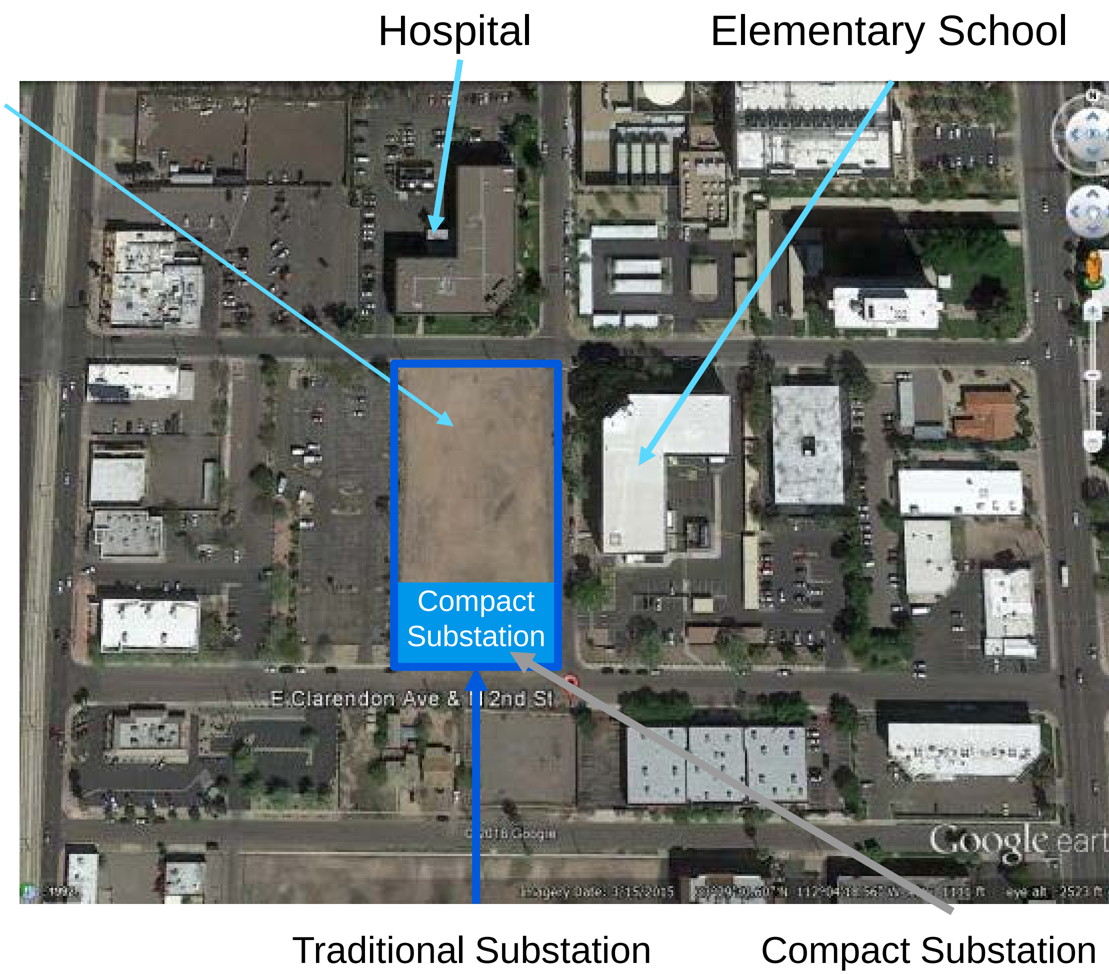


Traditional Substation

Compact Substation

Downtown planned AIS substation

Utility purchased 90’ x 190’ lot (17,100 sq ft) for $2.3 million



ABB

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GIS benefits

- Small footprint: can install inside a new or existing building or enclosed skid
- Lower real estate cost
- Less site preparation
- Reduced construction time: possible “plug & play” options
- Aesthetically pleasing: limited or no “wirescape”
- Substation security: build a small energy bunker not a large costly fortress
- Price competitive
- Mitigate storm damage & climatic impacts
- Easier to permit
- Locatable next to load centers
- 15 times the reliability of AIS

November 14, 2016

Modular Systems
E-Houses & Product Packaging Solutions

Power and productivity for a better world™ ABB

Agenda

- Introduction
- Types of Packages
- Value
- Summary

Introduction

- Package:
  - Multi-product Packaging implementation, either as loose equipment or in a containerized solution (E-house).
- With a wide variety of electrical products available, product packaging offers a seamlessly integrated solution.

Introduction
Responsibility

Ownership of the integration of electrical products, systems, and services by providing one point of contact for proposal engineering and project management through the complete project lifecycle

Introduction
Project Team

Packaging Team includes:

- Marketing/Proposal Engineers
- Project Engineers
- Project Managers
- Controller/Analyst
- Document Control

Types of Packages
E-House

- An Electrical House (E-House) **is a prefabricated walk-in modular enclosure** to house electrical equipment.
  - Power Distribution Center (PDC), Electrical Enclosure, Power Module, etc.
- Custom-engineered, walk-in metal enclosure specifically built to protect critical electrical equipment.
- Completely integrated then delivered to site

Types of Packages
Loose Equipment/Packaged Products

- Assortment of several kinds of equipment from different factories
- Coordination of equipment delivery based on site requirements
- Applications: additional capacity, equipment for existing structures, additional requirements for indoor and outdoor equipment

Value

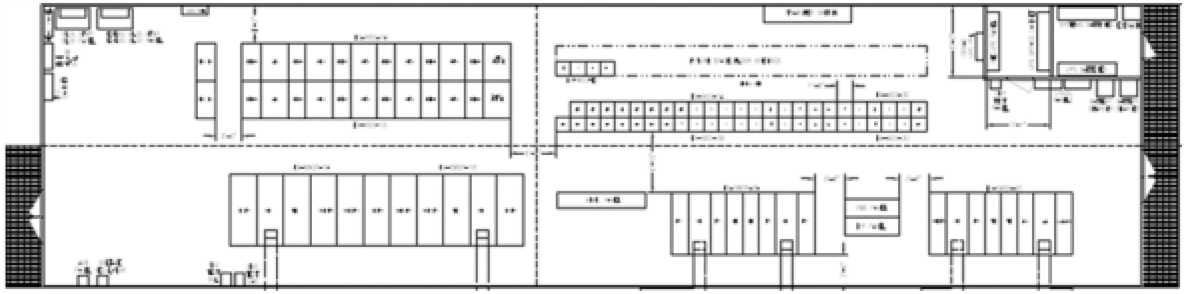
- Single commercial contract
- Alleviates customer resources
    - Estimators
    - Purchasers
    - Legal
    - Project managers
    - Engineers
- Risk mitigation
- Ease of communication
- Interface engineering
- Scheduling/delivery coordination
- Payment milestones based on entire package
- Reduced site work
    - Safer
    - Less expensive
- One set of warranty terms

Value
Proposal Phase

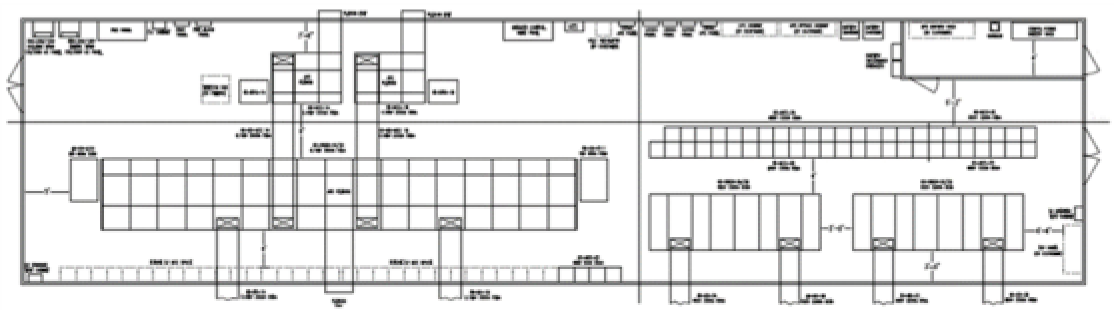
- Include equipment from multiple divisions/factories, with capabilities to include 3rd party products
- One proposal
- One set of terms and conditions
- One purchase order
- Preliminary Design Optimization
  - Optimization of products and one line to reduce space in layouts
  - Reduces mid-execution scope change to maintain project schedule

Value
Preliminary Design Optimization Example

Customer PDC Layout: 124’ x 32’ = 3,968 SQFT



Optimized PDC Layout: 114’6” x 28’9” = 3,292 SQFT



Space savings: 17%
Cost savings: 8.5%

Value
Project Execution Phase

- Internal Handover to transition from Marketing to Project Execution
- External Project Kickoff meeting with key stakeholders
- Weekly project status calls
- Project Manager coordinates all equipment from start to finish
  - Document tracking
  - Submittals of drawings
  - Organized delivery of all equipment
  - Post warranty issues

Summary

1 **Single Commercial Agreement**
One contract for the entire package, reducing requirements for multiple commercial agreements

2 **Reduces Client Resources**
Packaging group is responsible for scope, reducing resources needed to manage the project

3 **Custom Solutions**
Variety of offerings available which can be combined to accommodate largely differing scopes

4 **On-Schedule Project Delivery**
Project Manager providing a single point of contact

5 **Project Life Cycle Support**
Complete Service support through FAT and site installation to reduce project risk

Power and productivity
for a better world™