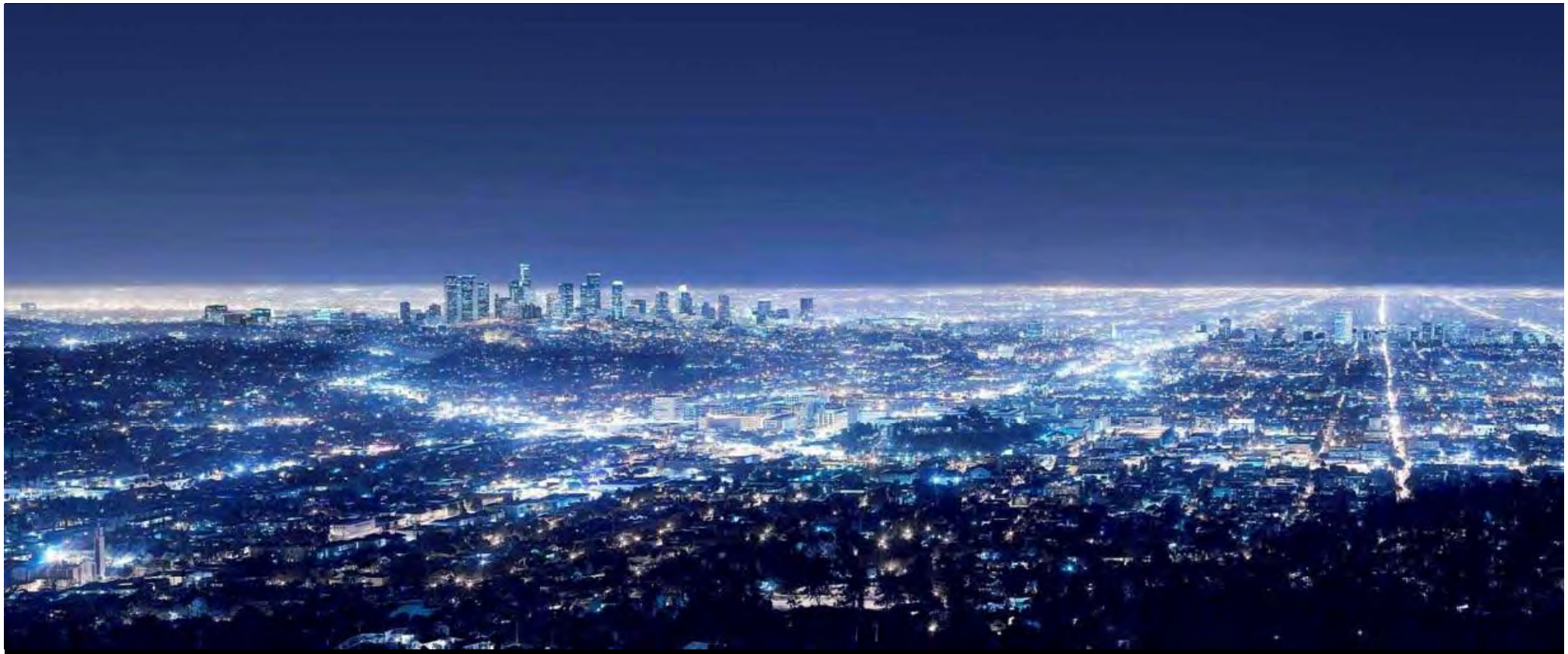


Anders Sjoelin, ABB Power Systems

IEEE Substations Committee Meeting

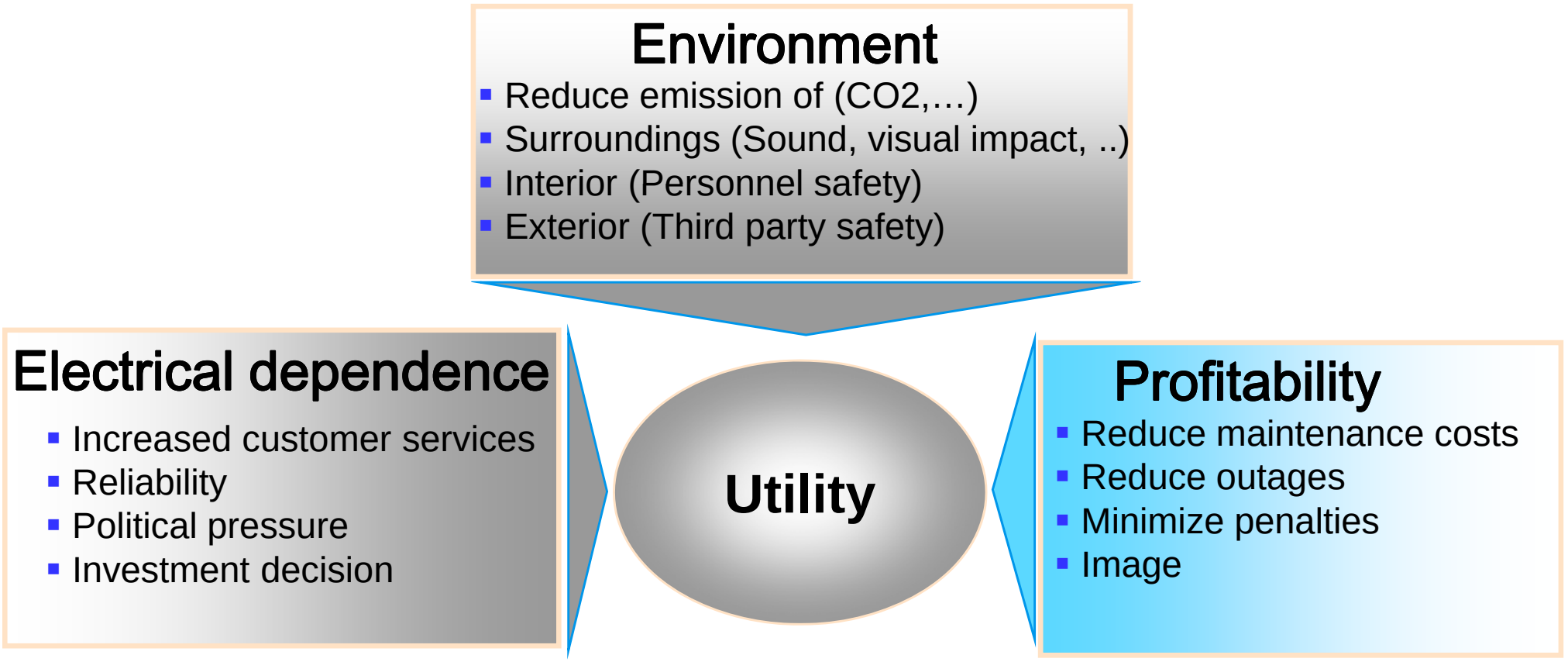
Substation Concepts for the Future

Reminder

- ***Anything that is in the world when you're born is normal and ordinary and is just a natural part of the way the world works.***
- ***Anything that's invented between when you're fifteen and thirty-five is new and exciting and revolutionary and you can probably get a career in it.***
- ***Anything invented after you're thirty-five is against the natural order of things.***

From the "Salmon of Doubt", by Douglas Adams

Customer Challenges



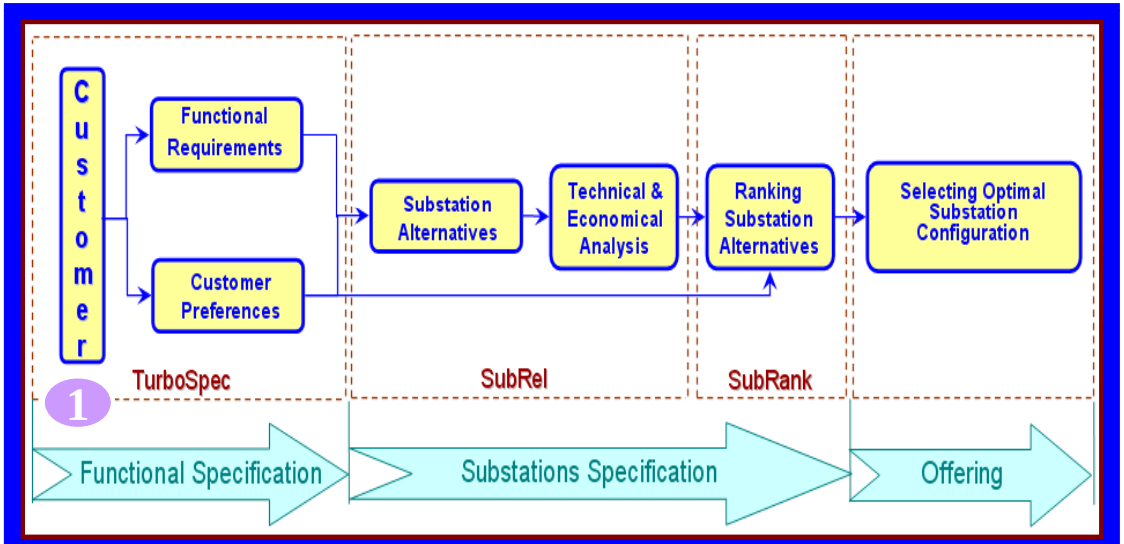
Vision

Support end-users rebuilding and reshaping the North American grid for the future, with present and future technologies in mind, based on:

- **Safety**
  - Less exposed energized (live) equipment
  - More equipment in “dead-front” enclosures
- **Reliability & Availability**
  - Less “Ad Hoc” reliability estimations
  - More sophisticated reliability analysis, incl. economic evaluations
  - Increased drive towards Total Cost / Life Cycle Cost (LCC) of ownership
- **Reduced Maintenance**
  - High performance equipment with minimum maintenance
  - Greater withstand against environmental impact
  - Reduction of number of components
- **Aesthetic & Environmental Impact**
  - Continued environmental concerns
  - More pressure on the aesthetics aspects
- **Modularity**
  - Factory assembly & testing
  - Reduced time on site
- **Minimum footprint**
  - Continued drive towards smaller & compact substations
- **Cost effectiveness**

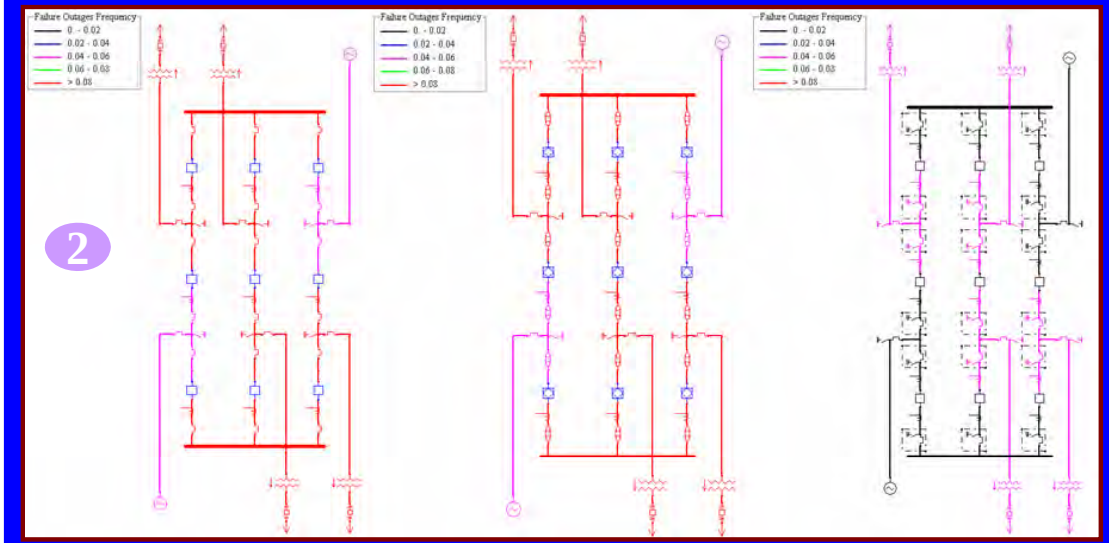
Safety - Dead front enclosure – AIS S/S

Reliability – Selecting Optimal Substation Solutions

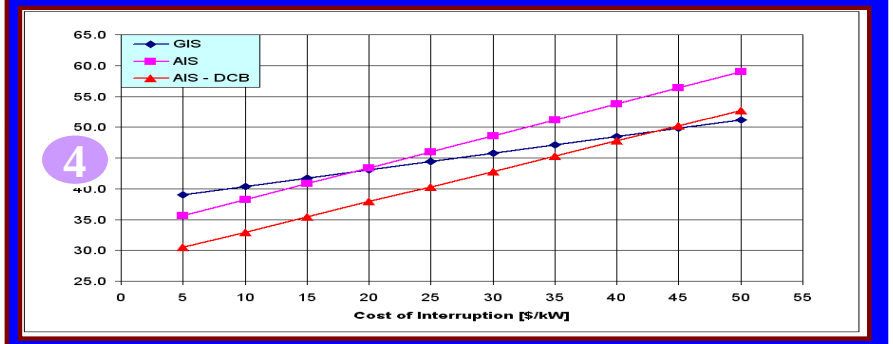


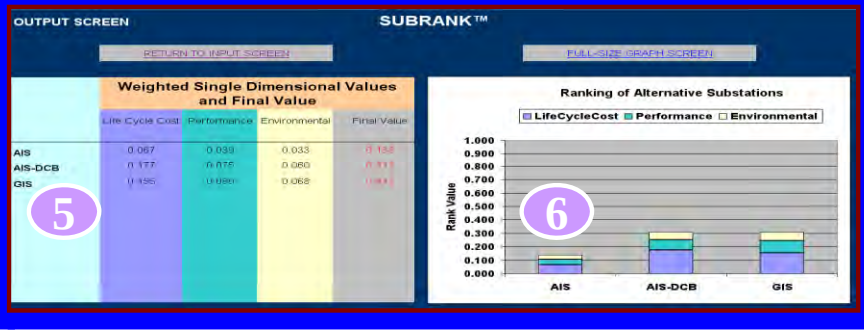
Methodology Major Pillars

1. Collecting S/S Functional Requirements
2. Identifying S/S Alternatives
3. Reliability Analysis
4. Economic Analysis
5. Ranking S/S Alternatives
6. Selecting Optimal S/S Solution



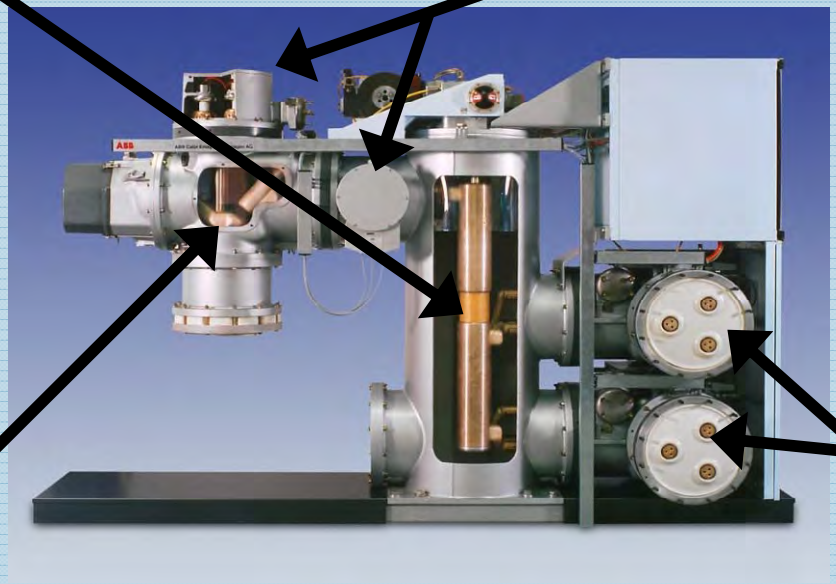
Configuration Type	Total OF /yr	Total OD hr/yr	Failure OF /yr	Failure OD hr/yr	Maint. OF /yr	Maint. OD hr/yr
3 AIS	0.94748	14.57	0.09748	3.17	0.85	11.40
AIS-DCB	0.54136	13.01	0.09136	3.21	0.45	9.80
GIS	0.36770	12.69	0.05100	3.16	0.32	9.53





Reduced Maintenance – Change the Component Environment

- Gas Insulated Switchgear
  - No exposed components => Inherently safer & less maintenance
  - Fewer components => higher reliability & less maintenance



Circuit Breaker

Instrument Transformers

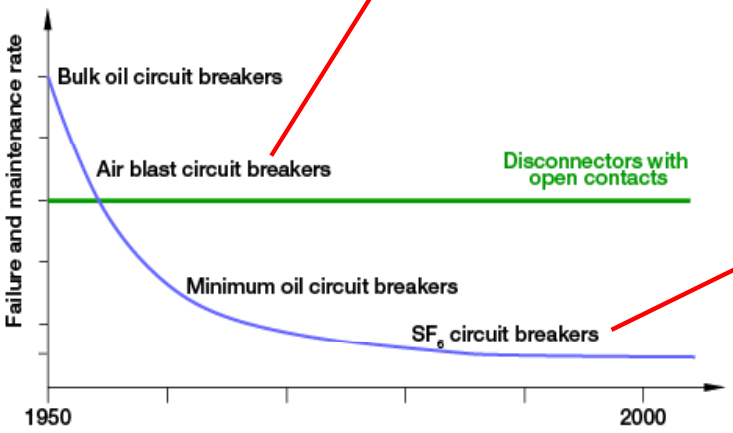
Busbar

Disconnect Switch

GIS

Reduced Maintenance – Reduce / Eliminate Components

- Magnetic Actuators vs. Spring Drive Mechanism
  - 7 vs. 100+ moving parts => less maintenance
  - 100,000 vs. 10,000 operations => longer life
- Elimination of AIS Disconnect Switches
  - Less components => higher reliability & less maintenance



Minimum Footprint

- Continuous drive towards compact substations:
  - Space savings / utilize available space
  - Cost reductions
  - Minimized aesthetic impact
  - Enabling future relocation

Compact Substation – GIS vs. Conventional AIS

Modular Approach

- Pre-Engineered, Pre-Fabricated and Factory Tested “Modules” with well defined interfaces.
  - Containerized approach, HV (GIS) and MV equipment
  - “Kiosk” approach for protection, control & monitoring systems
  - Benefits:
    - Reduced time on site for construction, installation & testing
    - Factory tested => Reduction of mistakes on site
    - Coincides with “Plug-and-Play” advances in SA
    - Potential for future relocation

“Kiosk” approach for Substation Automation system

Optimizes:

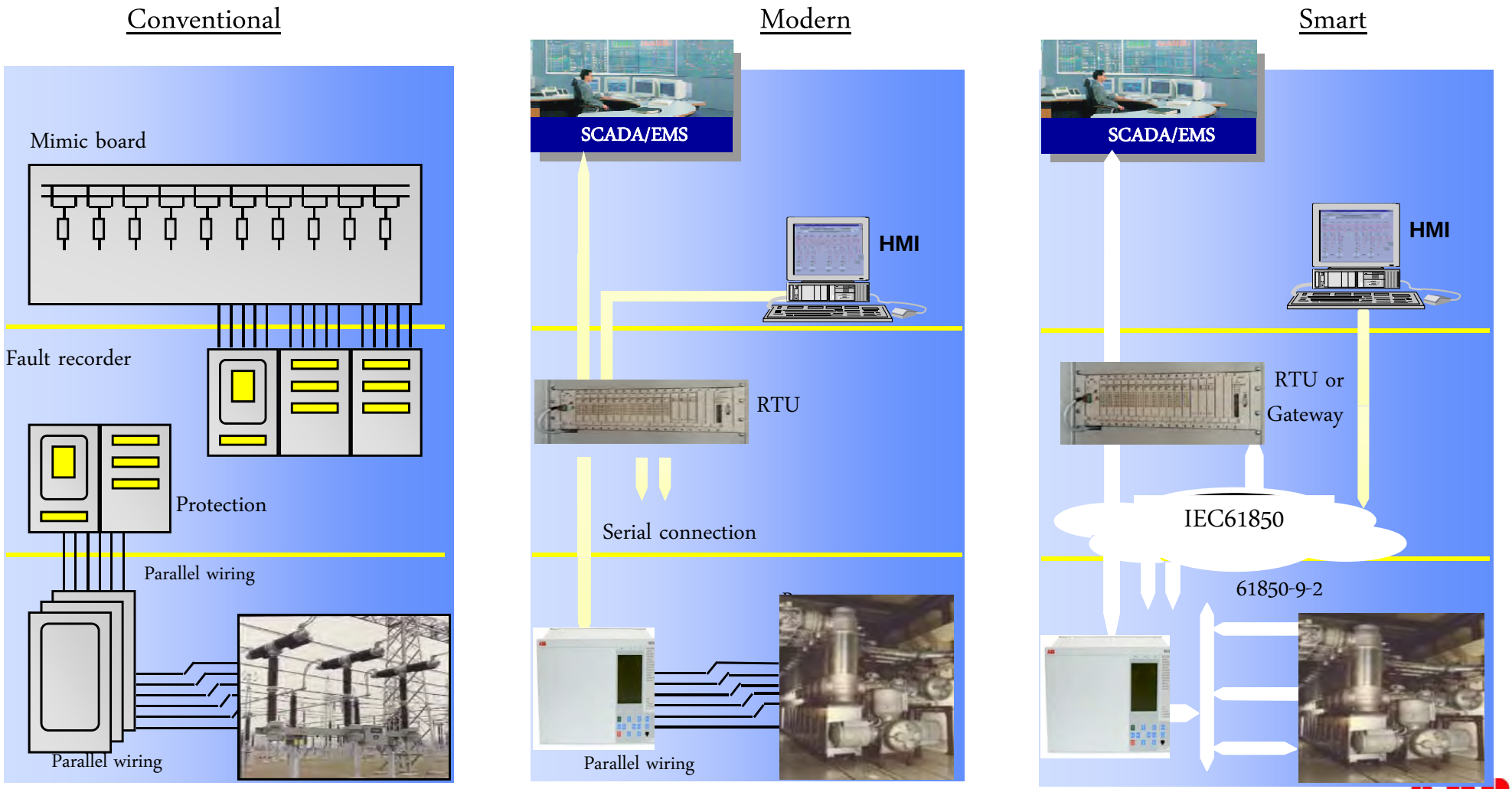
- Design
- Implementation
- Testing of P&C schemes
- while improving reliability

Facilitates:

- All intra-panel wiring intact
- Comprehensive FAT process
- SA system tested in the factory
- Transport to site
- Improves delivery quality

Monitoring and Control

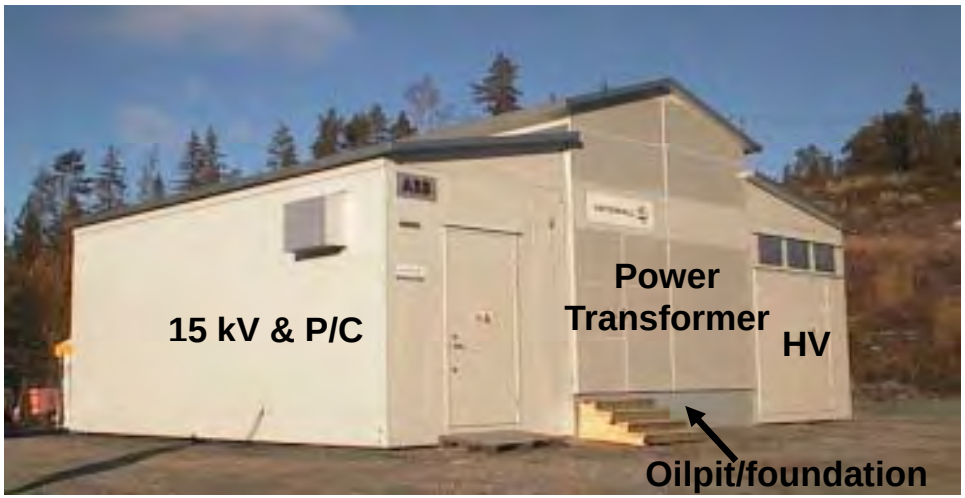
- Substation Automation vs. SCADA system



Alternative Technologies

- Compact Indoor AIS Substations
- Disconnecting Circuit Breaker (DCB)
- GIS
- Hybrid Solutions

Pre-Manufactured Indoor AIS Substation



- High availability (equip. indoor)
- Suitable up to 72 kV
- Small footprint
  - ~100 m^2 (1/3 of traditional)
  - Land preparation minimized, all equipment pre-fabricated
- Short time on site (~2 weeks)
  - 5 days for installation
  - connection to network
  - commissioning
- Low maintenance cost
- Can easily be relocated
- Environmentally friendly
- Personnel and third party safe

Disconnecting Circuit Breaker (DCB)

- **What is the purpose of a disconnect switch?**
  - Disconnect switches are traditionally used for:
    - Isolating the breaker for maintenance of the breaker itself
    - Isolation of lines, transformers, etc., for operational or maintenance purposes

In short - a disconnect switch is used to enable maintenance!

Disconnecting Circuit Breaker (DCB)

- **Disconnect switches can be operated by mistake due to**
  - **Fault in the interlocking logics**
  - **Fault in CB auxiliary contacts**
  - **Personnel fault**
    - By-pass of interlocking system
    - No interlocking system provided
  - **Mechanical problems**

- **Inadvertent opening will cause arcing, which will not be detected until it strikes to ground or another phase**.
  - This can lead to serious primary faults, e.g. faults between bus 1 and bus 2, which will shut down the whole substation
  - This can lead to major trouble for the network and in the worst case a black-out of part or the entire network

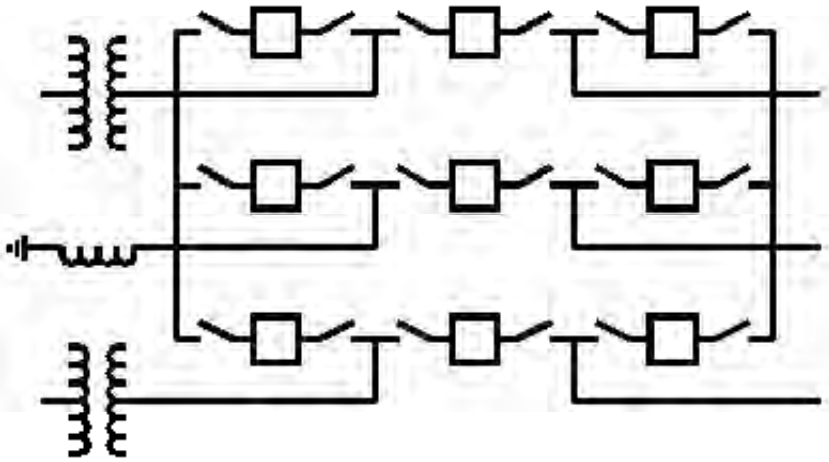
Disconnecting Circuit Breaker (DCB) - Operation

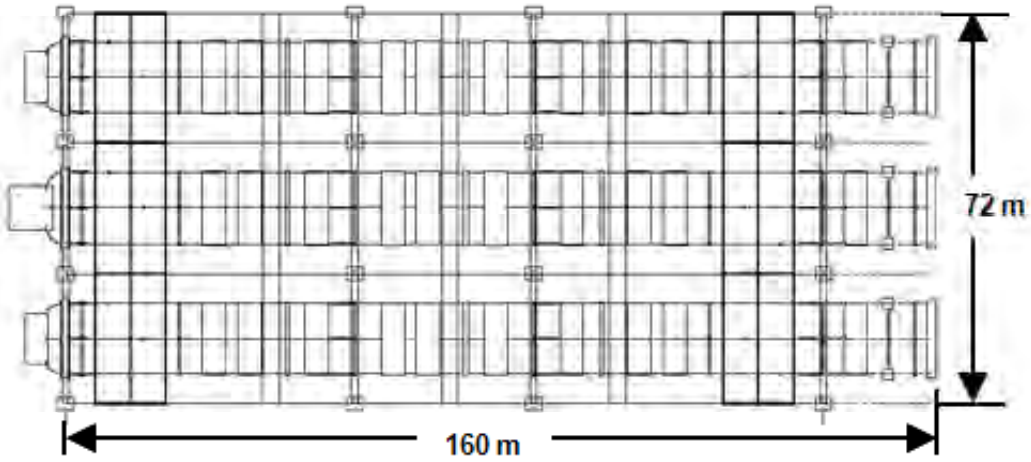
- Four different service positions:
  - Closed (as normal circuit breaker)
  - Open (as normal circuit breaker)
  - Disconnected (mechanical block of operating rod and electrical interlock of breaker mechanism)
  - Grounded
- Visual indication by position of the grounding switch

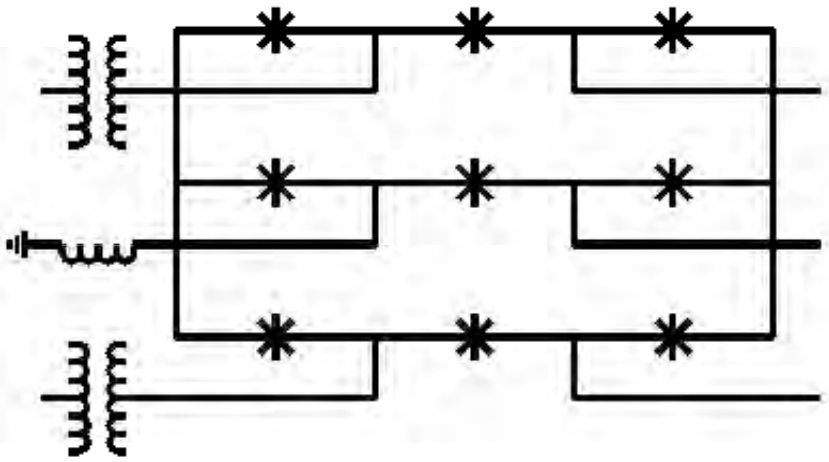
- Safe operating procedures
- Adaptable to local regulations

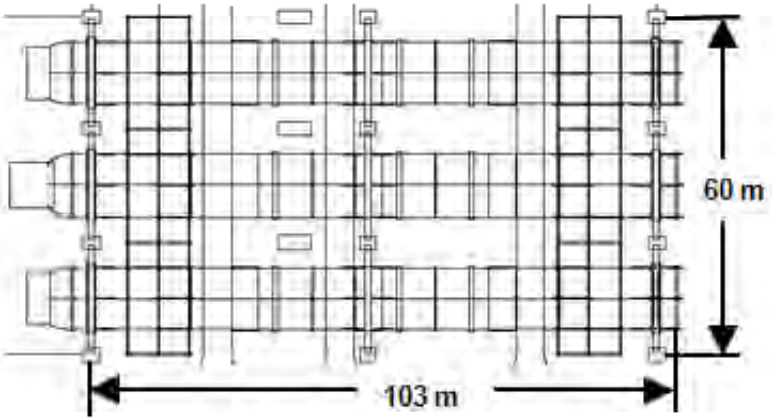
Disconnecting Circuit Breaker (DCB) - Savings

400-500 kV: DCB reduce space with ~50%









✱ = Disconnecting Circuit Breaker

Disconnecting Circuit Breaker (DCB) - Summary

- **Reduced capital investment cost**
  Differs from case to case, up to about 10% lower compared to traditional solution
- **Reduced cost for equipment maintenance**
  Over 50% (disconnect switches require most maintenance)
- **Increased availability, all primary contacts encapsulated in SF6**
  Unavailability due to maintenance appr. 85-90% less
  Unavailability due to primary faults 43-50% less
  This saves outage costs during S/S lifetime and reduce the risk of blackouts.
- **Reduced space**
  About 30-50% space reduction depending on the S/S configuration. Reduced cost for land and land preparation for greenfield S/S and enables easier rehabilitation of existing S/S.
- **Reduced environmental impact**
  Less concrete, copper, steel and small materials

GIS and Hybrid AIS / GIS Solutions
Functional Integration of SF6 technology
Overall description

Price

LTB
- Circuit Breaker

DTB
- Circuit Breaker
- Current Transformer

Hybrid Modules
- Circuit Breaker
- Current Transformer
- Voltage Transformer
- Disconnector
- Earthing Switch

GIS
- Circuit Breaker
- Current Transformer
- Voltage Transformer
- Disconnector
- Earthing Switch
- Busbar / Busducts

Functional Integration

High Voltage SF6 Insulated Substations
Why using SF6 insulated Technology

COMPACT

- Small footprint
- Easy Installation
- Installed in buildings

ENCAPSULATED

- Safe
- Reliable
- Flexible location
- Easy SS extension

- High Security
- Low Visual Impact
- Easy M&O

- Solution for remote and special locations
- Higher system efficiency

SF6 Hybrid Solution
Mixed Technology System - MTS

- Combination of AIS Substation with enclosed technology
- Up to 60% space saving
- Available from 46 kV to 1100 kV with up to 63 kA and 4000 A
- Gas segregation between circuit breaker and other compartments
- Based on well proven technology
- Realization of all common SLD's such as SBB, DBB, Ring, 1 ½ …
- Circuit breaker tested for LTB-requirement
  - No LTG capacitance required for 63 kA / 60 Hz
  - Tested according class C2 (very low restrike probability) and M2 (10'000 CO operations)

Benefits of MTS

- Combination of the advantages from **GIS** (**high reliability**) with those of **AIS** (**short repair time**)
  - Repair of “major failures” within 24 h
  - Replacement with a pre-tested spare-pole
  - High reliability due to encapsulated technology
  - High degree of safety
- Substation easy to extend during the whole life-cycle
- Easy combination of Hybrid GIS from different manufactures.
- Combination of Hybrid GIS with other single apparatus (AIS) is possible

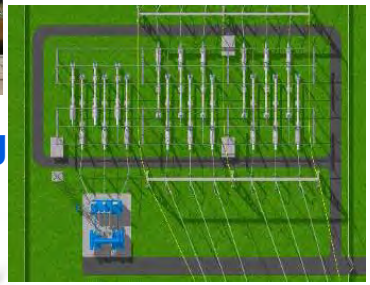
Benefits of MTS

- High Availability and low life-cycle cost for 40-50 year life-time
- All switching equipment within protected and sealed SF6 gas compartment.
- Significant reduction of air-insulated insulators
- No necessity of manual grounding
- Use of composite silicon rubber insulators
- All components are completely factory-tested as one pole assembly
  - Reduced installation time
  - Commissioning time can be reduced to a minimum
- Extremely short project execution time

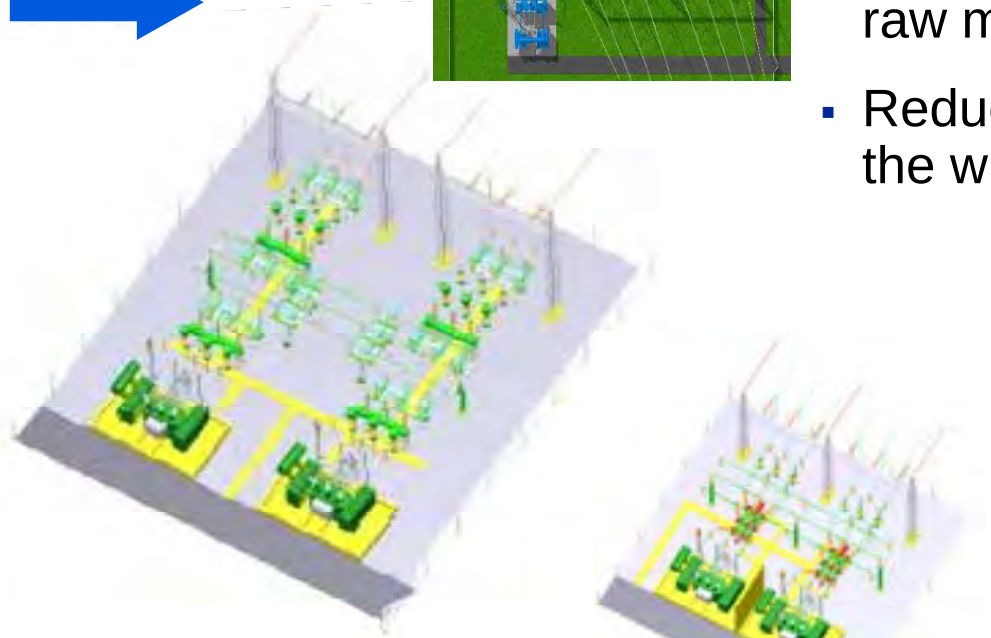
Benefits of MTS
Space Reduction and Environmental Friendliness

420 kV Substation Robbi, CH:
In-Line Configuration

60% space saving

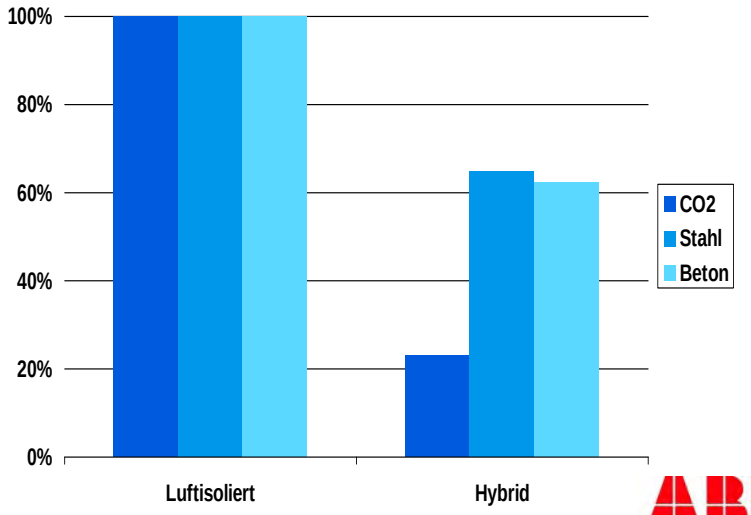


110 kV Substation
H- Configuration



40% space saving

- Significant space reduction of up to 60% to conventional AIS substation layout
- Use of In-line configuration or U-configuration (OHL)
- Significant reduction of resources, raw material and energy
- Reduction of CO2 emission during the whole life-cycle process by 77%



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