11TH INTERNATIONAL EXHIBITION OF ELECTRICAL AND INDUSTRIAL ELECTRONICS INDUSTRY
ELECRAMA-2014
8-12 JANUARY 2014, BIEC, BANGALORE, INDIA

SUBSTATIONS

In the Power System of the Future

Terry Krieg
Chairman CIGRE Study Committee B3 - Substations

SINCLAIR KNIGHT MERZ
SKM

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JACOBS

Overview

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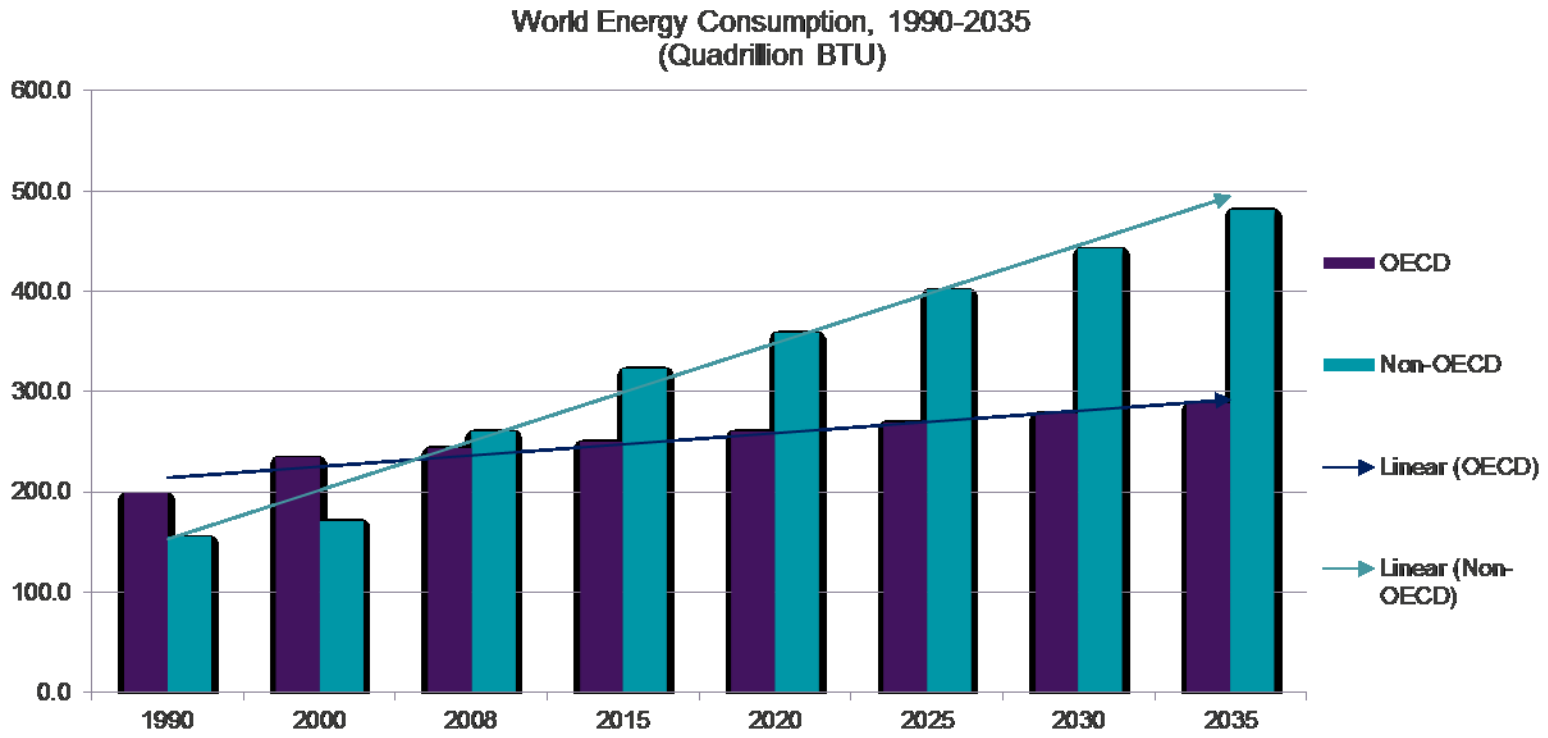
- Background
- CIGRE Study Committee B3 Activities
- Challenges in Industry
- Trends in Substation Development
- The Future Substation
- Questions

The big picture - global influences

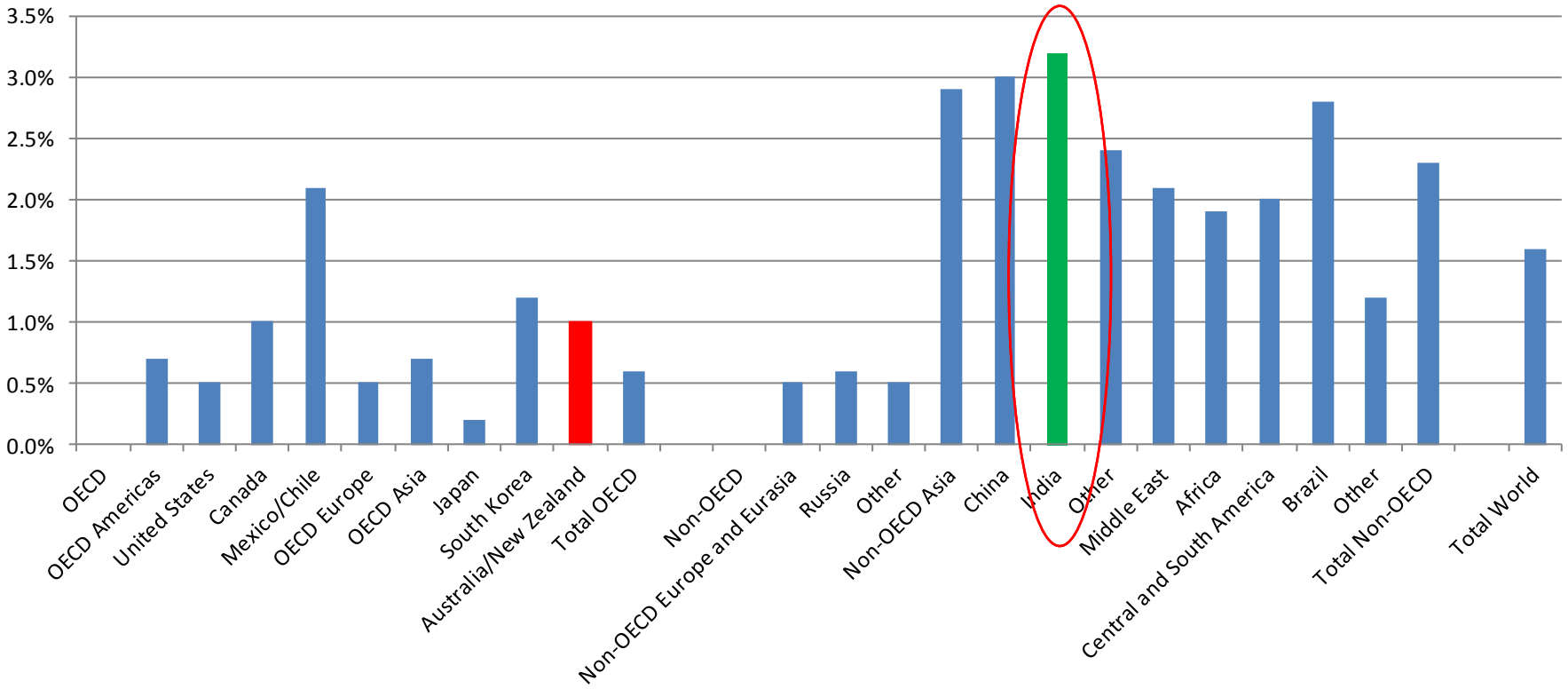
Background

World Energy Consumption



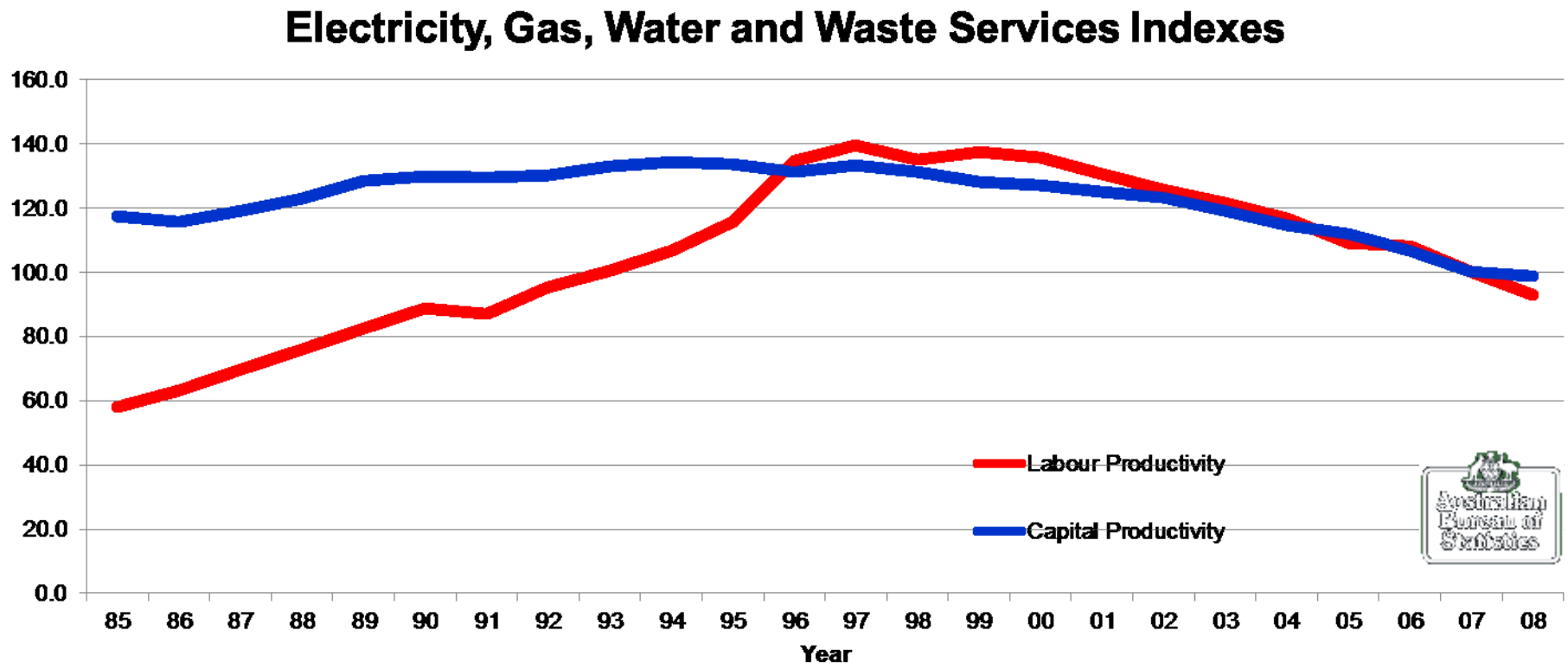
- Continued growth in demand expected
- Climate change impacts?

Energy Growth Rate to 2035



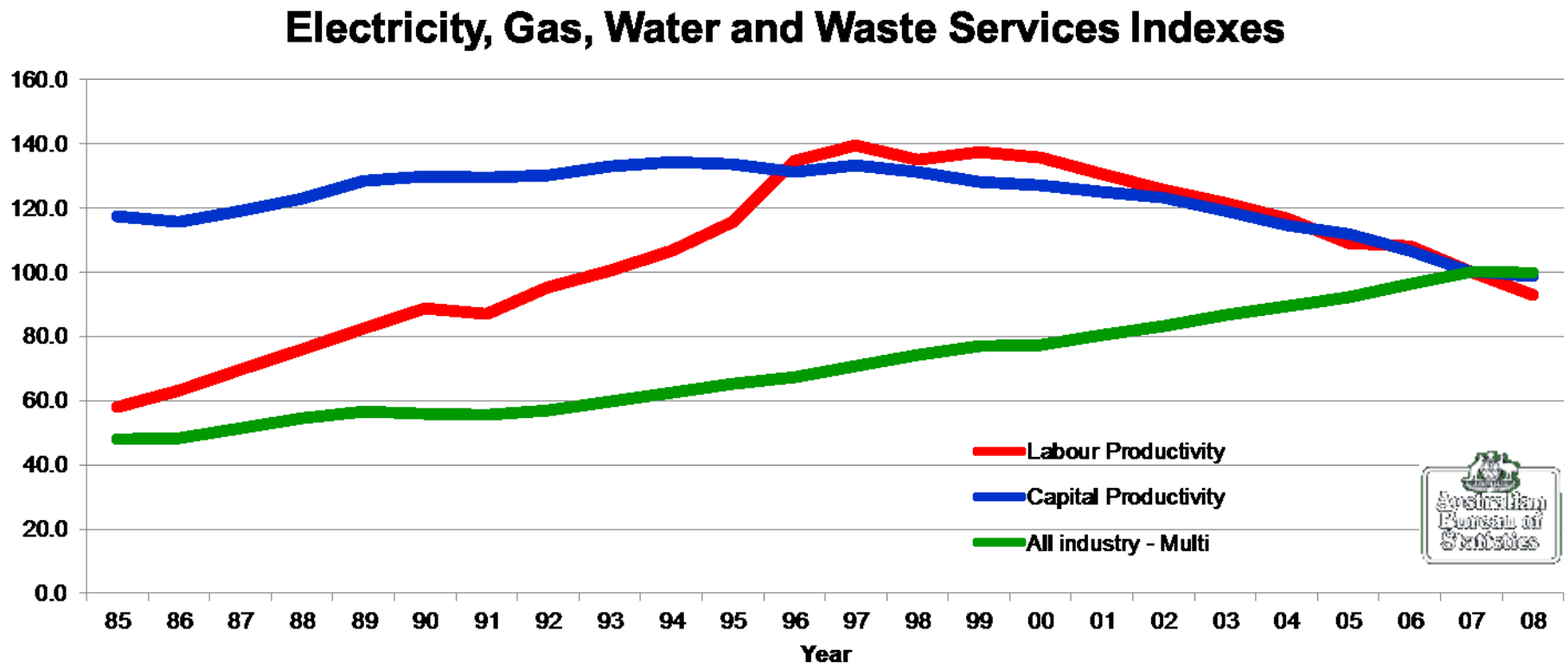
- Growth in demand: domestic, mining and industry
- Asset renewal and refurbishment
- Significant increase in infrastructure is required

Australian Productivity



- Combined water, gas, water and waste
- Source the Australian Bureau of Statistics

Australian Productivity



- Ranked 27th in quality of electricity supply (source WEF)
- Not as good as we thought?

Common Problems

Labour:

- Labour costs
- Increased level of management
- Skill shortages, staff retention
- Staff (and consultant) resistance to change!
- De-engineering of organisations, reducing innovation

Capital Delivery:

- Regulatory environment
- Industry unbundling and privatisation process
- Design standards & procurement options
- We need fast delivery, minimised, predictable costs
- We need to do more with less!

- Representing the power industry

CIGRÉ

Who is CIGRÉ?

Conseil **I**nternational des **G**rands **R**éseaux **É**lectriques

International Council On Large Electric Systems

- Founded in Paris in 1921
- Worldwide non-profit association.
- Addresses issues related to the development, operation and management of electric power systems
- Design, construction, maintenance and disposal of equipment and plants.
- 8000 members in 89 countries

CIGRE Technical Committees

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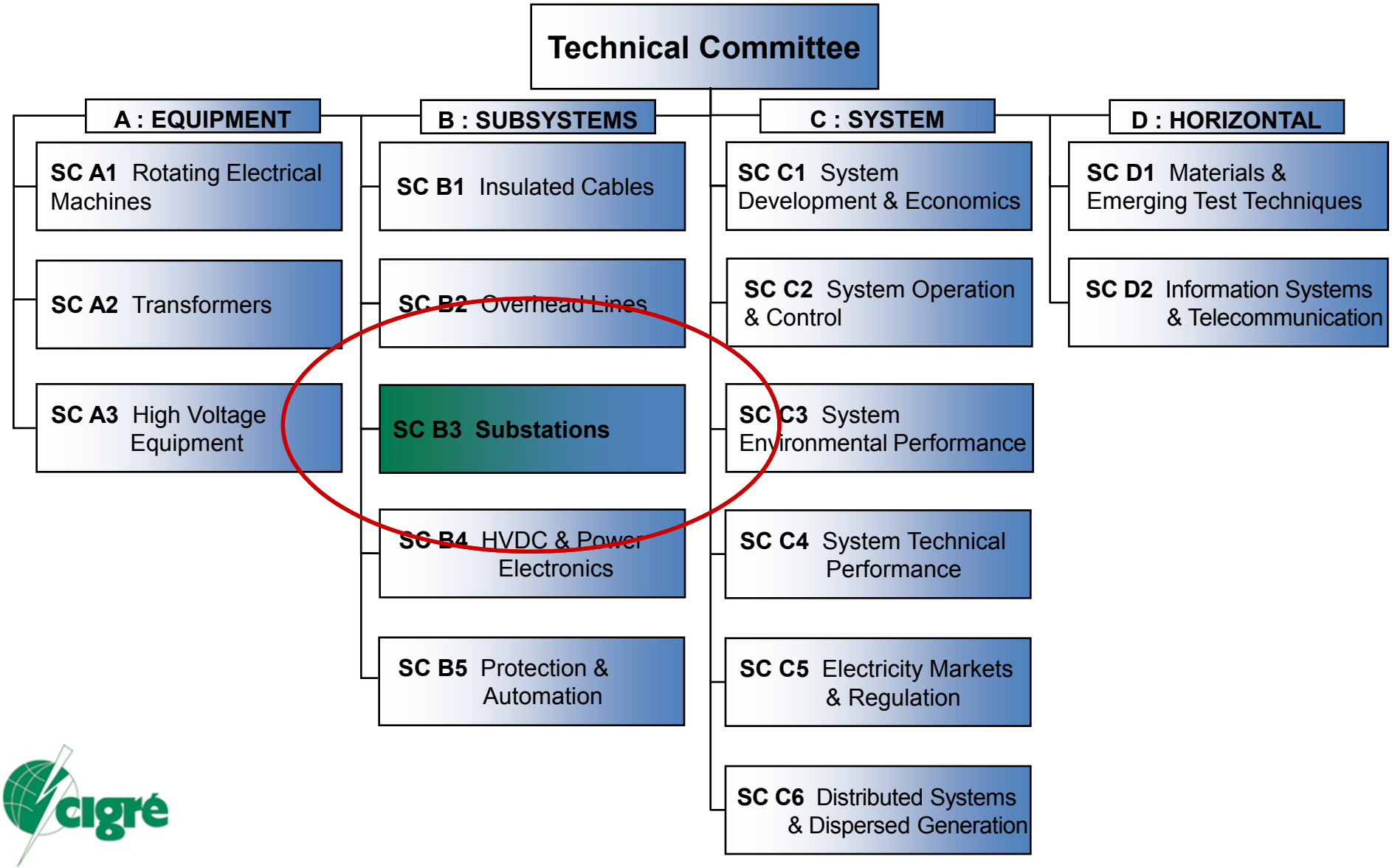


SC B3 Structure

Strategic Advisory Group

SC B3 Secretary

SC B3 Chairman

Customer Advisory Group

Tutorial Advisory Group

Study Committee
24 Regular Members, 14 Observer Members, 2 Special Reporter, all WB Convenors

B3.13
Reducing replacement time of HV Equipment

B3/C1/C2.14
Circuit Configuration Optimisation

B3.36
Special Considerations for AC Collector Systems and Substations associated with HVDC connected Wind Powers Plants

B3.35
Substation earthing system design optimisation through the application of quantified risk analysis

B3.25
SF6 analysis for AIS, GIS and MTS condition assessment

B3.29
Field test technology on UHV substation construction and operation

B3.30
Guide to minimize the use of SF6 during routine testing of electrical equipment

JWG B3/B1.27
Factors for investment decision GIL vs. Cables for AC Transmission

WG B3.24
Benefits of PD diagnosis on GIS condition assessment

WG B3.37
Internal arc effects in medium voltage switchgear (1-52kV) - mitigation techniques

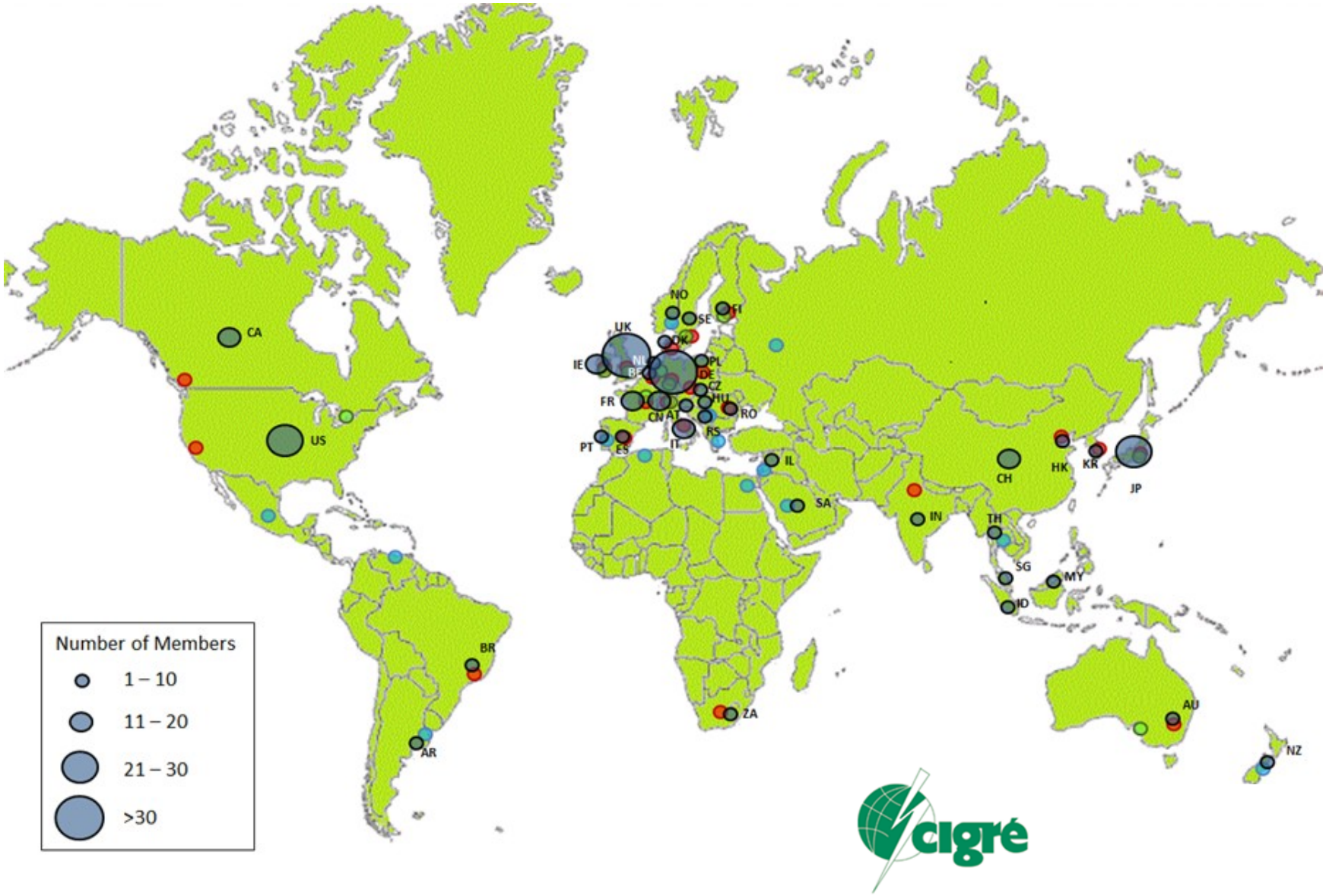
B1/B3.33
Feasability of a common dry type interface for GIS and Power cables of 52 kV and above

B3.31
Air insulated substations design for severe climate condition

B3.32
Saving through optimized maintenance of Air insulated Substations

B3.34
Expected impact of future grid concept on substation management

SC B3 – Membership



Study Committee B3

Mission:

- To facilitate and promote the progress of engineering
- International exchange of information and knowledge
- Add value to this information and knowledge by:
  - Synthesizing state-of-the-art practices and
  - Developing recommendations and providing best practice.

Scope:

- Design, construction, maintenance and management
- Technical, economic, environmental and social aspects for stakeholders
- Increased reliability and availability, cost effective solutions, managed environmental impact, effective asset management.
- Requires effective relationships with other SC's

Preferential Subjects 2014

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PS 1 : **Substation Developments to address future needs**

- Integration of new approaches to grid automation in Transmission and Distribution substations
- Impact of new grid developments on substation design
- Off shore substations
- Low cost and fast deployment distribution substations

PS2 : **Life-cycle management of substations**

- Renovation, refurbishment, extension and up-rating
- Asset management, maintenance, monitoring, reliability and sustainability issues
- Managing risk in design, installation and operation

cigré

SC B3 – Brochures

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B3.17	Residual Life Concepts Applied to HV GIS	499
B3.20	Mixed Technologies Switchgear MTS	390
B3.18	SF_6 Tightness Guide	430
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B3.25	**SF_6 Analysis for AIS, GIS and MTS Condition Assessment**	**567**
B3-C1-C2.14	**Circuit Configuration Optimisation (JWG)**	
B3.06	**IT Strategies for AM of Substations-General principles**	

Events

General Programme
Programme Général

CIGRE SESSION 45

24th to 29th August
Du 24 au 29 août
2014

Paris - France / Palais des Congrès
Porte Maillot - 75017 Paris



Register as from mid-January 2014
with your National Committee or with CIGRE in Paris.
Open to CIGRE members and non-members.

Inscrivez-vous à partir de mi-janvier 2014
auprès de votre Comité National ou auprès du CIGRE à Paris.
Ouvert aux membres CIGRE et aux non-membres.

For on-line registration and general information:
Inscription en ligne et autres informations générales sur :
www.cigre.org

INTERNATIONAL COUNCIL ON LARGE ELECTRIC SYSTEMS
Conseil International des Grands Réseaux Électriques
www.cigre.org

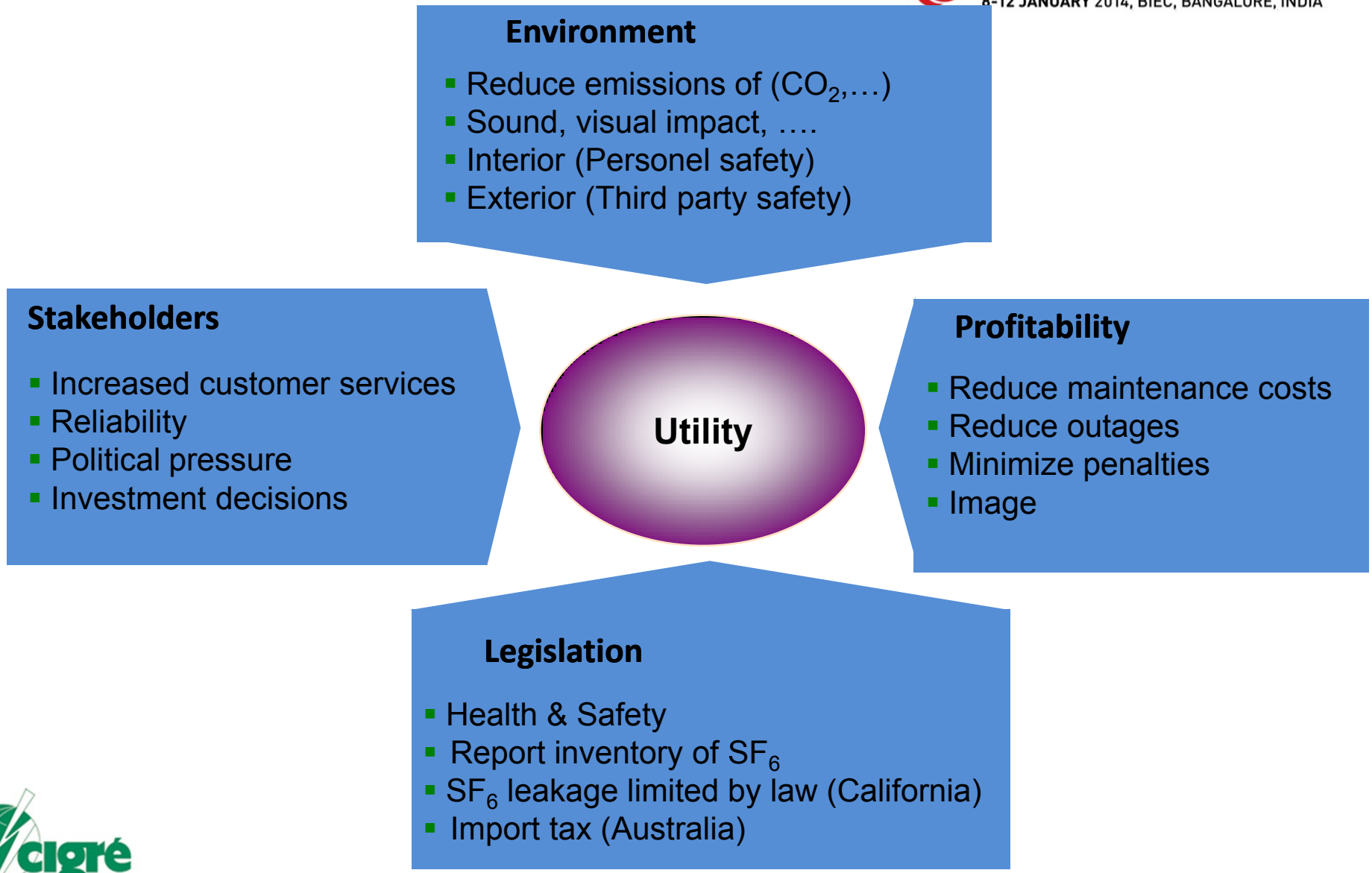
Life wasn’t meant to easy…..

Challenges

Some global challenges

- Increasing demand in some countries – megacities
- Integration of renewables and embedded generation
- Industry restructuring and regulation
- Cyber security
- Severe weather conditions
- Design standards and lack of innovation
- Aging assets
- Skill shortages, retention,
- Resistance to change
- Generation Y (born 1980 -1995)

Some Utility challenges



Trend 1

Standardisation to achieve innovation

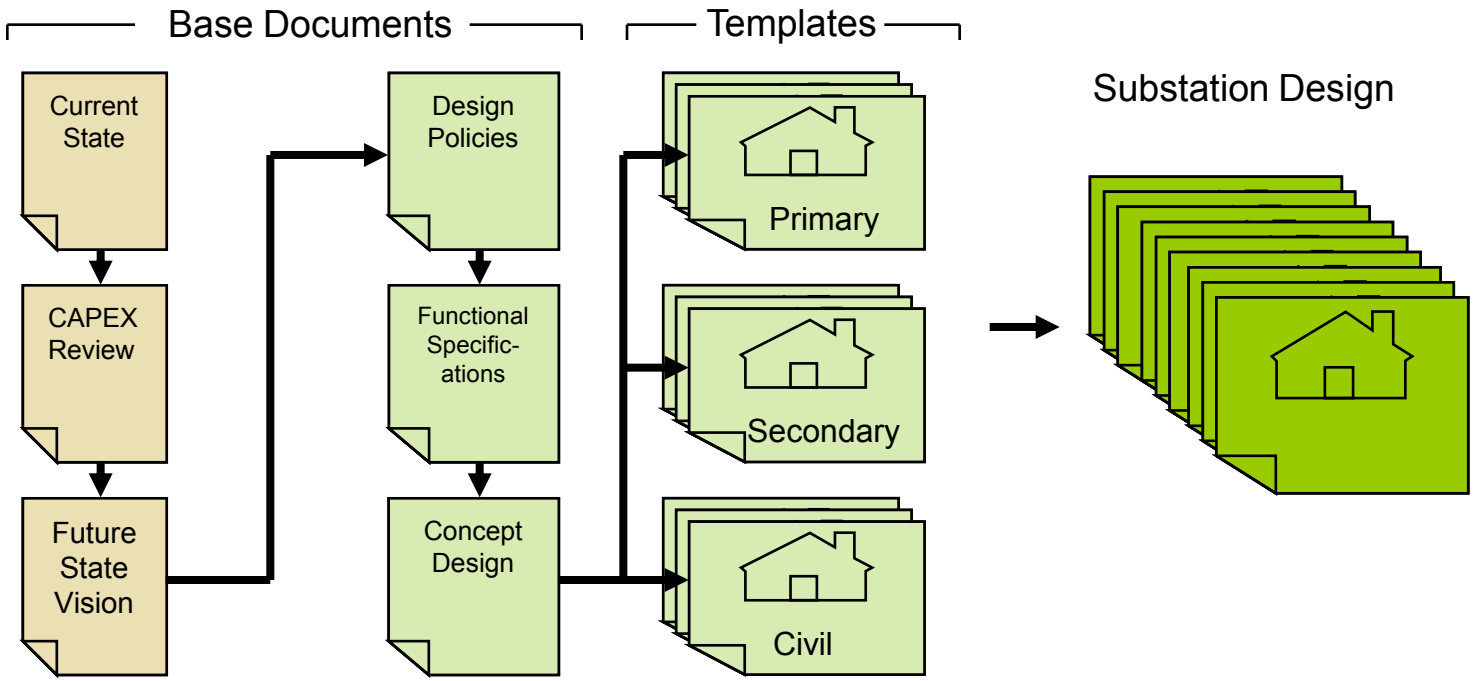
Traditional Design Standards

- Design using Design Manual, Specifications, Internal Standards, AS standards etc.
- Project Needs identified
- Procurement and delivery stage
- Result:
  - ✘ Stifled innovation,
  - ✘ Outcome not matched to needs or strategic objectives
  - ✘ Tailored solution, long delivery time
- Lack of skills to manage Design Manual changes
- Even the CEO can't change standards!

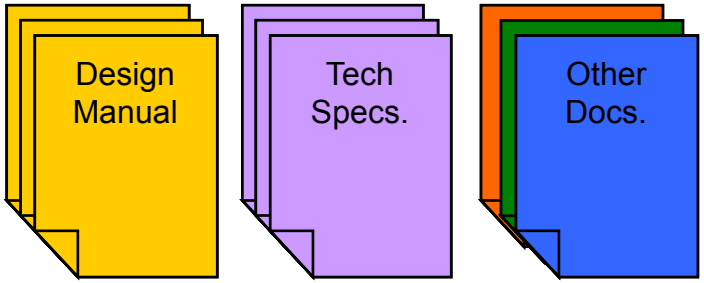
Standards – What we aim for?

- Reduce cost, reduce delivery time
- Add predictability and certainty
- Justification of design approaches
- “Standard Designs” rather than “Design Standards”
- Advantages:
  - ✓Optimised design to balance corporate objectives
  - ✓Reduced cost, optimised procurement
  - ✓More flexibility but with “Standard” advantages
  - ✓Documented and justified designs
  - ✓Step innovation
  - ✓Easier to manage with broad skill base

Standard design approach

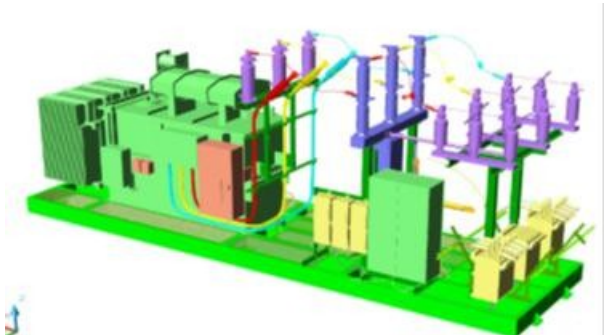


Reference



Standard Designs in Ergon

- Distribution company: <220kV
- Load growth and refurbishment
- New substation designs:
  - AIS, GIS variations
  - Skid, Modular, Mobile
- Standardised design elements
- Long term procurement contracts
- Implemented broader corporate aims

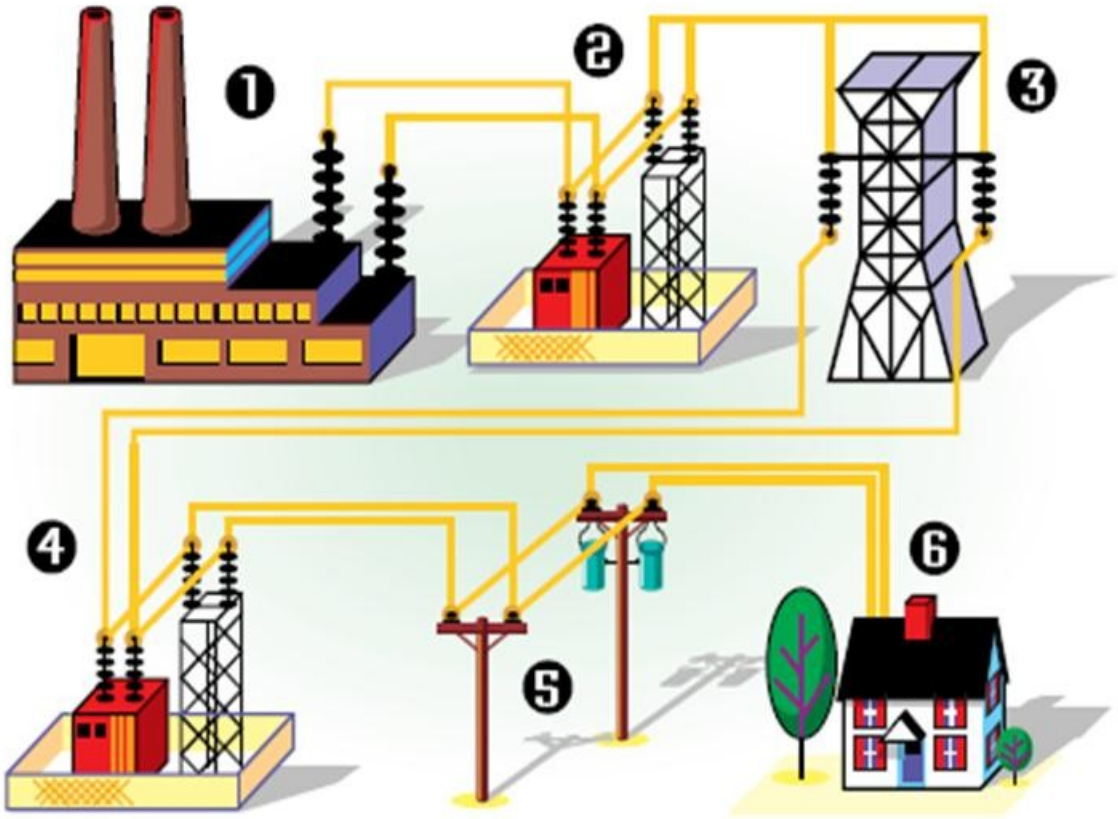


TB389

Trend 2

SMART Grids

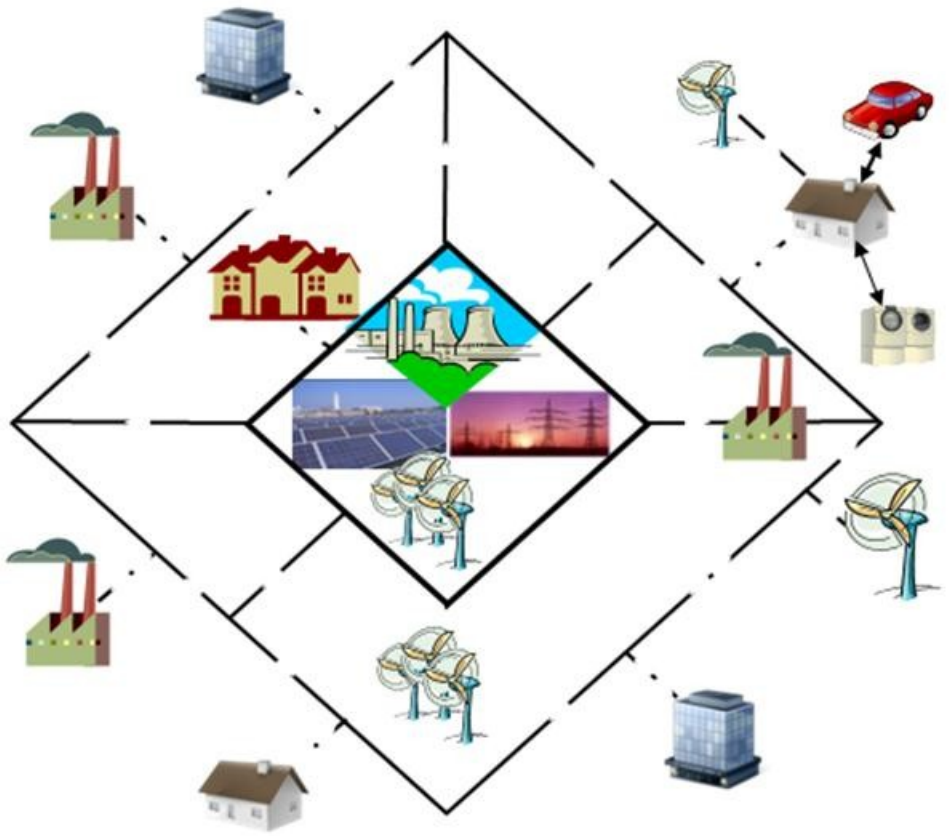
Traditional Topology



1. Power Station
2. Transmission step up (MV/HV)
3. Transmission Network.
4. Distribution step down (HV/MV)
5. Distribution Network
6. LV Supply to consumer

Source: Hans-Erik Olovsson, SC B3/AA1 2011

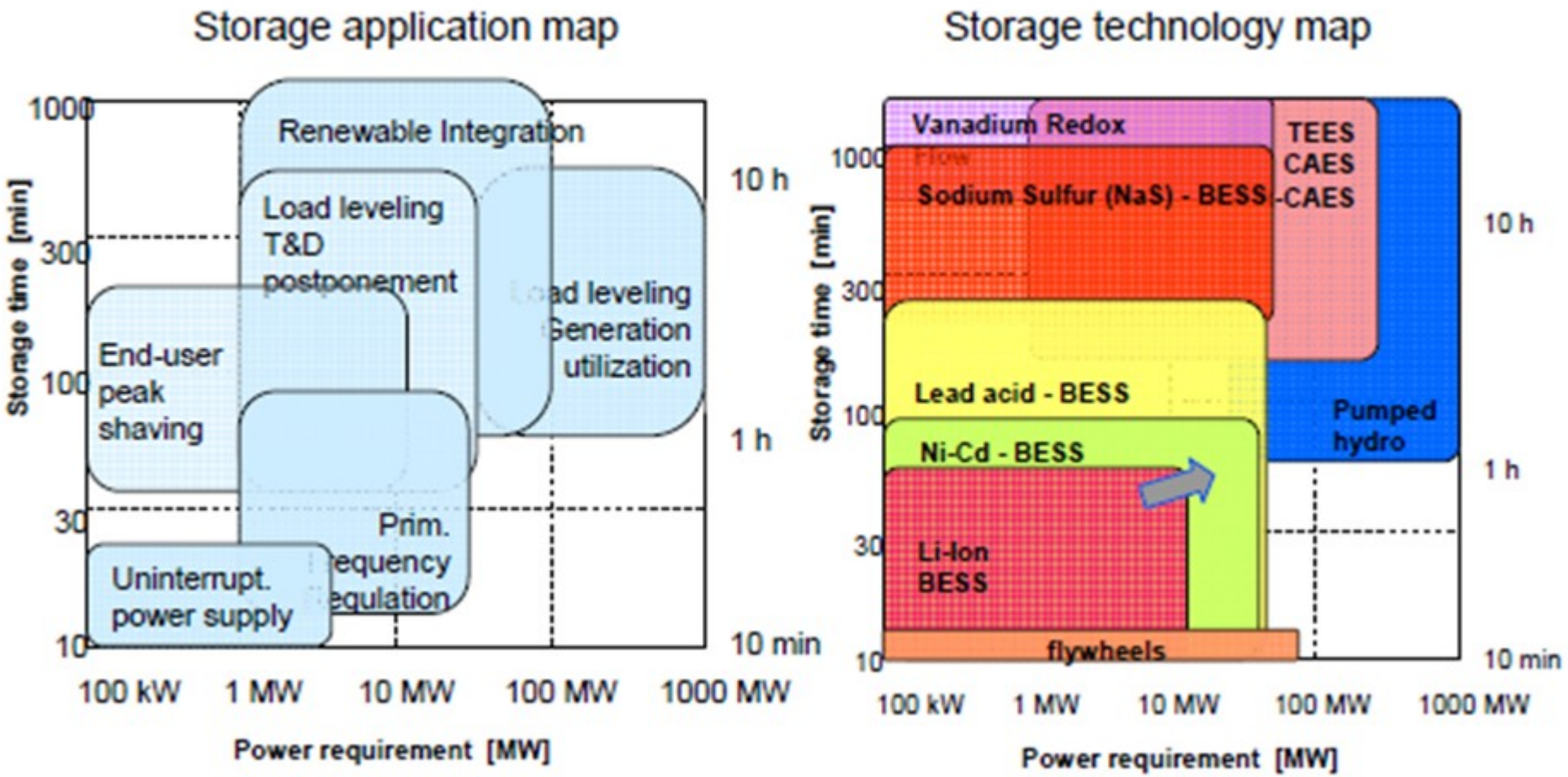
Future Networks



- Centralised and distributed generation
- Micro-grids
- Intermittent generation (wind/solar)
- Multi-directional power flow
- Load adapted to production
- Operations based more on real-time data
- Energy Storage!

Source: Hans-Erik Olovsson, SC B3/AA1 2011

Energy Storage



Source: Peter Terwiesch, Opening Panel CIGRE 2010

Trend 3

61850 Development

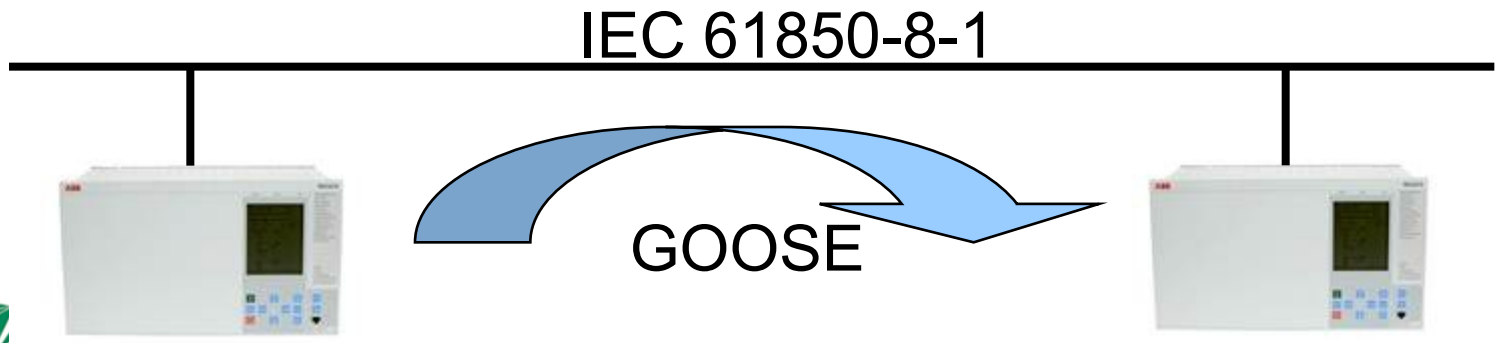
One Protocol for Substations

IEC 61850

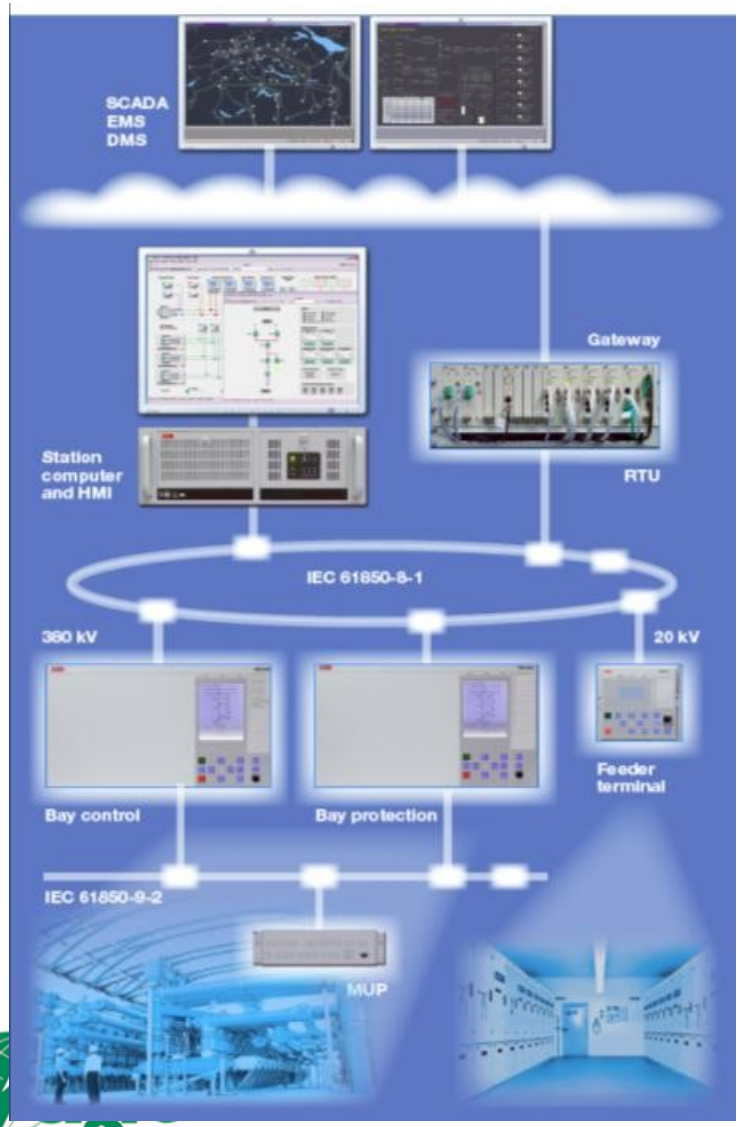
- Experience from earlier standardisation both in USA and Europe
- Combines best of many existing protocols

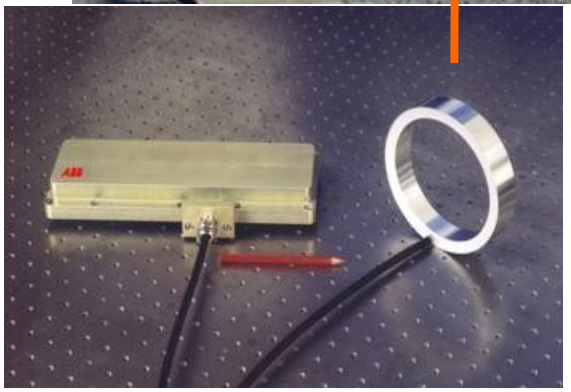
IEC 61850-8-1 - Station Bus

- Almost all transmission utilities use (or are considering) IEC 61850-8-1 protocol today;
- Very fast transition from proprietary protocols
- Aim for open architecture (using Intelligent Electronic devices (IEDs) from different manufacturers connected to the same station bus)
- IEC 61850-8-1 also enables splitting between function and physical location



61850 – The digital substation



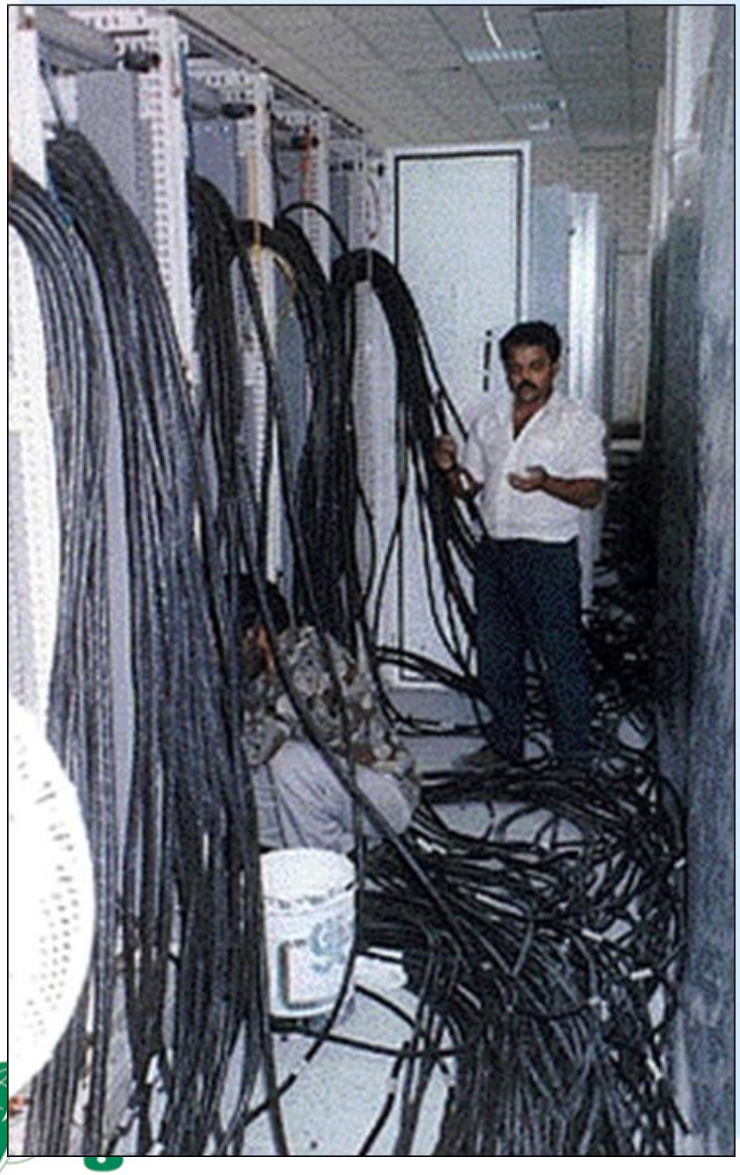


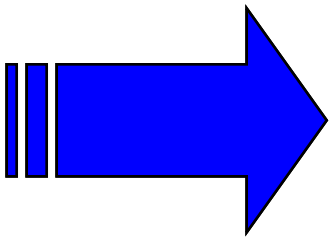
Source: Hans-Erik Olovsson, SC B3/AA1 2011

61850-8-2 - Process Bus

- This is next step and a more revolutionary change, (1A/110 V to fibre optic)
- All copper cable, except for power feeding, changed to fibre optics
- Many pilots installed around the world
- First commercial delivery was in Australia - Powerlink
- Enabler for introduction of Non Conventional Instrument Transformers (NCIT)

IEC 61850-8-2 - Process Bus





NCIT Development

- Process bus enables introduction of NCIT using fibre optic sensors
- Environmental friendly no copper, steel, iron, concrete, insulation material, etc.
- NCIT will be possible to integrate into high voltage apparatus and further reduce the footprint of substation
- Merging units on NCIT transfer sensor signals to 9-2 protocol
- Advantages:
    - Reduced substation environmental footprint
    - Design and construction savings

Trend 4

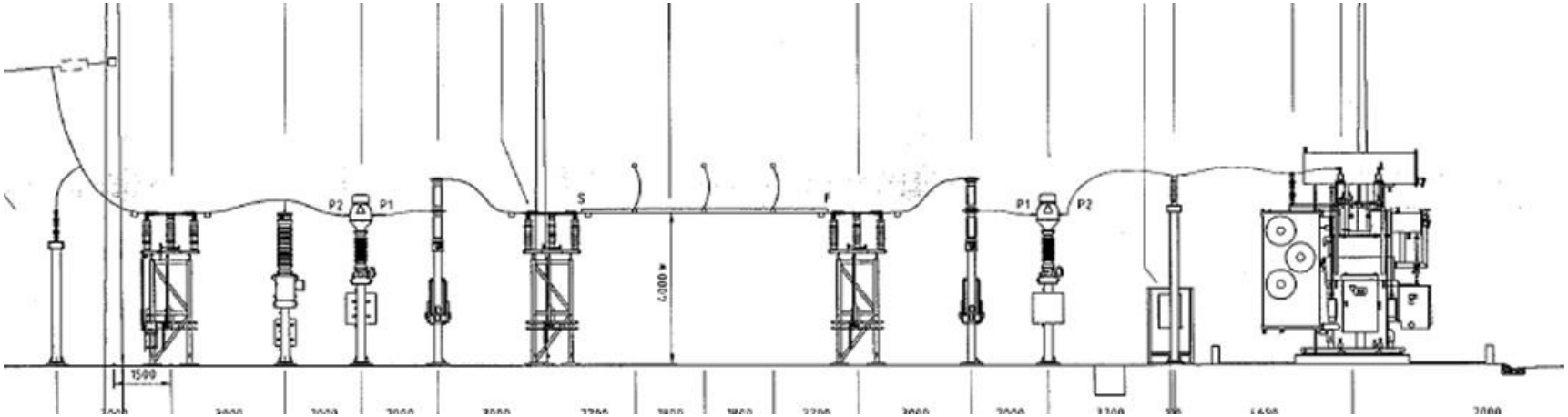
Plant technology and materials changes

Air Insulated Substation evolution

Source: Hans-Erik Olovsson, SC B3/AA1 2011

Primary Design Changes

- Historically AIS Substations were designed for high frequency CB maintenance,
- Single line configuration built with CB´s “surrounded” by disconnectors



Source: Hans-Erik Olovsson, SC B3/AA1 2011

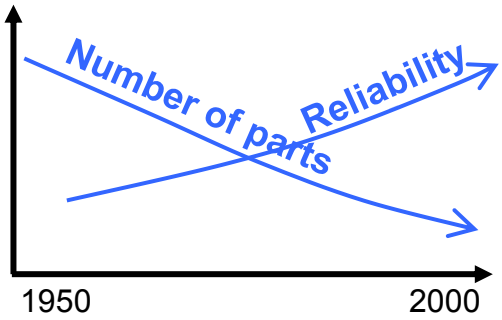
Evolution of CB´s and DS´s

420 kV Air blast

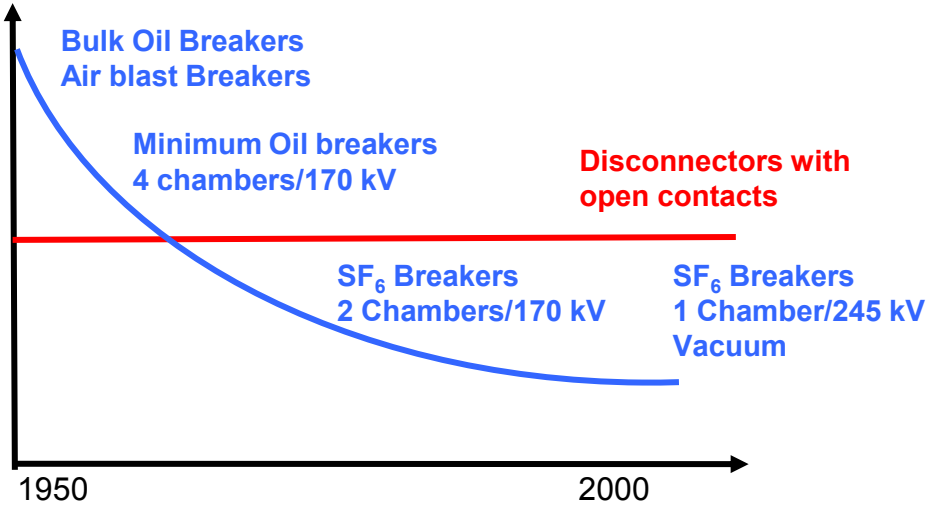
420 kV Minimum Oil

420 kV SF_6 CB

- Modern CB´s maintenance 15 years+, AIS DS´s unchanged



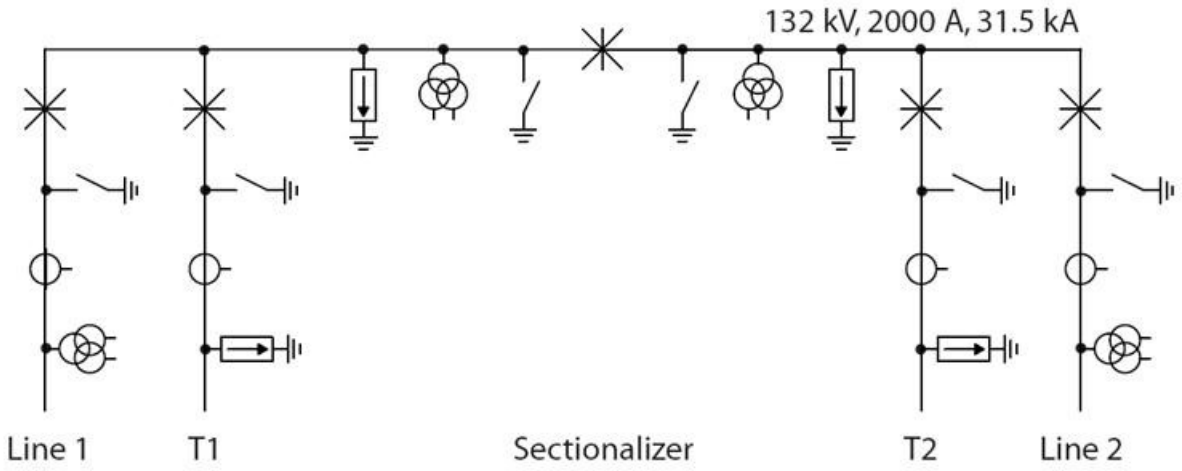
Maintenance Rate (primary system)



Source: Hans-Erik Olovsson, SC B3/AA1 2011

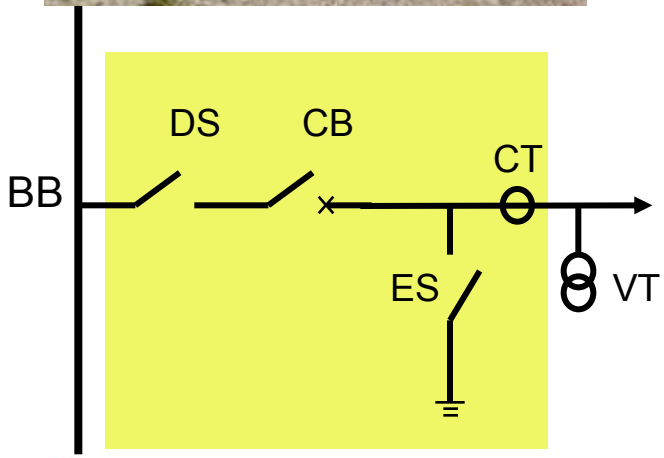
Disconnecting Circuit Breaker

- Combines the disconnecting function with CB
  - ✓ Reduces substation footprint
  - ✓ Extends maintenance intervals
  - ✓ Higher overall availability

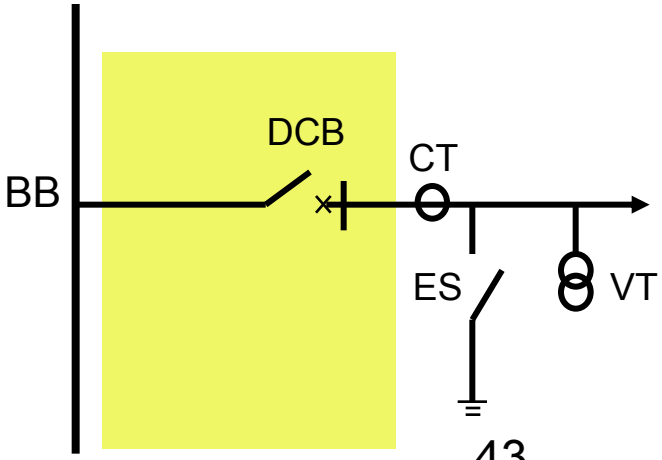


Source: Hans-Erik Olovsson, SC B3/AA1 2011

Hybrid

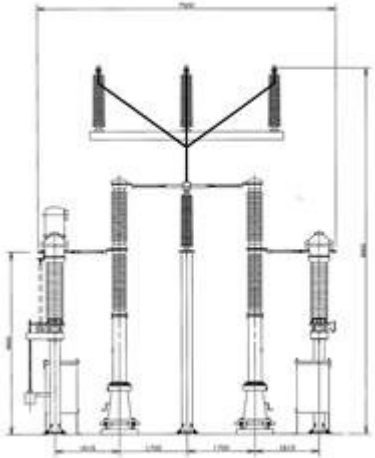


Disconnecting



Source: Hans-Erik Olovsson, SC B3/AA1 2011

Rotating



Withdrawable

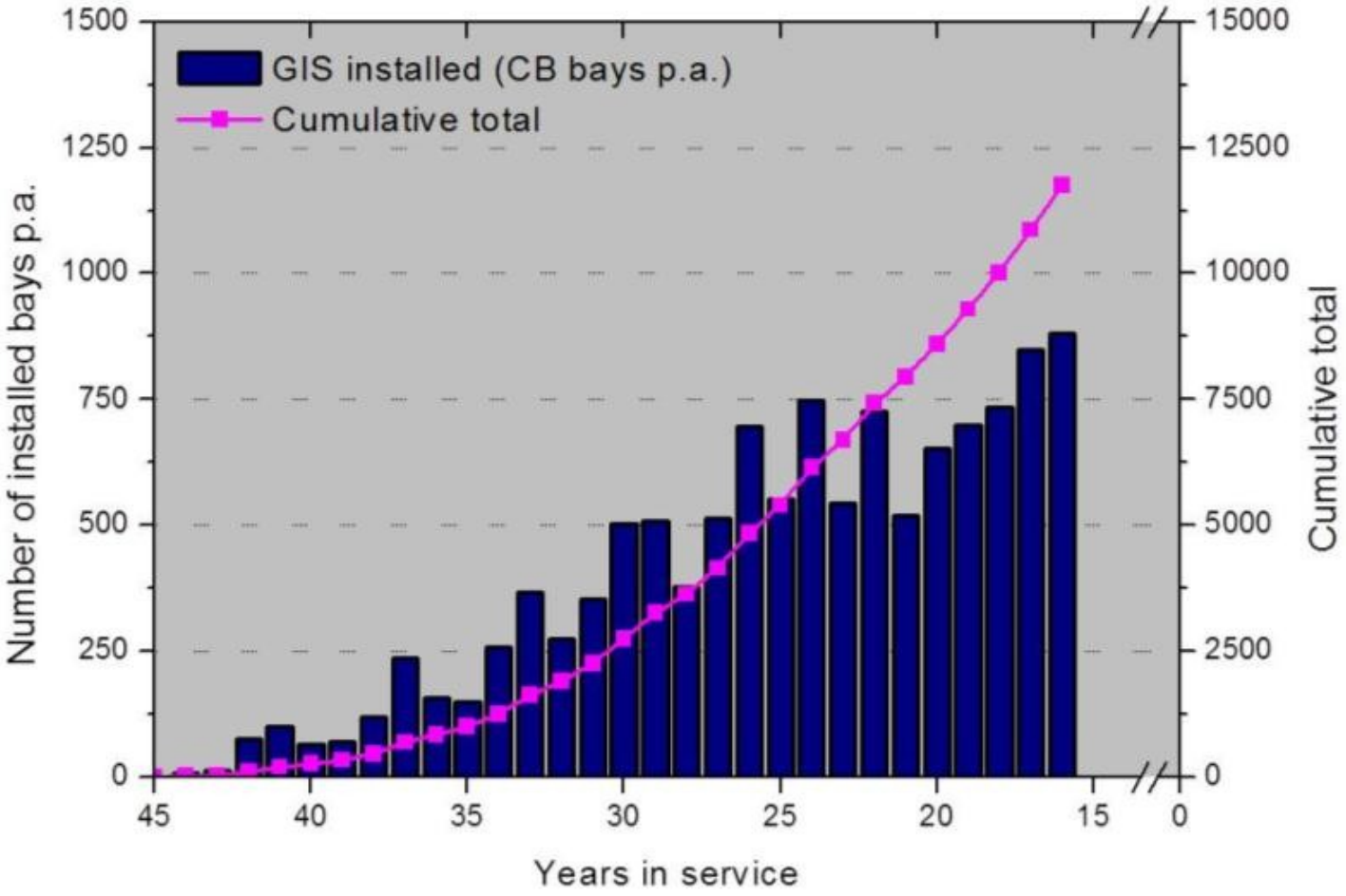
Source: Hans-Erik Olovsson, SC B3/AA1 2011

Gas Insulated Switchgear

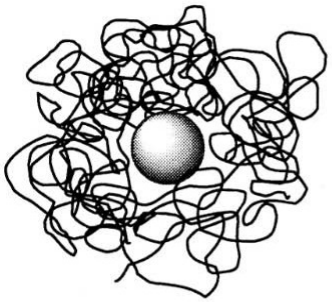
- Increasing production and installation
- Lifetime of early designs more than the design life of 25-30 years - today's expectation: >40 years
- No generic life limiting mechanisms have been reported so far

Source: CIGRE SC B3 WG17 - AA2 Residual Life Tutorial

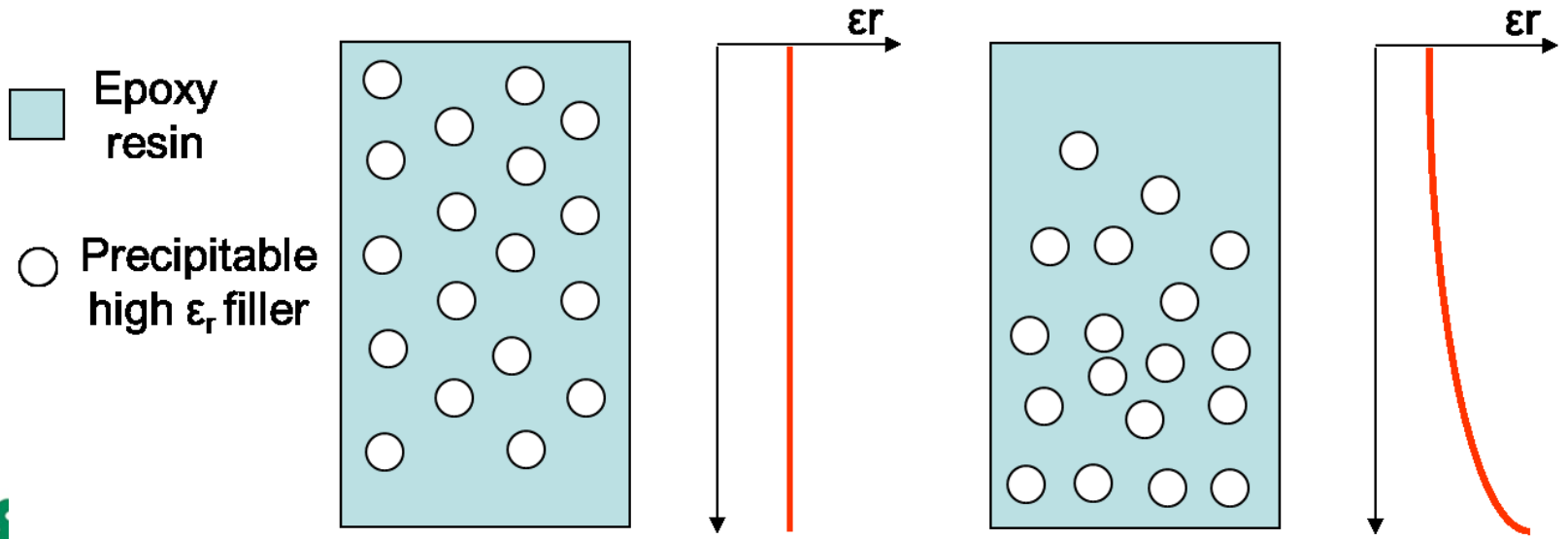
SF_6 Usage Worldwide



Nano-composites



- Now being applied to spacers in GIS
- Enhanced dielectric properties, heat resistance mechanical properties such as stiffness and strength
- Need to increase application to other areas where stress grading is a problem



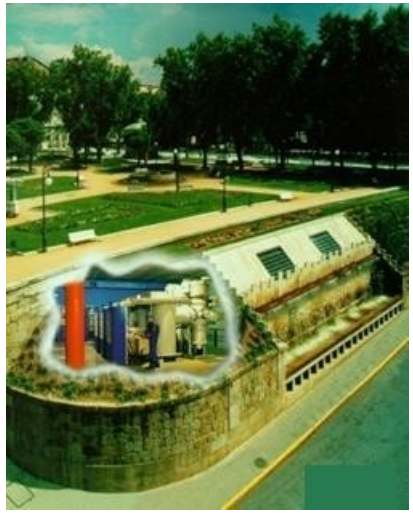
Trend 5

Increasing stakeholder awareness

Urban Substations

- Originally in outskirts of city, now surrounded by residential buildings, offices, shopping centers, hotels etc.
- Usually open air, poor aesthetics
- Third party safety has become an issue
- Planning and approvals processes have meant increased awareness
- Community expectation is now ”invisible” substations

Urban Aesthetics

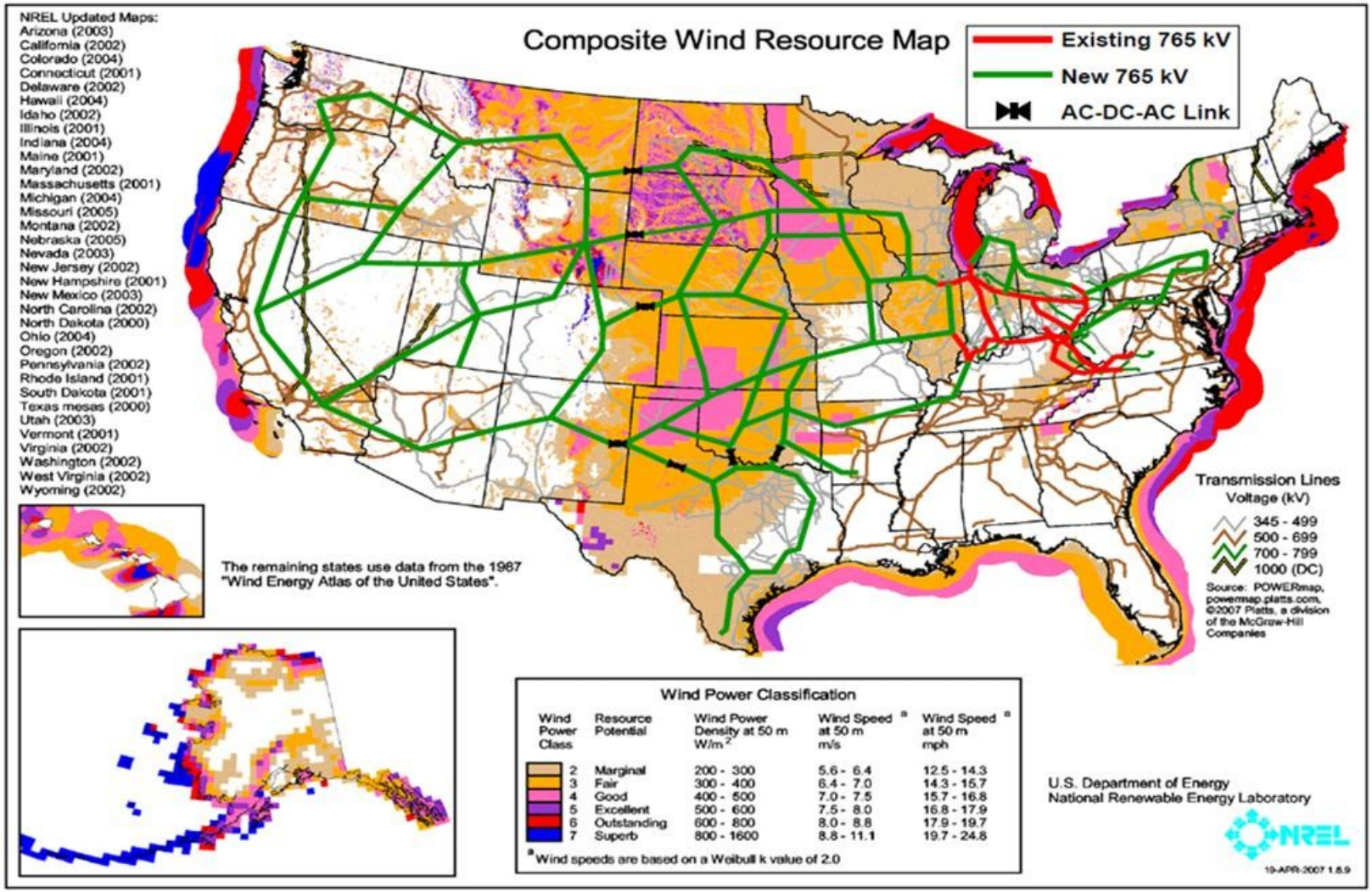


Source: Hans-Erik Olovsson, SC B3/AA1 2011

Trend 6

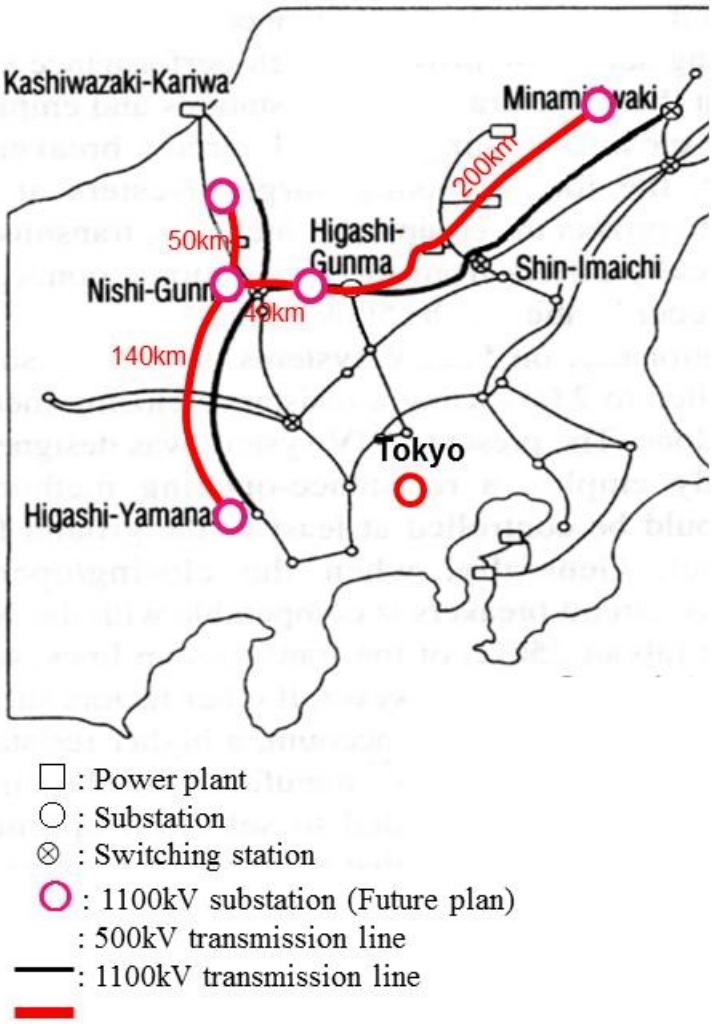
Ultra High Voltage

USA – 765kV


NREL Updated Maps:
Arizona (2003)
California (2002)
Colorado (2004)
Connecticut (2001)
Delaware (2002)
Hawaii (2004)
Idaho (2002)
Illinois (2001)
Indiana (2004)
Maine (2001)
Maryland (2002)
Massachusetts (2001)
Michigan (2004)
Missouri (2005)
Montana (2002)
Nebraska (2005)
Nevada (2003)
New Jersey (2002)
New Hampshire (2001)
New Mexico (2003)
North Carolina (2002)
North Dakota (2000)
Ohio (2004)
Oregon (2002)
Pennsylvania (2002)
Rhode Island (2001)
South Dakota (2001)
Texas mesas (2000)
Utah (2003)
Vermont (2001)
Virginia (2002)
Washington (2002)
West Virginia (2002)
Wyoming (2002)
Composite Wind Resource Map
Existing 765 kV
New 765 kV
AC-DC-AC Link
Transmission Lines
Voltage (kV)
345 - 499
500 - 699
700 - 799
1000 (DC)
Source: POWERmap, powermap.platts.com, ©2007 Platts, a division of the McGraw-Hill Companies
The remaining states use data from the 1987 "Wind Energy Atlas of the United States".
Wind Power Classification
Wind Power Class
Resource Potential
Wind Power Density at 50 m W/m2
Wind Speed at 50 m m/s
Wind Speed at 50 m mph
2 Marginal 200 - 300 5.6 - 6.4 12.5 - 14.3
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb 800 - 1600 8.8 - 11.1 19.7 - 24.8
a Wind speeds are based on a Weibull k value of 2.0
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
19-APR-2007 15:59

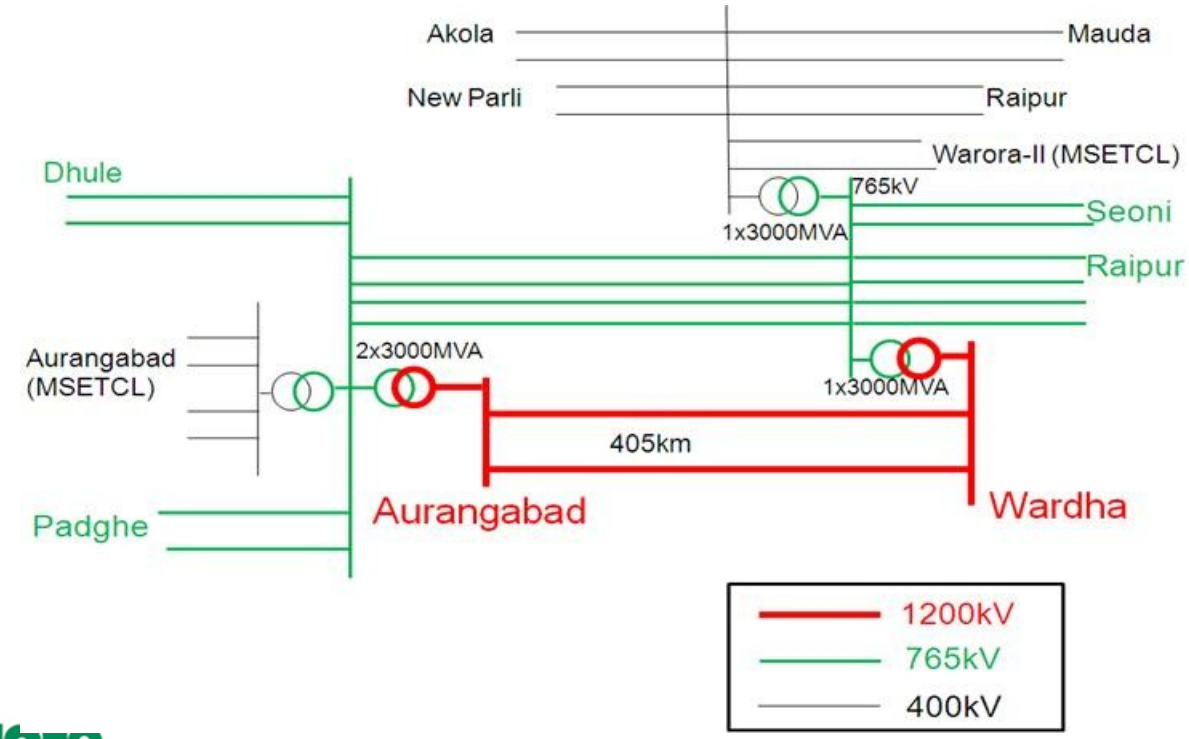
Japan – 1100kV

- Planning since the 90's
- Existing 500 kV to 1100 kV
- Some lines built for 1100 kV
- Energized at 500kV, later 1100kV
- 1100kV subs under construction
- Great Eastern Earthquake impact



India – 1200kV Network

- 2004 - 800 kV network
- Now building a 1200 kV system as a further backbone (by 2016) – first lines now energised



India – 1200kV Network

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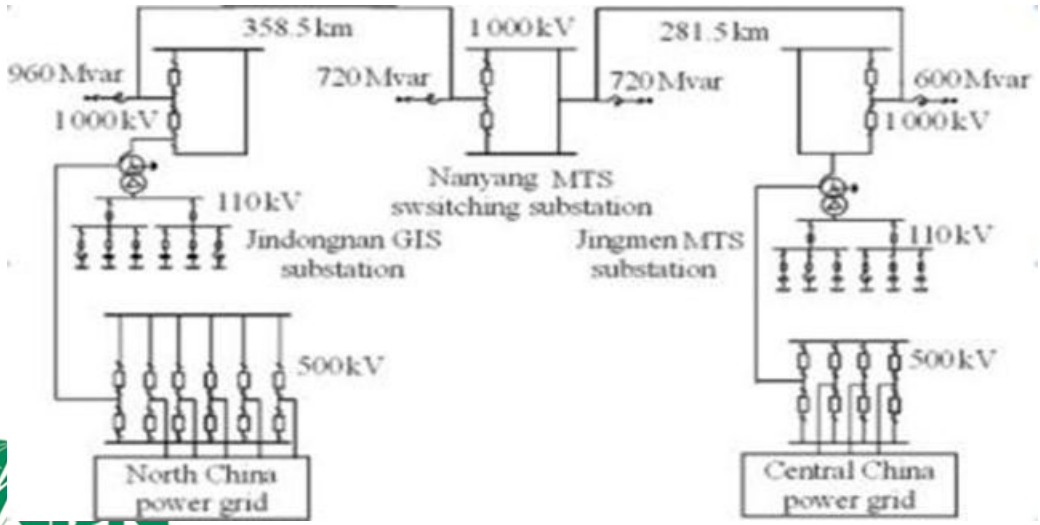
China – 1000 & 1100kV AC/DC

- 2009 South-North connection
- Capacity 2800 MW
- DC-connections East - West up to +/- 800 kV, 6400 MW
- Future: Beijing-Berlin, +/- 1100kV DC, 22000MW (2 cct)

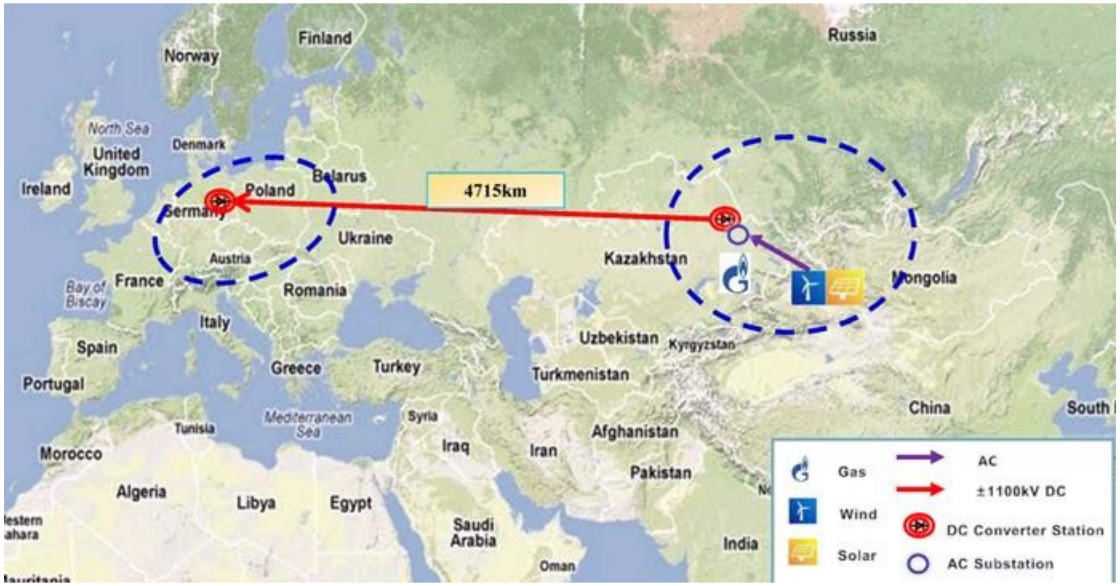


China – 1000kV AC System

- AIS, Hybrid and GIS solutions

Source: Hans-Erik Olovsson, SC B3/AA1 2011

Beijing to Berlin Proposal



Key Features:

- V = 1100kV DC
- P = 22,000MW
- L = 5,600kM
- Cost = ?

UHV – New Test Techniques

Trend 7

Enhanced Asset Management

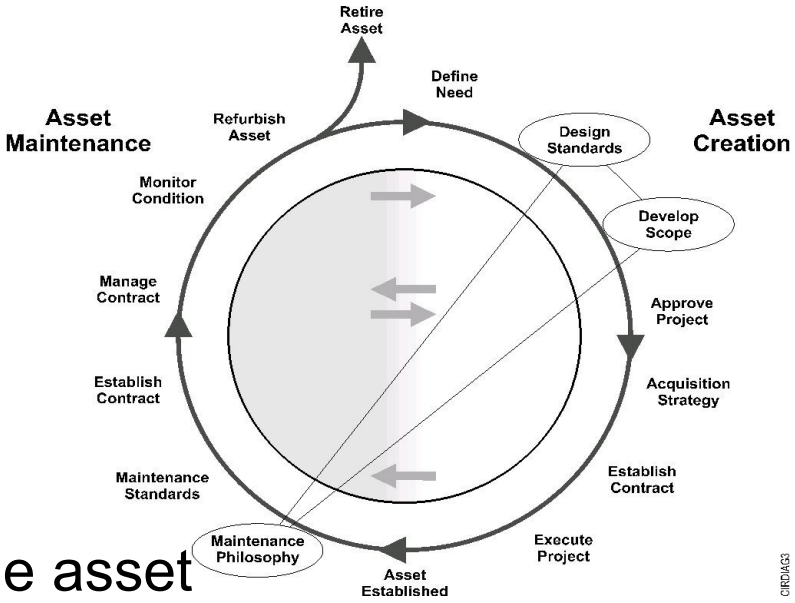
Asset Management

Modern asset management:

- Financial Sector:
  - Optimising risk, yield (performance) and long term security from a mixed portfolio of cash, stock and shares
- Oil and Gas Sector:
  - Asset Management was adopted following the oil price crash ‘86 after the Piper Alpha disaster in 1988…
  - Radical change was needed - small, dynamic, teams managing each oil platform (i.e. full asset lifecycle view).
- Public Utilities Sector:
  - UK, Australia and NZ challenges – Regulator pressure, reliability problems, escalating prices, poor planning
  - Optimising **Cost**, **Risk** and **Performance** over **whole of life**

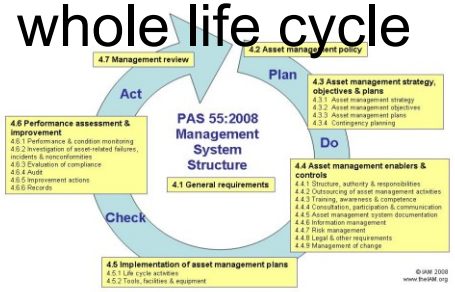
What is Asset Management?

- **Balancing** conflicting objectives:
  - Government, Statutory and Regulators – license
  - Customers
  - Shareholders:
    - Risk and Liability
    - Financial Performance
    - Safety
    - Reliability
- Its **whole-of-life** management of the asset
- There are different interpretations!
- Not just about information systems!

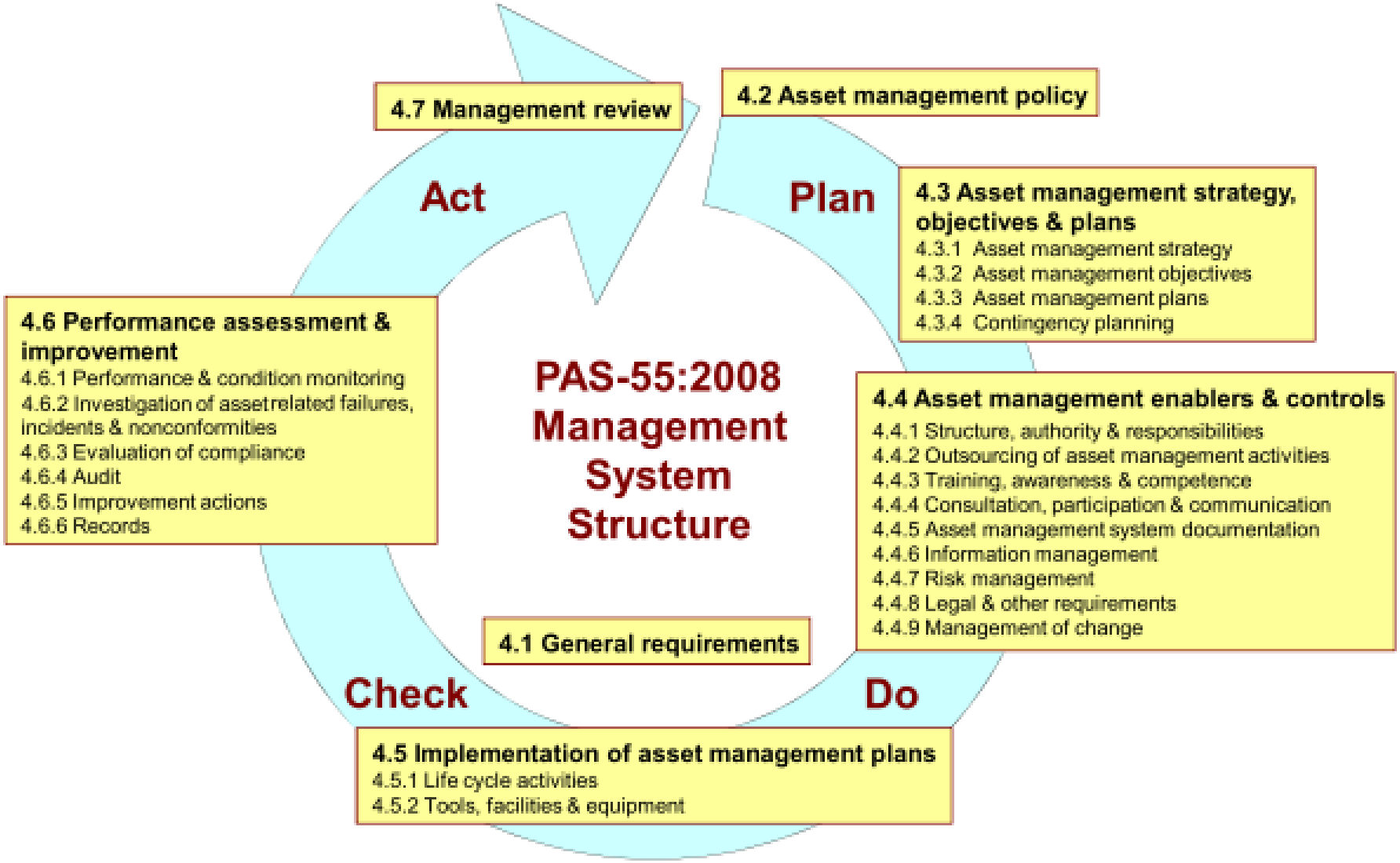


PAS 55 and ISO 55000

- PAS = Publicly Available Specification published by the British Standards Institution;
- Guidance and 28-point checklist of agreed good practices in physical asset management – international consensus;
- Relevant to electricity and water utilities, public facilities, road, air and rail transport systems, gas, process, manufacturing and natural resource industries;
- Applicable to public and private sector, regulated or non-regulated environments;
- World-wide specification for any organizations seeking to demonstrate a high level of professionalism in whole life cycle management of their physical assets;
- ISO 55000 to be released in early 2014



PAS-55 Framework



PAS-55 Adds Value

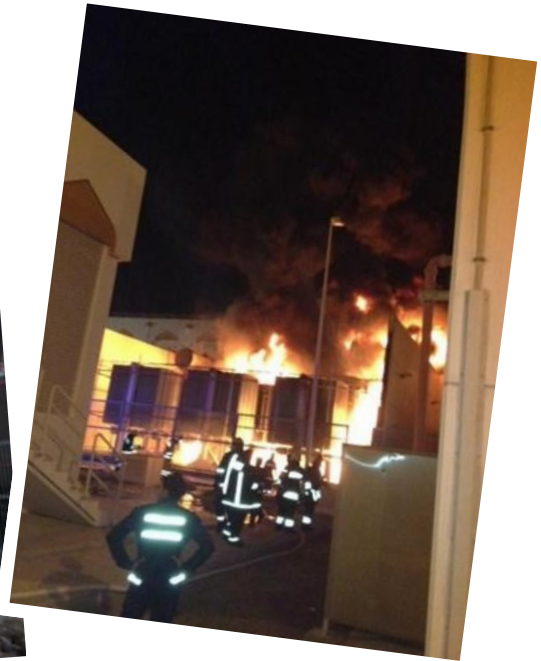
- Developed by industry, initially UK, but now international consensus of good practice;
- Promotes sustainable investment decisions
- Avoids long-term problems arising from attention to short term efficiency gains;
- Able to prove to stakeholders that the organisation is employing good practice asset management ;
- Widespread acceptance of the specification, cross sector and geography.

Why use PAS-55?

- To answer the following questions:
  - Are our current **policies, procedures** adequate?
  - Are we doing the **right things** for the business?
  - Is our asset maintenance program **aligned** with Corporate objectives?
  - **What do we need** for our new asset information system?
  - Can we **demonstrate to stakeholders** that we are good asset managers?
- PAS-55 provides a means of benchmarking and sharing best practice
- Now progressed to ISO standard

Asset Management Outcomes

- Consideration of risk
- Information systems
- Changes to design standards
- New test techniques:
  - On-line monitoring of DGA enhancing traditional methods
  - Integrated condition monitoring
  - Frequency Response Analysis



Trend 8

Other Substation and Network trends

Source: CIGRE 2012 – Various papers

Electric Vehicles - Estonia

Country wide network – Estonia
Europe's largest EV infrastructure project

Hardware

- ✓200 DC + AC Fast Chargers - 50 kW DC + 22 kW AC
- ✓507 AC chargers – 3 kW

Climate Change Impacts

Queensland, Australia, 2011

Earthquake – Japan, 2011

Alternative Materials

- SF_6 substitution: Pilot installation of 145kV CO_2 circuit breaker

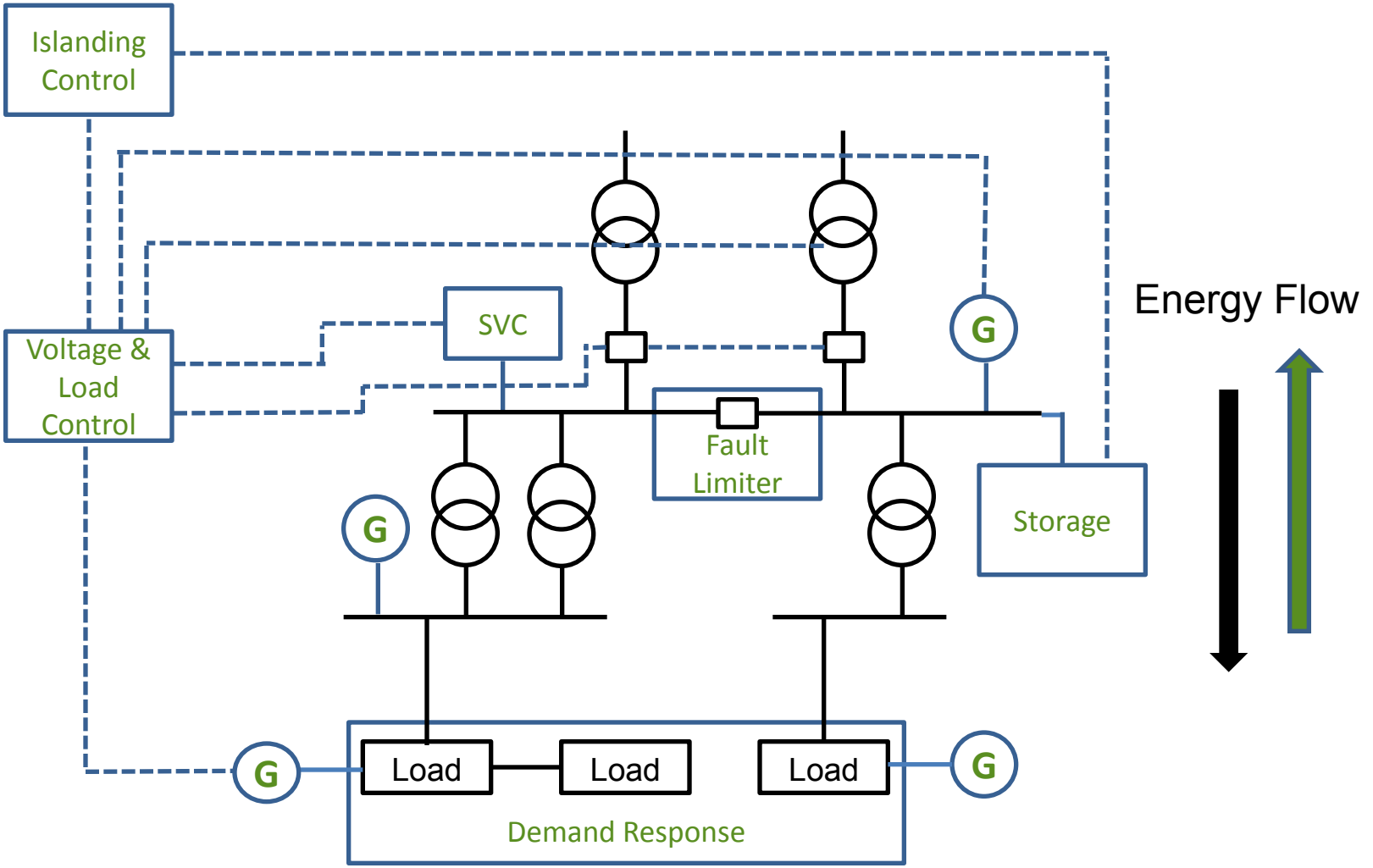
Robotics

- Lattice Tower corrosion inspection
- Post disaster inspections
- Substation surveillance and inspection
- Now air traffic control issues!

Network Trend Summary

1. Moving energy more efficiently:
   - HVDC
   - UHV
   - Energy Storage, new materials
   - Improved plant and equipment design
2. Exchanging Information more effectively:
   - Smart Networks
   - Inter-region control
3. Reducing risks and cost associated with infrastructure
   - Standardisation
   - Risk and Asset management

Substations Evolution



Future Substations

- Switching stations fully enclosed, contacts in SF_6
  - Reduced maintenance, fault tolerant 1 ½-CB, 2-CB
- "Invisible" substations for urban areas
- UHV (AC and DC) solutions in more countries
- IEC 61850 based substations
  - 8-1 station bus is already the preferred standard (6 in Electranet)
  - 9-2 process bus in Australia (Powerlink) , planned in Electranet
- NCITs to become universal, option for all primary plant
- Smart Grids integration – wide area control using phasors
- Standard Designs maintained by Gen Y

Conclusions

- Power Networks will continue to grow and expand;
- Aging will require renewal;
- Substations are integral to our power systems
- Standardisation can be used for step innovation;
- Condition Monitoring and asset management is vital;
- There are technological and external drivers to design development;
- Substation design is evolving to meet new requirements;
- CIGRE enables us to tap into worldwide experience;
- Allowing us to see what Future Substation may look like;
- Exciting times ahead for us all.

Future Substations

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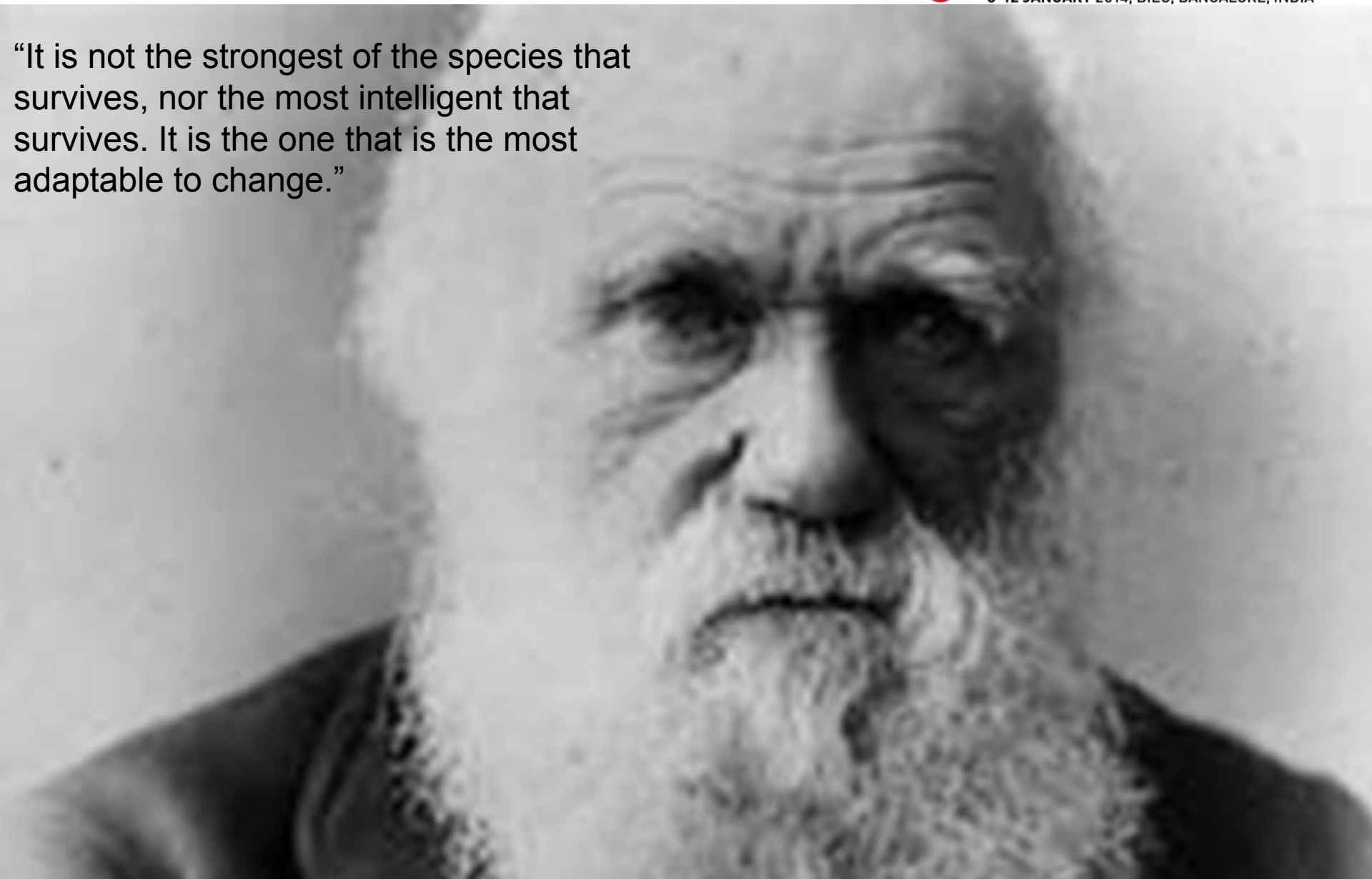
Questions



"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change."

Thankyou

- TERRY KRIEG
- tkrieg@globalskm.com