SUBSTATIONS

In the Power System of the Future

Terry Krieg
Chairman CIGRE Study Committee B3 - Substations
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Overview

• Background
• CIGRE Study Committee B3 Activities
• Challenges in Industry
• Trends in Substation Development
• The Future Substation
• Questions
The big picture - global influences

Background
• Continued growth in demand expected
• Climate change impacts?
- Growth in demand: domestic, mining and industry
- Asset renewal and refurbishment
- Significant increase in infrastructure is required
Australian Productivity

Electricity, Gas, Water and Waste Services Indexes

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

Electricity, Gas, Water and Waste Services Indexes

• 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 International des Grands Réseaux Électriques
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
SC B3 – Membership

Number of Members
- 1 – 10
- 11 – 20
- 21 – 30
- >30
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
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

PS 2: **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
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CIGRE SESSION

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
au prè 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
Some Utility challenges

Environment
- Reduce emissions of (CO₂, …)
- Sound, visual impact, ….
- Interior (Personel safety)
- Exterior (Third party safety)

Stakeholders
- Increased customer services
- Reliability
- Political pressure
- Investment decisions

Profitability
- Reduce maintenance costs
- Reduce outages
- Minimize penalties
- Image

Legislation
- Health & Safety
- Report inventory of SF₆
- SF₆ leakage limited by law (California)
- Import tax (Australia)
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

- **Base Documents**
  - Current State
  - CAPEX Review
  - Future State Vision

- **Templates**
  - Design Policies
  - Functional Specifications
  - Concept Design
  - Primary
  - Secondary
  - Civil

Substation Design

- **Reference**
  - Design Manual
  - Tech Specs.
  - Other Docs.
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
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

The international Goal

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

GOOSE
61850 – The digital substation

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

- 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

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
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

1.4. Polymer Nanocomposites
1.4.1. Interfaces and Interaction Zones

Figure 1.4.1. States of... is important to promote the study of characterization. (a) (b) (c)
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
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
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

4.1 General requirements

4.5 Implementation of asset management plans
4.5.1 Life cycle activities
4.5.2 Tools, facilities & equipment

4.3 Asset management strategy, objectives & plans
4.3.1 Asset management strategy
4.3.2 Asset management objectives
4.3.3 Asset management plans
4.3.4 Contingency planning

4.4 Asset management enablers & controls
4.4.1 Structure, authority & responsibilities
4.4.2 Outsourcing of asset management activities
4.4.3 Training, awareness & competence
4.4.4 Consultation, participation & communication
4.4.5 Asset management system documentation
4.4.6 Information management
4.4.7 Risk management
4.4.8 Legal & other requirements
4.4.9 Management of change

4.6 Performance assessment & improvement
4.6.1 Performance & condition monitoring
4.6.2 Investigation of asset related failures, incidents & nonconformities
4.6.3 Evaluation of compliance
4.6.4 Audit
4.6.5 Improvement actions
4.6.6 Records

4.7 Management review

4.2 Asset management policy

PAS-55:2008 Management System Structure

Act

Plan

Check

Do
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

• $\text{SF}_6$ substitution: Pilot installation of 145kV $\text{CO}_2$ 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

Islanding Control

Voltage & Load Control

SVC

Fault Limiter

Storage

Demand Response

Energy Flow
Future Substations

- Switching stations fully enclosed, contacts in $\text{SF}_6$
  - 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
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

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