**CIGRE - A 2017 Technical Overview**

**Prepared by Phil Southwell**

With the start of a new year it seems appropriate to review the current status of CIGRE, its key areas of focus and how the individual Study Committees are addressing the strategic technical challenges that the power system is facing. This article draws on the presentations by the International Chairman of Study Committee B3 and all the Australian Panel Convenors which were made at the Forum run by the Australian Technical Committee in November of 2017- the day before last year’s AGM in Adelaide.

Over the past ten years, global membership in CIGRE has grown by approximately 75% to more than 16000 equivalent members today across more than ninety countries. This includes a new and rapidly increasing membership of students over the last 2 years. Membership is made up of a range of categories including large companies, organisations and individuals. The 16 study committees of CIGRE have approximately 230 working groups with each having an average membership of 17 experts. Australia is a strong contributor to these working groups ranking in the top ten by membership across the world.

The rapid development of distributed generation, often in the form of renewable energy is changing the way that power systems are built and operated. This has required CIGRE to include distribution into its scope of works. To facilitate the more rapid inclusion of distribution in the scope of Study Committees, six additional members from a non-transmission background will be allowed per Study Committee, with two members allowed from one country in some circumstances. This is a temporary measure that is expected to be in place for eight years.

With some minor changes, there are still ten key technical areas which are guiding CIGRE work. These are:

1. **Active distribution networks**, particularly with the growth of distributed generation and smart load control at the distribution level.
2. **Massive exchange of information** related to improved power system operation and management, disaster recovery and cyber security
3. **Integration of HVDC and power electronics** and managing the challenges associated with lack of inertia, insufficient voltage support and the impact on power quality.
4. **Significant installation of storage**
5. **New system operations and control** to cater for a much more diverse and less predictable power system.
6. **New concepts in protection** to cover the changing power system while maintaining reliability.
7. **New concepts in plann**ing to manage the changing risks and nature of the power system as well as greater community awareness and expectations.
8. **New tools for technical performance,** particularly to ensure the whole power system can be modeled, studied and managed as the nature of the power system evolves.
9. **Increased utilization of existing lines and substations** recognizing the difficulties of building new infrastructure both financially and environmentally.
10. **Need for stakeholder awareness**

There is also recognition of the need to find innovative low cost solutions for the more than one billion people that still do not have access to electricity and workshops continue to be developed and supported to meet these challenges.

It is useful to consider the individual panels and how they are contributing to the ten technical areas of focus. You can find the focus of current work within each Study Committee by clicking on the heading below:

**[A1: Rotating Electrical Machines](#A1)**

[**A2: Transformers**](#A2)

[**A3: High Voltage Equipment**](#A3)

[**B1: Insulated Cables**](#B1)

[**B2: Overhead Lines**](#B2)

[**B3: Substations**](#B3)

[**B4: HVDC and Power Electronics**](#B4)

[**B5: Protection and Automation**](#B5)

[**C1: System Development and Economics**](#C1)

[**C2: System Operations and Control**](#C2)

[**C3: System Environmental Performance**](#C3)

[**C4: System Technical Performance**](#C4)

[**C5: Electricity Markets and Regulation**](#C5)

[**C6: Distributed Systems and Dispersed Generation**](#C6)

[**D1: Materials and Emerging Test Techniques**](#D1)

[**D2: Information Systems and Telecommunication**](#D2)

**A1: Rotating Electrical Machines**

Addressing challenges 1, 4, and 9.

Growing levels of intermittent generation are challenging the traditional maintenance regimes for conventional generation. In addition this new generation is often small scale and geographically dispersed leading to new operation and maintenance challenges. Key work of A1 includes:

* Maintenance of rotating machines used for renewable and dispersed generation.
* Condition assessment, refurbishment, upgrading, risk management and methods of predicting the remaining life of generators as well as how to improve efficiency.
* The effects of renewable generation on conventional generators
* Economic evaluation of refurbishment and replacement decisions on hydro generators. This is affected by the growing importance of pumped storage hydro as a storage medium for intermittent generation.

**A2: Transformers**

Addressing challenges 1 and 9.

Transformers continue to be critical and expensive power system components. New technologies are leading to higher system voltages and the development of very large transformers. To minimise costs and deliver expected system performance, considerable attention is paid to ensuring high reliability and long service life of transformers. In addition, with the growth of distributed generation, utilization of transformers at the zone substation level is changing. Key work of A2 includes:

* Transformer maintenance
* Transportation of transformers
* Thermal modelling
* Transformer reliability
* Intelligent condition monitoring
* Long term mitigation of copper sulphate effects
* Transformer design and specification
* Transformer fire safety practices
* Interpretation of dissolved gas analysis

**A3: High and Medium Voltage Equipment**

Addressing challenges 1, 3, and 9

The growth of HVDC and the need for DC circuit breakers to help manage the changing power flows on large interconnected systems is just one of the challenges for high voltage equipment suppliers and users. Improved technology is leading to enhanced capability and performance of high and medium voltage switchgear. In addition, there is a growing demand for improved monitoring and control and reduction of maintenance outage times. Key work of A3 includes:

* Innovative technologies (e.g UHV equipment and DC Circuit Breakers)
* Requirements for equipment in changing network conditions
* Incorporation of intelligence in HV equipment (e.g Controlled Switching)
* Monitoring and diagnostics of transmission and distribution equipment
* New and improved testing techniques
* Reliability assessment and end-of-life assessment of ageing equipment
* Mitigation methods for overstressing and overloads

**B1: Insulated Cables**

Addressing challenges 1, 3, 9, and 10.

Interconnection of offshore wind farms coupled with changing transmission power flows is leading to a demand for new transmission lines and cables. The challenges of obtaining approval for overhead lines are leading to a growth in the use of undersea and land based AC and DC cables. Key work of B1 includes:

* Improving technical performance to deal with increased capacity and reliability standards, coupled with the use of underground and subsea infrastructure.
* The growth in the application of HVDC at all voltage levels and the impact on standardisation.
* Maintenance, remaining life expectancy, diagnostics, upgrading and removal in order to develop best practices and prepare guidelines.
* Environmental performance improvement by reducing losses and using new materials and manufacturing processes.
* With no HV cable manufacturing capability in the Australasia region, forums such as CIGRE provide invaluable links to offshore suppliers.

**B2: Overhead Lines**

Addressing challenges 1, 3, 9 and 10

As well as the traditional need for overhead lines to meet new loads and generation sources, they are also in demand for new large-scale renewable generators and for greater interconnection to deal with larger inter-regional power transfers. In this context, B2 is focused on increasing the acceptability, capacity, reliability and availability of overhead lines. Work of B2 includes:

* Conversion of existing AC lines to DC operation
* Management of Risk Associated with Severe Climatic Events and Climate Change on Overhead Lines
* Thermal rating calculations of overhead lines
* Overall Line Design
* Operation of conventional conductor systems above 100°C
* Ground Potential Rise at Overhead AC Transmission Line Structures during Power Frequency Faults
* Experience with the mechanical performance of non-conventional conductors
* Repair of conductors and conductor-fitting systems

**B3: Substations**

Addressing challenges 1, 2, 3, 9 and 10

Advancements in technologies and the growing potential for distributed generation to cause two-way power flows through substations can change the more traditional role of substations. B3 is focused on developing new concepts to optimize substation design; monitoring GIS, GIL and insulating gases such as SF6; air insulated substations and; substation management. Work of B3 includes:

* Management of Risk in Substations
* Substation earthing system design optimisation
* Contemporary substation solutions for low cost substations
* Safe Work Methods in Substations
* Application of Robotics in Substations
* Mobile substations
* Cyber security
* Asset management

**B4: HVDC and Power Electronics**

Addressing challenges 3, 9 and 10

The ability of HVDC to control power flows coupled with its growing efficiency and cost effectiveness is leading to a growing use of HVDC. In addition, power electronics is improving power transfer capabilities and quality. Work of B4 includes:

* All aspects of HVDC
* All aspects of power electronics both in terms of usage and evolving technology improvements
* The potential benefits of Medium Voltage Direct Current
* The ongoing debate of “full bridge VSC technology” vs the need for DC circuit breakers for overhead VSC and multi-terminal applications.
* The need for VSC converters to be able to operate like synchronous machines

**B5: Protection and Automation**

Addressing challenges 1, 2, 3, 4, 6 and 9

Rapid advances in technology coupled with the changing nature of the power system, particularly in relation to growth in renewables and distributed generation provide plenty of challenges for B5. This Study Committee covers substation control and automation, substation monitoring and recording, remote control systems and equipment and metering systems and equipment. Work of B5 includes:

* Protection issues in modern power systems with wind generation and storage
* Impact on protection and control of working assets harder
* Impacts on Special Protection Schemes following network augmentation projects
* Influence of wind and snow causing galloping and swinging of conductors
* General improvement of availability and reliability of protection and control due to use of digital technology. Less need for testing and maintenance, greater interoperability and improved fault analysis
* Wide area protection and control technologies being introduced to help prevent blackouts, increase power flow capability and improve modelling and analysis.

**C1: System Development and Economics**

Addressing challenges 1, 2, 3, 4, 7, 8, 9 and 10

The rapidly changing nature of power systems presents particular challenges for planners as the levels of uncertainty increase the risk for investments, consequent delayed investments may adversely affect reliability and, in some cases, the rising cost of electricity is leading to public criticism. C1 uses its global connections to consider practices in a range of countries in relation to planning for rapid development, uncertain or changing generation and desired reliability. The Study Committee considers investment drivers, decision processes and tools and methods as well as taking a high level view of asset management practices across the world. In recent times work C1 has included:

* Planning criteria for future transmission networks with greater variability of power exchange with distribution
* Recommended voltages for HVDC grids
* Technical risks and solutions from periodic large surpluses or deficits of renewable generation
* Establishing best practice approaches for credible demand and energy forecasts for network planning
* Drivers for transmission investment

**C2: System Operation and Control**

Addressing challenges 1,2, 3, 4, 5, 8, 9 and 10

The changing nature of the power system may require short-term changes to how the power system is operated, monitored and controlled while longer-term solutions are developed. This is complicated by increased interconnection, the growing diversity of generation sources, rapid increases in data and greater uncertainty in relation to loads. C2 learns from power system incidents that have occurred across the world as well as power system operations and control practices including those related to human resource and institutional aspects. Work of C2 includes:

* Control of power system voltage, frequency and network loading
* Reserve and emergency management strategies,
* Management of fault and restoration situations,
* Evaluation and bench-marking of system performance
* Impact on system operations of new organisational and market structures
* Methods, tools and performance measures for operator training
* Development and use of power system analysis and security assessment tools
* Control centre computer and telecommunication systems
* Lessons to be learned from major power system disturbances
* The impact of declining system inertia and strength
* The need for increased co-ordination between transmission system operators and distribution system operators
* Restart and restoration plans.
* Maintenance of system security in the face of challenges posed by new generation technologies

**C3: System Environmental Performance**

Addressing challenges 4, 9 and 10

C3 considers a range of issues related to environmental performance of power systems. This includes the identification and assessment of the various impacts on the natural environment arising in electric power systems, and the recommendation of appropriate monitoring, management and control measures. Issues include climate change, pollution, EMF, noise, public acceptance and ecology. Recent work of the C3 includes:

* EMF and health
* Methodologies for Greenhouse gas inventory and reporting
* Corridor management
* Environmental issues of transmission lines
* Environmental liability
* Improving public acceptance of substations
* Interactions between wildlife, power lines and substations
* Emerging renewable energy sources
* Eco- friendly approaches to transmission and distribution

**C4: System Technical Performance**

Addressing challenges 1, 3, 4, 6 and 8

While modelling and analysis of the traditional power system provides its own challenges, the changing mix of resources and technologies is leading to a need for new and improved techniques. C4 covers a broad range of issues over the full frequency spectrum from very fast transients to unit dispatch and this can be summarised by the following diagram:



Work of C4 includes:

* Power system technical performance in light of the changing mix of resources and technologies with a focus on frequency stability and power system harmonics
* Challenges in transmission and distribution networks: Analysing and assessing power system dynamic stability.
* Interaction of new technologies with the traditional power system particularly in relation to stability phenomena (harmonics, frequency control, etc).
* Modelling challenges associated with renewables
* Role of new measurement technologies, big data etc.
* Power quality aspects of solar power
* Lightning shielding analysis methods for EHV and UHV DC and AC transmission lines

**C5: Markets and Regulation**

Addressing challenges 1, 2, 4, 5, 9 and 10

While the changing nature of the power system presents many technical issues there are also economic impacts that require new market mechanisms to ensure appropriate and timely investments and effective cost controls. This is particularly challenging as markets and regulation are still evolving and are at different stages of sophistication across the world. In recent times, C5 has been focussed on:

* Market design, efficiency and regulation
* Integration of renewable resources into market structures
* Generation and transmission investment
* Congestion pricing and management
* Market Governance arrangements
* Capacity Mechanisms: needs, solutions and state of affairs
* Move to paying for capacity in Europe
* Risk Management in evolving regulatory frameworks
* Regulatory aspects of Demand Response
* Market design for short term flexibility

**C6: Distributed Systems and Dispersed Generation**

Addressing challenges 1, 2, 3, 4, 5, 7, 8, 9 and 10

There is no doubt that one of the greatest changes to the power system in recent times has been the significant increase in dispersed generation, mostly in the form of solar and wind generation which is not dispatchable and often not monitored. This has significantly increased the complexity of both the distribution system and its interactions with the transmission system. In recognition of this change, CIGRE has greatly increased its attention to distribution across many of its study committees. C6 takes a lead role in a number of the critical aspects. Key areas of study for C6 include:

* Dispersed Energy Resources (DER) connection and integration
* DER concepts in distribution systems operation and planning (Microgrids and Active Distribution Networks)
* Demand management and active customer integration
* Rural electrification
* Applications of Energy Storage

**D1: Materials and Emerging Test Techniques**

Addressing challenges 8 and 9

Technology changes, often driven by or leading to new materials or changing test techniques, impact many aspects of power system design, operation and maintenance. D1 addresses areas covered by most study committees including aspects such as insulating liquids, conductors, nano-particles, superconductivity and testing techniques. Key areas of study for D1 include:

* HVDC transformer insulation
* UHF partial discharge detection for GIS
* Partial discharge in transformers
* Pollution testing of naturally and artificially contaminated insulators
* Properties of insulating materials under VLF voltages
* Atmospheric and altitude correction factors for air gaps and clean insulators
* Dielectric performance of eco-friendly gas insulated systems
* Methods for dielectric characterisation of polymeric insulating materials for outdoor applications
* Traceable measurement techniques for very fast transients
* Mechanical properties of insulating materials for power transformers
* Guidelines for test techniques of High Temperature Superconducting systems
* Understanding and mitigating corrosion
* Objective interpretation methodology for the mechanical condition assessment of transformer windings using Frequency Response Analysis
* Application of Robotics in Substations

**D2: Information Systems and Telecommunications**

Addressing challenges 1, 2, 4, 6 and 9

The changing nature of distribution and the consequent explosion in the quantity of data need to control and monitor the system, coupled with the growing level of transmission interconnection and the uncertainty of intermittent generation is creating a number of new challenges for information and communication systems. This is compounded by the growing threat of cyber terrorism and the need to continually improve system security. D2 is consequently researching information systems (such as smart meter systems and asset management), cyber security (controls, risks, mitigation, policies and standards) and telecommunication for current and emerging technologies. In recent times, D2 has been focussed on:

* Cybersecurity standards and architecture
* Telecommunication and information systems for assuring business continuity and disaster recovery
* A framework for system operators to manage the response to a cyber-initiated threat to their critical infrastructure
* Communication solutions for information exchange in the smart delivery of electrical energy