CIGRE

WG "Network of the Future"

ELECTRICITY SUPPLY SYSTEMS OF THE FUTURE

Final Report

On behalf of the Technical Commitee

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Contents

1. INTRODUCTION

The mission of modern power systems is to supply electric energy satisfying the following conflicting requirements:

- High reliability and security of supply
- Most economic solution
- Best environmental protection

The first requirement of reliability and security of supply has always been and still remains a key objective and has shaped the design and operation of power systems from the very beginning of their formation. In the last few decades, the need for a more efficient operation of the system with the aim to reduce prices and increase the quality of service has led to the **unbundling of the power system and to the liberalization of the energy markets.** It is fair to say that these actions are probably the *last decade's landmark* of the electric electric power systems framework. In more recent years, the increasing concern about climate change and the effects energy production may have on greenhouse gas (GHG) emissions have led to the wide integration of Renewable Energy Sources (RES) and Dispersed Generation (DG) in the power system with obvious advantages for the environmental behaviour of the power systems. Aggressive targets for the increased share of renewable generation in the overall power supply have been set, e.g. the EU Commission target known as 20-20-20 for 2020. Similar targets are set in US, Canada, Japan, and most parts of the developed and developing world. The efficient integration of large shares of RES and DGs imposes the need to revisit the current ways of thinking in respect of the planning, management and control of the power systems both at transmission and distribution level, with the introduction of higher intelligence to help further improve efficiency. These aims, which are primarily driven by the **environmental concerns** are the landmark of this decade and will certainly shape **the Energy Supply Systems of the Future.**

CIGRE is in a unique position to provide an independent and highly specialized vision of the Energy Supply Systems of the Future, since its membership includes a very large number of experts within the electric energy sector from all over the world, who are ideally positioned to express the views of industry and academia. The aim of this brochure is to

- identify the key parameters, which in these experts opinion will shape the Networks of the Future in a time horizon of a couple of decades,
- to highlight the relevant activities which have been and are already taken place within the various Working Groups of CIGRE
- to identify missing activities, which could be the objectives of future Working bodies,
- to identify synergies within and outside CIGRE.

The overarching aim is to contribute to the vision and the development of the future Energy Supply Systems in a global, co-ordinated way.

2. DRIVING FACTORS, NETWORK DEVELOPMENT SCENARIOS AND RELEVANT ACTIVITIES

The driving factors for the transition to the Future Energy Supply systems are generally identified as:

- Increased customer participation
- International and national policies encourage lower carbon generation, the use of RES and more efficient energy use
- Integration of RES and DG into the grids
- Need for investment in end-of-life grid renewal (ageing assets)
- Necessity to handle grid congestion (with market based methods)
- Progress in technology including Information and Communication Technology (ICT)
- Environmental compliance and sustainability of new built infrastructure

These factors suggest that two models for network development are possible, and not necessarily exclusive:

- An increasing importance of Large Networks for Bulk Transmission capable of interconnecting load regions, large Centralized Renewable Generation resources including offshore, and to provide more interconnections between the various countries and energy markets
- The emergence of clusters of small largely self contained Distribution Networks, which will include decentralized local generation, energy storage and active customer participation intelligently managed so that they are operated as active networks providing local active and reactive support.

These two models lead to the three scenarios shown in Figure 1. The CIGRE WG has debated several options ranging from choosing only Scenario 2, as the most realistic, or to choose scenarios 1 and 3 which give the extreme situations revealing particular issues that would not otherwise be obvious and eliminating scenario 2.

It was agreed that the most likely shape of the Future Energy Supply Systems will include a mixture of the above two models. The quantitative composition of Future Systems is not possible to predict, but this is not considered to be very important. The WG considers that both models are needed in order to reach the ambitious environmental, economic and security targets sought. Therefore, CIGRE has decided to deal with all technical issues relevant to both models including the study of isolated systems.

Emphasis of Future Development		Potential Trajectories
Larger Networks A shift towards larger and larger aggregated networks and new, major interconnections between large load and generation centres over long distances (including continents)	**Smaller Networks** Greater shifts to distributed generation and localised solutions, a slowing and reversal of greater interconnections between grids and parts of grids, more self sufficiency and reduced reliance on generation sources large distances from load centres	
Greater Emphasis on Large Networks	Less Emphasis on Small Networks	Scenario 1 Predominantly larger networks
No favour given to Large or Small Networks		Scenario 2 A mix between large and small networks
Less Emphasis on Large Networks	Greater Emphasis on Small Networks	Scenario 3 Predominantly smaller networks

Figure 1. System Models of Future Development

Relevant Activities

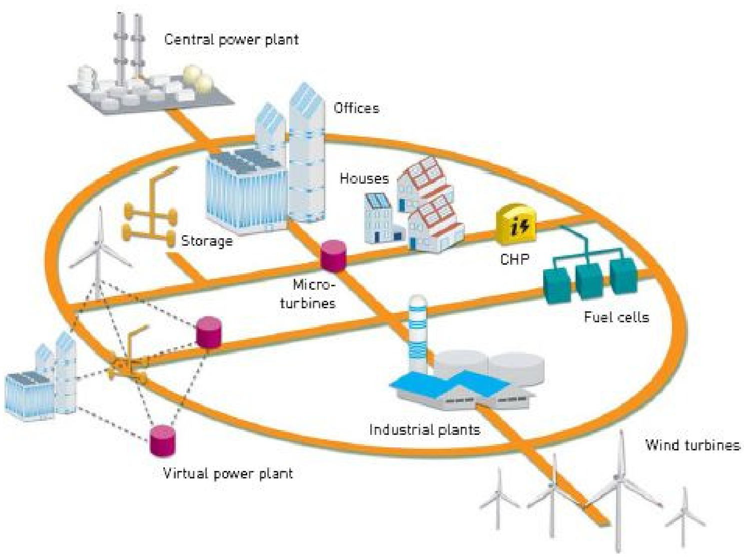

Fig. 2 – Operation of system will be shared between central

and distributed generators (second option).

There is a large number of activities around the world both at national level or within international organizations, aiming to predict and prepare all stakeholders for the Energy Supply Systems of the Future. In all these activities it is widely accepted that in order to be able to integrate efficiently RES and DG, advanced techniques and tools are required. In particular, the introduction of intelligence in the network by the wide application of ICT has led to the so-called **SmartGrids**, as the key enabler for these developments. It is worth noting that power systems have always been smart (especially at transmission level), however the distribution level, which is now experiencing an evolution in view of the penetration distributed generation (DG), needs therefore more 'smartness'. There is no generally agreed definition of the SmartGrids concept, as noted by the list of definitions provided next:

SmartGrids Definitions

- *European Technology Platform on SmartGrids "A SmartGrid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies."*

- *US Department of Energy: "A smart grid uses digital technology to improve reliability, security, and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources."*

- *Department of Energy and Climate Change, UK: "A smart grid uses sensing, embedded processing and digital communications to enable the electricity grid to be observable (able to be measured and visualized), controllable (able to manipulated and optimized), automated (able to adapt and self-heal), fully integrated (fully interoperable with existing systems and with the capacity to incorporate a diverse set of energy sources)."*

- *The Electric Power Research Institute of USA has an IntelliGrid^{SM} initiative which is creating the technical foundation for a Smart Grid. They have a vision of: "Power system made up of numerous automated transmission and distribution systems, all operating in a coordinated, efficient and reliable manner.", "A power system that handles emergency conditions with 'self-healing' actions and is responsive to energy-market and utility business-enterprise needs." and "A power system that serves millions of customers and has an intelligent communications infrastructure enabling the timely, secure and adaptable information flow needed to provide reliable and economic power to the evolving digital economy."*

- *EURELECTRIC: “A smart grid is an electricity network that can intelligently integrate the behaviour and actions of all users connected to it -generators, consumers and those that do both - in order to efficiently ensure sustainable, economic and secure electricity supply. As such, a smart grid, involving a combination of software and hardware allowing more efficient power routing and enabling consumers to manage their demand, is an important part of the solution for the future”.[from http://www2.eurelectric.org/Content/Default.asp?PageID=932]*

It is seen that some of the definitions are very generic, while some put emphasis on specific aspects like ICT and intelligence in operation and control.

3. THE ELECTRICITY SUPPLY OF THE FUTURE: CIGRE’s ROLE and ROADMAP

CIGRE does not undertake specific system or equipment development work, but is an independent and critical analyser of different solutions and the provider of high quality, unbiased publications and other contributions to the electrical supply industry.

CIGRE has the capability to add value by:

- *expressing its view on the different conditions/solutions in different regions of the world,*
- *identifying new issues and challenges to be investigated,*
- *providing information about the development of new techniques, indicating the challenges for new development or for new applications of existing techniques,*
- *supporting and or collaborating with associations like IEC, CENELEC, IEEE, etc. for the development of new technical standards.*

Figure 3 shows the roadmaps followed to provide this brochure.

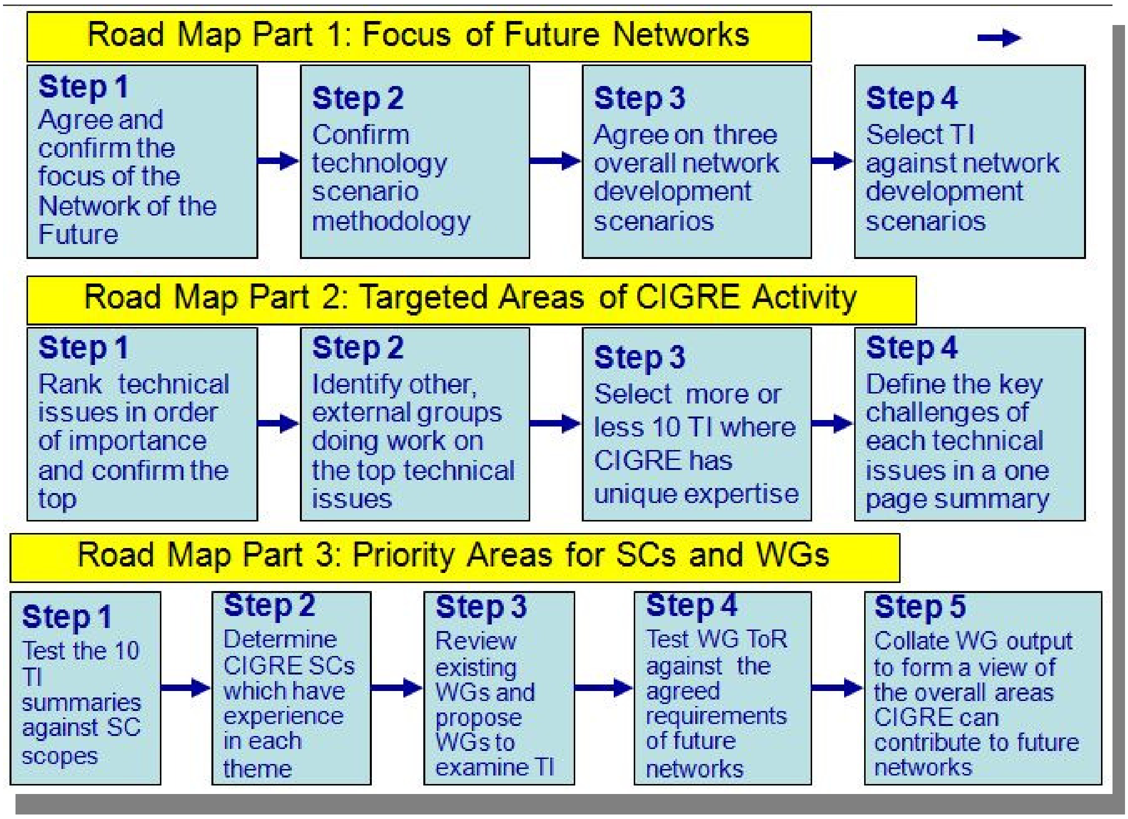

Fig. 3 - CIGRE TC Roadmaps

4. IDENTIFICATION OF KEY CHALLENGES BY CIGRE SCs

In Appendix I, the SC short descriptions are provided.

The Key Challenges for the future supply systems have been identified by CIGRE SCs. These are detailed in Appendix II:

B1. INSULATED CABLES

a. Dynamic and enhanced cable on line rating system

b. Utilization and coexistence with other utilities in shared structures

c. Managing bottlenecks in cities by High Temperature Superconducting Cable Systems

d. Increasing capacity of HVAC and HVDC Cable Systems

e. Advanced maintenance tools minimizing duration of planned and unplanned outages

f. Minimizing environmental impact during construction, by advanced installation techniques

B2. OVERHEAD LINES

a. Increase capacities of Overhead lines

b. Increase of reliability and of availability of overhead line

c. Increase the acceptability of overhead lines

B3. SUBSTATIONS

a. Connect Off-Shore Windparks including the application of Long High Capacity Gas Insulated Lines

b. Connect other renewable Power Sources

c. Connect Clean and Low Cost Energy

d. Combine networks with different parameters

e. Connect Long Distance Transmission Lines on UHV level

f. Building substations in load centers like megacities
   - as underground substations
   - as flexible solutions

g. Optimizing of the substation configurations – Equipment and Layout

h. Consider Social and Environmental conditions and Compatibilities

i. Consider dynamic loading

j. Build energy efficient substations

B4. HVDC and POWER ELECTRONICS

a. Increased introduction of HVDC within AC networks, and for power exchange between ac networks, requiring new HVDC technology solutions, and new methods for the control of the system interactions.

b. Increased introduction of FACTS devices to enable higher utilisation

B5. PROTECTION AND AUTOMATION

a. Islanding Detection and Operation (Microgrid)

b. Wide area monitoring, control and protection

c. New Protection and Automation Systems

C1. SYSTEM DEVELOPMENT & ECONOMICS

a. Planning for rapid development, uncertain generation and desired reliability

b. Investment drivers, decision processes and tools

c. Asset management practices including risk assessment now and in the future

d. New requirements and capabilities of new Generation technologies contributing to the stability of the Network

C2. SYSTEM OPERATION & CONTROL

a. Challenges in operation caused by the combination of stochastic generation and changes in electrical loads behaviour due to demand side management

b. Evolution of power system control at Continental, Country, Regional and local levels

c. Significant Increased level of automation in the control rooms

d. Definition of boundaries between distribution and transmission systems

C3. SYSTEM ENVIRONMENTAL PROTECTION

a. Climate Changes Adaptation and Mitigation

b. Development (and Planning) under environmental/social responsibility

c. Environmental compatibility of plants and infrastructures operation

d. Public Acceptance of plants and infrastructures, Stakeholders Engagement and Communication

C4. SYSTEM TECHNICAL PERFORMANCE

a. Modeling of new generation technologies and of their interaction with the power network

b. Addressing technical challenges with more embedded AC cables and HVDC systems

c. Advanced/improved tools and techniques for simulation

d. Power quality issues related to the massive use of power electronics

e. New requirements and capabilities of new generation technologies contributing to power quality of the network

f. Lightning protection and insulation coordination, their modeling and analysis with changing technologies (wind turbines, UHV lines, active distribution networks)

C5. ELECTRICITY MARKETS AND REGULATION

a. Multi-region market designs. Expanding markets in a system with insufficient transfer capabilities requires a trade-off between simplicity of rules and transmission network utilization.

b. Harmonization of market designs (market clearing principles, time horizons, gate closure)

c. Market designs to facility end-user participation and to account for the new trend in distribution system designs

d. Flexible market designs for large-scale integration of intermittent generation. (Coupling: Day-ahead, intra-day and balancing).

e. Regulation issues will be important in a future ”Smartgrid” concept: Smart metering, privacy of data, forced or voluntary participation, which kind of controls can be enforced

f. Incentives for investment in generation and transmission

C6. DISTRIBUTION SYSTEMS & DISPERSED GENERATION

a. Connection and the integration of DER, including small size generators, storage and relevant power electronic devices

b. Application of the DER concept as a part of the medium-long term evolution of distribution systems (Microgrids and Active Distribution Networks)

c. Demand management and Active Customer Integration

d. Rural electrification

e. Decentralized, intelligent control of a multitude of small resources and demand

D2. INFORMATION SYSTEMS & TELECOMMUNICATION

a. Highly critical information exchange may need to be increased by orders of magnitude with new issues of Reliability and Security

b. Cyber-security issues and Access Control become even more critical considering the close interactions across the network.

c. Disaster Recovery and Restoration Plans – Adequate communication resilience and specific measures need to be taken to mitigate risks of power blackout and allow communication service continuity to allow the recovery of the power system after any such blackouts.

d. Information exchange inside the LV Microgrid (Producer/Load) and between the microgrid and the higher levels, referred to as Active Network Control is a particularly bandwidth consuming concept.

e. Communications for HVDC and new power electronic subsysems and their associated Wide Area Control needs to be investigated in terms of coverage and communication requirements, considering the large usage of these techniques in the Future Network.

5. THE KEY TECHNICAL ISSUES

The WG considers that the main drivers for the power system evolution can be summarized as follows:

- Massive integration of RES and DER
- Active customer participation
- Increasing end-use of electricity and non acceptability for building new infrastructure

The evolution of today's power system towards the new models as described above is based on the following technical issues (TIs), that should be considered in detail:

TI1. Active Distribution Networks resulting in bidirectional flows within distribution level and to the upstream network

TI2. The application of advanced metering and resulting massive need for exchange of information

TI3. The growth in the application of HVDC and power electronics at all voltage levels and its impact on power quality, system control, and system security, and standardisation

TI4. The need for the development and massive installation of energy storage systems, and the impact this can have on the power system development and operation.

TI5. New concepts for system operation and control to take account of active customer interactions and different generation types

TI6. New concepts for protection to respond to the developing grid and different characteristics of generation

TI7. New concepts in planning to take into account increasing environmental constraints, and new technology solutions for active and reactive power flow control

TI8. New tools for system technical performance assessment, because of new Customer, Generator and Network characteristics

TI9. Increase of right of way capacity and use of overhead, underground and subsea infrastructure, and its consequence on the technical performance and reliability of the network

TI10. An increasing need for keeping Stakeholders aware of the technical and commercial consequences and keeping them engaged during the development of the network of the future.

These are detailed in the following:

TI1. Active Distribution Networks resulting in bidirectional flows within distribution level and to the upstream network

Introduction

The large introduction of DER and microgeneration affects mainly the Distribution networks both at MV and LV levels and turns them from passive to active components of the power system. The introduction of generation at these lower voltage levels results in a change in flows and even reverse flows to the upstream network.

Key Challenges

Power Systems have indeed always been smart (especially at transmission level), however the distribution level needs more 'smartness'.

The massive penetration of these smaller units imposes the need for their control and coordination. The coordination of milliards of small resources poses a huge technical challenge and calls for the application of more or less decentralized, intelligent control techniques. 'Smartness' will need to be heavily involved as provided by the availability of multi-agent techniques that may drive a power system revolution, and this at every voltage level (peer-to-peer concept applied to distributed resources).

Smart metering massive implementation will be a requirement for making the coordination of the above mentioned generation resources possible.

To take full advantage of the potential benefits provided by DER and Customer participation, novel distribution network architectures are needed. Microgrids (also called active cells) and Virtual Power Plants are two concepts that have proved worth further investigation and application.

TI2. Advanced metering and massive need for exchange of information

Introduction

Most of the consequences of the network of the future will rely on information systems and telecommunication networks and among them particularly:

- Massive exchange of information (needed to accomplish advanced metering in both steady state and emergency condition operation)
- Massive integration of HVDC and power electronics
- New concepts for system operation and control
- New concepts for protection

The information technology in general is one of the most advanced in the technologies to be involved in the network of the future. It can probably satisfy all the needs with the existing technology.

Key Challenges

The key challenge is to define the following requirements:

- What is the new architecture of the whole system for system operation, protection …
- What data must be exchanged and with what kind of requirements (volume, frequency, availability, security etc …)

Based on these requirements which do not have to be precise at that stage, it should be possible to describe the possible solutions to put in place.

In addition to that, the following aspects must also be studied:

- Disaster recovery and restoration plans
- Cyber security and access control

TI3. Massive integration of HVDC and power electronics at all voltage levels

Introduction

HVDC and Power Electronics (PE) are envisaged to be used in the network of the future to an increasing extent, because of the benefits they can bring:

- Transport of electrical energy and power over long electrical distances.
- Increasing the capacity and decreasing the power loss in the electrical network by providing better control over the power flow.
- Lower EMF for HVDC OHL and HVDC underground cables.
- Increasing the power quality in the electrical system through compensation.
- Increasing the amount of power in a given right of way (OHL and underground cables).
- Integration of renewable power plants (PV and wind) which uses PE converters.
- Increased efficiency of generation plant by enabling variable speed.
- Electrical consumers being fed to an increasing extent through PE converters.
- Energy storage using PE converters.

These benefits will result in a huge growth in the application of HVDC and PE. As a result technology developments in the area of semiconductors and control, there are likely to be evolutions of HVDC and PE into new application areas and for new generations of equipment to be developed, to meet ever increasing demands for higher efficiency, higher power and lower cost.

With an increasing amount of intermittent generation and a desire to minimise new transmission and infrastructure because of environmental concerns, a large increase in energy storage is envisaged. Energy storage is likely to use PE for the conversion of power between the storage medium and the ac network. Electric vehicles may provide a major element of energy storage and controllable loads.

HVDC Grids are now being considered, necessitating considerable development effort by manufacturers and the development of new standards, to ensure that a HVDC Grid can use converter stations from all different HVDC manufacturers.

HVDC and Power Electronics have different characteristics to those of systems based on synchronous generators, power transformers and ac circuit breakers, with primarily passive loads including resistive loads and asynchronous motors. When HVDC and PE becomes an increasing part of the network these different performance characteristics will make it necessary to carefully review the overall performance of the network, to ensure that the quality and security of supply remains acceptable. Appropriate tools and models will have to be developed to enable planners and operators to efficiently study the ac network.

Key Challenges

Some of the issues that have to be considered are as follows:

- HVDC and PE may create harmonic distortion that has to be managed with ac and dc harmonic filtering. With more harmonic sources magnification of background distortion will become a bigger issue, and appropriate guidelines will have to be prepared.
- During faults in the ac network HVDC and PE will respond differently to conventional generation and loads. B4 has published several TBs looking at these issues. The response from HVDC and PE can often be designed such that it benefits the ac network. The network performance need to be carefully studied, with appropriate models of the HVDC and PE systems.
- HVDC Grids are a new and different application of HVDC and requires the creations of a number of standards and grid codes to enable the grid to be built gradually, and with converters from different manufacturers. Similar standards and grid codes exist for ac networks, but have evolved over many years.

TI4. Massive installation of storage

Introduction

One of the significant drawbacks of several renewable technologies (wind, solar, biomass) and co-generation units (using biomass or natural gas) are:

- The intermittency of the electric generators due to the variability of wind and sun resources
- The dispatchability of possible electric surplus coming from co-generation plants that have been designed to meet heating needs first

Electricity storage systems can help alleviate the above problems, while, in many cases, offer new solutions that will accelerate the development of the electricity supply systems of the feature in the next ten to twenty years.

Three classes of benefits have been identified:

- electricity storage is required for the widespread renewable energy to become reality, in order to match the intermittent renewable supply with customer demand
- electricity storage is mainly valued by frequency regulation and wind power reshaping

- wind generation and intermittent renewable generation resources must use storage to be better coupled within existing grid systems

Key Challenges

As provided by the Energy Storage Association and The Association of European Storage Battery Manufacturers (EUROBAT).

A) Construction Issues

1. Use of advanced material for the construction of storage devices
2. Reduction of both installation and construction costs for storage devices
3. Reduce environmental impact due to their use especially focusing on Recycling issues as soon as they are depleted.
4. Reduce energy losses when electricity is converted to other form of energy, e.g. dynamic or chemical and thus improve efficiency of charge/discharge cycles.
5. Decrease weight and increase size density of the storage devices to adapt much easier to many applications
6. Development of life-time estimation models and further understanding of ageing mechanism, increase life-time expectancy.

B) Operation and network issues

1. Modeling of the operation of the storage devices for both steady state and dynamic simulations. Focus should be given on variable charge/discharge rate
2. Management procedures for storage devices so that the benefits for Distribution/Transmission network are increased.
3. Appropriate sizing of storage devices (power/energy) rating for providing aid to Distribution/Transmission congested networks especially when intermittent sources are included.
4. Co-operation of storage devices with RES units in order to formulate hybrid systems, especially in remote network areas.
5. Management of storage devices in Autonomous power systems.
6. Ability of storage devices to reduce peak units operation. Calculation of what are the limits and the circumstances under which storage devices can provide such aid, requires further investigation.
7. Co-operation of storage devices and Demand Side Management or Demand Side bidding to increase potential benefits to Distribution Networks and power systems in general.

TI5. New concepts for system operation, control

The evolution of System operation and control will be driven mainly by the changing nature of the generation and its location on the grid and the changing behaviour of the load due to market, energy efficiency programs and implementation of smart grid technology

Key challenges

1. Challenges in operation caused by the combination of stochastic generation (wind,solar,tidal etc...) and changes in electrical loads behaviour due to demand side management heavily influenced by pricing mechanism and efficient management of energy storage for the short and long term.
    - Power balancing
    - Congestion management
    - Active and reactive reserve
    - Implement Risk management techniques and introduction of probabilistic approaches
2. Evolution of power system control at Continental, Country, Regional and local levels
    - Improve the awareness of the overall system status in interconnected system with several control areas,
    - Define the boundaries between TSO and DSO systems in terms of Operational Control
    - Display of interconnected areas and trigger signals to operators with vizualisation techniques
    - Information exchange and operational interfaces between TSO and other actors: production and load centres
3. Significant Increased level of automation in the control rooms
    - New software tools to quickly determine the status of the system over wide area and to alarm system operators
    - Automated adjustment of the configuration and electrical parameters of the system
    - Automated service restoration and adapted disaster recovery scenarios
4. Assure the competencies and adapt the training of System operators

TI6. New concepts for protection

Introduction

The network of the future will give rise to significant challenges for the protection and automation systems. Large networks of bulk power will require higher levels of reliability and flexibility from protection, in order to avoid any risk of large incidents. In addition, new generation technologies behave differently under system faults, both in terms of steady state fault current contribution and dynamic response. This unpredictable behaviour could limit the protection performance.

On the other hand, Distribution Networks with large integration of DG will require protection and automation systems able to deal with bidirectional fault currents. This will affect the coordination, selectivity and sensitivity of protection. In addition, the expected massive application of power electronics will result in new kind of waveforms and transients that could also affect the performance of protection systems.

To face the aforementioned, significantly enhanced complexity (intelligence) for automation, control, operation and metering will be necessary

Main Challenges

In order to satisfy the new requirements, the protection and automation system should evolve in the following main issues

- New Wide area Protection concepts for Transmission networks.

A new generation of systems should be developed in order to overcome the present limitations of special protection schemes in terms of reliability, flexibility and maintenance cost. Also, new functionalities will de developed in order take advantage of the expected new capabilities of wind generation.

- Impact on the protection system of new generation technologies.

The protection devices should be adapted to the fault current and behaviour characteristics of the new generation technologies. Furthermore, system operators are demanding more capabilities from generators to stay connected under certain voltage disturbances (Fault Ride Trough). Coordination between protection and new generators capabilities is absolutely needed. The first step in this regard, should be the standardization (IEC) of the behaviour and performance of the new generation.

- Inadvertent Islanding detection

With growing DG penetration there is an increased need for high performance anti-islanding protection. New solutions are needed as the limitations of the existing methods may eventually pose a barrier to further integration of DG.

- Intentional islanded operation.

The increasing levels of DG penetration in distribution and sub-transmission networks open new opportunities to improve continuity of supply for customers. Control and protection of intentional islanding should solve aspects such as islanding detection, island configuration, synchronization, out of step protection, island transient and permanent stability and voltage regulation...

- New protection and automation functions for distribution network

Operation and protection of distribution system could become similar to transmission system. The use of distance and current differential protection could solve many of the problems encountered in distribution networks with greater integration of DG. The development of powerful communication networks in distribution systems could improve system operation and management trough monitoring and automation systems.

- Metering.

Metering is positioned as first step of active distribution networks. In addition to billing purposes, meter devices will act as information collectors for distribution networks automation, home energy management and electrical vehicle.
These new functions will be supported by three enabler:

- Architectures of the future.

IEC 61850 facilitates the efficient communication and integration at each of the three levels of Device level, Substation level and Network level. New architectures will support new concept of functional integration. The substation automation will be part of a more general network automation system.

- New protection and control algorithms.

New algorithms will be developed mainly in three directions: network stability, power electronics integration and adaptive techniques to cope with changing system conditions. Power electronics could include application such as light FACTS, fault current limitation, electronic switches, surge arresters, intelligent loads, etc.

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- Data management innovative applications.

The translation of the operation practices from transmission to distribution network will result in a dramatic increase in the complexity of the operation and maintenance of distribution network. New systems and procedures will be required to cope with huge amount of data. New data modeling standard should be developed at network level. Non-real time applications will be developed for engineering, automated disturbance data analysis, monitoring and maintenance for transmission and distribution networks

TI7. New concepts in planning

Key Challenges

- Changing role of the power system (impacts ability to plan to minimise asset stranding while maintaining reliability and quality)
    - Smartgrids
    - Renewables and distributed generation
    - Distribution networks influence/impact
    - Grid strength and capacity

- Changes in technology (need to understand cost, capabilities and lead times of each solution to enable comparison between options)
    - Renewables
    - Storage
    - Automation and smartgrids
    - Customer involvement and influence

    - New forecasting/modelling tools and technologies

- Changing economic drivers (Impacts availability of funding and investment risk)
    - Least cost solutions – credit crunches driving planning
    - Investment decisions – what are the criteria, ROI, how will it impact planning
    - Government funding – planning driven or driving planning
    - Innovation

- Changing market and regulatory environment (impacts on level of central planning vs market solutions)
    - Competition - low cost drivers, free market forces, regulation impact
    - Government control / regulation

- Changing nature of supply and demand (increases uncertainty of long term solutions and potential for asset stranding)
    - Changing role of the customer
        - Greater influence in running the network
        - New loads and electric cars
        - Changing load profile
        - Changing supply profile
        - Increased uncertainty – Controlled/regulated, market driven or free-for-all
        - Developing countries – different or same
    - Changing role of generators:
        - Customer becomes a supplier
        - Renewables
        - Increase uncertainty - Controlled/regulated, market driven or free-for-all
    - Different starting point, brownfield vs greenfield, developed vs developing
    - Network architectures, on-shore/off-shore grids
    - Rapid growth environment different to normal or low growth
    - Air conditioner growth in some environments, drives a very rapid peak increase over a very short period requiring unique solutions

- Need for database of utility experience with solutions such as smart grids, could include costs, applications and capabilities that utilities have gained though trials. This would be a way of sharing experience and developing a view as to what may be commercially available and when.

TI8. New tools for system technical performance assessment

More sophisticated tools for system performance analysis (steady state and transient conditions) will be certainly needed. The following points will need increasing attention.

1. Advanced numerical technique and numerical methods for the solution of multiphase load-flow problems, steady-state initialization of network studies and time-domain simulation
2. Bridging the gap between 3-phase and positive sequence modeling.
3. Advanced tools and techniques for power balancing and reserve requirement evaluation
4. Operational tools allowing a probabilistic and risk-based planning
5. Advanced load modeling techniques
6. Multi agent techniques. Better modeling tools are needed to be able to model some of the proposed active control strategies (e.g. centralized control systems, grid-friendly appliances that participate in load-frequency control, demand side management, etc.).

TI9. Increase of overhead, underground and subsea infrastructure

Introduction

a. Networks have traditionally been 40 to 50 year investments. How do we manage them in a climate of rapid change?
b. What generation technologies should we expect / plan for and how do we deal with the uncertainty?

Considering the difficulties to get new rights of ways for new overhead lines, the networks of the future will be mainly composed of :

1. existing rights of way which will be upgraded at a higher ampacity
2. new underground and submarine cables for connecting aeolian farms from North Sea to European countries or photovoltaic production from deserts of the south to the North of Europe.

Technical Issues

New technical Issues that have to be solved:

- Which technologies can be used for uprating existing lines : replace old conductors by high temperature conductors, re-tension existing conductors, upgrade tension level, use real time thermal monitoring,…
- Convert AC to DC lines,
- Develop new insulated AC or DC submarine and underground cables for offshore aeolian farms,

- Check the stability of the network taking into account this new materials,
- Check the ability of all components to withstand transients and over voltages,
- Check the ability of the network to be very reactive as problems will become more and more difficult in the future,

All these new techniques will have to take into account the new distributed generations (aeolian or photovoltaic) and the new metering techniques for improving diagnosis and asset management.

TI10. Need for stakeholders awareness and engagement

Introduction

Communication and Stakeholders consultation and engagement –aimed to a better awareness and participation- are crucial issues for the development and operation of Power Systems.

The development of Power System is facing, in almost all Countries, a mixed background of increasingly complex interests and concerns.

In addition, many utilities have been privatised, with growing risk of losing public goodwill in the development of infrastructure. Communities, who were prepared to allow projects 'in the national interest', now perceive them to be in the interests only of private companies.

Energy related projects are facing diffused opposition, or –at least- a difficult acceptance, as show in the table here below:

Public attitudes towards hypothetical developments proposed in their community

	Strongly oppose	Somewhat oppose	Somewhat support	Strongly support	Net opposition
Waste Collection/landfill site	80	6	3	9	-73
Power plant or utility	77	6	5	8	-70
Quarry	75	7	5	7	-70
Office	53	7	9	27	-24
Retail park	54	7	9	27	-24
Supermarket	50	7	10	31	-16
New road project	36	8	15	36	7
School	10	8	15	61	54

Source: K Barker, Review of Land use Planning, Interim Report – Analysis, UK, 2006

In particular, in Europe, according to UCTE - Union for the Co-ordination of Transmission of Electricity, average construction times are:

- 3 - 5 year for a GTCC (Gas Turbine Combined Cycle) power plant,
- 7 - 10 year for a HV OHL (High Voltage Overhead transmission Line),

because of complexity of authorization procedures including public debate and opposition.

Key Challenges

Stakeholder engagement is required:

✓ in the planning phase:
- to demonstrate the usefulness and the benefits given by the network,
- to guarantee that Sustainable Development principles and issues are being incorporated since this stage,
- to take into account public views and needs already in the design steps (e.g. the choice of alternatives)

✓ in the construction and operation phases;
- to demonstrate the compliance with environmental standards,
- to obtain a support to the necessary actions (e.g. maintenance, …).

Stakeholders engagement may be required by law and regulations, or by investors or governments may seek it; according to a more "pro-active" vision, good corporate governance in companies may require information and engagement and the responsibilities of Sustainable Development strengthen the need to engage with stakeholders.

6. RELEVANCE TO CIGRE SCs KEY CHALLENGES

KEY TECHNICAL ISSUES	CIGRE SCs	SCs KEY CHALLENGES
TI1. Active Distribution Networks resulting in bidirectional flows within distribution level and to the upstream network	**C6,** C3, C4, C1	C6.a, C6.b, C6.c, C4.e, C3.b
TI2. Massive need for exchange of information	B5, C6, **D2**	D2, C6.a, C6.c, B5.d, B5.c

TI3. Massive integration of HVDC and power electronics at all voltage levels	B1, B2, **B4,** C4, C6, C1, D1	B1.a-b, B1.d-f, C6.a, C4.b, C4.f, B2, B4.a, B4.b, B4.c
TI4. Massive installation of storage	**C6,** C4, C1, D1	C6.a, C6.b, C4.a
TI5. New concepts for system operation, control	**C1, C2,** B5, C6, C5	C2, C6.a, C6.c B5.c, B5.d, B5.a, C5.b, C5.a, C5.d
TI6. New concepts for protection	**B5,** B4, C4, C6	B5.b, B5.d, B5.c, C6.a, C4.c
TI7. New concepts in planning	**C1,** C3, C4, C6, B2, B4, B5, C5	C6.a, C6.b, C3.b, C3.d, B2, C4.d, B5.a, C5.a, C5.f
TI8. New tools for system technical performance assessment	**C4,** C6, B3, B4, C1	C4.a, C4.e, C6.a, C6.b, B3.h, B3.i, B3.j
TI9. Increase of right of way capacity and use of overhead, underground and subsea infrastructure	**B1, B2, B3, B4, C1, C3, C4**	B1.a-f, C4.b, C3.b, C3.c, C3.d, B2, B3.e, B3.f, B3.g, B4.b
TI10. Need for stakeholders awareness and engagement	**B1, B2, B3, B4,** C1, C3, C6, C5	B1.f, C6, C3.b, B2, B3.c, C5.a, C5.e

In Appendix III some of the recently completed or in progress relevant WGs are shown

7. FUTURE AREAS OF CIGRE CONTRIBUTIONS

In Appendix IV the relevance of the recently completed or in progress SC WGs to the Technical Issues is shown. It should be noted that this table provides a snapshot of the current SC activities, it is therefore subject to constant evolution and changes. It can be used however to:

- Provide guidelines for future activities

- Identify synergies among the various SCs

TI1. Active Distribution Networks resulting in bidirectional flows within distribution level and to the upstream network

The activities of **SC C6** are mainly driving TI1. Protection issues are an important challenge and are dealt with by **SC B5 in TI6**.

Future work

Modeling and analysis of active networks is important and should be dealt with by **SC C4**. Environmental issues are not yet covered and will be developed in cooperation with **SC C3**.

Indicative activities

- Smart buildings
- Smart cities
- DC distribution networks
- Potential ancillary services from distribution
- How to protect islanded electronically dominated distribution systems?
- How to address the micro grids issues?
- High renewable penetration in islanded communities

TI2. Massive need for exchange of information

The activities of **SC D2** are mainly driving TI2. Coordinated protection is an outstanding issue dealt with by **SC B5 in TI6**. The operation of active networks with increased DG and customer participation requires has increased exchange of information and this is dealt within **SC C6.**

Future work

Effects on power system operation and control are an important issue to be pursued by **SC C2**.

Indicative activities

- Evolution of existing telecommunications infrastructures to cover the new needs
- Cyber security
- New techniques and applications for maintenance of communication equipment
- How to cope with and best utilise the information from intelligent monitoring?

TI3. Massive integration of HVDC and power electronics at all voltage levels

The activities of **SC B4** are mainly driving TI3. The increased integration of power electronics requires new advanced modeling and analysis techniques, this is developed in co-operation with **SC C4**. Impacts on system development are dealt with in co-operation with **SC C1,** and the HVDC cable components by **SC B1**. Impacts on materials are dealt with by **SC D1**.

Future work

The penetration of power electronics at medium and low voltage levels is an important outstanding issue that should be pursued in cooperation with **SC C6.**

Indicative activities

- Power electronics at lower voltages including within generators
- FACTS applications for active and reactive power control
- New HVDC technologies
- Enabling of multi-vendor HVDC Grids
- Coping with multiple harmonic sources with the networks.

TI4. Massive installation of storage

TI4 is expected to be an important future activity, which is currently partially covered by **SCC6** at the distribution level only.

Future work

Issues not covered include the developments in storage technologies, in material and devices or methods, which could be developed by **SC D1** and **SC A1,** respectively and storage analytical models that could be developed by **SC C4**. Storage solutions which are connected to the network via Power Electronics will provide opportunities for reactive power management, and potential integration with HVDC Grids, and this aspect will be analysed by SC B4. The effect of large scale storage in the development and operation of the power system are important future issues to be pursued by **SC C1** and **SC C2**, respectively.

Indicative activities

- Storage techniques overview and selection
- Integrating energy storage in HV grids
- Influence of bulk energy storage
- Dual utilisation of power electronic converters associated with energy storage
- Maximise the value of energy efficiency measures by using energy storage to allow demand reduction to occur when it has the highest value.

TI5. New concepts for system operation and control

The activities of **SC C2** are mainly driving TI5. **SC C6** develops work on operation of active distribution networks and control of DER. **SC C4** develops models of specific components (gas turbines, wind parks, etc.) and risk-based and probabilistic tools.

Future work

TI5 is closely linked with the activities of **SC C2** and also **SC C1**, joint work is in progress and should be developed further. Protection is another relevant activity that should lead to joint work with **SC B5**.

Indicative activities

- Challenges in control centres due to renewable generation
- How much conventional generation is necessary in the future?
- Critical infrastructure protection against cyber attacks from outside
- ICT convergence
- Providing ancillary services from intermittent generation
- Harmonisation of grid codes for wind farms connecting to the grid
- Harmonisation of grid codes for connection of power stations to the network
- Impact of instrument transformers on substation concept
- Planned and unplanned outage management in a controlled and efficient manner

TI6. New concepts for protection

The activities of **SC B5** are mainly driving TI6. **SC B4** develops joint work on the impact of HVDC networks.

Future work

Modeling of protection devices and consideration of protection in analytical tools is an activity to be pursued by **SC C4**. Protection of active networks including low voltage networks is an outstanding activity to be pursued jointly with **SC C6**.

Indicative activities

- New protection , automation and communication for distribution networks
- Synchrophasors for system wide protection
- IEC 61850 Process bus and beyond the substation
- Advanced protection algorithms

TI7. New concepts in planning

The activities of **SC C1** are mainly driving TI7. **SC C4** develops probabilistic models for assessing network capability; **SC C1** is exploring how best to integrate these tools in making planning decisions on justifying network augmentations. **SC C6** develops work on planning active distribution networks.

Future work

Planning is closely related to environmental effects and the functioning of electricity markets. These are issues that can be the focus of joint work with **SC C3** and **SC C5**, respectively. The effects of protection should be considered by **SC B5**. The integration of HVDC Grids and AC Networks can be the focus of joint work with SC B4.

Indicative activities

- Demand forecasting recognising the changing nature of supply and demand
- Manage strong need for re-investment and new investments for future demand in the context of current and future technologies and growing uncertainty
- Future of reliability in terms of what the customer needs and the future system can deliver
- How can markets give incentives for improving the generation portfolio
- System flexibility for accommodating variable intermittent generation
- Impact of smart technologies on market designs
- More dynamic coupling between the markets and the infrastructure investments recognising the changing investment risk
- Integration of renewables potential from remote areas such as the North sea and African desert
- “Investigate tools and approaches for planning networks which integrate HVDC networks and HVAC networks solutions
- Future use of new unconventional generation technologies including Super conducting machines

TI8. New tools for system technical performance assessment

The activities of **SC C4** are mainly driving TI8. **SC C1** has also developed work on modeling complex networks.

Future work

The development and operation of active networks requires new tools for their technical performance, especially their dynamic behavior, islanding and power quality effects. Work should be developed in cooperation with **SC C6.** Models will be required for HVDC converter stations, HVDC Grids and for FACTS devices, and these can be developed jointly by B4 and C4.

Indicative activities

- Simulation tools for distribution levels
- Models for dynamic performance of PV, and wind mill generation
- Islanding
- Phasor Measurement Units use at distribution level
- Peer to peer approaches with multi agent techniques
- More transients and higher harmonic content in the network means to review test programmes

TI9. Increase of right of way capacity and use of overhead, underground and subsea infrastructure

The activities of **SC B2** and **SC B1** are mainly driving TI9. **SC B4** has also developed work on HVDC and FACTS, which can increase the right of way capacity. **SC C4** has developed models on long AC cables and HVDC cables jointly with **SC C1**. The effect of the transmission infrastructure on the environment is an important activity considered by **SC C3**.

Future work

The increased use of interconnections is a key component of the network of the future, as far as the supergrid is concerned. This development will have major implications on planning, operation & control and the establishment of electricity markets covering wider areas. Relevant activities could be developed in cooperation with **SC C1, SC C2** and **SC C5**.

Indicative activities

- Smart components for transmission lines
- Cost optimisation in new transmission lines
- Transmission interconnections
- Integration of superconducting transmission and distribution elements/lines
- Integration of power stations to the load centres by superconducting cables
- Off shore platform connection to the grid (reliability issue)
- Towards fluid free components (dry type)

TI10. Need for stakeholders awareness and engagement

The activities of **SC C3** are mainly driving TI10. The effects of cables and overhead lines on the environment are considered by SC B1 and SC B2.

Future work

Public opposition to new construction is a key problem impeding power system development. This issue concerns networks, substations, HVDC converter stations and generating stations. Relevant activities should be pursued by **SC B1, SC B2, SC B3 and SC B4**. Public opposition also affects power system development and should be considered in cooperation with **SC C1**. The facilitation of distributed generation (including renewable generation) and of active customer participation, are important relevant activities that should be developed in cooperation with **SC C6**. **SC C6** is also responsible for rural electrification, a subject very relevant to TI10. Finally, the development of electricity systems of the future in the new context requires extensive engagement with key stakeholders to ensure the required investments receive government and community support and gain access to scarce capital. These investments are required to both enable the new energy solutions and enhance the power system to deal with more extreme weather events.

Indicative activities

- Smoothing the public acceptability of power system infrastructures
- Leveraging CIGRE activities into developing countries
- Developing education tools together with methods to value the true cost of energy
- Producing simple public documents that promote key messages that are customer focussed

8. CONCLUSIONS

CIGRE is in a unique position to provide an independent and highly specialized vision of the Electricity Supply Systems of the Future. In this brochure the two characteristic models of development ranging from the Supergrid to the Microgrid have been reviewed, as the two are likely to form the basic components of the Future Electrical Energy Systems. Ten key technical issues have been identified and described in detail. The priorities of the Study Committees have been contrasted to the key technical issues and the recently completed or in progress CIGRE working groups have been aligned to the technical issues. This comparison has revealed new activities that can form the basis of future working groups, some of which will require collaborative work amongst a number of Study Committees. This ensures a more strategic approach to examination of these critical areas by minimising overlaps, addressing gaps and ensuring strong connection of the various activities. It should be noted that this work is based on the recent and current Study Committee activities and is therefore subject to constant evolution.

Appendix I. STUDY COMMITTEE SHORT DESCRIPTIONS

A1	Rotating Electrical Machines	• Life management • Machine monitoring and diagnosis • Renewable generation • Large generators • High efficient electrical machines
A2	Transformers	• Design and manufacture • Application of material • Utilization, e.g. maintenance and operation, condition monitoring, life management, repair and refurbishment, disposal • Safety and environmental aspects, e.g. noise, oil spill, fire hazard and explosion • Economic/commercial aspects • Quality assurance and testing
A3	High Voltage Equipment	• Design and development • New and improved test techniques • Maintenance, refurbishment and lifetime management • Reliability assessment and condition monitoring • Requirements presented by changing networks
B1	Insulated Cables	• Power cables in all phases of life • Submarine, underground, ducts, tunnels……. • HVDC and HVAC Cable Systems
B2	Overhead Lines	• Increase Acceptability of OHL • Increase Capacities of existing OHL • Increase Reliability and Availability of OHL
B3	Substations	• New substation concepts • Substation management issues • Life cycle management and maintenance • Impact of new communication standards and smart grids on existing and new substations
B4	HVDC and Power Electronics	• Responsible for HVDC systems and Power Electronics for AC systems • Its members are International Experts from Manufacturers, Operators, User Engineers, Consultants and Academics. • Provides unbiased and balanced documents concerning economical, technical and environmental

		matters associated with its area of responsibility. • The target audience includes engineers in the Electrical Supply Industry, Standardisation bodies, investors and regulators
B5	Protection and Automation	• Improved concepts of Substation Automation Systems • Technical recommendations for IEC 61850 • Application of numerical protections and substation automation systems • Methods to improve the performance of protection systems • Protection implications of new generation technologies.
C1	System Development and Economics	• Planning for rapid development, uncertain generation and desired reliability (newly and rapidly developing countries, system performance, contingency planning, mass penetration of renewables, a greenfield approach) • Investment drivers, decision processes and tools (investment drivers, planning criteria, grid codes and the role of new technology, new investment decision processes, new tools and methods for increasing uncertainty) • Asset management practices including risk assessment now and in the future (risk management, broad trends and practices, new solutions for changing power system designs)
C2	System Operation and Control	• Control and switching for reliability: voltage,frequency and capacity limits • Reserves and emergency strategies • Management of fault and restoration situations • Short term planning and coordination of system capacity needs • Requirements and use of power system analysis and security assessment functionalities • Requirements, methods, tools for training of operators • Impact on system operation from institutional structures: regulators,trading and contracted ancillary services.
C3	System Environmental Performance	• Environmental impacts of Power System development and operation; • Global environmental changes and Power System; • Public acceptance of Power System infrastructures; • Stakeholders engagement and communication; • Power System efficiency and environment.
C4	System Technical Performance	• Power Quality • Electromagnetic Compatibility/Electromagnetic Interference (EMC/EMI) • Insulation co-ordination • Lightning

		• Advanced Tools for the analysis of power system performance • Power systems dynamic/transient performance models and analysis.
C5	Electricity Markets and Regulation	• Consequences of regulatory changes for the electric power sector • Regulatory incentives for investment • System implications of new generation technologies • Markets design's impact on transmission system operation • Market design for integration of intermittent generation
C6	Distribution Systems and Dispersed Generation	• Dispersed Energy Resources connection and integration • Dispersed Energy Resources concepts in distribution systems operation and planning (Microgrids and Active Distribution Networks) • Demand management and Active Customer Integration • Rural electrification.
D1	Materials and Emerging Test Techniques	• Electrical insulating materials • Electrical conducting materials • High voltage and current test and measuring techniques • Diagnostic tools
D2	Information Systems and Telecommunication	• ICT applied to the networks of the future. • Telecommunication networks in Electric Power utilities (architectures, media, protocols…) • New ICT architectures to control the bulk power systems (smart meter, smart grid, intelligent grid, control centres EMS, MMS etc…). • ICT governance within utilities – in-house versus outsourced. • Information security within the Electric Power Utilities

Appendix II. DETAILED DESCRIPTION OF KEY ISSUES

The key issues identified by the SC Chairs are as follows:

A1. Rotating Electrical Machines

Erli Figueiredo

Key issues:

- Development of Large Capacity Generators

SC A1 will continue to follow the technological improvements in design, materials, insulation, cooling, bearings, availability, reliability, efficiency, monitoring, diagnosis, prognosis and maintenance of large electrical machines as the future network can not be dissociated from the centralised Hydro, Nuclear and Fossil Fuel Power Plants, although due to the increase in the use of renewable generation it is foreseen a decrease in these conventional generations. The development of super, smart and micro grids will additionally contribute to the reduction of the centralised generation in the future and to the improvement in grid efficiency due to reduction in transmission losses. Nevertheless, large generators will be necessary for the composition of the optimum generation mix. This has led and will lead to the significant enhancements in the construction of larger air-cooled, hydrogen-cooled and water-cooled turbo-generators, with a capacity of more than 2000 MW, what was not envisaged a few decades ago. Considering the hydro-generators, in a near future, the expectation is for the construction of units of more than 1000 MW.

- Modernization of Aged Generators

SC A1 will continue with the process of modernization of aged generators in the future.
Several thermal and hydro power plants which are in operation today, in a near the future, will reach the end of their useful life No matter of the type of generation, thermal or hydro, modernization of old generators is an economic alternative for extending their lives, deffering their replacement by new units.

However, due to the increase in renewable generation in the composition of the actual and future generation mix, as well the advent of super, smart and micro grids, some modernizations and eventual replacements of conventional generators may not be economically justified.

- Increase the Efficiency and Capacity of Wind Generators

SC A1 is presently and for many years ahead will be involved with the design, manufacture, efficiency, availability, maintenance, monitoring and reliability of wind generators which represent the most mature source of renewable energy production and whose participation in the generation mix of several countries is having a fast growing. Their common feature is that they produce little or no greenhouse gases, and rely on virtually inexhaustible natural sources for their 'fuel'. With the exception of hydroelectric generation, the wind generation has presented the greatest growth among the sources of renewable generation. At the end of 2009 the wind capacity worldwide was around 159,213.00 MW with 38,312.00 MW added in 2009, the highest volume achieved in a single year. The installed wind capacity is more than doubling every third year. If this trend continues the prediction of a global capacity of 1,900,000.00 MW is possible by the year 2020. New designs will be conducted to increase the efficiency of wind generators that is still low today. A design project is on going for a superconductor 10 MW off-shore wind generator.

The great farms of wind generators are connected to the main transmission grid through a low voltage subtransmission system. Small farms located nearby the centres of comsuption may be connected directly to the distribution systems. Wind generation, as well other renewable generation will have a great influence in the structuture of future networks by reducing the number of transmission/subtransmission/distribution lines which will be needed to supply the demand.

- Superconductor Synchronous Generators

SC A1 will be involved in the several technical issues related to Superconductor Synchronous Generators (SSG) which are the future promising alternative for increasing generation efficiency beyond 99%, reducing size, weigh, increasing capacity of reactive power and improving power system stability in comparison with conventional generators. In a SSG the field winding is made up of High Temperature Superconductor (HTS).

They will occupy less space in a power-house allowing more units to be installed and as a consequence increasing the capacity of the power plant. With this large thermal power plants, mainly nuclear due to restrictions to the emissions of greenhouse gases by the conventional thermal power plants, may be located nearby the load centers avoiding the construction of interconnection lines with other countries or regions, sometimes by transmission lines of great length. The result is a decrease in transmission losses improving the efficiency of the power system. Up to now the developments are in the direction of small synchronous compensators whilst a 36,5 MW superconductor motor was already produced and tested.

A2. Transformers

Claude Rajotte

Future transformers will need to be able to integrate with networks of the future, and should also be designed to address the critical issues that networks of the future will address. They should therefore be efficient and reliable, and should also be designed with consideration for both safety and environmental issues. Eco designs may result out of complete life cycle assessments of transformers for networks of the future.

Efficiency
Environmental concerns and possible legislation will result in pressures to reduce losses from the power system where possible. If the cost of energy increases, the losses of transformers will be more and more capitalised during the procurement process providing a financial incentive to reduce these losses. Through improved design and manufacturing techniques, it may be possible to reduce both load and no-load losses of new transformers. Further development of materials may also help in producing lower loss transformers in the future.

Reliability, Economics and Maintenance
Vacuum OLTC (On-Load Tap Changers), have reduced the need for tap changer maintenance. As manufacturers further develop these products, and the premium cost of this new technology reduces, it is likely that the use of these tap changers will increase.

The use of on-line monitoring and control systems will increase as the infrastructure to transmit this data, and the systems that turn the masses of data into more useful information, become more readily available. This will assist in the reliable operation of transformers and allow their economic life to be optimised, by reducing the need for maintenance tasks that are performed to evaluate the transformer’s condition.

This will be achieved by:

- allowing existing or developing faults to be assessed without taking the transformer off line;
- enabling informed decisions about transformer loading to be made so that the transformer life can be balanced against the benefits of supplying higher loads.

The remaining life of a transformer may therefore be estimated more accurately. This will assist with replacement planning, but also in the decision making when repairs or complete refurbishments have to be considered eg, as part of lifetime extension projects.

Information from other components or systems in the substation, eg protection relays, may similarly be used to provide information about the transformer which may be useful in ensuring its reliable operation. Examples of information that may be available include:
- magnitude and duration of fault currents supplied through the transformer; and
- both normal and harmonic load supplied by the transformer.

Environmental
The use of alternate insulating fluids may increase in the future, particularly those that are biodegradable and produced from a renewable source. These alternate fluids generally have higher fire points than mineral oil, as well as providing potential environmental benefits. Recycled, refurbished or re-refined mineral oils may also become more popular in the future. The increased use of these fluids will, however, be dependant upon future development and favourable in service experience with current liquids.
Further development of dry type or gas insulated transformers will also assist with adverse environmental impact of liquid filled transformers, oil containment issues, improved fire safety, reduced segregation, and more compact substations.

Transformer noise is a major issue when transformers are installed near residential areas. Hopefully designers will be able to continue to further reduce both load and no-load noise. The noise resulting from harmonic loads on transformers may also need to be addressed.

Noise levels from cooling systems are often more of a problem than the noise from the active part of the transformer. Lower noise cooling systems will therefore be required. This may be achieved by the use of cooling control systems, which minimise use of the fans at their highest speed, yet ensure that the transformer life is not compromised by continual operation at high temperatures.

Safety
Safety during operation and maintenance will be a major consideration for transformers of the future. There will possibly be a continuing move away from paper oil bushings with porcelain insulators and towards the use of dry type bushings with composite insulators. However, this will depend on continued development of these products, and favourable in service experience.

Transformer tanks of the future may be better designed to withstand the overpressures, that may result during fault conditions, and may include better methods of pressure relief, containment and fire prevention.

To ensure safety of staff maintaining transformers, future transformers may be designed to eliminate where possible the need to work at heights. For example, the increased of use plug in terminations would eliminate the need to climb on the tank to make connections to bushings.

Network Issues

Many transformers may be loaded differently in the future as demand management attempts to remove peaks from the system and results in a more constant load. This will potentially result in more efficient use of these transformers as they operate constantly near their rated load. However, network operators, who have enjoyed very long lives from transformers that have only been loaded heavily at times of peak demand and high temperatures, may find that their future transformers will have a reduced life.

Transformers that are connected to renewable generation sources, eg wind and solar generation, may be subjected to extreme peaks in load followed by sudden drops. This may result from wind or solar generators. This may cause voltage regulation problems with the changes in transformer load. It may be possible to overcome these issues through the development of control systems that integrate with the generators. The rating and loss of life of these transformers will also be an issue to be addressed by monitoring systems.

It is likely that embedded generation will result in reverse power flows on some transformers. Designers will need to ensure that this does not create issues for the transformer or its ancillary components. Some sources of generation may result in higher levels of harmonics than have otherwise been experienced on the network. This will need to also be considered in the design of the transformers. Dynamic rating systems will need to monitor harmonics and ensure that they are considered when providing rating information.

Key issues:

- Development of new sensors; more on-line monitoring and improved diagnostic
- Dynamic loading and increased transformer utilisation
- Better information; improved reliability and risk assessment through probabilistic approach
- Need to improve transformer safety and reduce environmental impacts
- More transients, possible need new test program

Regarding current work programme, the following groups might be considered to be directly related to key issues of the future network theme:

- WG A2.33 - Transformer fire protection
- WG A2.38 - Transformer thermal modelling
- JWG A2/C4.41 - Electrical transient Interaction between transformers and the power system

Future WG (under preparation) related to key issues of the future network theme:

- Transformer intelligent monitoring

A3. HV equipment

Mark Waldron

Key issues:

- the need for new technologies (e.g. DC circuit-breakers)
- the capability of new & old equipment to cater for increased current demands (load & fault)
- new system conditions applied to HV equipment (e.g. more severe out of phase switching conditions, switching of long offshore cable circuits, switching of complex circuit configurations)
- the incorporation of intelligence into HV equipment
- improved efficiency both in production (materials etc) and operation (losses etc)

Regarding current work programme the following groups might be considered to be directly related to the future network theme:

- WG A3.15 (Non-conventional instrument tramsformers)
- WG A3.27 (Vacuum switchgear for transmission use)
- WG A3.28 (UHV)
- WG A3.30 (Overstressing of equipment)

Discussion with SCB4 about DC CBs.

B1. Insulated Cables

Pierre Argaut

For more than hundred years, HV insulated Cables have been designed, produced and installed for a service life of around 40 years.
The first EHV extruded cables (245 kV and above) have been installed more than 40 years ago and they are still giving now an outstanding return of experience, but the question of their remaining life is raised.
The life of cables is completely covering the time interval of the expected changes towards the Network of the Future.
Consequently, to fulfill the basic needs of customers towards the supply of a electric power with a high level of availability, reliability, flexibility, quality and cost, the actions in the field of insulated cables should address all the steps of the service life of cable systems:

- design,
- installation,
- operation,
- upgrading and uprating.

These actions refer to SCB1 Strategic Plan and cover the main targets of the SB1 Action Plan through dedicated Working Bodies to produce guidelines and implement state of the art technologies necessary to meet the requirements of the Network of the Future.

1. Design and Testing

a. Review of Cable Systems Electrical Characteristics: WG B1.30 working in parallel and with cross-participation to "Modeling and analysis of the technical performance of electrical power networks with very long/large number of HV/EHV AC cable lines"(WG C4.502)"

b. Increasing capacity of HVAC and HVDC cable systems:

Increasing Ampacity and cross section of cables: WG B1.34 and WG B1.35
Increasing voltage : WG B1.27 (HVAC) and WG B1.32 (HVDC)

c. New technologies: Advanced design of cables with laminated coverings WG B1.25

d. Managing bottlenecks in cities by High Temperature Superconducting Cable Systems: WG B1.31

e. Life Cycle Assessment and Environmental impact: TB B1.36

2. Installation

Utilization and co-existence with other utilities in shared structures: WG B1.08
Large Cross Section cables: WG B1.34
Feasibility of a common interface with GIS: JWG B1/B3.33
Cable Accessories workmanship: WG B1.22

3. Operation

Dynamic and enhanced cable on line rating systems: WG B1.35
Testing and on line monitoring (including PD testing and monitoring): WG B1.28
Maintenance: WG B1.04
Remaining life management: WG B1.09
Third party damage: WG B1.21
Maintaining the integrity of XLPE transmission cable accessories: WG B1.29
Operation Guide for fluid filled cable systems: WG B1.37

4. Upgrading:uprating

Guidelines for upgrading/uprating: WG B1.11
Transition joints: WG B1.24

B2. OVERHEAD LINES

Bernard Dalle

1. Increase capacities of Overhead lines
   a. New conductor technologies for increasing power capacities of existing lines or of new corridors
   b. - Dynamic and enhanced line rating system :

B2 has to put a strong focus on the real-time monitoring and uprating of the HV-lines, as we are convinced that important quick wins are possible in a relative small time span.

2. Increase of reliability and of availability of overhead lines
   a. Knowledge of weather behaviour around lines
   b. Knowledge to allow more efficient utilisation of existing structures and foundations
   c. Use of robots for maintaining OHL in live conditions : to perform live line maintenance in a safe way even for compact lines
   d. Increase of different diagnostic methods and condition based maintenance due to the demand on low-cost maintenance on one side and high reliability on the other side

3. Increase the acceptability of overhead lines
   a. Electric and magnetic fields due to DC Lines
   b. Optimization of the design of new OHL towers and foundations , minimising clearance requirements along line corridors e.g. “compact” lines reducing environmental impact of OHL

B3. Substations

Franz Besold

Transmission and Distribution substations play a central role in providing reliable energy with high availability in the network of the future. High voltage power transmission research & development continues to make advances in new technologies and applications that give transmission owners and operators the flexibility, security and stability they need to continue to expand their systems reliably and efficiently. As the electric power infrastructure expands and global demand for power grows, suppliers and customers alike will have to cooperate to ensure that the appropriate technologies are developed and deployed in a sustainable manner. At the same time the sector will have to maintain the availability of the energy delivery system, provide dependable and affordable sources of electricity, and ensure the highest standards of public welfare and safety.

<u>1. Concepts and Developments</u>
New concepts with regard to actual changes and developments in the power grid and compacting substations through the insulation reduction are some of the goals. Technical solutions as well as safety aspects have to be taken into account as well as circuit configuration optimization. Security, availability, accessability, maintainability and different technologies like AIS, GIS, MTS influence the circuit configuration. To get maximum benefit from new solutions whilst improving the network performance a process of optimisation has to be performed.

The impact of new functionalities on the substation design is another aspect. Mixed technology solutions (Hybrid AIS/GIS), compact AIS switchgear, non conventional instrument transformers, reactive compensation, wind farms, active power flow control, fault current limiters, HVDC, protection, GIL/superconductors, monitoring & diagnostics etc. are influencing and changing the substation designs. In particular the impact of new solutions of the substation equipment like MTS or compact AIS and the distributed power generation like wind farms on the substation concepts will get an increased importance.

Substation condition monitoring permits to have an actual picture of the substation situation and helps to increase the performance of the network.

2. Gas insulated substations

To be able to meet the requirements regarding space and high availability and reliability of substations in the network of the future HV GIS are the solution. There are GIS applications for all voltage levels up to 1100 kV. In addition there is a wide range of various technologies applied in mixed technology switchgear (MTS) used in substations.

3. Air insulated substations

For normal applications air insulated substations are used. Special focus has to be given on environmental aspects, construction, operation and maintenance of AIS during their whole lifetime.

In addition there is an ongoing process of uprating and upgrading of substations to adapt them to the requirements of the network of the future.

4. Substation Management

Asset management is an important part of a sustainable substation management. Replacement and refurbishment strategies are key to meet the reliability and availability goals of existing substations.

State-of-the-art interfaces with primary/secondary equipments are necessary to operate and manage substations during their whole life cycle time. The process bus defined in IEC 61850 is the base for a modern substation management.

Addressing the challenges for a reliable, efficient and sustainable supply of electricity – now and in the future substations play an important role. State-of-the-art technologies and concepts as well as handling and operating guidelines are necessary to meet the requirements of the network of the future.

B4. HVDC and POWER ELECTRONICS

Bjarne Andersen

B4 is responsible for HVDC, FACTS and other Power electronics devices. These devices provide economic solutions to many steady state power transmission and power exchange requirements. They also provide fast and intelligent responses to system dynamics and transients, and will therefore become an ever increasing part of the Network of the Future.

B4 is committed to facilitate this evolution, through the provision of unbiased application guides, which will include technical issues, e.g. interactions between the device and the

ac network to which it is connected, economic aspects, including life time costs such as power losses etc. B4 is also committed to assisting the standardisation process, by the provision of high quality technical information which can be used as a base from which standards can be developed.
The following bullet points summarise some of the work that has already been done, and some which will be initiated in the short term.

1. HVDC Transmission Applications and Interactions with the ac network(s)
    a. To provide up to date and unbiased application guides for all types of HVDC schemes, including offshore wind applications. These include feasibility studies, which may later be developed to include more technical details.
    b. To present up to date and unbiased information about the performance of HVDC schemes embedded in ac networks. The activities also include environmental impact and how these can be mitigated,
    c. To support the standardisation in the field of VSC HVDC and UHVDC transmission, including power loss calculations and harmonics.
    d. To study the feasibility of HVDC Grids and to support the standardisation necessary in this field. Another significant point is to develop pro-forma connection agreements for DC Grids, with the aim of enabling converter stations from different manufacturers to be connected to the HVDC grid.

2. FACTS (Flexible AC Transmission Systems)
    a. To provide up to date and unbiased application guides for all types of FACTS devices.
    b. To provide guidelines for the studies required to determine the increased network capacity that can be released by appropriate application of FACTS devices, this task to include the description of appropriate models – need JWGs with C1.
    c. To support the standardisation in the field of FACTS devices.

3. Other Power Electronics
    a. To provide up to date and unbiased information about the power electronics systems and control and control and protection requirements for various energy storage methods and technologies.

4. Energy Storage – Activities outside of B4 scope needing JWGs
    a. To provide application guides for energy storage systems – this needs to be done by other SCs
    b. To support the standardisation in the field of large scale energy storage devices – B4 can do this for the power electronics.

In terms of ranking the order is 1d, 1b, 2b, 4a, 1a, 2a, 3a, 1c, 2c, 4b

B5. PROTECTION AND AUTOMATION

Javier Amantegui

1. New requirements and capabilities of new Generation technologies contributing to the stability and power quality of the network

1.1.-Transmission

Present situation

There is a general concern about the stability problems created for the connection of large Wind Mill Generation. This is in spite of the requirements for Fault Ride Through required in several countries. These requirements are different in each country and are probably are too limited in order to guarantee the stability of the grid: an integrated approach is needed

On the other hand the technology and control Wind Mill Generation with fast and flexible reaction has the opportunity to improve the present behavior. In particular has been identified possible benefit regarding small angle stability. There are also requirement in some countries for frequency control.

Additionally, the previous mentioned constraints are heavily influenced by commercial interests

Possible Actions

To launch a Joint WG in order to define the optimum requirements to Wind Mill Generation in order that the new generation achieve or exceed the performance of conventional synchronous generation. It would cover all stability phenomena: angle, voltage, frequency, small angle. This requirement would be proposed to IEC for international standardization. The added value of CIGRE comes from his huge amount of experience in the field and his unbiased view.

1.2.- Distribution

Present situation

Large Photovoltaic generation is connected in some countries. There is a trend towards the connection of new generation such as small wind or cell and -perhaps –Electrical Vehicle. In all the cases the connection is trough Power Electronics inverters. Requirements are according to IEC standards. In spite of this standard severe problems related to islanding operation have been reported (Spain). Photovoltaic inverters could operate in unwanted island and severe transient overvoltage have been reported. Apparently present IEC standard do not totally cover the real phenomena and new standards are required.

Present inverters do not contribute to the short circuit power nor supply negative sequence current. This will endeavor future expected application like islanded operation. No significant cost benefit will be obtained as the distribution network would be designed for the totally of the load in spite of the amount of local generation

At present, distributed generation do not control voltage nor reactive power. This result in voltage problems that also limit the amount of local generation that could be connected

Possible Actions

To create a JWG to specify the requirements to inverter in order to contribute to guarantee the Power quality covering aspects of transient overvoltage limitations, fault contribution, on line voltage control…..etc

2.- Islanding detection and Operation. (¿microgrid?)

- Islanding detection, probably based in communication
- Intentional islading operation. Protection,automation and control requirements

The added value of CIGRE could come from its experience in operation of transmission networks and its application to the distributions network. Also by the interchange of experiences all around the world.

3.- Wide area monitoring, control and protection

In order to take full advantage of the new stability capabilities proposed in point 1, new wide area protection and control concepts should be investigated. Based in the state of the art CIGRE WG could propose new specifications and requirements for SIPS , generation control , defense systems, EMS applications, stability coordination between transmission and distribution networks, self healing, intelligent load shedding,..etc.

4. New protection and automation systems for the network of the future

Present Situation

The connection of DG has the following impact on the present protection practices:

- Reduction of fault detection sensitivity and speed in tapped connections
- Reduced reach of impedance relays
- Unnecessary tripping of utility breaker for faults in adjacent lines due to fault contribution of the DG (sympathetic tripping)
- Changes in the value and direction of short circuit currents, depending whether the generator is connected or not, which affect the co-ordination and operation time of the overcurrent relays
- Unintended islanding which can prevent automatic reclosure, unsynchronized reclosure and in some cases operation of the parts of the system without effective grounding
- Out-of-step conditions
- Over-voltages due to resonance conditions

- Impact of the reduced fault contribution of inverter based generators on protection performance

In spite of that, there is not clear solutions for these problems. In general practice utilities are not changing their well proved protection practices .One example could be islanding detection protection practices .This has is resulted in unwanted tripping of large amount of DG during major disturbances as has been the case in the disturbance of 2006 in the UCT network and in UK in 2008.

Present protection practices could limit the expected benefit of the Network of the Future. One must take into account that it takes a long time to modify the protection philosophy of a whole grid and the experience shows that renewable energy - and probably the Electrical Vehicle -will run faster that the possibilities of the Distribution Utilities.

Proposal

To create a WG to analyze the problems and solutions and propose a change in the protection concept in order to take full advantage of the new generation technologies opportunities.

This will result in new applications for utilities and new requirement for manufacturer of protection, automation and communication.

The CIGRE added value will be to translate its experience in Transmission network to the new meshed distribution network (no more radial)

5. More issues

5.1. Communication. F.e Application of internet to protection and control

5.2. Data integration. Standardization proposal for Smart Grid concept of " Plug and play".(NIST report). Possible application of 61850

FUTURE ACTIVITIES (Contribution for TI6)

The following actions are considered

- **New Wide area Protection concepts for Transmission Networks.**
  WG B5.14 and B5/D2.25 are working on wide area protection technology and application of communication. In the short term no new activity is required from B5/D2.
  After 2012, new activity based on the conclusions of both WG and on the activity of other SC would be required. This activity would be probably oriented towards new concept architectures to integrate distributed generation and intelligent loads. These new Wide Area protection should be able to take advantage of the expected new transient stability capabilities of DG.

- **Impact on the protection system of new generation technologies**

  New generation technologies, such as inverter based generators, could evolve to provide new capabilities concerning steady state and transient stability. At present there is no CIGRE activity to evaluate those opportunities.

  Two CIGRE actions are proposed

  Wind generation Stability requirements
  A Joint WG **(C2,** C1, C4, and B5) would investigate the optimum requirements for Wind Mill Generation in order that the new generation achieve or exceed the performance of conventional synchronous generation. This could be achieved by using the potentialities of power electronics based generation. It would cover transient stability phenomena: angle, voltage, frequency, small angle. Voltage and frequency control would be also included. The WG would produce technical recommendation for further IEC standardization

  Inverter based generation Power Quality requirements
  A joint WG (**C4**, C6; B4 and B5) would investigate the requirements for inverter based DG connected at the distribution network including LV. The analysis would be mainly focused on photovoltaic power plants and would evaluate the possible contribution of power electronics inverter to power quality of distribution networks. Aspects such as transient overvoltage limitations, contribution to balanced and unbalanced faults, on-line voltage control, harmonics, etc would be considered. Also mechanisms regarding active island detection and intentional islanded operation should be included. The WG would produce technical recommendation for further IEC standardization.

- **Inadvertent Islanding detection**
  WG B5.34 has recently presented the state of the art of this topic. The conclusion is that with growing DG penetration levels of all sizes there is an increasing need for high performance anti-islanding protection and new solutions are needed. No additional activity is required in the short term.
  In the medium term a new WG would follow the development regarding research, new products and application experiences.

- **Intentional islanded operation**
  The new WG C6.22 (2010) is working on a road map evaluation of microgrids, including control technologies.
  Based in the findings of that WG, some B5 activity would be required in the medium term

- **New protection and automation functions and concepts for distribution networks**
  SC B5 has been traditionally focused on the transmission networks. A new WG is proposed to evaluate the future trends on distribution networks.

Evaluation of new protection and automation concepts for distribution netwoks.

This B5 WG will analyse the opportunities and implication of the application of transmission protection and control practices to distribution. The use of distance and current differential protection could solve many of the problems encountered in the distribution networks with greater integration of DG. The development of powerful communication network in the distribution system could improve system operation and management trough monitoring and automation systems. Automation application would include new control capabilities, reconfiguration, synchronization , reclosing and advanced adaptive techniques

The WG would produce a report aiming to be a reference for utilities and manufactures regarding trends and new development and serve as the basis for further CIGRE work in the field

- **Metering**

  The new WG B5.41 and C6.21 are working on metering systems for billing purposes in substations and smart metering.

  Further CIGRE activity will be based in the findings of both WG scheduled by year 2012

- **Architectures of the future.**

  B5 has several WG dealing with the application of 61850, standardization and process bus.
  Further B5 activity will be based on the findings of present WG by year 2012

- **New protection and control algorithms.**

  WG B5.25 and B5.23 are working on HVDC and cable protections.
  Further B5 activity after year 2012 will be based on the conclusion of the presently active WG. This activity will be mainly focused on protection for network stability, power electronics and application of adaptive techniques.

- **Data management innovative applications.**

WEG B5.20 has recently presented (2009) the report on automatic fault analysis.
WG B5.06 and B5.31 are working on protection maintenance and setting management (2010).

New B5 activity will be required in the medium term according to the conclusions of the presently active WG. According to the evolution of the data modeling standardization process, some activity related to 61850 could be needed.

C1. SYSTEM DEVELOPMENT AND ECONOMICS

Phil Southwell

Key issues are:

1. Planning for rapid development, uncertain generation and desired reliability
    - Newly and rapidly developing countries
    - Determining and delivering desired system performance
    - Contingency planning
    - Mass penetration of renewables
    - A greenfield approach
2. Investment drivers, decision processes and tools
    - Investment drivers, planning criteria, grid codes and the role of new technology
    - New investment decision processes
    - New tools and methods for increasing uncertainty
3. Asset management practices including risk assessment now and in the future
    - Risk management
    - Broad trends and practices
    - New solutions for changing power system designs

CIGRE SC's Experience

Current working groups that are potentially relevant are listed below with most relevant ones highlighted in blue.

SYSTEM DEVELOPMENT

- Planning issues for newly industrialised and developing countries (C1-9)
- Green field network design (C1-19)
- Drivers for transmission investment decisions and the role of technical planning criteria in investment (C1-15)
- Advanced components and technologies required to assist system development and planning (C1-21)
- New investment decision processes and regulatory practices to deal with changing economic drivers (C1-22)
- Transmission decision points and trees (C1-23)
- New tools and methods to model and understand the uncertain nature of future power systems (C1-24)

GRID CODES

- Impact of transmission codes on the planning of systems (C1-12)

SYSTEM ANALYSIS

- System complexity and dynamic performance (C1-13)

ASSET MANAGEMENT

- Transmission asset risk management (C1-16)
- Asset management in a low carbon future (C1-25)

SYSTEM SECURITY

- Planning to manage power interruption events (C1-17)

SUSTAINABILITY, ENVIRONMENT, WIND INTEGRATION

- Coping with limits for very high penetrations of renewables (C1/C2/C6-18)
- Accommodating high load growth and urban development in future plans and their environmental effects (C1-20)

C2. SYSTEM OPERATION AND CONTROL

Michel Armstrong

SC C2 should define how future networks will be operated and controlled.

As new structures are proposed C2 should be involved in assessing the impacts on the ability to operate the system in a safe, secure and reliable manner.

1. Challenges in operation caused by the combination of stochastic generation (wind,solar,tidal etc...) and changes in electrical loads behavior due to demand side management heavily influenced by pricing mechanism :

- Power balancing
- Congestion management
- Active and reactive reserve
- Energy storage
- Risk management techniques and shift from deterministic to probabilistic approaches

<u>Relevant working groups</u>

- WG C2.13 Voltage and VAR support in system operation
- WG C2.22 Application of resilience engineering to safety management principles in control centres, ensuring and enhancing power system reliability
- JWG C1-C2-C6 Coping with limits for very high penetrations of renewables

2. Evolution of power system control at Continental, Country, Regional and local levels

- Improve the awareness of the overall system status in interconnected system with several control areas
- Define the boundaries between TSO and DSO systems in terms of Operational Control
- Display of interconnected areas and trigger signals to operators. Vizualisation techniques
- Information exchange and operational interfaces between TSO and other actors: production and load centres

Relevant working groups

- JWG C2-C5.05 Developments and changes in the business of system operators
- WG C2.34 Capabilities and requirements of a control centre in the 21st century, functional and human resources view

3. Significant Increased level of automation in the control rooms
    - New software tools to quickly determine the status of the system
    - Automated adjustment of the configuration and electrical parameters of the system
    - Automated restoration and adapted disaster recovery scenarios.

Relevant working groups

- WG C2.32 Emergency organisation and crisis management in system operation
- WG C2.21 Lessons learnt from recent emergencies and black out incidents

4. Assure the competencies and adapt the training for System operators

Relevant working groups

- WG C2.31 Joint and coordinated development of operators in Control centres from different companies and Nationalities
- WG C2.33 Control centre operator requirements, selection, training and certification

C3. SYSTEM ENVIRONMENTAL PERFORMANCE

Antonio N. Negri

Introduction

Very important challenges are to be faced by Electric Power Sector in its development, namely:

- to respond and adapt to Climate Change
- to ensure the environmental compatibility of plant operation
- to face the extreme events and the natural hazards, improving system safety and reliability
- to obtain the public acceptance of plants and infrastructures
- to find innovative ways to integrate Sustainable Development practices into existing operations
- to support future energy options that meet the expectations of stakeholders as well as the sustainability needs.

The Electric Power Sector could be part of the solution to these challenges, through:

- the diversification and de-carbonization of the fuel mix
- the increase in the use of Renewable Energy Sources and renewable/recyclable Materials
- the increase of electricity penetration in End Uses
- the improvement in energy efficiency
- the expansion and reinforcement of the grid
- the improvement of the stakeholders engagement and communication.

The environmental issues that should be addressed by CIGRE work in giving technical support to the development of the “network of the future” can be summarized as follows:

- Climate Changes Adaptation and Mitigation
- Development and Planning under environmental/social responsibility
- Environmental compatibility of plants and infrastructures operation
- Public Acceptance of plants and infrastructures, Stakeholders Engagement and Communication

1. Climate Changes: Adaptation and Mitigation

This topic is of paramount importance for Electric Power Sector Utilities; the issues to be included in this topic are as follows:

a. Investigation and comparison among the various needs and responses of the Power Sector utilities to Climate Changes
b. Integration of Renewable Energy Sources (dealing with the related Environmental and Social Issues)
c. Increase in Power System Efficiency (dealing with the related Environmental and Social Issues).

To the issue under (a) has been dedicated the first Preferential Subject of the SC C3 Group Discussion Meeting during the 2008 Paris General Session. Now a WG, dedicated to “Greenhouse gases emission inventory and reporting methodologies” has been launched (WG C3.12).

The issue under (b) was the topic of the International Colloquium organized by SC C3, together with Portuguese CIGRE NC, in September 2009 (in Oporto, P).
This issue could be dealt with in future working bodies. Co-operation with other SC’s is envisaged, especially with C1 and C6.

To the issue under (c) is now dedicated a TC Project, under the co-ordination of SC C3 and C1.
A specific working group is active inside SC C3, namely the WG C3.05 “Environmental impact of dispersed generation”, in co-operation with SC C6. Other issues like high efficient equipment and components, Smart Grids and Electric Vehicles (EV) could be dealt with under this topic. SC C6 just launched a WG dedicated to EV; some members from SC C3 will participate.

2. Development and Planning under environmental/social responsibility

The future evolution of Electric Power Sector Utilities should carefully take into account environmental and social responsibility issues; the main aspects to be considered are as follows:

a. Integration of Sustainable Development practices/goals into expansion planning
b. Definition of the environmental costs/benefits for different network topologies (e.g. dispersed generation, smart grids…)

The issue under (a) is currently being dealt with in the WG C3.06 “Strategic Environmental Assessment” and was the second Preferential Subject of the SC C3 Group Discussion Meeting during the 2008 Paris General Session.
A continuous co-operation with other SCs, especially C1, C5 and C6, is envisaged.

The issue under (b) is the second Preferential Subject of the SC C3 Group Discussion Meeting during the 2010 Paris General Session. A continuous co-operation with other SC's, especially B1, B2, B3, B4, C1, C4 C5 and C6, is envisaged. There should be a need to launch co-operative working bodies on this issue

3. Environmental compatibility of Plants and Infrastructures:

The development of EPS (in accordance also with the new CIGRE Strategic Plan) should:

a. To guarantee and increase the environmental compatibility of plant operation,
b. To integrate Sustainable Development practices/goals into existing operations

The issue under (a) is currently dealt with in the WG C3.01 –as far as EMF are concerned- and is the first Preferential Subject of the SC C3 Group Discussion Meeting during the 2010 Paris General Session, as far as Transmission Corridors are concerned. A WG to be launched soon (JWG B1/B2/C3.13 will deal with overhead and underground T&D lines in urban and rural environment).

The work on this issue will continue, taking into account the new technological development foreseen in the evolution of EPS; good co-operation has been already established with SC B1 and B2, and improving with B3 and B4.

The issue under (b) was dealt with in recently disbanded WG's (namely the WG C3.02 "Sustainable development performance indicators for T&D Utilities" and WG C3.03 "Utilities practices toward Sustainable Development") and will be continued in the WG C3.10 "Sustainable development performance indicators for Power Generation Utilities", recently launched.

4. Public Acceptance of Plants and Infrastructures

This topic is critical for an effective development of EPS worldwide. The EPS is facing growing concern and difficulties in planning, building and operating infrastructures and plants. There is, therefore, the need of:

a. Improving the Stakeholders engagement and Communication
b. Striving for the Public acceptance of plants and infrastructures.

The issue under (a) is currently dealt with inside the WG C3.04, specifically dedicated to this question.

The issue under (b) is strictly connected with that one on "Stakeholders engagement and Communication", actually dealt with inside WG C3.04; a new WG could start from the conclusion of this latter group.

For both issue SC C3 shall increase the co-operation with other CIGRE SC's, especially those dealing with sub-system and C1, C4 and C6.

C4. SYSTEM TECHNICAL PERFORMANCE

Carlo Alberto Nucci

1. Modeling of New Generation Technologies:

To be able to assess the reliability of future networks we need suitable models for operational/dynamic studies for many of the emerging generation technologies, e.g. combined-cycle generation, wind generation, etc.

- Combined-cycle power plants (SC C4 TF C4.02.25 did this)
- Wind Generation (SC C4 WG C4.601 took the first step in this); presently IEC TC88 WG27 is carrying on this work (one C4 member is also a member of that IEC WG, what represents an important liaison between CIGRE SC C4 and IEC)
- Intentional Islanding (new WG to be proposed by SC C4, hopefully jointly with C6 and/or C2)
- Storage systems and their network interaction . A new WG is going to be proposed.

2. Addressing Technical Challenges with more imbedded AC cables and HVDC Systems:

As more renewable generation technologies get incorporated into the system (e.g. off-shore wind, wind in remote areas, large PV, off-shore tidal power etc.) there is a great likely hood of increased deployment of both HVDC systems and AC cables; systems like Denmark, UK, and proposals in the US to carry wind generation from the Midwest to PJM are an example. Thus, we need greater guidance on the incorporation of such technologies in the networks of the future and possible technical challenges and solutions. The SC C4 WGs addressing these issues are:

- SC C4 WG C4.502 (long AC cables)
- JWG C4/C1/B4.406 (on HVDC).

3. Lightning protection of wind turbines:

The issues with lightning and wind turbine blades as being address by SC C4 WG C4.409; and issues in low-voltage networks (since these networks are becoming more complicated) so e.g. SC C4 WG C4.408 are being dealt with.

4. Insulation Coordination issue for UHV transmission systems

UHV lines are in any case expected to play a major role in the network of the future too, and some important issues dealing with lightning attachment for this type of lines is being dealt with by CS C4 WG C4.405 while insulation coordination studies are carried out by WG C4.306. A global approach to insulation coordination - more appropriate for the future network - is one of the aims of WG C4.305).

5. Advanced/Improved Tools and Techniques for Simulation:

As the network of the future becomes more complex we are going to need better and more sophisticated tools for both planning and operations, and for electromagnetic transient analysis. Thus the areas were development and study is need, are:

- Better numerical technique and bridging the gap between 3-phase and positive sequence modeling (Proposed SC C4 WG C4.503 and - in part - active SC C4 WG C4.501)
- Better tools and techniques for power balancing and reserve requirement evaluation (SC C4 WG C4.603)
- Moving towards probabilistic and risk-based planning and operational tools (SC C4 WG C4.601)
- Reviewing recent improvements in load modeling techniques (SC C4 WG C4.605)
- Modeling the "Active or Smart Grid". Better modeling tools are needed to be able to model some of the proposed active control strategies (e.g. centralized control systems, grid-friendly appliances that participate in load-frequency control, demand side management, etc.). This may be a subject for review by a joint WG among C2, C4 and C6.

6. Power Quality issues related to the massive use of power electronics:

There is general consensus that one of the key issues of the network of the future will be to comply with progressively more and more severe EMC and Power Quality requirements, which are crucial for the appropriate operation of protections and of state estimation/measurements systems spread over a network that will experience also at the low (distribution) voltage level some bi-directional flows of energy, not to mention that electricity, as a commodity, should satisfy strict quality requirements. The SC C4 WGs addressing - at least in part - these issue are JWG C4.107 (Economic framework for Voltage Quality) and JWG C4.109 (Emission Assessment Techniques).

C5. ELECTRICITY MARKETS AND REGULATION

Olav B. Fosso

Key issues are:

1. Multi-region market designs.
    a. Expanding markets in a system with insufficient transfer capabilities requires a trade-off between simplicity of rules and transmission network utilization.
    b. Congestion management and electricity market coupling principles.
    c. Coupling between different markets (gas and electricity)

The JWG C2/C5-05 addresses this topic. Interfaces between the different market actors have been a key issue. A group within C5.7 addresses this.

2. Harmonization of market designs (market clearing principles, time horizons, gate closure)

The JWG C2/C5-05 addresses this topic.

3. Market designs to:
    a. Facilitate end-user participation
    b. To account for the new active distribution systems

    The C5 WG addressing this topic is the C5.9 “Retail Market designs – Enhanced Customer Competition”.

4. Flexible market designs for large-scale integration of intermittent generation. (Coupling: Day-ahead, intra-day and balancing).
    a. How to design markets with different kind of generation source characteristics.
    b. Firmness of generation
    c. Ability to provide system services
    d. More dynamic world in terms of planning and operation

The C5 WG addressing this is the C5.11 “Market designs for large scale integration…”. The disbanded group C5.6 “Security of supply..” also touched upon this.

5. Regulation issues will be important in a future ”Smartgrid” concept:
    a. Smart metering
    b. Privacy of data. Collection of much data can make profiling possible.
    c. Forced or voluntary participation. Should it be an offer to the customer or a centrally controlled action to balance the system
    d. Which kind of controls can be enforced

    There is currently no activity on this in C5 but a proposal will be made.

6. Incentives to investment in generation and transmission.

The C5.10 “ Establishment of Effective and Sustainable Regulatory Incentives…” deals with this. The C5.03 “Economics of T&G assets in a deregulated environment” has also funding of investments as topic. A group within C5.7 addresses this.

C6. DISTRIBUTION SYSTEMS AND DISPERSED GENERATION

Nikos Hatziargyriou

The key issues of the future networks are completely aligned to the main technical directions defined by the SCC6, namely:

1. Connection and the integration of DER, including small size generators, storage and relevant power electronic devices

These are the basic components that characterize the future distribution networks and the way they are connected in the system (“fit and forget” vs. “active involvement in management and control” is key to their formulation. SCC6 has dealt with several issues in this area within the TF C6.04.01 “Connection Criteria at the Distribution Network for Distributed Generation”, TF C6.04.02 “Computational Tools and Techniques for Analysis, Design and Validation of Distributed Generation Systems”, and the WG C6.08 “Grid Integration of Wind Generation”, already completed, , WG C6.15 “Electric Energy Storage Systems” near completion and JWG C1-C2-C6.18 “Coping with limits for very high penetrations of renewable energy” starting. A new relevant activity under TC approval is a new WG on “Electric Vehicles Connection to the Grid”.

2. Application of the DER concept as a part of the medium-long term evolution of distribution systems (Microgrids and Active Distribution Networks)

The networks of the future require among other development novel distribution network architectures in order to be operated as active distribution networks. Two innovative structures proposed are the Microgrids and the Virtual Power Plants. The way these approaches are integrated in the operation and also medium-long term planning procedures is another key issue.

Relevant activities have been performed within WG C6.10 “Technical and Commercial standardisation of DER/Microgrids components” completed, WG C6.05 “Technical and Economic Impact of DG on Transmission and Generation Systems” at its final stage and WG C6.11 “Development and operation of active distribution networks” in progress. A new WG on 'Planning and optimization methods for active distribution systems” is under TC approval.

3. Demand management and Active Customer Integration

The new role of the small producer/consumer “prosumer” is another key issue in the future network development. Relevant activities have been performed within WG C6.09 “Demand Side Response” currently at final stage, while a new work on “smart metering” is being submitted to the TC for approval.

4. Rural electrification

Rural electrification, although not directly relevant to the networks of the future, provides interesting insights on how the new systems should evolve in areas where networks are not yet fully developed and pose the basic question, if the same route of centralized systems similar to the developed countries should be followed or a more decentralized approach should prove more efficient and cost effective. In SCC6 WG C6.16 “Technologies for rural electrification” is currently in progress.

D1. MATERIALS AND EMERGING TEST TECHNIQUES

Josef Kindersberger

Key issues:

- High performance materials and new materials for severe operating conditions
- Materials for HVDC
- Eco-friendly materials
- Superconducting materials

- Advanced materials for storage
- UHV Test techniques
- Tools for monitoring in smart grids

Regarding current work programme, the following groups might be considered to be directly related to key issues of the future network theme:

- WG D1.12 – Material properties for HVDC Applications
- WG D1.23 – Diagnostics and accelerated life endurance testing of polymeric materials for HVDC application
- JWG A2/D1.41 – HVDC transformer polarity reversal: Role of oil conductivity
- WG D1.40 – Functional Nanomaterials for the Electrical Power Industry
- WG D1.38 – Emerging test techniques common to High Temperature Superconducting power applications
- WG D1.36 – Special Requirements for dielectric testing of UHV equipment
- WG D1.39 – Methods for diagnostic/failure data collection and analysis

Future WG (under preparation) related to key issues of the future network theme:

- Insulation performance of eco-friendly gases

D2. INFORMATION SYSTEMS AND TELECOMMUNICATION

Georges de Montravel

The Telecom point of view and issues of concern are:

- Telecom service delivery and technology evolution up to 2020 is uncertain (10 years is a lifetime in telecom technology).
- Time to specify, standardize and implement for new power applications and the evolution process of the legacy systems may be extremely long (10 years is short in Power System deployments).
- Information system issues are numerous and should be identified by the concerned SCs. Communication is only the enabler and will follow these information system requirements. Communication technology is probably <u>the most mature component</u> of the whole system.
- Specification of communication requirements is an essential task to be performed by SCD2 in conjunction with the other SCs
- Cost issues and Return-on-Investment for the telecom infrastructure and services may be prohibitive for some applications. The balance between Cost and “Security / Availability” is a sensitive issue.
- Highly critical information exchange may need to be increased by orders of magnitude with new issues of Reliability and Security
- Cyber-security issues and Access Control become even more critical considering the close interactions across the network.
- Disaster Recovery and Restoration Plans – Adequate communication resilience and specific measures need to be taken to mitigate risks of power blackout and allow communication service continuity to allow the <u>recovery of the power system after any such blackouts.</u>

- Information exchange inside the LV Microgrid (Producer/Load) and between the microgrid and the higher levels, referred to as Active Network Control is a particularly bandwidth consuming concept.
- Communications for HVDC and new power electronic subsystems and their associated Wide Area Control needs to be investigated in terms of coverage and communication requirements, considering the large usage of these techniques in the Future Network.

SC contribution:

➔ Present WGs have a scope which covers present issues but solutions will not be implemented completely before a 10-12 year time scale. This time scale takes us to 2020 !

➔ The perimeter of new applications for the "Network of the Future" is covered by the present WGs D2.28, D2.29 and JWGB5D2.30 as far as the required communication services are concerned and by WGD2.26 for Service Delivery and Management issues:
  - WG D2.26: Telecom service delivery model, Architecture, Management and support in the Electric Power Utility
  - WG D2.28: Communication architecture for IP based substation applications
  - WG D2.29: Communication access to electrical energy consumers and producers
  - JWG B5/D2.30: Communication for the HV substation & wide area protection applications
  - SC D2 can produce a document based on the work of the different WGs, describing the communication implications for the Network of the Future

Appendix III. CIGRE's WORK RECENTLY COMPLETED OR IN PROGRESS

STUDY COMMITTEE B1 – Insulated Cables

TECHNICAL ISSUES	SC KCs	Relevant WGs and TFs	Relevance	Status
TI3.Massive integration of HVDC and power electronics at all voltage levels	B1a, b B1.d-f	WG B1.32 Testing extruded DC cables up to 500 kV	high	Finish 2011
TI9. Increase of right of way capacity and use of overhead, underground and subsea infrastructure	See also above B1.c	WG B1.11 Upgrading and uprating of existing cable systems WG B1.35 Cable Rating WG B1.27 Test Recommendations on XLPE AC Submarine Cables from 170 kV to 500 kV	High High High	Close to publication To be launched Finish 2011
TI10. Need for stakeholders awareness and engagement	B1.f	WG B1.36 likely to be launched 2010, related to LCA and Environmental Impact of Cable Systems WG B1.23 Impact of EMF on current ratings and cable systems	High Medium	Planned Finish 2010

STUDY COMMITTEE B2 – OVERHEAD LINES

TECHNICAL ISSUES	SC KCs	Relevant WGs and TFs	Relevance	Status
TI9. Increase of right of way capacity and use of overhead, underground and subsea infrastructure	**B2a**	JWGB2/B4.17 : IMPACTS OF HVDC LINES ON ECONOMICS OF HVDC PROJECTS WGB2.26 “A Guide to Evaluating and Accepting New Types of Overhead Conductor including those running at high temperature” JWGB2/C1.19 “INCREASING CAPACITY of OVERHEAD LINES-NEEDS AND SOLUTIONS WGB2.36 “Guide for Application of Direct real time monitoring systems on Overhead Transmission lines”. WGB2.38 : Evaluation of High Surge Impedance Load solutions for increased natural capacity of OHL WGB2.41 “Guide to the conversion of existing AC lines to DC operation” WGB2.42 “Guide to Operation of Conventional Conductor Systems above 100oC” WGB2.43 “Guide for Thermal Rating Calculations for Overhead Lines with high temperatures and real-time weather & load data “		August 2009 August 2010. June 2010

	B2.b	WGB2.28 : Meteorological data for assessing climatic loads. Update of IECTR 61774 WGB2.29 : Anti- and de-icing systems for HV and UHV overhead lines WGB2.22 : Mechanical security of overhead lines with effective failure containment measures : design loading cases and strategies for effective anti-cascading supports WGB2.23 : Geotechnical and structural design of the foundations of HV & UHV Lines, application to the updating to the refurbishment and upgrading guide WGB2.24 : Qualification of HV & UHV overhead line supports under static and dynamic loads WGB2.35 : Validation of Design guidelines implemented for High Intensity Wind JWGB2-B3.27 : Live line maintenance : a management perspective WGB2.40 : Calculations of the electrical distances between live parts and obstacles for OHL WGB2.34 : The Impact of Line Configurations on electric and magnetic fields, radio interference and audible noise for 800 and 1100 kV OHL		

STUDY COMMITTEE B3 – SUBSTATIONS

TECHNICAL ISSUES	Key Challenges	Relevant WGs and TFs	Relevance	Status
TI8. New tools for system technical performance	Condition Monitoring of Substations	B3.12: Obtaining Value from Substation Condition Monitoring		**2010**
	SF6 Tightness of HV Equipment	B3.18: SF6 Tightness Guide		**2010**
	Life Cycle Assessment	B3.17: Residual Life Concepts Applied to HV GIS		**2010**
	Performance of primary /secondary interfaces	B3.10: Primary /Secondary system interface modelling for total asset performance optimization		**2010**
TI9. Increase of right of way capacity and use of overhead, underground and subsea infrastructure	AIS,GIS, MTS Condition Assessment	B3.25: SF6 Analysis for AIS,GIS, MTS Condition Assessment		**2012**

	Better use of existing substations	B3.23: Guidelines for upgrading and uprating of Substations		**2012**
TI10. Need for stakeholders awareness and engagement	Environmental aspects of substation	B3.31 Substation in Severe Climate Condition		**2012**

STUDY COMMITTEE B5 – PROTECTION AND AUTOMATION

TECHNICAL ISSUES	Key Challenges	Relevant WGs and TFs	Relevance	Status
TI6. New concepts for protection	New Wide area Protection concepts for Transmission network	B5-14: Wide Area Protection and Control Technologies . B5/D2-30: Communications for HV Substation Protection & Wide Area Protection Applications.		2011
	Impact on the protection system of new generation technologies and inadvertent Islanding detection	B5-34: Impact of renewable energy sources and Distributed Generation on SP&A.		2009

	Metering	WG B5.41 Investigation of possibilities to improve metering systems for billing purposes in substations.		2012
	Architectures of the future.	WGB5-13: Acceptable functional Integration in HV Substations WGB5-36: Application for protective schemes based on IEC 61850 WGB5-38: The impact of implementing security requirements using 61850 WGB5-32: Functional Testing of 61850 based systems		Completed in 2008 and 2009
		WGB5-24: Requirements on transient response of current and voltage acquisition chain WGB5-27: Standardized protection schemes WGB5-12: Engineering Guidelines for IEC 61850 based Systems		2012 2010
	B5c. New protection and control algorithms	B5/B4-25: Impact of HVDC Station on Protection of AC Systems B5-23: Short circuit protection of circuits with mixed conductor technologies in transmission networks.		2011 2011

	Data management innovative applications	B5-20 : New trends for automated fault and disturbance analysis		
		B5-31: Life time management of protection settings		2010

STUDY COMMITTEE C1 – SYSTEM DEVELOPMENT AND ECONOMICS

TECHNICAL ISSUES	Key Challenges	Relevant WGs and TFs	Relevance	Status
TI7. New concepts in planning	System development	WGC1-9. Planning issues for newly industrialised and developing countries WGC1-19 Green field network design. WGC1-15. Drivers for transmission investment decisions and the role of technical planning criteria in investment WGC1-21. Advanced components and technologies required to assist system development and planning WGC1-22. New investment decision processes and regulatory practices to deal with changing economic drivers WGC1-23. Transmission decision points and trees. WGC1-24. New tools and methods to model and understand the uncertain nature of future power systems		

	Grid Codes	WGC1-12. Impact of transmission codes on the planning of systems		
	System Analysis	WGC1-13. System complexity and dynamic performance		
	Asset Management	WGC1-16. Transmission asset risk management WGC1-25. Asset management in a low carbon future		
	System Security	WGC1-17. Planning to manage power interruption events		
	Sustainability, Environment, Wind Integration	JWGC1/C2/C6-18 Coping with limits for very high penetrations of renewables WGC1-20 Accommodating high load growth and urban development in future plans and their environmental effects		

STUDY COMMITTEE C2 – SYSTEM OPERATION AND CONTROL

TECHNICAL ISSUES	**Key Challenges**	**Relevant WGs and TFs**	**Relevance**	**Status**
TI5. New concepts for system operation, control	C2.a	WG C2.13 Voltage and VAR support in system operation WG C2.22 Application of resilience engineering to safety management principles in control centres, ensuring and enhancing power system reliability JWG C1-C2-C6 Coping with limits for very high penetrations of renewables		

	C2.b	JWG C2-C5.05 Developments and changes in the business of system operators WG C2.34 Capabilities and requirements of a control centre in the 21st century, functional and human resources view		
	C2.c	WG C2.32 Emergency organisation and crisis management in system operation WG C2.21 Lessons learnt from recent emergencies and black out incidents		
	C2.d	WG C2.31 Joint and coordinated development of operators in Control centres from different companies and Nationalities WG C2.33 Control centre operator requirements, selection, training and certification		

STUDY COMMITTEE C3 – SYSTEM ENVIRONMENTAL PERFORMANCE

TECHNICAL ISSUES	Key Challenges	Relevant WGs and TFs	Relevance	Status
TI10. Need for stakeholders awareness and engagement	C3.a	WG C3.12 "Greenhouse gases emission inventory and reporting methodologies" WG C3.05 "Environmental impact of dispersed generation"	High	In progress
	C3.b	WG C3.06 "Strategic Environmental Assessment"		
	C3.c	JWG B1/B2/C3.13 "Overhead and underground T&D lines in urban and rural environment" WG C3.02 "Sustainable development performance indicators for T&D Utilities" WG C3.03 "Utilities practices toward Sustainable Development" WG C3.10 "Sustainable development performance indicators for Power Generation Utilities"		
	C3.d	WG C3.04 "Stakeholders engagement and Communication"		

TI9. Increase of right of way capacity and use of overhead, underground and subsea infrastructure	C3.b, C3.c	WG C3.01 "EMF and Health" WG C3.09 "Corridor management"		ongoing ongoing

STUDY COMMITTEE C4 – SYSTEM TECHNICAL PERFORMANCE

TECHNICAL ISSUES	Key Challenges	Relevant WGs and TFs	Relevance	Status
TI1. Active Distribution Networks resulting in bidirectional flows within distribution level and to the upstream network	C4.e	C4.503 " Numerical techniques for the computation of power systems, from steady-state to switching transients." To be initiated soon.		To start
TI3.Massive integration of HVDC and power electronics at all voltage levels	C4.b	WG C4.502 (long AC cables) JWG C4/C1/B4.406 (on HVDC).		

	C4.f	JWG C4.107 Economic framework for Voltage Quality (at least in part) JWG C4.109 Emission Assessment Techniques		
TI6. New concepts for protection	C4.c	new WG on "Intentional Islanding" to be proposed by SC C4, hopefully jointly with C6 and/or C2?		
TI7. New concepts in planning	C4.d	WG C4.601 "Moving towards probabilistic and risk-based planning and operational tools"		
TI8. New tools for system technical performance assessment	C.4.a C4.e	TF C4.02.25 "Combined-cycle power plants" (SC C4 TF did this) WG C4.601 "Wind Generation"; presently IEC TC88 WG27 is carrying on this work Proposed WG C4.503 and - in part - active SC C4 WG C4.501 "Better numerical technique and bridging the gap between 3-phase and positive sequence modeling" WG C4.603 "Better tools and techniques for power balancing and reserve requirement evaluation" WG C4.601 "Moving towards probabilistic and risk-based planning and operational tools" WG C4.605 "Reviewing recent improvements in load modeling techniques"	High	completed

TI9. Increase of right of way capacity and use of overhead, underground and subsea infrastructure	C4.b	SC C4 WG C4.502 (long AC cables) JWG C4/C1/B4.406 (on HVDC).		

STUDY COMMITTEE C6 – DISPERSED GENERATION AND DISTRIBUTION SYSTEMS

TECHNICAL ISSUES	SC Key Challenges	Relevant WGs and TFs	Relevance	Status
TI1. Active Distribution Networks resulting in bidirectional flows within distribution level and to the upstream network	C6.a	TF C6.04.01 "Connection Criteria at the Distribution Network for Distributed Generation"	High	Completed
		TF C6.04.02 "Computational Tools and Techniques for Analysis, Design and Validation of Distributed Generation Systems",	Medium	Completed
		WG C6.15 "Electric Energy Storage Systems"	High	Final stage
		JWG C1-C2-C6.18 "Coping with limits for very high penetrations of renewable energy"	Medium	In progress
		WG C6.22 "Microgrids Roadmap".	High	Starting
		WG C6.20 "Electric Vehicles Connection to the Grid"	High	Starting

	C6.b	WG C6.10 “Technical and Commercial standardisation of DER/Microgrids components” WG C6.11 “Development and operation of active distribution networks”. WG C6.19 'Planning and optimization methods for active distribution systems”	Medium High High	complet ed, in progress Starting
	C6.c	WG C6.09 “Demand Side Response” currently at final stage, WG C6.21 “Smart Metering – state of the art, regulation, standards and future requirements”		
TI2.Massive need for exchange of information	**C6.a**	WG C6.20 “Electric Vehicles Connection to the Grid”.		
	C6.c	WG C6.09 “Demand Side Response” currently at final stage, WG C6.21 “Smart Metering – state of the art, regulation, standards and future requirements”		Final stage Starting
TI4. Massive installation of storage	C6.a	WG C6.15 “Electric Energy Storage Systems” near completion WG C6.20 “Electric Vehicles Connection to the Grid”		
TI5. New concepts for system operation, control	C6.b	WG C6.11 “Development and operation of active distribution networks” in progress.		near completi on
	C6.c	WG C6.09 “Demand Side Response” currently at final stage, WG C6.21 Smart Metering – state of		

		the art, regulation, standards and future requirements		
TI7. New concepts in planning	C6a C6b	WG C6.05 "Technical and Economic Impact of DG on Transmission and Generation Systems" at its final stage		

STUDY COMMITTEE D2

TECHNICAL ISSUES	**Key Challenges**	**Relevant WGs and TFs**	**Relevance**	**Status**
TI2. Massive need for exchange of information	• Required communication services	WG D2.28: Communication architecture for IP based substation applications WG D2.29: Communication access to electrical energy consumers and producers JWG B5/D2.30: Communication for the HV substation&wide area protection applications		
	Service Delivery and Management	WG D2.26: Telecom service delivery model, Architecture, Management and support in the Electric Power Utility		

Appendix IV. CIGRE's WORK RECENTLY COMPLETED OR IN PROGRESS GROUPED ACCORDING TO THE KEY TIs.

KEY TECHNICAL ISSUES	CIGRE SCs	WGs and TFs
TI1. Active Distribution Networks resulting in bidirectional flows within distribution level and to the upstream network	**C6**	**TF C6.04.01, TF C6.04.02, WG C6.15, JWG C1-C2-C6.18 WG C6.22, WG C6.20, WG C6.10, WG C6.11, WG C6.19, WG C6.09, WG C6.21**
	B5	WG B5.34
	C4	WG C4.503
	C3	____
TI2. Massive need for exchange of information	B5	WGB5.20, WG B5.41
	C6	WG C6.20, WG C6.09, WG C6.21
	D2	**WG D2.26, WG D2.28, WG D2.29, JWG B5/D2.30**
	C2	______
TI3. Massive integration of HVDC and power electronics at all voltage levels	B1	WG B1.32
	B4	**JWG C4/C1/B4.406**
	C1	JWG C4/C1/B4.406
	C4	WG C4.502, JWG C4/C1/B4.406 (at least in part), JWG C4.107, JWG C4.109
	B2	______
	C6	______
TI4. Massive installation of	**C6**	**WG C6.15, WG C6.20**

storage	C4	______
	C1	______
	C2	______
	D1	______
TI5. New concepts for system operation, control	**C2**	**JWG C1-C2-C6, WG C2.13, WG C2.22, JWG C2-C5.05, WG C2.34, WG C2.32, WG C2.21, WG C2.31, WG C2.33**
	C4	WG C4.603, WG C4.601
	C6	WG C6.09, WG C6.11, WG C6.21, JWG C1-C2-C6
	C5	JWG C2-C5.05
	C1	JWG C1-C2-C6
	B5	______
TI6. New concepts for protection	**B5**	**WG B5.14, WG B5.34, WG B5.13, WG B5.36, WG B5.38, WG B5.32, WG B5.24, WG B5.27, WG B5.12, JWG B5/B4-25, WG B5.23, WG B5.20, WG B5.31**
	B4	JWG B5/B4-25
	C4	______
	C6	

TI7. New concepts in planning	**C1**	**WGC1.9, WGC1.19, WGC1.15, WGC1.21, WGC1.22, WGC1.23, WGC1.24, WGC1.12, WGC1.13, WGC1.16, WGC1.25, WGC1.17, WGC1.20 JWGC1/C2/C6-18**
	C4	WG C4.601
	C6	WG C6.05
	C3	______
	B2	______
	B5	______
	C5	______
TI8. New tools for system technical performance assessment	**C4**	**TF C4.02.25, WG C4.601 (presently IEC TC88 WG27 is carrying on), WG C4.503, WG C4.501, WG C4.603, WG C4.601, WG C4.605**
	C1	WGC1.13
	C6	______
	B3	WG B3.10, WG B3.12, WG B3.17, WG B3.18
TI9. Increase of right of way capacity and use of overhead, underground and subsea infrastructure	**B1**	**WG B1.11, WG B1.35, WG B1.27**
	B2	**JWGB2/B4.17, WGB2.26, JWGB2/C1.19, WGB2.36, WGB2.38, WGB2.41, WGB2.42, WGB2.43, WGB2.28, WGB2.29, WGB2.22, WGB2.23, WGB2.24, WGB2.35, WGB2-B3.27, WGB2.40, WGB2.34**
	B3	WG B3.23, WG B3.25

	B4	JWG C4/C1/B4.406
	C3	WG C3.01, WG C3.09
	C4	WG C4.502, JWG C4/C1/B4.406
	C1	JWG C4/C1/B4.406
TI10. Need for stakeholders awareness and engagement	B1	WG B1.36, WG B1.23, JWG B1/B2/C3.13
	B2	WGB2.34, JWG B1/B2/C3.13
	B3	WGB3.31
	C3	**WGC3.12, WGC3.05, WGC3.06, JWG B1/B2/C3.13, WGC3.02, WGC3.03, WGC3.10, WGC3.04**
	C5	______
	C6	______