ELECTRICITY SUPPLY SYSTEMS OF THE FUTURE

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1 Active distribution networks resulting in bidirectional power and data flows within distribution level and to the upstream network

- Distribution level needs more 'smartness' - massive penetration of smaller units (generation and intelligent loads) imposes the need for their control and coordination.
- The coordination of a large number of small resources imposes a technical challenge that requires application of decentralized, intelligent control techniques.
- Massive implementation of smart metering and demand-side response - metering as information collectors for distribution networks automation, home energy management and electric vehicles.
- Potential evolution of market and regulatory constructs to manage efficiency, equity and cost recovery
- Novel distribution network architectures that include microgrids.
- New market oriented control of distributed generators, such as in virtual power plants, interact with distribution grid operation.

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

- New measured parameters, architectures of information, communication technologies and algorithms for system operation, protection, maintenance, life management, etc.
- Identification of the data to be exchanged and its requirements (volume, frequency, availability, security etc ...); interface with standardization of use cases in IEC.
- Disaster recovery and restoration plans.
- Cyber security and access control.

3 The growth in the application of DC and power electronics (PE) at all voltage levels and its impact on power quality, system control, and system security, and standardisation

- Study of ac network performance with appropriate models of high-voltage DC (HVDC) and PE systems.
- Harmonic distortion of HVDC and PE to be managed with AC and DC harmonic filtering.
- DC and PE-based generation has significantly different dynamic response and performance than conventional generation and ac lines during faults in the ac network; in many cases, if applied with judicious and properly coordinate design and controls, these technologies can provide great benefits and performance enhancements to overall system reliability.
- HVDC Grids are a new and different application of HVDC and require standards and grid codes to enable the grid to be built gradually, and with the flexibility of utilizing converters and lines from different manufacturers, similar for AC applications.
- Looking at the increased use of DC at end-use premises (i.e. in home and commercial buildings etc.).

4 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

- Construction: advanced materials, reduction of installation and construction costs, reduction of environmental impact, improvement of efficiency of charge/discharge cycles, decrease weight and increase of size density, development of life-time estimation models.
- Operation and network issues: impact of storage on all voltage levels, modeling for steady state and dynamic simulations, management of charging-discharging, sizing of storage devices, co-operation with RES for hybrid systems, management in island systems, ability to reduce peaks, co-operation with DSM.

5 New concepts for system operation and control and market /regulatory design to take account of active customer interactions and different generation types

- Operational challenges by combination of stochastic generation and modified loads due to DSM and energy storage: power balancing, congestion management, evolution of market design and regulatory mechanisms to promote consumer involvement, active and reactive power reserves, risk management.
- Evolution of power system control at continental, country, regional and local level: awareness of overall system status, boundaries between transmission system operator (TSO) and distribution system operator (DSO) systems, information exchange and operational interfaces between TSO and other actors, i.e. production and load centres.
- Increased level of automation - New software tools to quickly determine the status of the system over wide areas and to alarm system operators, automated configuration and electrical parameters adjustment, automated service restoration and adapted disaster recovery.
- Ensure competencies and adapt training of system operators.

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

- New wide area protection systems (WAPS) for transmission, to overcome limitations of special protection schemes in terms of reliability, flexibility and maintenance cost.
- Impact on the protection system of new generation technologies (decreasing short circuit power and causing flows reversal).
- Capabilities for Fault Ride Through (FRT) - coordination between protection and new generators capabilities.
- Inadvertent islanding detection and intentional islanded operation.
- New protection and automation functions for distribution networks using powerful communication networks.

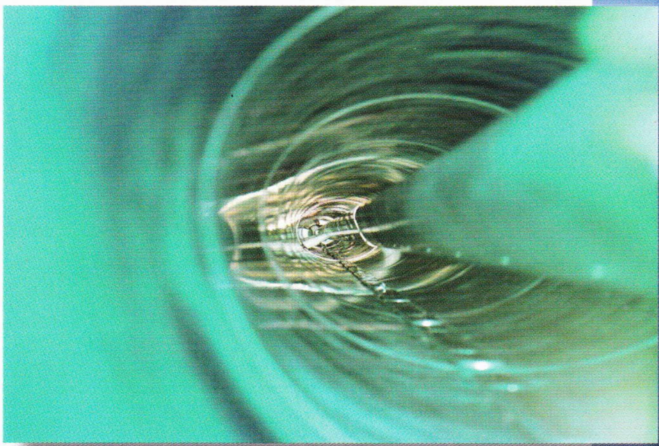
7 New concepts in planning to take into account increasing environmental constraints and new technology solutions for active and reactive power flow control

- Changing role of the power system and changing nature of supply and demand impact the ability to plan to minimize asset stranding, while maintaining reliability and quality. Uncertainties are very high and taking them into account in the planning environment is a major need and challenge. One approach is risk-based planning.
- Given demand response and distributed generation, and given the much higher aggregate length of distribution lines compared to transmission lines, the interaction of transmission and distribution expansion investment needs to be addressed.
- Changes in technology (need to understand cost, capabilities and lead times of each solution to enable comparison between options).
- Changing economic drivers (impact availability of funding and investment risks).
- Changing market and regulatory environment (impacts on level of central planning vs. market solutions).

8 New tools for system technical performance assessment, because of new customer, generator and network characteristics

- Advanced numerical techniques and numerical methods for the solution of dynamic problems in integrated timeframes and multiphase power-flow problems.
- Bridging the gap between 3-phase and positive sequence modeling.
- Advanced tools and techniques for power balancing and reserve requirement evaluation.
- Planning and operational tools allowing for probabilistic and risk-based planning.
- Advanced load modeling techniques.

- Multi-agent techniques.
- Modeling of active and adaptive control strategies (centralized control systems, grid-friendly appliances, demand side management, etc.).
- Models for new and advancing technologies
- Tools and techniques for assessing the harmonic performance of the grid in light of greater DC and PE penetration.



9 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

- Technologies for uprating existing lines: replace old conductors by high temperature conductors, re-tension existing conductors, upgrade voltage level, use real time monitoring.
- Convert AC to DC lines, consider hybrid lines, compact lines and aesthetic supports.
- Follow the development of new insulated AC or DC submarine and underground cables for high voltage applications, such as offshore wind farms.
- Check the stability of the network taking into account these new technologies.
- Check the ability of all components to withstand transients and overvoltages.
- Check the ability of the network to be very flexibly managed and developed, as issues will become more and more complex in the future.

10 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

In the planning phase: to demonstrate the benefits which will result,

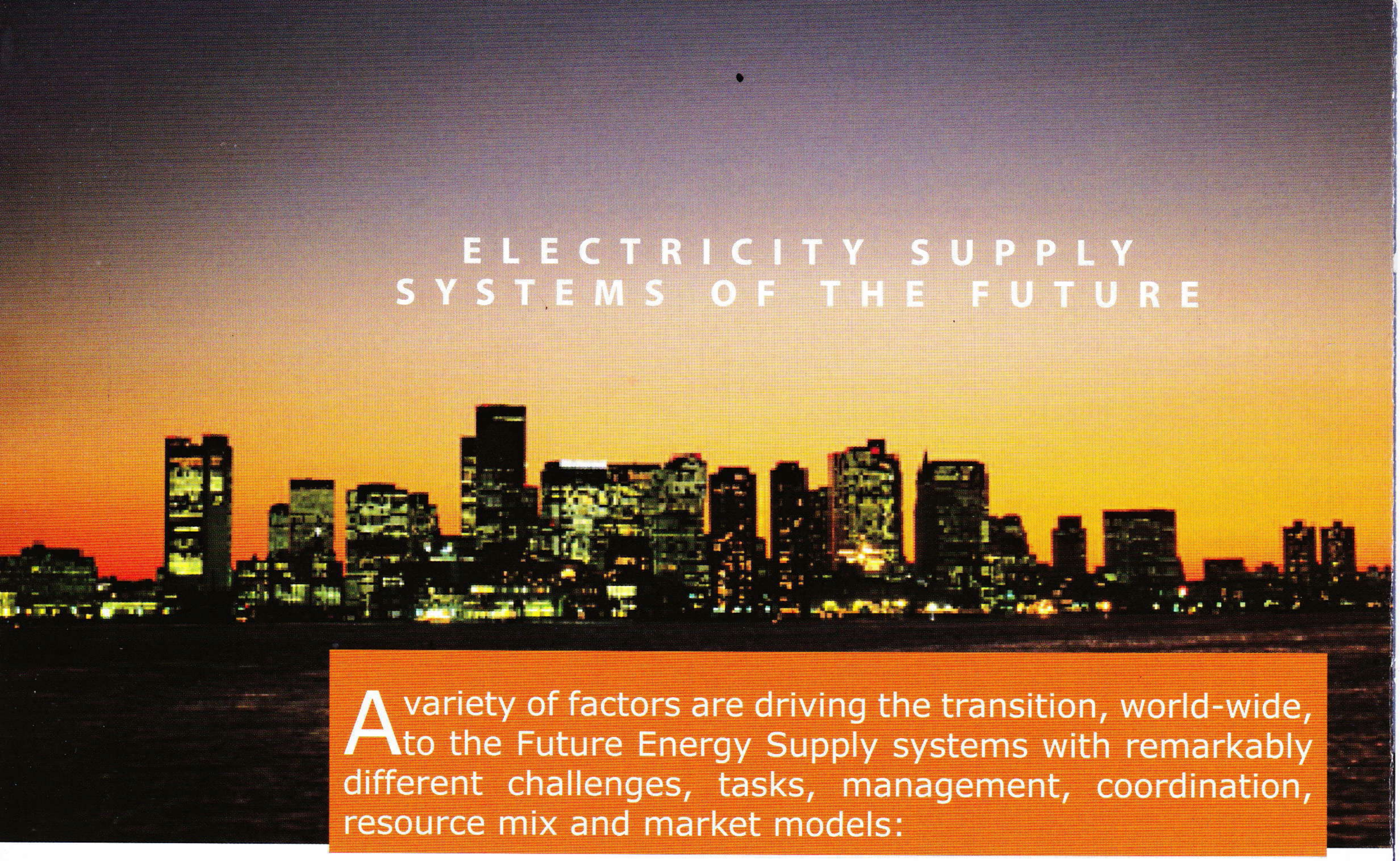
- to guarantee that sustainable development principles and issues are being incorporated,
- to take into account public views, consultation and needs already in the system planning and design and options (e.g. the choice of alternatives).

In the construction and operation phases:

- to demonstrate the compliance with environmental standards,
- to obtain support for the necessary actions (e.g. maintenance).

These ten technical issues, already cut across the 16 CIGRE Study Committees show how the CIGRE work supports development of the Future Energy Supply Systems. Through the products CIGRE is creating, and will create in future years, governments, regulating authorities, system planners and operators, vendors, academics and consultants will be equipped with valuable published resources on these very diverse technical aspects of the future system. We hope and anticipate it will guide their decisions towards optimal reliability, security, economy, sustainability and customer-friendliness of the future systems.

[[1] **CIGRE White Paper "Network of the Future", on behalf of the TC AG (advisory group) -** 'Electricity Supply Systems of the future', (www.e-cigre.org reference: ELT_256_12), AG Convenor Nikos Hatziargyriou , ELECTRA, N° 256 - June 2011, pp. **42-49**



ELECTRICITY SUPPLY SYSTEMS OF THE FUTURE

A variety of factors are driving the transition, world-wide, to the Future Energy Supply systems with remarkably different challenges, tasks, management, coordination, resource mix and market models:

- International and national policies that encourage lower carbon generation, the use of renewable energy sources (RES) and more efficient energy use.
- Integration of RES and distributed generation (DG) into the grids.
- Increased customer participation and thereby new needs especially for the distributions grids.
- Progress in technology including Information and Communication Technology (ICT).
- Need for investment in end-of-life grid renewal (ageing assets).
- Necessity to handle grid congestion (with market based methods).
- Evolution of market design and regulatory mechanisms to manage the transformation in an equitable, cost-effective manner.
- 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 and large centralized renewable generation resources including offshore, as well as to provide more interconnections between the various countries and energy markets.

- The emergence of clusters of small, largely self-contained distribution networks, which 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.

The most likely shape of the Future Energy Supply Systems will include a mixture of the above two models, since additional bulk connections and active distribution networks are needed in order to reach the ambitious environmental, economic and security-reliability targets sought for.

The evolution of today's power system towards the models described above is based on the following ten technical issues and the associated technical challenges. This summary paper [1] provides CIGRE's views on the know-how needed to manage the transition towards the Future Energy Supply Systems. Different systems in the world may need to put more emphasis on some points and less on others, but we see relevance to all parts of the world from these technical issues.