

# Tackling emerging and future issues in Power system development

by COLIN RAY – Chairman of SC C1

## Preamble

Study Committee C1 was created following the restructuring of CIGRE in 2002, some of its work follows on from the former SC 37 and its mandate is focused on the issues surrounding the development and economics of power systems. This has enabled it to concentrate on the key strategic decisions faced by transmission and generation companies at the development phase, decisions which are fundamental to the companies in setting their future operating costs (capital expenditure, maintenance costs) and which may impact on overall system security/reliability. In establishing study activities the SC members must consider the technical aspects of power systems; the requirements and expectations of customers that use the power systems; new technologies which lower cost and/or enhance system capacity or service quality; total asset lifetime issues and the overall business impact.

As such the members of C1 must have an appreciation of all parts of the industry and business processes to ensure their work encompasses the issues facing countries where markets define the structure of the industry as well as those countries where a vertical structure remains appropriate.

The scope of C1 can be categorised into three main themes: Asset Management, System Development, Business Environment. Advisory Groups for each of these subject areas identify the target groups for these subjects and the corresponding working group activities. This report outlines the activities completed and in progress in these areas. The work of the Advisory Groups is to anticipate emerging issues within the industry and recommend working group activities to examine these issues. Where possible the target group will be encouraged to become engaged in the work through its CIGRE member. In this way the working group reports will have increased value and relevance within the industry. Many

of the issues of interest within the industry will span more than one SC. This will require SC's working in partnership to an agreed scope of work and timetable.

Younger members are encouraged to get engaged in the activities of C1 to help maintain interest in becoming regular/observer members in the future. Succession of Regular members is important to maintain the continuity of work.

The former SC 37 pioneered tutorials with the first in 1999 on the restructuring taking place in the industry, the sharing of knowledge in this way continues in SC C1.

## Asset Management

Work on asset management began some years ago when it was clear that in many countries the assets in the electricity industry were being both worked harder, for longer and many would need replacing at the same time. A WG was established to examine the age of equipment in different systems and quantify system problems due to ageing as well as the particular equipment types subject to deterioration due to ageing or technical obsolescence. The work identified the range of options available to deal with ageing equipment in the system and guidelines for selecting the appropriate option. This report TB 176 presented the statistics showing that many companies and countries have significant blocks of network assets that will approach the end of their estimated lives in the coming years. The work showed that the problem of ageing assets facing many companies in the coming years requires the selection of one or more overall strategies rather than addressing the issue on a case by case basis. A set of alternative generic strategies was presented together with a process for the selection of an appropriate strategy and identification of the factors that may dictate the eventual choice of strategy. ●●●



The work on asset management continued in a joint WG 23.18 involving the former Study Committees 23, 37, 12, 13 and 22, as well as other experts in the field of asset management. The work addressed several issues including, the definition and role of asset management, core skills required, organizational issues, the relationship with service providers, skills retention and skills development within asset management and service providers. The WG also looked at the risk of a loss of effective "stewardship" through maintaining too stringent a separation between asset management and service providers. The work on the implementation of asset management in electric power transmission is documented in report 23-303 presented at the CIGRE 2002 session.

Under the new organisation of CIGRE, Study Committee C1 took over the co-ordination of topics related to asset management and a new WG C1.1 was established to build on the work already done and focused on decision processes to manage the impact of ageing assets in a transmission network. WG C1.1 reported at the CIGRE SC C1 Session 2004, Report C1-106 in TB 309: "Asset Management of Transmission Systems and associated CIGRÉ Activities" and in ELECTRA article 229-5. Both CIGRÉ Reports (23-303, 2002, and C1-106, 2004) are included in the TB which describe the asset management processes in relation to the decision making framework, based on key business drivers together with a survey of the CIGRÉ Technical Brochures of other Study Committees.

The work on asset management continues in two current WG's.

The first WG C1.11 is examining performance benchmarking. This is an area of growing importance due to the fact that transmission businesses are typically regulated and the regulating authority has interest in using benchmarking for the purpose of monitoring utility performance and costs. In addition, the benchmarks help companies identify utility best practices, for business improvement. The work will establish from a corporate level perspective the metrics currently in place and identify those which are important to participating utilities across the world. Based on this result, interested Committees can follow up on specific benchmarking interests. It will also establish an information source related to metrics used for measuring system level reliability and other performance and cost metrics and relate these to applicable system characteristics. This work will be published in 2008.

The second WG C1.16 is to provide an insight into the application of asset management in electricity transmission companies, the risks due to an ageing asset base and how these are managed. Many transmission networks contain assets that are approaching their design life. Some groups of assets may have increasing failure rates due to ageing and may show an impact on supply reliability. Determination of failure rates, condition monitoring of assets and forecasting end-of-life have become key activities for network companies to enable their asset managers to make timely decisions on measures to be taken such as maintenance, replacement, refurbishment etc. Expenditure in a network through either CAPEX or OPEX to maintain or improve reliability performance will be limited to some budgeted/regulated level and it is paramount for a network company to target this investment to achieve maximum benefit. This work will be reported in 2009.

## System Development

### *Network planning*

Development strategies and subsequent investment plans will commit companies to assets for many years and such plans should be set in the context of a long term view of the industry taking into account Government energy policy, market conditions, changes in customer requirements, changes in transmission system utilization and the reliability and cost implications of incorporating new technologies. The study committee monitors these areas to spot emerging issues that will affect future system development. The aim is to focus the work on those topical subjects that will be of greatest value to the industry. The industry continues to evolve apace and the output of WG's has to keep ahead and anticipate future issues to ensure the work is of value.

Changing conditions due to liberalisation and environmental considerations have introduced uncertainties in predicting future system conditions and the timescales to complete investments. Network planning has to take account of a number of uncertainties and a WG examined its future role to determine whether such planning should be relaxed, tightened or remain unchanged. The WG analysed the approach being used in many countries to plan in a deregulated environment. One of the main issues found was the uncertainty surrounding generation involving the commissioning of new and decommissioning of old plant. The work was reported in ELECTRA article 206-6 and TB-220. ●●●



The issues raised by this earlier work are in the forefront of concerns that face network planners. There is therefore a need to explore some of the key issues further and a current WG C1.2 has examined this area, its work is complete and will be published in 2007. The areas of particular interest are the question of what is an acceptable level of reliability, how was this level determined and how is this reliability measured and assessed. The issue is further complicated by pressure to increase the utilisation of network assets and, at the same time, tailor the performance of the system to satisfy changing customer needs.

It is now clear that in many parts of the world, generation quantity and characteristics are now largely a matter determined outside the transmission planning arena. Generation at any network location can therefore be uncertain. At the same time interconnector flows are difficult to forecast as they are based upon market conditions at each end. This can give rise to significant network risks or constraints. System planners are also charged with accommodating large volumes of non-firm generation at various network levels. A WG C1.3 has been examining these areas in particular the critical factors and approach in establishing the economically efficient levels of non-firm generation in various planning timescales. The first results from this WG were given in ELECTRA article 225-5 and in TB-293. A further report which examines the investment in new plant and the interaction between neighbouring markets will be published soon.

This issue of interconnector flows was the subject of a WG 37/39-25 that reported in 2002. It was recognised then that international interconnection had occurred to different stages throughout the world and for different reasons. This WG reviewed the business arguments used in justifying interconnection projects and the different approaches adopted. The challenge was to find a way to gather and share experiences, establish a typology of problems encountered and explore solutions with a common benefit to all members, taking into account these differences. The WG established the technical choices made by different countries, estimation of the development opportunities for electricity exchanges between these countries for the next 20/30 years, and estimation of the network developments required to meet these anticipated demands. Reference on this work can be found on Session report 37-115-2000: "International interconnections of power systems. What trends for the next decade?"

The issues raised by these earlier working groups, and the results they have achieved, demonstrate the difficult challenges faced by system planners. However a great deal

of knowledge has been gained over recent years and investment strategies have evolved to recognise the growing uncertainties in markets, loads and generation. A current WG C1.7 is reviewing the methods now being used to develop system plans that balance reliability, economy and risk. This WG will publish its findings in early 2008.



A major business driver in many companies is to minimise the environmental impact of their operations and for companies managing a transmission network this means they need to maximise the capacity of existing transmission routes. This has led to greater use of FACTS type devices (SVC's/MSC's/series capacitors/phase shift transformers) to increase the utilisation of existing transmission routes. At the same time generation characteristics are changing, the generation mix is changing and more intermittent energy sources are being connected with lower inertia. As a result power systems are increasingly becoming more complex both in terms of design and operation. As the system evolves in this way this brings new challenges to manage the changing dynamic behaviour resulting from power swings, dynamic interaction between devices, less synchronized coupling etc.

A current WG C1.13 is examining the changing nature of systems and its dynamic behaviour to identify future issues that either need resolving or define limits to the degree of complexity that can be tolerated. The areas to be examined cover:

- ✓ the maximum amount of FACTS equipment that can be accepted i.e. the reactive density measured in terms of SVC/MSVC Mvar/peak MW demand or total FACTS density.
- ✓ the critical interactions between devices
- ✓ the impact wide area control systems would have on a) and b)



✓ whether there is a level of wind generation capacity and FACTS type devices above which the system becomes uncontrollable under certain conditions

This work will be published in 2009.

Power systems are planned and investments made to meet a defined level of redundancy or failure of certain systems assets (transmission, generation or demand). Even with this inherent security, failure of power systems will and do occur simply because it is impossible to completely eliminate all risk. Increasingly networks are planned to their technical limits in a move to meet the demands of electricity markets and environmental constraints. The impact of network failure may become more widespread and the need to plan and manage these events is becoming more important. When failure occurs this should take place on a controlled basis and planners will need to define suitable strategies for managing the failure path and invest to achieve this. A current WG C1.17 is examining suitable plans for the controlled management of failure due to unsecured events including restoration and which investments the planner can make to minimise the impact of power failures. The WG will identify possible technical options as well as the justification of the investments to the stakeholders. This work will be published in 2009.

Network planning brings together many different skills and within CIGRE this means working with other SC's on particular topics. SC C1 are involved with three joint WG's, B3/C1/C2.14 reviewing the circuit configuration options for substations to be reported end 2008, B2/B4/C1.17 examining the impact of HVDC lines on the economics of HVDC projects to be reported in 2008 and B2/C1.19 which brings together both planners and overhead line specialists (SC B2) so they can share common ideas on increasing the power capacity of lines taking into account all aspects i.e. economics, technical feasibility, security, legislation aspects, maintenance etc. The aim of B2/C1.19 is to identify a range of optimal solutions to increase capacity of existing networks. Designers describe the main existing solutions and their needs whilst the researchers define the prospects to uprate. This will lead to a 10 year ahead roadmap for designers, manufacturers and researchers. WG B2/C1-19 will organise a preferential subject at the 2008 SC B2 session and will report by the end of 2008.

## Newly industrialised and developing countries.

It was recognised that much of the work in C1 was focused on countries where restructuring was taking

place and it would be helpful to explore the activities in newly industrialised and developing countries. A WG examined the approach to system development applied in utilities in the ASEAN region. A workshop was held on 3<sup>rd</sup> and 4<sup>th</sup> August 2004 in Bangkok, Thailand which provided opportunities for utilities in the ASEAN region to exchange information and discuss planning issues. The work was reported in ELECTRA article 222-7 and TB-282. This proved a successful exchange of technical information and a current WG C1.9 is continuing the work focusing on African countries and utilities. A regional meeting was held with the Southern African Power Pool (SAPP) countries on 14<sup>th</sup> March 2007 in Livingstone, Zambia where a presentation and discussion took place between the country planning managers. Similar sessions are planned for the last quarter of 2007 for the remaining countries. It was found that many countries are using modern planning approaches for the basic studies. Few countries are doing advanced and special planning studies. Many of the African countries are developing rapidly and therefore information about mistakes and successes from developed countries need to be shared. An Electra article and TB will be published in 2008. Work in this area provides a benchmark of planning methods and development strategies providing a useful guide for countries in the African region.

## Network Analysis Tools

Forecasting the dynamic behaviour of power systems is currently an increasingly important issue in the development of power systems. This arises because of a number of factors such as a tendency to exploit power systems closer to their technical limits, increased uncertainty in the generation expansion, shorter construction time for new power plants, need to accurately define the Net Transfer Capacity (NTC) between interconnected systems, use of interconnections for commercial energy transactions, new devices for power transmission, such as electronically controlled phase shifting transformers, high voltage direct current (HVDC) links, or Flexible AC Transmission System (FACTS) devices.

A WG has examined the new dynamic issues that need to be considered in the planning process and the mathematical models that are currently available. The aim of the WG activity has been to provide the planner with useful information on the main dynamic phenomena to be addressed in the planning stage, the dynamic models available and what new models would be desirable. Where new models are required this was passed to study committee C4 to explore the development ●●●

of such models. The WG (C1.4) presented its work in ELECTRA article 230-4, February 2007 "Application and required developments of dynamic models to support practical planning" and TB 312, issued in February 2007.

The results from mathematical models depend on accurate data on all components of the system and network businesses have expressed concern about the lack of generator models appropriate for system simulation studies and that these are often not available in time to assess applications for access to network. This was raised as a general problem in the industry and a survey was conducted to see if the problem is widespread and whether the measures to address this problem are consistent. The results of the survey were reported in ELECTRA article 224-6, February 2006 "Results of survey of requirements for generator data and the need for confidentiality". The replies indicate that it is becoming crucial for the industry to have a source of information that defines the control and protection characteristics of new plant particularly if they are new technologies. This would allow greater confidence to be placed on the results of computer simulations. It would also provide confidence in the future performance of the system, as well as streamlining the work of utilities (and other parties) and helping them run their businesses more efficiently.

## Generation margins

One of the main concerns raised by many countries during the restructuring process was whether adequate generation margins would result. As the electric utility industry restructures, the former vertically integrated utility un-bundles into separate business units of generation, transmission and load serving entities. Genera-



tion supply becomes a competitive commodity, and consequently, questions arise as to how the adequacy of generation supply will be assured in a competitive generation model. There are those that would argue that in competitive generation markets, prices will determine the generating capacity to serve forecasted demands. Others believe that strict rules and regulatory intervention are necessary to ensure adequacy. Also of concern in this new competitive generation model is the issue of how and with what assurance will the inherent generation services, such as load following, frequency regulation, black start capability, etc., be provided. A WG (37.19) examined the generation adequacy issue and reported in ELECTRA article-213-2.

## Terminology

Different words or phrases are often used by CIGRE members to explain or define the same concept. In many cases these words or phrases are embodied within local legal or technical documents and have specific meanings for that local application. It is therefore not possible to replace these many terms with a set of universally adopted terms as the implications to change would be too great. Recognising this, the SC's 37, 38, and 39 published in July 2001 a glossary of the many different terms used within NERC, NECA and IEEE, this is in TB-198. With the continuing changes in the electricity industry it is important to keep this glossary updated with any new terms and to expand its coverage to include the terms used in other organisations. A current WG has recently updated this glossary and a new version will be issued early in 2008 in English and French.

## Business Environment

With the electricity industries in many countries in the world undergoing restructuring one concern was that this will impact the traditional approach to system planning. To ensure the system planning process adapts to the new structure it is first necessary to understand the new shape of the electricity industry. However, each country follows its own path towards the reform for historical or socio-economic reasons and a WG (37.32) explored the restructuring taking place which illustrated the approach taken by various countries in moving from a monopolistic to competitive structure.

Changes in the industry have continued and a current WG C1.8 is building on the previous work ●●●



looking at what structures and processes were adopted in relation to system development in particular adequacy and security of the electric system, generation and transmission development plans and access to the transmission network. This WG will report in 2008.

Efficient operation and investment in electricity transmission plays a critical role in energy markets but transmission companies are natural monopolies and regulation is used to ensure these companies deliver similar outcomes as would be expected in competitive markets. Investment decisions in the transmission network have to take into account the expectations and regulations set by Governments and Regulators. Planners need to have an appreciation of the expectations of customers in terms of quality/reliability of supply, of generators to provide unconstrained access, of the regulatory authorities and the various shareholders/stakeholders in terms of utility revenue requirement, rates of return and profits. Transmission Planning therefore now requires a mix of engineering, financial, economic, legal and political skills. A WG C1.6 has examined the impact of regulatory environments on investment decisions and how the planner deals with this balancing act. Its work is complete and will be published in 2007.

## Planning issues

As the electricity supply industry has restructured there has been the need to develop grid codes covering specific issues such as renewable resources, interconnection transfers, system access, new technologies and quality of supply for modern industries. The approach adopted in developing these codes can vary between countries and a current WG C1.12 is examining the codes developed to identify the differences and whether a benchmark can be established for best practice. The exchange of experience would clarify the basis for the different codes and assist in system planning. The WG will conduct a survey of national, state and utility transmission and distribution codes, categorise the technical issues in the codes, and assess the impact of codes on approaches to planning. The WG will publish a TB in 2008.

In many electricity markets the transmission networks are considered a monopoly activity and investments are made directly by a network company or through an auctioning process. The arrangements for generation to access the network differ between countries and while the transmission cost should be minimised, the allocation of this cost between the generator and network company (i.e. deep or shallow connection) could encourage or inhibit generation development. Often the site chosen for a generation development will be driven by issues such as fuel supply, cooling water, planning permission, etc. The sites chosen on these criteria may require extensive investment in the network to manage the changing power flow. Incentives are used to encourage generation to develop sites where there is spare transmission capacity to minimise transmission investment. A current WG C1.14 is reviewing the various access arrangements, the incentives used, and the role that planners can take to maximise the use of existing transmission capacity in order to identify best practice. The WG will publish a TB in 2008.

In the market environment the transmission system users and the transmission owners/operators may view transmission capacity differently. The users view the transmission as their means of accessing a liquid energy market enabling them to generate/offtake at certain points. For the TO/SO transmission capacity comes from combining individual transmission equipment whose contribution to capacity is governed by the laws of physics. Understanding and defining transmission capacity available to the market, its allocation to market players, and its management over time are important issues to planners who are trying to meet the needs of transmission users. WG 37.31 examined this area and published its report in 2002 as TB-235 and described the options and the status of the debate at that time.

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