Österreichische Gesellschaft für Umwelt und Technik

iea-experts group on r&d priority setting and evaluation

liberalisation of the electricity market

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I. REPORT AND RECOMMENDATIONS FROM THE MEETING ON ELECTRICITY LIBERALISATION

The October 2001 meeting focused on the effects of electricity market liberalisation on R&D and on the gaps in R&D programs that are appearing as liberalisation proceeds. Experts Group members contributed papers and presentations on experiences with liberalisation in their countries and in the EU as a whole. Previous work by the CERT Group of Experts on Electric Power Technology and by the IEA Secretariat were among the materials considered by the Group.

The Experts Group reviewed experience among European countries with various degrees of market opening and with "green pricing" schemes. It also discussed the recent problems in California, reviewed a detailed list of contributors to those problems, and considered the extent to which those contributors – especially, tight capacity margins – might cause problems for Europe in the future, despite the positive experience so far with liberalisation and the continuing over-capacity in power generation in Europe.

In considering the effects of electricity market liberalisation on R&D, the group first considered the goals that competitive markets are intended to achieve and the demands that those markets will place on the electricity network of the future.

Competitive Markets are Intended to Achieve Many Goals

The Experts Group noted that efficient and competitive markets in electric power are expected to:

- lower overall costs to households, businesses and other consumers
- promote economic efficiency in all aspects of supply, demand, transmission and distribution
- stimulate innovation
- bring forth creative, new products and services to meet growing and changing demands for power and for high-quality power.

Despite the recent setbacks in the United States, the public policy goals of advancing efficient and competitive markets in electric power remain compelling and attractive, as demonstrated by the positive experience in Europe.

Competitive Markets Place Stringent Demands on Electricity Networks

The Experts Group noted that electricity is currently dependent on a network infrastructure that must be constantly monitored and maintained within acceptable operating parameters to avoid overheating, loss of voltage stability and loss of system synchronisation. These operational limitations are made even more acute in a dynamic market situation, because the system's infrastructure was designed to maintain reliability locally, not to promote large-scale transfers among different paths.

Future demands of competitive markets include

- wholesale and retail wheeling,
- power flows in all directions,
- instantaneous sensing of status and switching,
- inclusion of distributed and intermittent energy resources,
- supply and demand pricing, and
- a full range of varying quality and reliability requirements.

These demands are beginning to be felt today. With the growth in the numbers of independent power producers, and the responses of certain customers to the system outages, the lines dividing an electricity supplier providing power from an intermediary system operator, or from customer, are all beginning to blur. Many of the power suppliers are positioning themselves downstream of the congestion points on the transmission grid, and are connected instead to the local distribution system, or at the point of load, such as a building or factory. The supplier and the consumer are becoming the same entity. The need for technologies for sensing, monitoring, communicating with, and integrating intermittent, non-synchronous, and distributed energy resources into the larger electric power system is growing.

As the Experts Group discussed, the demands for the benefits that competitive markets can bring, and the stringent demands that competitive markets place on the electricity network, mean that today's network will be insufficient for tomorrow's needs. To meet these demands reliably, the Group argued that it will not be enough to refine regulatory approaches or to invest and expand the network so as to maintain the operating standards of the 20th century. Rather, a profound transformation must take place in electricity networks, technologies and supporting infrastructure, monitoring and controls. In essence, the 20th century network must be transformed into the 21st century network, and 20th century management and operation tools must be replaced by 21st century tools.

The technology and tools that will be needed to effect these transformations must still be developed or further developed. National R&D has a crucial role to play. But the challenges are not only national; they are also international. The companies that must meet the challenges are no longer only national companies; they are global players. Hence international collaboration also has a vital role to play.

The Experts Group reviewed evidence that energy technology R&D investments in the private sector tend to drop and become more short-term in focus as energy markets are liberalised. At the same time, the Group noted that there are foreseeable challenges to electricity networks as the connection of intermittent and distributed generation sources reaches critical levels and electricity trading increases. The Group argued that electricity network security cannot be guaranteed with existing grids, existing technologies and existing operation, management and modelling tools. In fact, electricity network security is a growing concern among Member countries; several are developing or contemplating new or expanded R&D initiatives in this area.

The Group identified several R&D needs in the liberalised electricity market arising from the new demands placed on electricity networks in competitive markets.

Electricity Network Technology and R&D is Needed to Meet the Demands of Liberalised Electricity Markets

The Experts Group developed four categories of technology and R&D recommendations for the CERT. The Group's view is that these recommendations warrant international attention and possible collaboration. They are cross-cutting in nature and so have no natural "home" in the CERT Working Party structure. The Fossil Fuel Working Party, which has been asked by the CERT to serve as the home for electricity issues, is the appropriate recipient of these recommendations, but the recommendations should be shared with all Working Parties since all deal with electricity to some extent. (For example, the Renewable Energy Working Party is considering further collaboration on distributed generation, and the Demand-Side Management Implementing Agreement, under the End Use Working Party, is considering further collaboration on producer-consumer interactions.) Assessments of the full potential for new international collaboration in the areas below would be carried out under the umbrella of the Fossil-Fuel Working Party but should likewise involve all three Working Parties and all relevant Implementing Agreements.

The four main recommendations for the CERT and the Working Parties are summarised on the next page. The technology and R&D needs mentioned are just a representative sample; a summary of the full list developed by this Group is included as Attachment 1.

RECOMMENDATIONS TO THE CERT AND THE WORKING PARTIES FROM THE EXPERTS GROUP ON R&D PRIORITY-SETTING AND EVALUATION, MEETING ON ELECTRICITY LIBERALISATION AND R&D

1. Governments Have a Vital Role to Play in Medium- and Long-Term R&D, and High-Risk R&D, to Meet the Needs of the 21st Century Electricity Network.

Energy market liberalisation and global competition have driven the former electric utilities to decrease investment in R&D and re-orient remaining investment toward short-term competitive concerns, and may be having similar effects on other energy technology R&D in the private sector. Under these conditions, the government role in supporting medium- and long-term, and high-risk, R&D on advanced energy technologies and analysis tools is becoming increasingly important.(These categories of R&D include use-inspired basic research as well as more applied technology R&D that requires a commitment of resources for periods longer than the increasingly short-term investment horizons of the private sector.)

Governments also have a crucial role to play in setting incentives, regulations and market rules in ways that:

- stimulate private companies to provide adequate network security and thus to conduct any network-related R&D needed to support network security; and
- allow regulated transmission and distribution companies the financial capability and flexibility to conduct needed R&D.

2. System Analysis Studies are Crucial

The California experience is but one example warning of the risks inherent in allowing low system over-capacities in a competitive market. The behaviour of the producer-grid-customer system under conditions of tight capacities should be studied carefully. Strategies should be developed to avoid foreseeable problems under these conditions. These may include providing incentives for maintaining adequate over-capacity – and the definition of "adequate" may differ for different categories of supply (e.g., intermittent or distributed sources).

Other systems analysis topics needing attention involve energy-economic modelling and socio-economic studies (see Attachment 1).

3. Technology Development is Needed to Enhance Electricity Networks

In the 21st century, electricity network security will be an increasingly important component of energy security. Networks will need to remain stable and reliable even under high levels of integration of intermittent, non-synchronous and distributed electricity sources. Rapid dispatch of electricity sources, fast-acting load control and increased electricity storage capacity will have vital roles to play.

Additional technology R&D is needed to meet these needs and transform existing electricity networks into 21st century networks. Among the technologies that will be needed are grid hardware enhancements and real-time system monitoring, control and storage devices. (See Attachments 1 and 2.)

4. R&D is Needed to Bring Customers Fully into the Market

While real-time pricing on the production side is well established, it is not yet in place on the demand side. Customers having less than full knowledge of the price they are paying for electricity at any given time cannot respond to market price signals. Innovations needed to support a better balance between offer and demand pricing include intelligent metering systems and other information technologies that allow automated responses to real-time pricing. (See Attachments 1 and 2.)

Attachment 1

RECOMMENDATIONS FROM THE CERT EXPERTS GROUP ON R&D PRIORITY-SETTING AND EVALUATION: R&D NEEDS FOR 21ST CENTURY ELECTRICITY NETWORKS

At its October 2001 meeting, the Experts Group identified technology and R&D needs to support future electricity networks. These are summarised below in three categories: grid/networks, consumers, and producers.

I GRIDS/NETWORKS

1. Electric Grid Enhancements

The transmission grid was originally designed to transmit the output of the generation units in one direction, and over relatively short distances, to local load centres or distribution points. Today, the utilisation of the grid has drastically changed. It is expected to accommodate huge volumes of energy transfer, in both directions, and over very long distances.

This reliance on the grid as the essence of market facilitation is radically different than the purpose for which it was originally designed. However, this is expected purpose of the grid of the future and it raises many new technological needs for electric grid enhancements:

- Conductors: Advances in conductor technology fall into three areas:
  - *High Temperature Superconducting Technology*
  - *Below Surface Cables*
  - *Advanced Composite Conductors.*

- Transmission Line Configurations: Advances are being made in the configuration of transmission lines. New design processes coupled with powerful computer programs optimise the height, strength, and positioning of transmission towers, insulators, and associated equipment in order to meet engineering standards appropriate for the conductor (e.g., distance from ground and tension for a given set of weather parameters).
  - *Tower Design Tools*
  - *Modular Equipment*

- Transmission Alternatives: The following technical approaches have been proposed to reduce losses, increase capacity, and/or address situations where traditional energy transport mechanisms have shortcomings.
  - *Power Beaming*
  - *Higher Voltage Levels*
  - *6- and 12-Phase Transmission Line Configurations.*

- Transmission System Devices: Implemented throughout the system, these devices adjust the impedance of the system. They can increase the transfer capacity of transmission system, support bus voltages by providing reactive power, or be used for dynamic or transient stability enhancement.
  - *High Voltage Direct Current*
  - *Flexible AC Transmission System (FACTS)*
  - *FACTS Phase-Shifting Transformers*
  - *FACTS Dynamic Brakes.*

2. Real-Time System Monitoring, Control and Storage Devices

Additional concerns focus on managing the grid, which requires new technologies for monitoring and controlling power networks and flows, and for energy storage.

- Real-Time Monitoring Devices. These devices enable real-time sensing of both the loading and limits of the individual system devices, and the overall state of the system. The capability of the electric grid is limited through a combination of the limits on the individual devices and by the composite loadability of the system. The capability of the grid can be increased by better monitoring to determine these limits in real-time, and to directly measure the system state, so as to facilitate operation closer to technical limits.
  - *Power System Device Sensor*s
  - *Direct System State Sensor*s
  - *Power System Monitor*s
  - *Phasor Measurement Unit*s.

- Energy Storage Devices: The traditional function of an energy storage device is to store generated off-peak energy that can be dispatched during peak demand periods to obtain production cost savings. By virtue of its attributes, energy storage can also provide improved power system control. Different dispatch modes can be superimposed on the daily cycle of energy storage, with additional capacity reserved for the express purpose of providing these control functions. Energy storage devices have been investigated or used for many years, but additional research can produce further improvements in each of these technologies.
  - *Batterie*s
  - *Superconducting Magnetic Energy Storag*e
  - *Pumped Hydro and Compressed Air Storag*e
  - *Flywheel*s.

3. Convergence of Information Technology With System Controls

With the establishment of market clearing institutions, such as independent system operators (among firms) and the regional transmission organisations (among regions), there will be increasing needs for real-time information of all kinds and the tools to manage and interpret it almost instantaneously. These may be provided by new data management and computational systems, linked to and enabled by the Internet and other information technology and related communication networks.

4. System Analysis Studies

The California experience is but one example warning of the risks inherent in allowing low system over-capacities in a competitive market. The behaviour of the producer-grid-customer system under conditions of tight capacities should be studied carefully. Strategies should be developed to avoid foreseeable problems under these conditions. These may include providing incentives for maintaining adequate over-capacity – and the definition of "adequate" may differ for different categories of supply (e.g., intermittent or distributed sources).

Other systems analyses tasks needing attention include:

- the enhancement of energy-economic models of electricity systems to incorporate more of the experience to date with liberalisation
- analysis of the potential levels of demand for specialised electricity products such as green electricity and electricity meeting various standards for power quality and reliability, to enable future planning

- studies of the potential to integrate distributed generation sources, originally intended as stand-alone systems (e.g., to provide backup power for "data hotels"), into the network – for example, to meet the need for additional over-capacity
- scenario analyses of the behaviour of entire energy systems – the electricity network(s), gas networks, and end-use demand sectors – under highly integrated conditions with high reliance on electricity.

More sharing of information and experience among countries as liberalisation progresses would also be very useful in areas such as experience with different system configurations and with approaches to "incentivising" system security.

II CONSUMERS

1. Retail-Load Participation and Real-Time Pricing

The ability of consumers to vary their demand in response to varying prices is a fundament element of a competitive electricity system. In theory, if every electric load saw instantaneous real-time pricing, customers would be willing to discontinue service or reduce consumption as prices rose. The equilibrated price feedback would serve both to moderate demand and promote adequate supply.

- Dynamic Retail Pricing. Technologies needed for enabling retail-load participation in competitive markets, with real-time and dynamic pricing, include:
  - *Intelligent Metering*
  - *Networked Communications*
  - *Computing Technologies*
  - *Electronic Devices and Information Buses (for use throughout the grid to provide high sampling rates for real-time pricing)*

- Controllable "Dispatchable" Loads. Fast-acting load control is also an important element in active measures for enhancing the transmission grid. Automatic load shedding (under-frequency, under-voltage), operator-initiated interruptible load, demand-side management programs, voltage reduction, and other load curtailment strategies have long been an integral part of helping the system cope with unforeseen contingencies as a last resort, and/or as a means of helping the system become overloaded by reducing load during periods of high grid stress. Future advances in load control technology will leverage the advent of real-time pricing, enabling consumers to "back off" their load (either automatically through grid-linked controllable appliances, or through manual intervention) when price dictates.
  - *Price-Responsive Load*
  - *Intelligent Building System*s *(these optimise energy consumption for building operators and have the potential to provide system operators with additional tools for managing load or increasing local power generation based on real-time market conditions).*

2. Reliability and Quality of Service Choices

Another critical aspect of a competitive market is distinguishing varying requirements for the quality of service among different types of consumers, and at different times. In the traditional electricity setting, each customer was presumed to have generally similar requirements for quality of service, which resulted in reliability of supply 99.9 percent of the time, with modest variations from standard frequency and voltage parameters. The costs for such reliability were spread among all consumers. In a competitive market, different customers will have different requirements. In a digital economy, or on a high-technology production line where service interruptions may result in millions of dollars of losses, quality of service may require 99.999999 percent or higher levels of reliability, with virtually no measurable variations in voltage or frequency. Some consumers will be willing to pay higher costs for such quality and reliability. Others will surely not. There are few means today for facilitating the competitive pricing of quality and reliability in real time.

3. Socio-Economic Studies

Experience in some Member countries indicates that consumers may need more help with understanding the choices available to them as liberalisation proceeds. Socio-economic studies of topics such as customer awareness of choices in liberalised markets, tailoring information programs to meet the needs of various segments of the customer market, and customer attitudes toward more decentralised power systems (e.g., to installing a fuel cell in every home) would be useful in this context.

III PRODUCERS

1. Intermittent, Non-Synchronous, and Distributed Energy Resources

With the growth in the numbers of independent power producers, and the responses of certain customers to the system outages, the lines dividing an electricity supplier providing power from an intermediary system operator, or from customer, are all beginning to blur. Many of the power suppliers are positioning themselves downstream of the congestion points on the transmission grid, and are connected instead to the local distribution system, or at the point of load, such as a building or factory. The supplier and the consumer are becoming the same entity. Technologies for sensing, monitoring, communicating with, and integrating intermittent, non-synchronous, and distributed energy resources into the larger electric power system will need to be enhanced.

- Intermittent or Non-Synchronous Generation: Devices are needed to improve the efficiency and interface with the grid of intermittent or non-synchronous generation resources. These devices can also be used for power system control. Advanced converter concepts will play an increasing role providing power conversion between DC and AC power, important for resources such as wind, solar, and any non-synchronous generation source. Converter concepts such as pulse width modulation and step-wave inverters are particularly useful for incorporating DC sources into the grid, or provide an asynchronous generation interface. Asynchronous generation has also been proposed for increasing the efficiency of hydroelectric generation, which would have the advantage of providing certain control functions, such as the ability to modify the effective electrical inertia of generators.

- Distributed Energy Resources: Fuel cells, micro-turbines, diesel generators, and the like are also being integrated using power electronics. As these distributed energy resources (DERs) increase in numbers, they can become a significant resource for reliable system operations. Because DERs are relatively easy to site and permit, have low initial financial outlay, rapid installation, and the potential either to supply local loads or sell into the system, and also provide a certain degree of self-reliance, DERs are attractive and expected to grow in number. Because of this, and their inherent teaming configuration with local loads, they may be considered in a category similar to controllable (dispatchable) loads. Along with technologies for sensing, monitoring, communicating with, and integrating DERs into the larger electricity network, basic reliability issues for these technologies – such as fire protection – will need attention.

- Renewable Energy Resources: Work is needed on short-term resource prediction for intermittent renewable energy resources, so as to enable their rapid dispatch, and on new network planning (software) tools that incorporate the uncertainties associated with intermittent resources.

Attachment 2
Members of the Experts Group on R&D Priority-Setting and Evaluation, as of October 2001

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