Special Report - Technical Theme 4

DISPERSED GENERATION - MANAGEMENT AND UTILISATION OF ELECTRICITY

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Ever increasing competition in the utility and energy markets combined with continuing public support for environmental issues has insured that the topics covered in this session of CIRED continue to grow in importance. Significant numbers of generators of all types have been connected within distribution networks encouraged by legislation opening up access and giving incentives to renewables and lower CO_2 emitting equipment. This growth shows no sign of decreasing. There is high international interest in the experiences of the generator developers and network operators. These drivers not only impact upon generation and network operation but also upon planning, load prediction and demand management. The new structures of the power market and utility organisations are having to deal with end use energy efficiency goals in new ways. Examples of how these challenges are being met complete the scope of this session.

For 2001 the session format contains some new innovations.

- The main Alpha day (Tuesday 19th June) will first cover the issues in managing and using electricity. Then, following lunch, the afternoon will cover the greater number of papers and topics in dispersed generation. A keynote presentation will introduce topical issues at the start of the morning and afternoon.
- On the Beta day (Wednesday 20 June) there is the opportunity to attend the Dispersed Generation Tutorial, a round table on Prime Movers for Dispersed Generation where developers of each technology will contrast their offerings and finally the Working Group update.
- The opportunity to discuss with authors on a one to one basis and see demonstrations of their work in the Interactive Forum.

Preferred Subject 4.1: Dispersed Generation

Twenty two papers have been selected for preferred subject 4.1 in the afternoon session. They cover generators ranging from 1kW photo-voltaic (PV) panels to multi-MW windfarms and co-generation schemes. The review of papers below has been grouped by key issue rather the numerical order to assist the reader in comparing the authors contributions (which often cover more than one issue) and the Rapporteur's questions. Eight authors will present the updated highlights of their work before all the authors form a panel to interact with the delegates in the discussion period. All delegates are encouraged to prepare contributions and answers to the questions below.

Our keynote speaker T Krogh brings experiences of the Danish utility Eltra in facing the challenges of developing and operating a network containing dominant embedded generation

Generator Technology Issues

Wind generators are now widespread in many countries, however design improvements are required as they increase in size and are deployed into more challenging locations, for example offshore.

Paper 4-14 from Denmark describes how lightning protection is being deployed for offshore turbines. Their conclusion that a systematic, complete and well documented lightning protection concept had not been available in the past but is needed for operational reliability will interest all workers in this area. The paper gives a good guide for others to follow and take forward.

Paper 4-5 gives Spanish experiences in simulating wind speed changes on the performance of whole wind farms. The authors conclude that even if wind conditions of each machine are highly changeable the overall system dynamics are very homogeneous. They are optimistic that overall the farm exhibits first order performance and therefore power factor control is not difficult.

Incorporation of wind turbines into weak networks is a challenge faced in many areas given the wind resources are typically located well away from centres of population or load. Paper 4-16 from Norway applies the new procedure of IEC 61400-21 to determine the impact of wind turbine on voltage quality. It shows how this allows significantly more capacity to be connected than previous rule of thumb methods. Selecting the appropriate wind turbine type or adjusting control parameters also can overcome problems. A further assessment of thermal capacity and voltage stability constraints demonstrates how further increases can be achieved.

Question 1:

Network operators may now accept wind power as a known quantity in planning and operational terms. Do authors and delegates have practical experiences to validate the solutions offered in these papers and their cost implications. Also, what are delegates experiences of applying IEC61400-21?

Small-size gas turbines and micro turbines have been the subject of claims that they are ideally suited for industrial and commercial co-generation and CHP schemes. Initial deployment is most talked off in the USA but papers 4-19 and 4-21 from Italy give a European perspective. Figures are given from early tests of a 45KW microturbine unit.

Fuel cells have are making progress toward providing a very clean modular generation source for deployment in urban environments.

Paper 4-12 from Germany puts forward the case for fuel cell based CHP plants in meeting emission targets. It is also suggested that fuel cell CHP should be seen as an electricity plant that produces some heat in contrast to conventional CHP which requires a large heat load. An outline of two pilot 250kW proton exchange membrane (PEM) plants installed in 2000 is given. It is clear that the large investment in development of PEM technology for automotive applications is driving this technology forward.

The economic feasibility of deploying fuel cell generation units into the distribution network as an alternative reinforcement is considered in paper 4-15. Two example Brazilian networks are studied and some conclusions drawn.

Question 2:
Reliability, availability and efficiency in real world load cycles will be vital to the success of small turbines and fuel cell plants. What are the authors experiences of operating 250kW fuel cell units and 45-100kW micro-turbines on these criteria and can delegates offer views on operating similar plant outside the laboratory?

Network Impact

When engineers consider the impact of dispersed generation on the distribution network their thoughts typically go to voltage control, power quality, loss of mains protection, short circuit currents and perhaps stability. This section starts with a paper considering the impact on the whole electricity industry supply chain of domestic scale combined heat and power units (micro CHP). Paper 4-4 reviews some of the technologies and units that are set to be commercially available within 2 years, their potential impact on both the network operator and the energy supply company and the positive environmental benefits that could be gained.

Question 3:
How might distribution network operators handle the issues from domestic scale micro-CHP given that most of the opportunities are for other players in the electricity supply chain?

Flicker from embedded generators has been mainly considered in relation to wind turbines. However wave power station could also show wave induced flicker. Paper 4-2 describes how a low sample rate software flickermeter was built and tested. The initial results of trials on the LIMPET wave power station on the west coast of Scotland generating 100-150kW show the level of flicker to be well within acceptable limits.

Stability of MV networks with significant amounts of CHP in a glasshouse region of the Netherlands is analysed in paper 4-17. With an average load of 7.5MW and average generated power of 5MW the calculations show that during faults such as short circuits and voltage sags high current peaks may occur. Series coils between network and generator are shown to be an effective solution.

Control of the voltage in networks with dispersed and especially independantly controlled generators has been recognised as a key requirement, for example see CIRED WG4 report at CIRED 99.

Paper 4-3 studies the options in connecting at voltage levels from 415V to 33kV in the UK network with particular interest in multiple generators. Five conclusions are given including that real-time communication between network operator and generator controller is needed (see paper 4-8 for how this is being considered in France). The authors also suggest commercial measures should be developed to encourage better network utilisation.

The linking of dispersed generators to the French distribution network SCADA system is described Paper 4-7 Linking an electronic meter to the RTU enables monitoring to be implemented simply and cost effectively. This has made the generator activity visible to the SCADA system and thereby the network operators.

An approach to implement on-line voltage control on feeders with generation is described in paper 4-8 from France. Using a recently developed algorithm which estimates the voltage constraints taking into account the uncertainties from the limited voltage and load measurements available they expect to be able to improve on conventional compounding type control. The system will require measurement of voltage, active and reactive powers along with remote control of primary on load tapchangers.

Managing networks containing significant distributed generation will be a key competence for network operators.

Paper 4-31 describes how neural networks and evolutionary algorithms can be used to forecast both demand and renewable generation output to optimise short term scheduling. Examples are given of application to a network in Germany.

Both operating and planning issues are studied in paper 4-20 from Italy. The authors propose a control method for inverter connected generators which is claimed to give better performance in disturbances and islanding situations. Combining the dispersed generation with network automation (automatic sectionalising switching devices) is simulated to quantify the improvements in the SAIFI and SAIDI indexes.

Question 4:
Various technical solutions are offered in the papers above (control strategies, inductors, meter-RTU links, control functions etc.). Who will pay for them, are they proven and what effect will the additional equipment have on overall network reliability?

Network Connection Issues

Connection requirements - Common approaches in different countries should assist in reducing equipment costs. The WG4 report to CIRED 1999 gave survey information which will be updated in the Beta day at this conference. The papers below describe the current approach in their respective countries.

Paper 4-6 describes the Belgian requirements in isolation, earthing, protection and flicker. Further progress in international standardisation is encouraged.

The technical regulations for connection to LV and MV in France are summarised in Paper 4-10. It can be noted that plant over 1MW *may* be requested to control the voltage within the limits of their capacity for reactive power output and absorption whilst those over 10MW *must* be so equipped.

Technical specifications and requirements for DG connection in the USA are given in paper 4-13. The author goes on to review the impact of network design and configuration on performance levels. How the latest generation of multi-function relays can contribute to obtaining high reliability in these situations is considered.

Paper 4-1 debates some of the issues of how network reinforcement requirements can be balanced against constraints on operation to enable cost effective connection of embedded generation in the UK regulatory environment. A simple case illustrates the point, unfortunately no generally applicable resolution is found.

A tool to study connection to MV networks is described in paper 4-9. It was developed to assist French distribution engineers complete the technical compliance assessment of applications within the 3 month statutory period. The software also produces and checks the settings for protection on the feeder.

The potential for renewable generation (both photo-voltaics and wind turbines) in the Netherlands networks is assessed in paper 4-18. This showed that a $12m^2$ solar panel could be fitted on 1 in 4 houses without major network modifications. Similarly a 5kW wind turbine on 1 in 6 houses. With this level of renewables in place 35% of annual electricity consumption would be from the renewable source.

The reasons for loss of mains **protection** are set out in Paper 4-11 The operation of the ROCOF (rate of change of frequency) relay is outlined and guidelines given for the settings. Other issues such as phase shift and pole slipping are mentioned. However the key breakthrough to a much lower cost multifunction relay which all involved developing generation schemes await hasn't yet emerged.

Question 5:
Are the various national connection regulations easily satisfied with design/modelling tools and protection equipment that is available today? Timescales approval and installation will need to shorten if increases in generator deployment are to occur.

CIRED Working Group 4 (WG4) has been active producing an updated version of the 1999 survey, collecting and compiling a directory of legal and technical regulations and producing an extensive bibliography. The round table on the Beta afternoon will enable delegates to contribute to these activities.

Preferred subject 4.2: Energy Efficiency

The **keynote address** for the morning session is titled **'Climatic change and the European response'**. This sets the scene for the papers in both preferred subjects 4.2 and 4.3, indeed it is an important driver for the growth of 4.1 dispersed generation. Following the keynote address six authors will present the updated highlights of their work before all the authors form a panel to interact with the delegates in the discussion period. All delegates are encouraged to prepare answers to the questions below.

Storage Systems
Developments in electrical energy storage systems and the new drivers from competitive power markets have lead to a range of potential applications in distribution networks. Indeed, the second international conference EESAT 2000 on this subject was held last year in the USA. Storage systems have been claimed to improve overall energy efficiency by meeting peak demand, reducing the amount of spinning reserve required and assisting in the integration of renewables.

Paper 4-26 reviews some of the new technologies of energy storage systems ranging across super-conducting magnets, super capacitors and redox flow batteries (also termed regenerative fuel cells) to traditional pumped hydraulic systems. This gives a useful guide to the current literature on this evolving topic.

The paper 4-22 describes how a regenerative fuel cell based energy storage system has successfully operated at 1MW in the UK and a system with 120MWh capacity is being constructed to provide black start and other ancillary services.

Question 6:
Efficiency, availability and capital cost will be vital for storage systems to be accepted. Can the authors of 4-26 comment upon these for the systems surveyed and authors of 4-22 give them for their 1MW facility?

Energy efficiency in the network
Whilst energy saving in the end use of electricity is described in the papers below, Paper 4-27 shows how the deployment of energy efficient transformers within the distribution network could contribute 7TWh of savings by 2010 representing 1% of the European commitment to reducing carbon emissions. They conclude that utilities in deregulated markets are faced with reduced capital budgets and unless regulators give much higher priority to energy efficiency there will not be incentive to invest in more expensive efficient equipment. This is illustrated by only 161 installations of amorphous transformers in the EU.

Paper 4-29 describes how a fuzzy reasoning approach has been used to reconfigure part of the Isfahan MV network in Iran. The results show reduction in losses and improved load balancing.

Question 7:
What examples are there of legislators and/or regulators giving strong enough signals for investment in network energy efficiency to achieve real improvements?

End use energy efficiency
The energy saving and economic benefits from the installation of variable speed drives is shown in paper 4-25. The authors give three case studies from Belgium with payback in 14 months. Deterioration in power quality and sensitivity of the converter to short interruptions and dips are two issues that must be addressed.

Paper 4-34 covers a set of tools used by energy consultants in Denmark funded through Public Service Obligations (PSO) to fulfil international climate change obligations. The PSO charge on the electricity bill has enabled this thorough programme to develop over ten years. A CO_2 tax introduced in 1996 was used until 2000 to support replacing equipment. The success in keeping CO_2 emissions in check means that all the programmes will now have a larger private initiative content.

Paper 4-23 describes how expert system software has been developed and is being used in the UK to assist in choosing the right drying technology to meet both financial and energy efficiency goals.

The potential of mechanical vapour recompression to reduce energy consumption in the Italian food industry is assessed in paper 4-38. Test results have shown product quality is not impaired and consumption of primary energy and CO_2 can be reduced to one seventh. The author's claim to have disproved the industry perception that the use of this more complex equipment requires additional skilled personnel.

Question 8:
With liberalised energy markets and varying commitment to Kyoto goals, how can the examples of good practice in the papers be generalised in their own countries and overseas?

Preferred subject 4.3: Demand Side Management

Electricity utilities world-wide are faced with conflicting business drivers as restructuring and open power markets are introduced at the same time as public opinion and governmental action looks for improved energy efficiency to meet Kyoto CO_2 goals. The seven papers in this section show how these challenges are being tackled in different countries.

The arrival of both competition and choice in the energy supply market does not always fit well with either supply or demand side management programmes. Paper 4-24 reviews industrial customer behaviour in the UK competitive market. The authors conclude that if regulatory initiatives are in place for value added services then opportunities can be there for energy services, improving energy efficiency and implementing load management.

Paper 4-37 from Egypt considers the optimum energy supply mix between on-site co-generation and utility network for a ceramics plant. This study spans issues from all 3 preferred subjects in the session. It concludes that an islanded approach does not deliver the benefits in reduced costs or reduction in emissions compared with the right import/export approach.

Energy pools with spot and forward markets are now operating in Europe so the energy trader as well as the network operator and energy user needs to understand and be able to forecast load curves. Paper 4-32 describes how model has been built and applied in short term forecasts for Dresden and medium term planning at E.ON in Germany. Tools like this are important for demand and supply management in the future.

Programmes to promote Compact Fluorescent Lamps (CFLs) have been shown to reduce peak loads and save energy. Paper 4-36 describes how an international collaborative programme has quantified these saving through a detailed measurement programme and assessed the impact upon the electricity distribution company in Argentina.

Load forecasts are well known to be dependant upon the weather (especially temperature) in regions where there is significant heating or cooling load. Paper 4-35 describes how a simple model has been derived for weather sensitive load forecasting in Argentina. The accuracy of better than 3% is good enough for operational and planning purposes.

Paper 4-28 describes how the latest generation of protection and control equipment can be deployed in a layered manner for both industrial and utility networks. By linking with process control systems in industrial plants and generators situations such as load shedding on loss of generation can be quickly implemented and major disruption avoided.

Paper 4-33 from the USA reviews the issues that influence the choice of power line communications for automatic meter reading across a range of network configurations. The conclusions being that frequencies of 1kHz or below give the best performance and that data concentrators are needed only at MV substations.

Question 9:
Is there evidence that demand and load profiles are changing under the influence of liberalised electricity markets or specific targeted programmes? If so can models be adapted to remain valid without a significant period of stability during which they are re-validated?