Workshop on Network Issues associated with Distributed Generation

Hosted by the Australian CRC for Renewable Energy and
The Electricity Supply Association of Australia
Room G3, Electrical Engineering Building (Building G17)
University of New South Wales
Monday 27 May

Workshop Summary & Outcomes

Introduction

The objective of this workshop was to discuss network-related issues associated with distributed generation (DG), including protection, legal and regulatory issues, and investment planning. The 36 participants were drawn from the electricity supply industry, DG proponents, regulators, government officials and research institutions.

The workshop program is set out in Table 1. The workshop presentations and this summary can be downloaded from the ACRE-UNSW web site (www.acre.ee.unsw.edu.au) by following the "ACRE EASY" link.

Table 1. Program

Time	Speaker	Topic
0800		Registration & tea/coffee
0830	Hugh Outhred, ACRE-UNSW	Workshop overview and program
0900	Ted Spooner, ACRE-UNSW	Technical issues and the role of technical standards
0930	Ron Stillman, UNSW	Legal liability issues
1000	Eric Groom, IPART	Regulator's perspective
1030		Tea/Coffee
1100	Patrick McMullan, ESAA	Supply industry perspective
1130	Jon Ford, Australian Ecogeneration Association	Distributed generators' perspective
1200	Alex Baitch, Integral Energy	Distribution planning issues
1230		Lunch
1400	Guy Grunwald, EnergyAustralia	Protection issues
1430	Leith Elder, Country Energy	Distribution planning software tools
1500		Tea/Coffee
1530	Alister Gardiner, ACRE-IRL	ACRE-IRL-Curtin DG projects
1600	Gerard Ledwich, ACRE- QUT	Distributed generation in weak rural networks
1630		Discussion
1700		Close

Summary of workshop presentations

Workshop program and overview

In this presentation, Hugh Outhred (ACRE-UNSW) provided an overview of the issues associated with grid-connection of distributed generation, raising the following key points:

- For the purposes of the workshop, distributed generation (DG) was defined as generation connected to a radially operated distribution network, "downstream" of a zone substation.
- Compared to remote generation, DG may be able to reduce network losses and substitute for some services provided by the electricity network, provided that the local network to which it is connected continues to import energy via the zone substation under most conditions.
- DG introduces a configuration pattern for the electricity industry that has become unfamiliar over recent decades – a pattern in which there is significant generation close to load. This changes some of the basic assumptions under which networks are now designed and operated, particularly with respect to protection, voltage control and behaviour following contingencies.
- Physical, commercial and accountability issues arise in assessing the value of DG.
- The physical issues arise because substitution for network services is conditional on DG meeting possibly onerous physical performance requirements. This is because the electricity industry operates by maintaining a continuous flow of electrical energy to end-use equipment of sufficient availability and quality to meet informed end-user expectations of end-use energy service delivery.
- The commercial issues arise because the commercial model used to represent restructured electricity industries is incomplete. To date, considerable attention has been given to the design of "wholesale" electricity markets (in Australia, the National Electricity Market is the most important of these). However, network representation and retail electricity market design is still work in progress. In particular, retail markets, in which most consumers and DG participate, are dysfunctional and lack consistency in design between jurisdictions. Also, availability and quality of supply, in which network services play a key role, are largely managed by standards and guidelines rather than commercial instruments. Thus the commercial value of DG is difficult to assess.
- The accountability issues arise because it is impossible to operate the electricity industry in a manner than eliminates the risks of death, injury, damage to equipment and non-delivery of end-use energy services. Also, the legal basis for liability is unclear and, in the absence of a well-designed retail electricity market, liability appears to reside by default with the distribution network service provider.
- The legal accountability issues are exacerbated by the "just in time" and "shared accountability" characteristics of physical electricity industry operation and by the lack of metered information at end-user points of connection. At the same time, issues of accountability are strong drivers for network investment and for important industry operating procedures, such as security-constrained dispatch. This is an important underlying cause for the difficulty in removing the bias towards supply-side options in investment decision-making.

Technical issues and the role of technical standards

In this presentation, Ted Spooner (ACRE-UNSW) summarised the main technical issues that arise in connecting DG to the network. He also discussed the role of Standards in managing these issues, as well as the role of the Standard development procedures in providing a structured negotiating process for reaching consensus among stakeholders on technical issues:

- The main technical issues for DG connection relate to reliability and quality of supply, protection, metering, and operating protocols for connection and disconnection, islanding and reactive power management.
- Voltage regulation, voltage flicker, harmonic voltages and DC injection are key quality of supply issues.
- Protection issues arise both for DG equipment and network equipment. The DG protection issues depend on the type of generator and the characteristics of the network. Network protection issues depend on the type and location of the DG installation and network characteristics. Thus protection design requires good communication between DG project developer and network service provider during the design process.
- Different issues arise depending on the type of generator used in a DG installation:
    - Asynchronous generators operate according to the same principle as induction motors but are driven by a prime mover rather than drive a load. They draw "inrush" currents on starting to establish their internal magnetic fields. The initial magnitude of inrush current is independent of whether or not the prime mover is self-starting but the duration of the inrush current is longer if it is not. "Soft start" devices can be used to reduce the initial magnitude of the inrush current.
    - Asynchronous generators absorb reactive energy from the network during operation to maintain their internal magnetic fields. The reactive energy requirements may be partly or fully met by connecting "power factor correction" capacitors at the machine terminals.
    - The terminal voltage of asynchronous generators collapses once they are disconnected from the network, unless they have power factor correction capacitors that correct to near-unity power factor (in which case they may self-excite). For similar reasons, asynchronous generators provide only short duration fault currents if there is a network fault.
    - Synchronous generators use an internal excitation system to provide a magnetic field. Thus their connection current can be very small so long as they are carefully synchronised to the network. This requires an excitation control system and a primer mover control system, which can then be used to control stator terminal voltage and power output during normal operation. Synchronous generators are capable of supporting "islanded" operation for load within their rating, and can inject high fault currents if there is a network fault.
    - Power electronic converters can be used to inject DG power into an electricity network. There are two important categories: passive, line-commutated inverters and actively switched high frequency (HF) inverters. Line-commutated inverters can only inject energy into a network that is energised by a separate source, and thus will not support islanded operation. By contrast HF inverters can support islanded operation and must be actively synchronised to the network supply. In general, HF inverters produce lower harmonic currents than line-commutated inverters and are capable of very fast response, but some configurations can inject DC currents into the network. Electromagnetic interference and control (EMI and EMC) must be considered for power electronic inverters.
    - The ability of generators to "ride through" a disturbance on the network, and thus contribute to enhancing power system security, may also vary with technology. Synchronous generators with controlled prime movers are likely to be the most robust. While DG installations that use asynchronous generators or power electronic converters may be less robust, depending on design.

- Industry regulators can use Standards to manage concerns about safety and technical incompatibilities between DG and network. Thus Standards provide a useful mechanism to link economic and technical regulation. The process of developing a Standard is a consensus building one that stimulates comprehensive and rigorous discussion of the issues. Standards are subjected to industry consultation and voting procedures prior to formal adoption, and after adoption they provide Australia-wide consistency, which reduces barriers to entry. AS4777 covers inverter connected DG up to 30 kVA and there is an important opportunity to develop Standards relevant to other DG categories.

Legal liability issues

In this presentation, Ron Stillman (UNSW), discussed the legal issues associated with poor availability or quality of supply:

- End-users use electricity to deliver end-use energy services. Poor availability or quality of supply may lead to non-delivery of services and/or injury or damage to equipment.
- Under contract law (private law-making by the contracting parties) such an outcome may represent a breach of contract. Under tort law (community-based civil law concerned with duty of care between people), such an outcome may provide an opportunity for the end-user to seek restoration to the prior state or “bad as old” condition.
- Under both tort and contract law, there is a question as to whether any, and if so which electricity industry participant would be liable for a problem arising from poor availability or quality. The recent case between the ACCC and ESAA failed to absolve the supply industry from liability and, for the time being, the answer must be determined for each incident on its individual merits.
- Legal precedents provide some guidance as to where liability might lie:
    - The electricity retailer that sold the electrical energy to the consumer appears to be analogous to an insurance agent and, if so, would not be expected to have detailed knowledge about the state of electricity delivered to the end-user’s premises.
    - It seems unlikely that remote generators would be held accountable because of the “pooling” characteristic of power system operation. Note that distributed generators, being located close to end-users, may be more at risk.
    - The distribution network service provider (DNSP), which provides the end-user’s electrical connection to the network, appears to be most likely to be held liable for problems caused by poor availability or quality. If so, the DNSP is likely to want to manage, through contractual arrangements with a DG, any additional risk to end-users’ availability or quality of supply that clearly results from the presence of the DG. This could become an important aspect of DG-DNSP negotiations.

The regulator’s perspective

In this presentation, Eric Groom (IPART) discussed the regulator’s perspective on network issues associated with DG, with particular reference to the Inquiry into Demand Management (DM) that IPART is currently undertaking. In that Inquiry, IPART is due to report to the Premier by June 2002 on the extent to which greater use should be made of DM options, which, for the purposes of the Inquiry, includes DG.

As part of its Inquiry, IPART released a discussion paper on distributed generation in March 2002 and an interim DM inquiry report in April 2002 (submissions on the latter are due by 12 June). Some important points from the interim report are as follows:

- The key components of the present regulatory arrangement are:
    - Chapters 5 & 6 of the National Electricity Code; the NSW Demand Management Code of Practice; and the1999 pricing determination for distribution networks.

- The present regulatory arrangements require consideration of DG options as alternatives to network augmentation, with the threat of disallowance into the DNSP's rate base of the full cost of a network option if a lower-cost DM option as available. However a number of practical barriers have been identified to DG:
    - A lack of standard network connection agreements; uncertainty regarding payment to a DG owner of avoided TUOS and distribution costs; and the lack of a clear and accessible framework for small DG
- In its interim DM inquiry report, IPART has proposed a number of options relevant to DG:
    - Develop national standards and guidelines for connection agreements, in which DG is only to pay "deep" connection costs if it can recover avoided "transmission use of system" (TUOS) and "distribution use of system" DUOS costs from the DNSP.
    - Clarify rules for the treatment of avoided TUOS and DUOS costs
    - Support the DM Code of Practice and develop Standard Offers
    - Encourage the adoption of "smart" meters
    - Provide incentives for DNSPs to undertake DG projects.

The electricity supply industry perspective

In this presentation, Patrick McMullan (ESAA) discussed the supply industry perspective on DG, raising the following key points:

- The cost of DG technology is decreasing and its reliability is increasing. Some DG technologies can offer environmental benefits as well as opportunities to improve the availability and quality of supply. DG may also provide a limited substitute for transmission capacity.
- The trend for DG is to increase its level of penetration, and it has risen to 30-40% of installed capacity in the Netherlands and Denmark.
- Technical constraints to the connection of DG can include:
    - DG connection capacity limits in rural distribution networks set by voltage limits
    - DG connection capacity limits in urban distribution networks set by fault level restrictions
    - Constraints set by the traditional design assumption that no generators would be connected to distribution networks
    - Constraints set by safety concerns, metering arrangements and control protocols.
    - With increasing penetration, issues may arise with respect to generator dispatch, voltage and frequency control, power system security and black start.
- Commercial challenges to increasing use of DG can include:
    - Information requirements and timing issues with respect to proposed new installations
    - Negotiation issues, including a need for transparency, and a need to manage "second comer" issues
    - Design of connection and "use of network" charges, including treatment of existing DG
- Internationally, solutions to the technical and commercial challenges raised by DG are being pursued through standards, uniform business practices and regulatory protocols. The development of cost-effective storage technologies would facilitate the use of DG.
- DG proponents tend to overstate the advantages of DG and understate its disadvantages, particularly on power system security and use of network. There are real costs to DNSPs in connecting and maintaining high levels of DG.

The distributed generator's perspective

In this presentation, Jon Ford (AEA) discussed the distributed generator's perspective:

- Technological progress and declining costs are improving the competitiveness of DG and this trend is expected to continue.

- Policies such as the Renewable Energy (Electricity) Act, which introduced mandatory renewable energy targets (MRET) for retailers and direct consumers, are driving growth in DG.
- NSPs are perceived to be resisting growth in DG penetration, through delays in processing applications and a lack of staff with relevant expertise and experience. One problem is that DNSPs see little if any incentive to facilitate DG connections. Some practical examples were given of this problem.
- Priorities for the AEA are to achieve speedier and lower cost of connection by:
  - Streamlining access and connection processes
  - Identifying market and network obligations and responsibilities for generators
  - Fostering and participating in the distribution component of NECA's transmission and distribution review
  - Identifying traps for the unwary DG proponent, providing advice and developing further user guides. An updated Cogeneration Ready Reckoner and Guide to Connection of Embedded Generation are currently available at the Association's website, *www.ecogeneration.com.au*.
  - The current development of a "Technical Guide to the connection of Renewable Generation to the local Electricity Network" in association with the Australian Greenhouse Office. The draft document will soon be available for consultation and comment by developers and network service providers.

Distribution planning issues

In this presentation, Alex Baitch (Integral Energy) discussed distribution-planning issues that arise from the presence of DG:

- The principle objectives for distribution planning are:
  - Adequate network capacity to supply load
  - Adequate network redundancy to meet security standards
  - Adequate availability and quality of supply
  - Adequate safety and capability to identify and clear faults
- Prior to the introduction of DG, distribution planners only had to consider the effect of supply from the main grid generators.
- DG introduces energy sources in distribution networks where they had not existed before, with a wide variety of technology types and characteristics.
- As the distribution network provides the main conduit for the distribution of electricity, the planner's main challenge is to be able to estimate and forecast the location and magnitude of DG on the network and to ensure that the principle objectives as set out above are achieved.
- DG brings both positive and negative values from the perspective of DNSP planning:
  - Positives can include the potential to defer expenditure on network augmentation, reduce network losses and improve outcomes for the environment, voltage control and/or availability and quality of supply
  - Negatives can include concerns about safety and protection, increased capital expenditure, deleterious effects on security and reliability of availability of supply, and worse outcomes for the local environment, voltage control and quality of supply
- DG installations must be assessed on an individual basis, because of the variation in DG sizes and technology types, and because the impact on the network can be location specific. This results in long application processing times and may incur significant costs. With improved knowledge on both the distributor's and proponent's side of the distributor's requirements, the assessment of impacts will improve. For small installations, there is a need for better standardisation of

conditions of connection. For larger installations, there are significant issues to be addressed which tend to result in long application processing times and unexpected costs for the proponent.

Protection issues

In this presentation, Guy Grunwald (EnergyAustralia) discussed issues associated with the protection of embedded generation and the network to which it is connected:

- There is presently about 150 MW of embedded generation connected to EnergyAustralia's network at connection voltage levels ranging from 240V single phase to 132 kV (line-line). Connections at 132 kV are complex but well understood, whereas connections at 240/415V and 11 kV can be more difficult, particularly if they involve net injections into the network.
- The key factors that affect protection design are:
  - The magnitude of power flow in each direction at the point of connection
  - Whether the generator is to provide a stand-by supply for the end-user (island operation)
  - Whether the increase in fault level from the installation of the generator exceeds interruption capacity in the network or the customer's installation
  - Whether the point of connection is on a radial or ring feeder, and whether the feeder is overhead or underground
- The goal of protection design is to:
  - Maintain the pre-existing standard of network reliability, security and quality
  - Coordinate with existing network protection and provide reasonable backup
  - Use dedicated, utility quality protection devices rather than rely on DG control equipment that is used in normal operation.
- EnergyAustralia's minimum interconnection protection requirement is:
  - Generator over current and earth fault
  - Generator over and under voltage and frequency protection
  - Possibly rate-of-change of frequency or vector surge protection
  - Residual voltage protection on the 11kV side of a generator transformer connected to an 11 kV line, possibly at significant cost, but required to detect an earth fault on an 11 kV line that has been isolated from its earth point at the zone substation
- Each installation must be designed individually, which should be done as early in project design as possible.

Distribution software planning tools

In this presentation, Leith Elder (Country Energy) discussed a spreadsheet tool for planning radial distribution networks. In its present form this tool doesn't model embedded generation.

The spreadsheet tool was used "on-line" to demonstrate the design process. Key conclusions were that property frontage length was an important cost-driver for urban networks, and that losses could be high in rural networks. Typically, urban networks had a similar cost per customer to rural networks but delivered significantly higher reliability.

Studies of embedded generation in rural networks suggest that fixed tap transformers are a limitation with respect to voltage control. On load tap changers might solve the problem but they would be too expensive for small distribution transformers. Other options that might be applicable in some circumstances include voltage regulators and transformers with saturable cores that regulate output voltage. However the tapping rate of voltage regulators would not be sufficiently fast to eliminate voltage transients and maintenance costs may be high, while saturable core transformers usually distort the voltage waveform unacceptably.

ACRE-IRL-Curtin distributed generation projects

In this presentation, Alister Gardiner (IRL) discussed outcomes from projects that being undertaken by Industrial Research Ltd (IRL), New Zealand, and Curtin University, WA. These projects have reviewed DG technology, investigated distributor perspectives on DG and developed DG-network modelling tools. Key outcomes include:

- Technological progress and policy drivers (sustainability, restructuring) support growth of DG
- The costs of most types of DG remain above cheap coal-fired central power stations, therefore DG proponents look for network-displacement values to improve project viability
- DNSPs are reluctant to trust DG options in the face of consumer demands for improved availability and quality of supply
- The competitiveness of DG options is hampered by the need for individual project analysis and a lack of Australia-wide connection standards
- DG can impact on network voltage and reliability both positively and negatively
- There are still many issues to sort out for DG with ratings between 10 kW and 10 MW.

A report is being produced that will document the outcomes of these projects, although it is not yet clear if it will be made available outside the ACRE community. Further ACRE projects are anticipated.

Distributed generation in weak rural networks

In this presentation, Gerard Ledwich (QUT) discussed issues associated with DG connected to rural distribution networks, under the topics of protection, islanding, power quality and schedulability:

- Two key protection issues are whether DG will increase fault levels and whether DG will make high impedance faults difficult to detect. These were illustrated by case studies for DG connected to a SWER feeder.
- Islanding can raise safety concerns. It can be avoided by appropriate DG connection requirements, however islanding may be a desirable response to the loss of a rural distribution feeder if it allows supply to be maintained to high-value loads.
- DG with appropriate performance capability can provide voltage support on a radial line. However reverse power flow may lead to excessive voltage rise. The location of DG along a feeder will influence its ability to control voltage.
- Depending on its technology, DG can cause voltage disturbances during starting, however such disturbances can be reduced by "soft-start" techniques. When operating, some types of DG can reduce voltage disturbances caused by the starting transients of motors in its vicinity. Other types of DG with fluctuating power inputs (eg wind generators) can cause fluctuating network voltages.
- DG can be designed to avoid increases in voltage harmonics and in some cases may reduce voltage harmonic distortion in its vicinity.
- The ability of DG to allow network augmentation to be deferred depends on a strong correlation with demand on the feeder. Schedulable DG may be able to follow load subject to ramping limits and other objectives. Non-schedulable DG such as wind turbines or photovoltaics must rely on correlation between the renewable energy flux and feeder demand. Solar energy and in some cases wind energy may show a useful correlation with demand for space conditioning.

Discussion session

The discussion session was organised according to the following topics:

- Connection standards and contracts
- Network planning tools

- Retail ancillary service and energy market design
- Legal liability issues
- Institutional factors

Connection standards and contracts

As discussed by Ted Spooner in his presentation, the systematic development process for standards provides a useful discipline for reaching consensus among stakeholders. It was agreed that further work to develop connection standards and standardised contracts would be valuable.

Geoff Webb, from Standards Australia, provided the following description of the Standards development process:

"Standards Australia produces 2 major products. These are:

- *Standards (AS & AS/NZS documents), which give technical requirements (eg product specifications as for air break switches), installation codes (eg the Wiring Rules) or instructions (eg structural design codes).*
- *Handbooks (HB) which are discursive documents which discuss the issues associated with a given subject (eg Bathroom Handbook). These documents provide explanations on the requirements contained in Standards and indicate methods that can be used to meet these requirements.*

The processes of Standards Australia are best used once the initial requirements for a proposed Standard have been resolved (even if these requirements are wrong). The Standards process has a transparency and openness to it, which allows a healthy debate and discussion on proposed Standards and which is intended to flush out concerns about requirements to be put into a Standard. Hence it is recommended that UNSW use workshops to identify concerns and solutions which could be addressed by an Australian Standard and develop a framework document which could be used as the base for an Australian Standard."

This suggests that the best starting point would be to conduct a workshop specifically on grid-connection standards and then develop a framework document to be used as a basis for developing an Australian Standard.

Network planning tools

The distributors present at the workshop indicated a preference to use commercially available network planing tools. For example, Neil Browne of Integral Energy submitted the following comments:

"In response to the prompt regarding network analysis tools, I have the following comment. Most distributors use commercially available packages for network analysis - load flow, fault studies, harmonic analysis, reliability, protection coordination and transient stability. Typically these allow for some forms of load modelling - fixed impedance, maximum demand with an assumed daily load profile, etc. However generators usually are given a fixed output. Some software for modelling generator operation based on various parameters such as weather conditions would be useful. Software packages for modelling operation of wind, hydro, solar and other generators may well be commercially available already but are not commonly used by distributors as far as I know. Ideally such software should be incorporated in the distributor's network analysis package."

Thus it would appear that researchers working on analysis tools for DG-network issues should work closely with DNSPs or with software houses that provide distribution-planning packages to Australian DNSPs. In developing software tools, it will be important to develop efficient ways to represent future uncertainty in the planning process.

Retail ancillary service and energy market design

This is a complex area, and it may be useful to run a workshop on this topic as a starting point.

Legal liability issues

It was agreed that although legal liability issues have received little attention to date, they are likely to become very important in future. Again, it may be helpful to commence with a workshop on this issue.

Institutional factors

Institutional factors did not receive much attention in this workshop. They relate to the policy context and the electricity industry structure in which DG operates. For example, if DNSPs were to install most DG, they could internalise the accountability risks that have been discussed above. However, many DG proponents would regard such an approach as a barrier to competition.

Governments are primarily responsible for decisions about institutional factors and the present IPART DM inquiry and the COAG Energy Market Review provide forums for such discussions.

Conclusions

Participant feedback about the workshop was very positive. However more needs to be done to reduce the barriers to efficient outcomes that the workshop identified. In particular, there appears to be support for further workshops and possibly on-going work programs in the areas of:

- Grid connection guidelines and standards
- Retail ancillary service and energy market design
- Legal liability issues.

Network analysis tools were also regarded as important but should probably be developed within partnerships between research institutions and DNSPs or appropriate software houses.