Quality and Reliability of Electrical Supply

Conference proceedings – selected papers

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Chris J Hewitt BEng (Hons), CEng, MIEE - is an Associate of Ove Arup & Partners Ltd. He is the Business Area Leader of Arup's Mission Critical Facilities Group. He has extensive experience of the design, site implementation and project management of large scale data centre projects with multi-national blue-chip companies. He has experience of the HV and LV design of supply critical facilities including large scale static and rotary UPS and generator systems. He has been involved with forensic failure analysis of UPS, generators and switchgear and works with clients to investigate power quality issues. His knowledge of electrical design and construction management has been gained throughout Europe and South East Asia.

OPENING ADDRESS

A REGULATORY PERSPECTIVE
DELIVERING SECURITY IN CHANGING TIMES

Steve Argent, Ofgem

A REGULATORY PERSPECTIVE
DELIVERING SECURITY IN CHANGING TIMES

Steve Argent, Ofgem, UK

Author Biographical Notes

Steve Argent joined Ofgem last year as Technical Adviser. He is project manager for Ofgem's Asset Risk Management activities and the forthcoming price review capital expenditure assessment. He has specific interests in security of supply, representing Ofgem on both the October 2002 storm review steering group and the Joint Energy Security of Supply Working Group (JESS). Steve has a wide experience within the energy industry. His early career with the former CEGB encompassed power station operation and maintenance, grid control, transmission reliability and security standards. He moved to Powergen where he had significant roles in electricity and gas project development, before transferring to Powergen International where he led the technical evaluation and acquisition of international energy assets, plus related consultancy services.

Abstract

Ofgem, via the regulatory framework and incentives, seeks to ensure that the interests of consumers, both present and future, continue to be protected, covering costs, appropriate levels of service and quality and reliability of supply.

Significant changes are occurring in the utilities that serve the UK gas and electricity markets. New Government policy, including the Energy White Paper, reflects global environmental challenges. This is leading to changing production, supply, transmission and distribution characteristics, which have implications for overall system resilience and security. Of particular note is the expected increased contribution from distributed generation, including renewable technologies and CHP.

Ofgem is reviewing innovative regulatory options to facilitate these changes whilst ensuring that the interests of consumers continue to be protected.

The regulatory perspective outlined in this Opening Address will provide the context for what promises to be a very interesting and topical conference.

Ofgem's role

Ofgem's principal statutory objective is to protect the interests of consumers (present and future), wherever appropriate by promoting effective competition. Many areas of the gas and electricity industries are subject to, or are in the process of being opened to, competition – including electricity generation, supply and the provision of metering and connection services. To help ensure that consumers' interests are protected Ofgem will continue to monitor these markets to ensure that they operate effectively.

There are some areas of the gas and electricity industries where companies retain an effective monopoly in the core services they provide to consumers because it is not possible or appropriate to introduce competition. This applies to the bulk transportation and distribution of energy to consumers via monopoly networks. In these circumstances, Ofgem seeks to protect the interests of consumers through the use of price controls and mechanisms such as standards of performance. The costs of operating and maintaining the transmission and distribution networks account for a significant proportion of the total energy bill that consumers pay-- approximately 27 per cent of a typical domestic consumer's electricity bill. Ofgem recognises that Network companies have a crucial role to play in helping to ensure long-term security of supply and the quality of service that consumers receive.

Energy White paper

The recent Energy White paper outlines four specific goals, which are:

1. to reduce CO_2 emissions by 60% by 2050,
2. to maintain the reliability of energy supplies,
3. to promote competitive markets in the UK for businesses, industries and households,
4. to ensure affordable energy for the poorest.

And envisages that these will be achieved via carbon emissions trading, investment in renewable sources of energy, raising standards for energy efficiency, promoting competitive energy markets, in the UK and beyond and developing the skills needed for a changing energy industry.

As the UK's indigenous energy supplies decline, we will become a net importer of gas and potentially more vulnerable to price fluctuations and interruptions to supply in other parts of the world. Electricity networks will need to adapt to more renewables often in peripheral parts of the country or offshore and to small-scale, decentralised power generation in homes and businesses. New control, storage and metering techniques may be necessary to handle the greater intermittency of renewable generation.

The White Paper envisages the energy system in 2020 being much more diverse than today. At its heart will be a much greater mix of energy, especially electricity sources and technologies, affecting both the means of supply and the control and management of demand.

Environmental Challenges for Networks including Distributed Generation

The government targets for renewables and CHP by 2010 are well established and achieving these will have significant impact on the networks; the recent white paper reinforces this position and sets sights yet higher for 2020. Onshore renewables and CHP are technologies that comprise relatively small generation packages and these are most economically and conveniently connected to distribution networks rather than the high voltage national transmission grid.

Most distribution networks are 'passive' systems. These networks have unidirectional power flows, with very little need for 'active' intervention either by their operators or by automation. A number of technical barriers arise if power flows are reversed by connecting significant amounts of distributed generation. If distribution networks become increasingly like mini transmission systems, costs will change (both opex and capex), as will risk profiles. Ofgem is keen to encourage innovation that will result in a strategic approach to accommodating high levels of distributed generation. Given the present mature environment, innovation brings particular challenges – management of risk, access to skills, and collaboration with R&D organisations, manufacturers and so on. Whatever the solutions, Ofgem will want evidence of good customer value.

It is worth noting that changes could penetrate right through to 230volts, the lowest tier on the distribution network. For example, one interesting technology is domestic CHP, where a domestic gas boiler will be replaced with a unit that not only provides hot water, but generates 1kW of electricity as a by-product.

Ofgem has already carried out a significant amount of work, with the industry, on removing regulatory and other barriers to the accommodation of distributed generation on distribution networks. The Distributed Generation Co-ordinating Group (DGCG) and the Technical Steering Group (TSG) have been helpful in developing thinking on a wide range of issues associated with distributed generation, including on technical issues such as revisions to engineering standards

Distribution network operators (DNOs) have a licence obligation to plan their networks in accordance with Engineering Recommendation P2/5 (the minimum security standard for distribution network design). This standard recognises the contribution to network security that can be provided from distributed generation, but assumes that such generation is centrally dispatched, persistent and connected securely at key network nodes. P2/5 will be amended to ensure that the contribution to network security from most modern types of distributed generation can be recognised. Once these changes are made it will then be necessary to consider the incentives that DNOs will require to seek out these opportunities and operate their network on an efficient, economic and coordinated basis.

Ofgem is considering a range of incentive mechanisms for encouraging distributed generation, including those related to MW capacity and MWh energy. Special regulatory treatment of particular sections of a network (power zones) may also be a way forward.

There is the opportunity here not only for the network companies to develop a new business proposition, but also to investment efficiently in our national infrastructure, setting it up for the next 50 years of its service.

Network companies also face other environmental challenges beyond distributed generation. For example there may be pressures on losses, energy efficiency, the impact of overhead lines on visual amenity, demand side management and the use of materials that may damage the environment such as sulphur hexaflouride.

Resilience and Security

In October 2002 the UK experienced severe storms, which led to around 2 million consumers having their supply interrupted. Most of these had their supply restored within 18 hours although large numbers of consumers only had their supply restored a number of days after the initial storm. The Department of Trade and Industry (DTI) launched an investigation of companies' performance, carried out by British Power International (BPI). Their report concluded that:

- nearly all the interruptions to supply were tree related.
- resource availability was not a problem, but the mutual support arrangement that is used DNOs was not effective or properly utilised in some cases;
- recent automation investment (e.g. remote restoration) proved important in early reconnection of large numbers of customers within the first day of their supply being interrupted;
- the effectiveness of information systems was a key differentiator between companies who performed well and those that did not;
- better performing companies mobilised their resources quicker and provided better information to consumers, for example through more effective use of the media and fostered better media relations; and
- the worse performing company experienced significant call handling difficulties, including problems with the British Telecom 0800 platform that was in use.

Ofgem is taking forward the recommendations of the report during our review of quality of service measures within the price review.

Ofgem standards and incentives

Ofgem's Information and Incentives Project (IIP), introduced in April 2002, provides financial incentives to DNOs with respect to the overall quality of service they deliver to consumers in three main areas

- the number of interruptions to supply;
- the duration of interruptions to supply; and
- the quality of telephone service.

Ofgem also sets guaranteed and overall standards of performance (GOSP) which cover a range of service areas as outlined in table 1.1. During the forthcoming price control review, Ofgem will consider the appropriate scope and levels of the GOSPs and the associated exemption criteria and levels of compensation. Ofgem will also consider whether it is necessary to introduce additional standards in any areas where consumers require protection or where the existing level of protection needs to be strengthened.

In taking this work forward it will be important to gain an understanding of the areas of quality of service that consumers' value and their willingness to pay for any improvements. Surveys are being undertaken to support this.

Table 1.1: Range of service areas covered by the GOSPs

Guaranteed Standards	Overall Standards
Responding to failure of mains fuse	Restoration of supply within 18 hours
Restoration of supply following a fault	Voltage faults corrected within 6 months
Multiple interruptions	Connect new domestic customers within 30 days
Estimating charges for connection	Connect new non-domestic customers within 40 days
Notice of planned interruption to supply	Respond to customer letters within 10 working days
Investigation of voltage complaints	Multiple interruptions
Making and keeping appointments	
Notifying customers of payments owed under the standards	

Asset Risk Management

Good asset risk management in gas and electricity networks helps maintain and improve quality and security of supply. The aim of effective asset risk management is satisfactory asset integrity, i.e. assets that are fit for purpose and whose performance and risk of failure meet acceptable standards. It is not about achieving a 'nil risk' of failure at unlimited expense, or the over-engineering of the network infrastructure.

In 2002, Ofgem appointed British Power International, ERA Technology and Mott MacDonald to conduct a high level survey, which sought evidence and assurance that good asset risk management policies and practices are genuinely integrated into a company's business and are delivering material benefits. The key aims of this initiative were:

- To allow Ofgem to gain reassurance of the quality of the approaches being adopted by the network companies to the risk management aspects of their stewardship of the asset base
- The identification and encouragement of good practice in the area of asset risk management

The survey particularly addressed:

- Asset Registers;
- Utilisation of Assets;
- Use of Contractors and Suppliers;
- Asset Inspection and Monitoring Regimes.

The 2002 survey was the first stage of an evolving process. It provided valuable information in understanding how the companies carry out the process of asset risk management and highlighted areas of the survey where further development will enhance it for future years. Results were presented as a series of 'radar plots'.

General findings were that companies demonstrated stronger levels of development in identifying risk, setting strategy and assigning accountabilities than in the delivery of the associated day-to-day procedures. In the areas of security of supply and asset utilisation there was a notably higher degree of development in place for the upstream networks e.g. the higher voltages of the electricity companies' systems.

The majority of companies have developed good processes to identify and assess the risks to medium/long term network performance and, in some cases, have quantified those risks in terms of their probability and impact on network performance. Some companies have documented these risks into a well-managed Risk Register, which is integrated with their corporate register and thus allows for an integrated and balanced suite of mitigation approaches. The strongest-performing companies in this area demonstrated clearly defined and systematic approaches to risk management and decision-making, including the use of a wide range of modelling tools.

The greater understanding provided by the survey is proving valuable in the review of the network regulatory framework and incentives as part of the forthcoming price review.

Moving forward

Over recent years, one of the most significant improvements to the system of price control regulation, both in the energy sector and in other regulated industries, has been brought about through more explicit focus on outputs.

A key area of focus for the next round of reviews will be to ensure that the overall package of incentives is appropriate and well-balanced, and that the trade-offs between quality outputs and prices reflect customers preferences. Ofgem's view is that, in general, the balance will best be struck by improving incentives on delivery of outputs rather than weakening incentives for cost efficiency.

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Continuity of supplies - achieving the desired level of security of supply

John Hewitt, Arup R+D

This paper is written by an engineer. It is not a legal review and the interpretations and conclusions drawn are not definitive

1 Introduction

The reliability of the public electricity supply system in this country is good but not perfect. Better levels of reliability have been recorded in other countries, most notably Japan where actual reliability approaching 100% has been achieved.

Reliability is affected by several factors. Overhead systems are badly affected by adverse weather. Underground systems can be affected by careless excavation, a particular nuisance during major construction works. Faulty overhead equipment can often be quickly repaired and restored to service but faulty underground equipment can take many hours, even days, especially when the position of the fault has first to be confirmed by instrumentation.

Good standards of maintenance can improve reliability but if the equipment needs to be taken out of service to maintain it, the system down time is increased.

Many theories about the frequency of maintenance have been put forward. The ideal would be to maintain or replace the equipment just a couple of hours in advance of it going faulty but how do we know when it is about to go faulty? If only condition monitoring could be perfected! It is possible to over maintain and continuity of supply is adversely affected by extended maintenance outages. But when we increase the intervals between successive maintenance then reliability falls unacceptably.

Achieving a good level of supply continuity is not just about how often we maintain or what condition the network is in. It has much to do with design and this paper analyses some of the factors in system design that can have a dramatic effect on supply reliability. Areas of design affecting the incoming mains are the responsibility of the Distribution Network Operator (DNO) but the DNO alone cannot achieve the levels of reliability demanded by today's industry.

2 Is total security of supply achievable?

It is a fact of life that systems will fail. The consequences of a breakdown will impact on business and may affect the health and safety of staff and property. To expect a public electricity supply to be 100% reliable is perhaps asking just too much. This has nothing to do with privatisation or the effectiveness of the design or operational capability of the supply system. Systems simply will fail from time to time. The engineering challenge is to ensure that the desired level of supply is delivered to the appropriate area or areas of the plant at the most economic cost and to pre determine the course of actions, automatic and manual that will be taken in every area of the plant after an enforced disconnection. This is not a challenge for the supplier alone, neither is it for the customer alone. Such things are only achieved when both parties act together in partnership.

An examination of both the internal and external supply network will indicate areas of vulnerability. A single point failure of any part of either network that can affect all supplies to the plant are the Achilles heels. Well-designed networks, designed with continuity in mind seek to eliminate the effects of single point failures.

Many will rest on the assumption that, although part of the network is vulnerable to a single point of failure the essential parts are covered on a generator or uninterruptible power supply (UPS). The assurance upon which they rest may be a false one. The UPS protected section of the customer's distribution system may operate for many hours on battery or supported by on site generation. However, are the fans and coolers connected to the UPS or are they connected to a section of the system that has no supply due as a result of the power failure? An easy error to make, but one that is made again and again.

Even if there are no single points at which a failure will result in loss of supply to all or part of the plant, as has been demonstrated recently during storms, multiple faults have occurred leaving whole areas, even regions, without supply for considerable periods of time. How long will the UPS batteries last? How much fuel do you carry for the generators? Can you get additional fuel to the day tank without full supply availability?

Good design of our networks, both externally (where we are to a large extent in the hands of our DNO) and internally (where we can implement our influence) can take us towards the mythical 100% reliability.

2.1 The need for a standard of planning for security of supply

In the early 1980's, in the middle of August, at a time when very large power stations were still responsible for most of the nations electricity load, generation availability was tight due to the summer maintenance programme. A major fault occurred at a Midlands power station resulting in a generator set tripping from the grid. The inability of the grid to meet demand in that area led to cascade tripping and loss of further generation and load. A large part of the West Midlands, South Wales and the West Country was disconnected from the Grid with consequential loss of all supplies for several hours. The cost to industry was immense. This was an exception but it could happen again.

The DNOs and National Grid are required develop a plan within the constraints of their licence conditions by which their supplies to any part of their network meet a level of supply security. Engineering Recommendation P2/5 sets out the various levels of security for supplies of various demands.

The Standard Licence Conditions for the DNOs, Condition 5 paragraph 1 states:

'The licensee shall plan and develop the licensee's distribution system in accordance with a standard not less than that set out in Engineering Recommendation P2/5 (October 1978 revision) of the Electricity Council Chief Engineers' Conference in so far as applicable to it or such other standard of

planning as the licensee may, following consultation (where appropriate) with the transmission company and any other authorised electricity operator liable to be materially affected thereby and with the approval of the Authority, adopt from time to time.'

Engineering Recommendation P2/5 was compiled to give the old Electricity Boards (now the DNOs) in the pre-privatisation era a standard by which they would design their network to ensure that supplies to the public were protected in the event of faults. P2/5 is the most recent revision of the standard P2. There is a suggestion that the licensee could agree an alternative but today P2/5 remains the only UK universal design standard. In today's political climate it is worth remembering that the same standards affecting the security of supply operate as they did prior to the privatisation of the electricity supply industry.

Under Condition 6 of the Standard Licence Conditions the DNO must provide an enquiry procedure for customers when the security, availability or quality of supply is affected by any incident.

3 Engineering Recommendation P2/5

3.1 Group demand

P2/5 divides customers of a DNO into classes depending on their 'group demand'. A group demand is the total demand measured in kilowatts of any number of DNO customers. As far as supplies to most customers are concerned, only three classes of group demand need be considered:

CLASS A-Group demand up to 1 MW

CLASS B-Group demand over 1MW and under 12 MW

CLASS C-Group demand over 12 MW and under 60MW

The principal adopted is that each class has a target restoration time after an outage due to a fault such that:

CLASS A-the group demand must be restored within the time taken to repair the fault.

CLASS B-the group demand less 1 MW must be restored within 3 hours for the first circuit outage. The final 1 MW must be restored within the repair time for the fault (i.e. treated as CLASS A load). Faults occurring on the second circuit have no target restoration time.

CLASS C-the group demand less 12 MW or $^{2}/_{3}$ of group demand, whichever is the smallest, must be restored within 15 minutes. The whole group demand must be restored within 3 hours. Faults occurring on the second circuit have no target restoration time.

3.2 Implementation of P2/5

The supplies to a section of network with a combined group demand of less than 1MW will only require one supply line or cable. When the line or cable or any other equipment attached to them faults, the DNO will put it right but is under no obligation to provide supplies to any customers in that group whilst the fault is repaired. The DNO will be under pressure to repair the faulty equipment quickly, the repair time allowed does not include waiting for a nice day. It means that the repair has to progress at a reasonable rate. In the interests of public relations, the DNO may provide some back up supply in the form of a generator or some other means of relieving hardship but is under no obligation. Should the repair take longer than 24 hours then the DNO will find himself in breach of his 'Guaranteed Standards of Service' and may well have to compensate his customers.

If that group is considered with its neighbouring group and the total combined demand exceeds 1MW, then the DNO has just 3 hours to restore supplies. This means that the DNO cannot rely on his ability to restore supplies merely by rectifying the fault. He must provide a switchable alternative. The alternative supply will almost certainly be provided by manual switching. Someone has to go to site to move switch handles. This requirement gave rise to the traditional ring system of 11,000 volt distribution where supplies to all but up to 1MW of load must be switched to an alternative source. The load can literally be fed either way around a ring system by means of an operator going to site and operating switches. Again, the DNO's, motivated by the need to improve their reputation as caring for their customers and also having in mind the expensive operation of calling out staff and them travelling to site, are installing an increasingly high level of system automation with either automatic restoration or switched restoration from a remote control room.

There is a safety matter here as the possibility of re-energising faulty equipment remains a possibility during manual or automatic restoration and progress is being made with tools that identify the faulty location before restoration.

Within the Licence Conditions a DNO has just 3 hours to complete the restoration to all but 1MW customer demand.

If the neighbourhood demand is increased by combining neighbouring groups so that the combined group demand exceeds 12MW the DNO has just 15 minutes to restore the larger proportion of customer demand. The time constraint does not provide for calling out staff and manual switching and so the process to restore this demand must be by automatic means or by remote switching commands from the control room.

The above considerations have been formulated by assuming that the demand is across a group of customers but the demand could equally be that appertaining to a single large customer.

3.3 What if the DNO is in material breach of P2/5

It should be noted that these are the minimum levels of security of supply and a higher level could be provided or may be demanded by a range of circumstances. In the latter instance the supply company will normally make a charge. If the security level is below the standard laid down, then the DNO will be required to carry out reinforcement at his own cost.

However, life is never that simple. The actual contract between a DNO and a customer may have clauses by which the customer accepts a lower standard of security. This may arise because the customer was required to pay a contribution