DTI/OFGEM Embedded Generation Working Group
Rapporteur Contribution

Future Network Design, Management and Business Environment

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1 Introduction

It is likely that in the future generating plant embedded in distribution networks will contribute a larger proportion of total national generation, considering the Government's policy objectives for renewable plant and CHP and the wish among developers to introduce various types of generating plants to distribution networks. This paper discusses the possible technical changes required to connect this increased level of generation together with the creation of an appropriate business environment to encourage those changes.

In particular this paper discusses what direction the technical and commercial arrangements for network design and management may take, in the medium and longer term, to assist the development of networks to accommodate these increasing levels of embedded generation. The paper forms part of a suite of seven papers, and it should be read in conjunction with the other six papers which focus on some of the short term possibilities.

2 The way forward – an overview

The creation of the DTI/Ofgem working group on embedded generation in March 2000 has moved the embedded generation debate in the UK forward by a significant step. Discussions have not only taken place between the members of the working group itself but also within the organisations that the members represent. As a result of these discussions there is a much greater understanding of the issues and there is consensus on the key areas that need to be addressed to ensure that network issues do not stand in the way of the government targets for renewable energy and CHP.

It is understood by all parties that accommodating the proposed levels of additional embedded generation on networks demands significant changes not only to the approach taken by Distribution Network Operators (DNOs), but also other stakeholders including generators, suppliers and the government bodies involved. It is clear that the current network operator approach to embedded generation is influenced by the regulatory regime in which they operate and that a change in this approach will require associated changes to the regulatory regime.

This paper builds on the analysis of the current situation and projects forward to present a range of possible solutions for future network design and management. It also discusses the business environment which should encourage the required technical and commercial innovation that is inhibited by the present regulatory regime. The focus of any changes should be to minimise the overall cost of integrating the likely increased levels of embedded generation into the distribution networks, in terms of capital and operational costs whilst maintaining the quality of supply to customers.

Firstly it describes technical initiatives that, if developed and implemented, could facilitate the connection of embedded generation. These initiatives can be grouped in to two main areas, changing the way in which networks are designed and changing the way they are operated. Secondly this paper presents options for ensuring that the right framework is developed to ensure that the correct incentives are established for all parties and which enables the appropriate flow of funds between them. In order for the players to proactively adopt the appropriate technical possibilities and develop other innovative options they must be confident that they represent business opportunities.

This paper focuses on the role of embedded generation although it is recognised that increasing the application of demand side management is equally important. Hence a high level principle on which any of the proposals should be based is the establishment of a level playing field whereby the services provided from embedded generation and load customers are treated equally alongside those which are traditionally provided by the network itself. It is possible that, once this position is established other more direct support targeted at particular generation technologies may be required to meet the Government's renewable targets. This issue is not considered further in this paper.

Whilst a key focus of this paper is minimising the overall costs of connecting sufficient embedded generation to meet the Government's targets, the allocation of these costs needs to be considered to make sure that each party involved is treated in an equitable way. For example, if in order to reduce the capital connection cost of a generation project, DNO operational costs are increased, they must not feel threatened by such an increase and should be able to see the creation of a new business opportunity, possibly by means of an incentive arrangement, arising from the situation.

3 Understanding the role of the other stakeholders

There is potential to overcome the technical issues by making changes in design and operational practice, by development and deployment of new technologies and most importantly, by collaborative effort between all the stakeholders, including generators, network operators, suppliers, government and Ofgem. A precursor to this is a commercial and regulatory regime which creates the right business environment for all stakeholders to make appropriate cost / benefit judgements.

In addition to the technical issues there are other issues that are outside the scope of the Embedded Generation Working Group such as the impact on the Balancing and Settlement processes, planning consents and direct government stimulation of particular technologies.

This paper develops possible changes in the DNOs environment, but it is important not to loose sight of those changes which may be initiated by other stakeholders. This section discusses the possible impact on some of the others stakeholders.

3.1 OFGEM/DTI's role in creating the business environment

OFGEM/DTI have a key role to facilitate the creation of a legal and regulatory framework that creates the right environment for change and innovation to take place. In particular, as discussed below, the regulatory mechanisms associated with embedded generation need carefully examined and developed.

They also have a role in helping to establish the optimum balance between the needs of different customer groups which may conflict in areas such as network cost, supply quality and security.

The impact of the market mechanisms being developed under NETA for embedded generators and the associated change to the network access regimes, is outside the remit of this paper. However, there is a key link between such market mechanisms and the development of active distribution networks. Consideration is needed as to how active network management will interface with the national trading mechanisms and whether there is a need for a local market mechanism which allows the distribution network operator to “balance” the system to accommodate load and generation needs at minimum network costs.

3.2 Improving the integration of generators and networks

Embedded Generators may need to develop and install plant that is more suitable for providing the network services that would be valued by network operators. This may involve designing and installing plant and equipment which is more flexible and is more capable of providing the types of local ancillary services identified in this paper. The traditional view of the embedded generator has been that the grid acts as an “infinite bus” with large generators providing the bulk of network security and response services. Embedded generation will need to play its part in providing these services where they form a significant part of the national generation portfolio. If providing this additional flexibility increases plant costs, generators will need to be sure that that the market environment make this commercially attractive.

Generators also have a role in managing the operation of plant to increase the value to a distribution network. For example this may involve co-ordinating planned outages to increase availability at times such are more critical to network operators.

The generator community will have a key role in developing, with DNOs, the commercial frameworks that will enable generators to form an more integral part of a distribution network.

Another key role for embedded generators will be in working pro-actively with network operators to develop mechanisms in areas such as the connection application process and provision of information which assist both parties in arriving at optimum processes whilst minimising any additional costs.

3.3 The role of the Transmission Network Operators

Whilst this section specifically focuses on the implications of increased levels of embedded generation for NGC, there would be similar implications for the other two transmission licensees. It does, however need to be recognised that the markets for network services are more developed within NGC than for other transmission licensees.

NGC foresees no major transmission issues associated with accommodating the embedded generation associated with the 2010 targets for CHP and Renewables. However, changes in the structure of the electricity market, as a larger proportion of distributed generation is connected, is likely to require further evolution of NGC’s role and operating practices beyond those already planned or anticipated for NETA, GB wide trading and new transmission access arrangements.

The anticipated development trends associated with an increasing proportion of embedded generation and the potential implications for NGC are identified as follows:

a) The larger grid connected power stations, which have traditionally provided the major portion of frequency response, system balancing, reserve and transmission voltage control services, will become a decreasing proportion of total system generation. NGC believes that the continued development of the open market arrangements for procurement of these services is the best approach to encouraging their cost effective provision from all possible service providers including embedded generators. (See paper on Balancing Services [1]). In particular, NGC will continue to be proactive in removing barriers to smaller participants entering these markets, for example, by encouraging aggregators/agents, using modern control/communication technology and working closely with DNOs as they establish their own service markets.

b) The further development of agents to aggregate and co-ordinate the action of smaller service providers (be they embedded generators, demand side measures or DNO network actions). NGC has actively encouraged third parties to develop these roles. In the future it is likely that such agents will include (but not be wholly replaced by) DNOs, perhaps operating various local markets to acquire services that they require in order to operate active distribution networks. The respective network operators will need to develop and facilitate the mechanisms by which services available in, for example, a distribution services market can be provided to a transmission services market.

c) A trend towards smaller generators having no direct commercial relationship with NGC will require the development of improved information exchange processes with DNOs who will have the sole network interface with the embedded generator. Such information exchanges will be required to co-ordinate network developments and operational/technical issues necessary to ensure the safe and secure operation of both transmission and distribution networks. While such arrangements are already in place to some extent, it is anticipated that a significant number of further developments will be required. For example, various technical and information obligations within the Grid Code and NGC Use of System Agreements for medium and large power stations are likely to be more appropriately located in the Distribution Code or Distribution Connection and Use of System Agreements. The form of these obligations may well require substantial changes and these together with the associated development of the associated new NGC and DNO roles and responsibilities will need to be managed over a transitional period.

d) Some development trends, such as a general move to micro-chp and chp district heating systems, would move the source of generation nearer to the location of electricity consumption and so could tend to reduce bulk power transfers on the transmission system. The actual change in patterns will depend on the location of generation retiring from the market, for example whether it is northern or southern located coal or nuclear generation. Due to their locations, larger industrial chp

[1] **Use of embedded generators for the provision of ancillary services (and 'balancing services' under NETA)**

schemes, various renewable sources and international electricity exchanges may be expected to maintain or increase the existing north south bulk power patterns. Development of the transmission system will continue to need an active assessment and response to market trends. In turn, it is likely that the market will receive sharper locational signals from new transmission access arrangements proposed by Ofgem as these would encourage market participants to explicitly value the short-term value of capacity while trading out congestion.

e) There is potential for the amount of unpredictable or fluctuating generation to increase as a consequence of, for example, large tranches of wind generation. While the transmission system can accommodate a significant amount of fluctuating generation or demand, and is likely to accommodate more renewables than that required to meet the target for 2010, it is possible that further development beyond 2010 may require additional balancing services to be purchased. However, this should not present an insurmountable barrier to accommodating further renewables or other fluctuating sources. The inherent ability of the transmission system to exploit diversity between sources in different areas will mitigate such a trend and the response of service markets should ensure sufficient controllable capacity to meet such trends.

Given the above measures and opportunities for addressing the transmission system issues associated with an increasing proportion of renewables, CHP and embedded generation in general, NGC looks forward to playing its part in adapting the role of the transmission system to meet the future market requirements.

3.4 Suppliers role in the new environment

Suppliers have a role in helping to create a commercial environment whereby energy and future network services are traded in a manner that not only facilitates competition in itself, but also helps to encourage network operators and generators to develop innovative ways of managing networks with an increasing proportion of embedded generation.

This may require developing tariff and metering arrangements that facilitate active load and generation management. There are issues relating to network constraints, and scheduling of generation to meet local network service requirements, which will become increasingly important as networks become more actively managed. Tariffs will need to consider the implications for suppliers and the other stakeholders of increasing exposure to NETA imbalance charges.

4 Addressing the technical issues

4.1 Introduction

A number of the challenges that will need to be met in order to meet the governments proposed levels of embedded generation are of a technical nature. The laws of physics fundamentally drive these technical issues. The challenge is to understand how these principles influence the economic model of all the stakeholders concerned so that their business models can be changed to overcome them.

This section outlines the nature of these technical issues and presents them to help understand how the business model of all parties can be modified in order to change these barriers into opportunities. The aim is to understand the impact of these technical principles in sufficient detail to allow the management of them to be valued as business opportunities rather than technical obstacles.

Most of these technical issues are substantial issues and will ultimately require a significant amount of work to solve them. In this paper, the issues and possibilities are presented in only enough detail to allow a meaningful discussion about the options for solving them.

The material in this paper builds on the ideas presented in the paper 'Assessment of Embedded Generation Contributions to Network Performance' which focussed on the technical issues that could be moved forward in the shorter term. The key recommendations were that:

- Certain aspects of network design should be reviewed, particularly in relation to the contribution from generation to network security and operating in island mode.
- The impact of introducing basic active management should be investigated. Basic active management was defined as being the level of active management that could be implemented using existing DNO SCADA control and information systems.
- Consideration should be given to assessing the impact of introducing a probabilistic approach to certain design standards.

4.2 What are the issues to be addressed

Introducing embedded generation into distribution networks has technical implications in four key areas; fault levels, voltage control, load flows, network security and stability. A brief description of these issues is presented below to give a basis for understanding the technical issues and hence pave the way for identifying the most appropriate way of managing them.

4.2.1 Fault levels

In urban areas, networks are designed to have as high a fault level as possible, consistent with switchgear ratings and operational limitations. This enables high and fluctuating loads to be connected economically, whilst minimising the effect on other customers. Due to the small margin between operation and rating of equipment, the presence of generation in urban areas is likely to increase short circuit current above plant capabilities. Induction motors, which form part of the general load, contribute to short circuit current and also erode this margin.

4.2.2 Voltage control

A key element of the design philosophy for radial networks is the use of tapered circuits where the size and capacity of the circuit reduces along its length. This maximises the use of the voltage variation allowed within statutory regulations whilst minimising the cost. On 11kV networks, appropriate tap settings on local 11kV/LV transformers and possibly high source voltages accommodate the reduction of voltage along the circuit. Generation connected to tapered circuits tend to increase voltages, potentially above statutory limits, particularly when connected to long rural circuits.

4.2.3 Load flows

Network equipment is designed to accommodate the loads experienced on the network with appropriate contingencies to maintain supplies under abnormal conditions and hence meet the security requirements. Inappropriately sized generation connected to the network can change these power flows sufficiently to either exceed plant capabilities and/or adversely affect network losses.

4.2.4 Network Security

Planning standards provide the benchmark of network security against which new connections are assessed. The standards aim to maintain the supply security of the general customer base at an agreed level. The current methodologies for connecting embedded generation ensure that the security of the overall network is maintained, although these methodologies could change if networks are managed differently. Operation of generation plant in island mode could bring security benefits under outage conditions.

4.3 Opportunities to solve issues by changing network designs

There are options to resolve some of the technical issues that arise when embedded generation is connected to a network by changing the way in which the plant and equipment on the network is specified and connected together. Changes can be introduced over time in a targeted manner which focuses on those parts of the network which have the greatest potential for connecting embedded generation. This section explores some of the possible methods that could be adopted.

It is important to recognise that these possibilities have not been rigorously developed and that in addition to potentially reducing some of the technical barriers to connecting embedded generation, some may have an adverse, as yet unquantified, impact on network operation and performance.

4.3.1 Possibilities for increased management of network risks

Currently embedded generator (and load) connections are designed to ensure they have no adverse impact on other customers in all credible situations. This may lead to higher connections costs than if a less conservative view was taken of likely network conditions. This could be achieved by reviewing the probabilistic basis underpinning the current planning standards, which are largely deterministic, to develop new deterministic standards. Adopting such an approach would increase the knowledge of such risks and this would enable them to be managed more effectively, however the overall tendency would be for network risks to increase. There are three risk areas that need to be considered:

a) Legislative.
It would be inappropriate to increase the network risk in some areas such as safety, but there may be scope in others e.g. by moving towards a probabilistic approach for meeting voltage requirements provided that there was agreement from all stakeholders.

b) Regulatory
Regulatory risks cover areas such as meeting network performance requirements (CI/CML) and the minimum security standard ER P2/5. Embedded generation may reduce regulatory risk exposure, if for example improved security benefits could be delivered by introducing contracts with embedded generators for supporting an islanded network, or increase it if for example networks are split to manage fault levels. In some instances regulatory risks may be considered as being commercial, for example the requirement for making Guaranteed Standards payments for outages in excess of 18 hours is a regulatory requirement but with commercial implications.

c) Commercial
Commercial risks are those where there are adverse business implications associated with a design approach. For example if DNOs relied on generators for network security and paid for those services, the DNO is exposed to the cost of those services increasing.

It is in the commercial area where there is greatest scope for DNOs to manage their risks in a way that aligns with their risk profiles provided that there is an appropriate return.

Examples where network design principles could be reviewed with a view to increasing the degree of risk management are:

Design area	**Risk area**	**Possible mitigation**
Splitting networks (e.g. operating with Bus Sections open) to manage fault levels	Quality of Supply, CI, CML	Contracting for security from generators Increased network interconnection with remote control
Adopting a probabilistic approach to voltage control to enable voltage rise outside statutory limits under normal operational conditions	Electricity Supply Regulations, Customer Voltage profile Commercial risk relating to increased damage claims	Recognition of any claims cost with incentives to minimise them
Review probabilistic basis used to establish circuit ratings. Application of short term plant ratings for selected plant.	Electricity Supply Regulations Premature ageing & plant failure CI, CML	Increased condition and capability monitoring

4.3.2 Options for increasing network capability

There are things that a network operator could do which would enhance the capability of networks to accept more embedded generation without changing the existing basic design philosophies. The opportunity could be taken to raise the capability of the network when the network is being developed for new connections, asset replacement or reinforcement reasons. Investments could also be made in particular parts of the network that have the greatest prospects for connecting embedded generation and where the network has a restriction in its capability that can be removed in a cost efficient manner. Where investments would be required the funding mechanism would need to be agreed. The technical options fall in to several broad categories:

4.3.2.1 Strengthening the network

a) Using higher impedance transformers would reduce network fault level contributions, allowing increased contribution from embedded generation without encroaching on the capabilities of the existing network equipment. Issues that would need to be considered include: impact on power quality delivered to customers when generation is not operating, increased requirement for reactive power, impact in network losses and protection co-ordination.

b) Using equipment (switchgear, cables, overhead lines and ancillary plant) with higher continuous and short circuit ratings would help. Identifying and replacing those items of plant in a circuit which limit its capability would enable network capacity to increase. Issues that would need to be considered include: impact on the compatibility with existing networks (e.g. when the network is switched to supply customers from non enhanced circuits), capability of earthing systems and other customers' equipment.

c) The practice of tapering circuits when developing networks particularly where there is potential for embedded generation to be connected should also be reviewed. This would help to manage voltage rise on networks as well as provide additional current carrying capacity. Issues that would need to be considered include: matching network capability to predicted future usage, prevention of over-engineering and treatment of 'stranded' assets.

4.3.2.2 Revising network configuration

a) It would be possible to reduce fault levels by splitting networks that have been designed to operate in parallel for security reasons. In many cases this could simply be achieved by opening bus section circuit breakers. However network security would generally reduce until there was sufficient generation to compensate for the lack of alternative circuit security. Providing additional equipment to interconnect networks could provide this security. Interconnected networks would generally require some degree of active management to operate them successfully. It should also be possible to install the additional equipment to enable some island mode operation. Issues that would need to be considered include reduced network security, operational management when coupling circuits/transformers prior to taking outages and the implications of reduced fault levels (increased voltage flicker and voltage distortion).

b) It is possible to install reactors to manage the increased fault levels that tend to occur with interconnected networks. Active management techniques could probably be used to manage the voltage issues that arise with the use of reactors.

4.3.2.3 Introducing new technology

a) One of the most exciting new developments is the superconducting fault level limiter that is sponsored by the DTI Link programme. This equipment has the potential to deliver the benefits of the Expulsion Link (Is) Fault Limiters without the safety concerns. This equipment has the potential to be used on the distribution networks to resolve some of the fault level problems associated with connecting embedded generation and creating interconnected networks. In effect networks with such equipment could 'radialise themselves' for the duration of a fault and re-interconnect afterwards.

b) It should be possible to develop interactive control systems that would integrate the voltage control provided by transformers and generators by sensing the voltage at key points on the network and manage it within the required limits by adjusting the most appropriate equipment. This could be either a generator voltage regulator, circuit voltage regulator or transformer tap changer. Such an approach would involve some, probably local, communication between the key components.

c) There is currently considerable interest in the application of energy storage technologies to power systems. There are various technologies, including batteries, 'regenerative fuel cells, superconducting magnetic energy storage (SMEG), high speed flywheels and large capacitors each of which are at different stages in development and have different potential applications. Applications include deferment of reinforcement where the additional capacity is required only for short periods, improvement in power quality and integration with renewable embedded generation technologies to improve the availability of the output. The application of energy storage devices has the potential to either reduce, as a competing technology, or enhance, as a means of increasing the availability, the prospects for embedded generation.

4.3.2.4 Taking on board the positive impact of embedded generators

a) The 'Assessment Paper' makes recommendations for taking forward the issue of how to recognise the genuine contribution from embedded generators to network. The study will lead to a method of assessing the contribution to network security which has the potential to reduce DNO capital investment in plant. The study will also investigate the possibilities of unbundling network service such as voltage support; provision (or absorption) of Vars; frequency response; reserve and black start. Unbundling and valuing these services could enable markets to be established.

4.3.2.5 Leveraging the benefits from technology in the home

a) The uptake of certain embedded generation technologies could have a major influence on distribution networks. In the domestic arena, developments in PV, fuel cells, micro turbines and Stirling engine technology could make homes predominantly self sufficient in electricity terms. Future developments of these technologies could make them independent of a synchronising mains supply so that they could operate in a 'home island mode'. This could reduce the need for and change the services required from the low, and to some extent higher, voltage networks. If such technology was coupled with energy storage device, a minimum infrastructure may be required to provide for 'average' energy delivery.

b) The Internet is revolutionising communication across the country. There is scope for using this communications medium to actively manage both energy usage and embedded generation in a domestic environment. Technologies are being developed which will enable domestic generation, appliances and metering to communicate without wires with the metering system forming the local hub providing tariff and control information. Tariffs could be designed to send cost reflective signals to manage overall network load. Such a mechanism could be extended to control such appliances (and CHP units provided there was heat sink) in real time to manage loads in specific geographic areas in response to particular incidents or to co-ordinate with the overall scheduling of generation plant. Such control could become part of normal active management of a distribution system.

4.4 Realising the advantages of operating networks more proactively

As an alternative to changing the design of network, it would be possible to increase the amount of generation that can be connected to an existing network by changing the way in which it is operated.

4.4.1 Changing the technical focus of network operation

Historically distribution networks have been designed to operate with minimal real time intervention except to respond to faults, allow routine maintenance and network modifications. The limits that this approach places on the amount of generation that can be connected would be increased if networks were operated more proactively.

By managing distribution networks more actively, the nature of networks would change from passively serving load, to being more fluid and responsive, balancing load and generation requirements. As with changes to the design of networks the extent to which the network is operationally managed could be introduced over a period of time in those areas which represent the best opportunities for connecting embedded generation. There are no specific definitions of the stages of active management progressing from passive towards a fully interactive managed system possibly similar to the NGC System Operator model. The table below presents an indication of typical network operator behaviours and infrastructure requirements associated with different degrees of active management.

Level	Operator behaviour	Infrastructure requirements
1 Passive	Reactive to abnormal situations	Existing monitoring and control at key nodes only
2 Basic	Reactive to planned abnormalities or longer term restrictions (e.g. seasonal)	Selective extension of existing monitoring and control infrastructure on restricted number of circuits
3 Intermediate	Some real time network monitoring, scheduling / constraining of generation and load management across parts of network. Automatic interaction between DNO plant and embedded generation.	Further extension of monitoring and control systems but still on restricted number of circuits. Communication between key network plant and generator for voltage control together with intertripping for load flow and fault level management
4 Fully Active	Real time network monitoring, scheduling /constraining of generation, load management across all network	Monitoring and control at key network nodes, communication with controllable generators and, loads. Real time modelling capability of power, active power, voltage, fault levels & security.

A key issue that arises in the transition from passive to fully active network management is need for market mechanisms, which allow the network operator to manage generation and load. At a transmission level these mechanisms exist. At distribution levels there are rudimentary rule-based systems, enacted through connection agreements, which allow the network operator to manage generation and load on the network. Fully active management of the distribution system would require the development of market mechanisms which are closely linked, or are a development of the NETA arrangements tailored to meet the requirements for small load and generation connections. The contractual framework of the market mechanism will need to ensure that services procured from embedded generators compare equitably with those provided from networks.

4.4.2 Enhancing existing control and communication facilities

The facilities provided by existing DNO SCADA system could be developed and enhanced to provide the additional functionality that would enable networks to be operated more actively. Enhancements would be needed to make additional information on the real time performance of the system available to the network operator so that they can make the right decisions. In order to implement those decisions, facilities to control key plant items such as generator active and reactive power output, transformer tap position and circuit breakers would be needed. To provide these information and control facilities communications between network plant, generators, load customers and control rooms will be needed. Some of the existing SCADA systems will be extensible to provide these additional features. Those that have more limited capacities may require upgrading or possible replacing.

The requirement for active management will initially be small focussing on a localised part of a network, building to become more widespread operation as the penetration of generation increases over a period of time. The need for the increased sophistication of the control, information communications systems together with the enabling marketplace will therefore develop over time, as will the requirement for DNO staff to become familiar with operating a network actively.

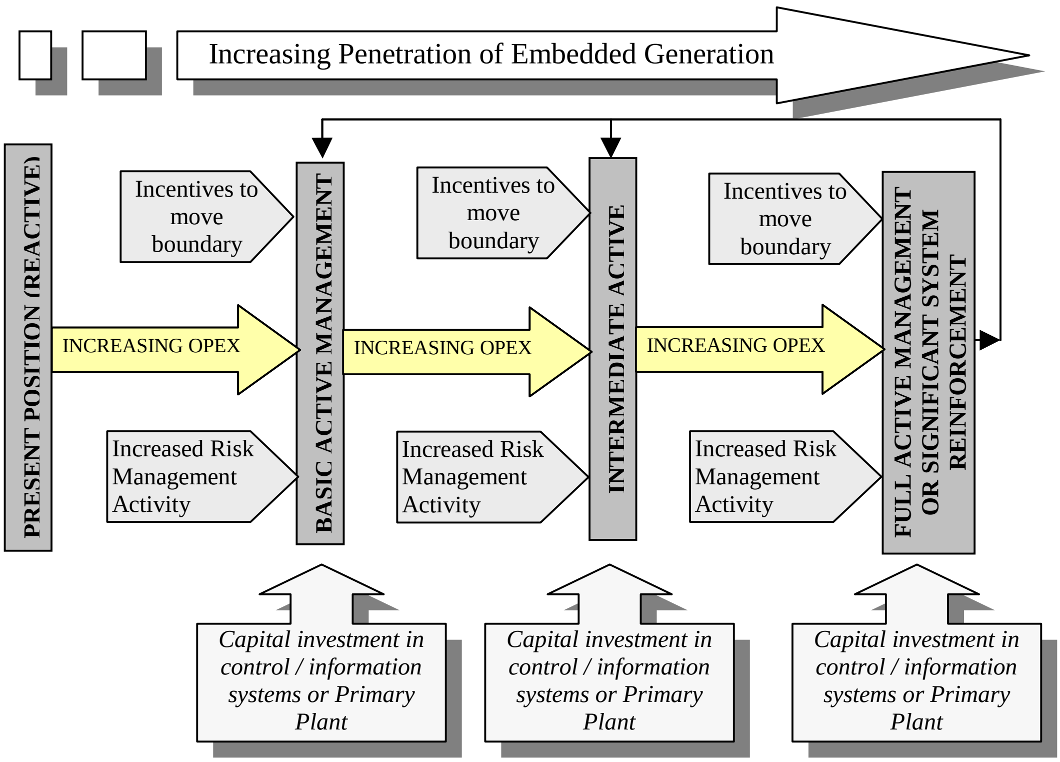
4.5 Summary of opportunities for DNO enhanced service offering

Connecting increasing amounts of embedded generation to a distribution network, at the lowest overall cost, is dependent upon two key technical elements. Firstly the efficient design and development of the network and, secondly, the successful operation of that network to meet customer expectations. The DNO is best placed to manage both these processes as a business opportunity however it is essential that the right commercial framework is in place to facilitate this.

4.5.1 Planning for a network with new design approaches and active management

The concept of changing the design of networks and operating networks more actively can be combined and in practice are inextricably linked. As networks are designed so that embedded generators become increasingly integrated in to distribution networks, the degree of active management will increase.

The diagram below illustrates how part of a network could be developed over time to meet the requirement to connect additional embedded generation by increasing the degree of active management.



Starting from the present passive position, a modified design approach could be applied to 'stretch the capability of the existing network'. A level or risk would be reached beyond which the risk to network performance delivery would be considered unacceptable. DNOs should be incentivised to maximise the acceptable risk exposure. At this stage capital investment in control, information and communication infrastructure would be implemented. The aim of this would be to significantly reduce the risk level on that part of the network. Further connections could be offered on the network based on the enhanced facilities provided by active management infrastructure. This concept could be continued to increase the active management facilities until a stage was reached when an investment in primary plant is required. The investment would then provide additional capacity to connect embedded generation which would also benefit from the investments already made in active management facilities.

This example assumes that at each decision stage an investment is made to increase the active management capabilities. More likely, primary plant reinforcement would also be considered. The decision would be based on the network and business risks, capital and operational cost requirements, potential for connecting further generation, other customer driven and asset replacement considerations.

Determining the optimum way of combining the two technical approaches i.e. how the network is designed and how it is operated is one of the key value added services that a DNO should provide.

4.5.2 Operational services that the Network Operator could provide

Operating a distribution network in a more active way is more complex than operating a passive system. There are many areas where existing planning and operational practices and procedures would need to be enhanced and new ones developed. It would be essential to introduce these changes along with the appropriate enabling market mechanisms. In this respect, the DNO is central to the concept of managing the network to enable generators, suppliers and customers to trade efficiently and effectively whilst ensuring an acceptable level of supply security and quality.

Although some of the services shown below are already provided, once the required market framework is established the total management services package provided by the DNO could comprise:

a) Real-time studies/state estimation
b) Dispatch/scheduling of generation
c) Control of power flow
d) Control of voltages
e) Contribution to security
f) Impact on power quality
g) Ensuring network and generator stability
h) Interaction between generators
i) Outage co-ordination
j) Constraints management
k) Control of fault level during abnormal system conditions
l) Recovery after system faults

m) Operation of a network in island mode (which would require at least level 2 active management for the islanded network).
n) Facilitating system access

5 Creating the right commercial and regulatory environment

In order to ensure that the appropriate technical changes are made to the way networks are designed and operated, the right commercial and regulatory framework has to be in place. If the commercial and regulatory drivers remain unchanged from their present position, increasing the amount of embedded generation connected to the system will be slow. Success will require the business model to actively encourage network operators to further facilitate embedded generation. In other words the commercial framework and incentives must align with the required outputs.

5.1 What are the issues to be addressed?

There are a number of commercial and regulatory issues that arise when considering the implications of introducing embedded generation into distribution networks. Brief descriptions of these issues are presented below so that they can be understood and ideas to resolve them can be developed.

5.1.1 Uncertainty of the regulatory process

The regulatory process implemented by Ofgem has developed through the three distribution price control reviews and is set to develop further during the current review period. This continued change can lead to uncertainty in the approach that may be taken in the future and can tend to discourage DNOs from taking decisions that may lead to an additional regulatory risk. Given that the decisions and investments required to meet the governments targets will have timespans across a number of DPCRs, stability in the process is essential.

5.1.2 Treatment of connection charges

Connection charges for generator connections are made on a deep charging basis. Such an approach can lead to connection charges for an individual generator being sufficiently high to render the project unviable and can lead to an unfair allocation of infrastructure development costs, the benefits of which may be shared by future network customers.

5.1.3 Lack of a local 'ancillary' services market

The lack of a local distribution network market place for some of all of the ancillary services that are traded by larger transmission network connected generators creates two issues. Firstly it creates a difference in the services that small and large generators can trade. Secondly there is no mechanism whereby the services that embedded generation could provide can be treated equitably alongside those services that are currently provided by distribution networks.

5.1.4 Treatment of DNO business costs

The regulatory regime currently agrees a cash settlement covering both capital and operating expenditure over the price control period. At the end of thise period companies will be judged on how efficiently capital and operational expenditure has been spent. The treatment of these expenditures in the price review process influences the DNO decision making process. For example, as all DNOs are driven down to an operating cost efficiency frontier, it might prove difficult to justify developing an innovative solution that increased opex as opposed to a more traditional capital investment solution.

5.2 Developing the options for progress

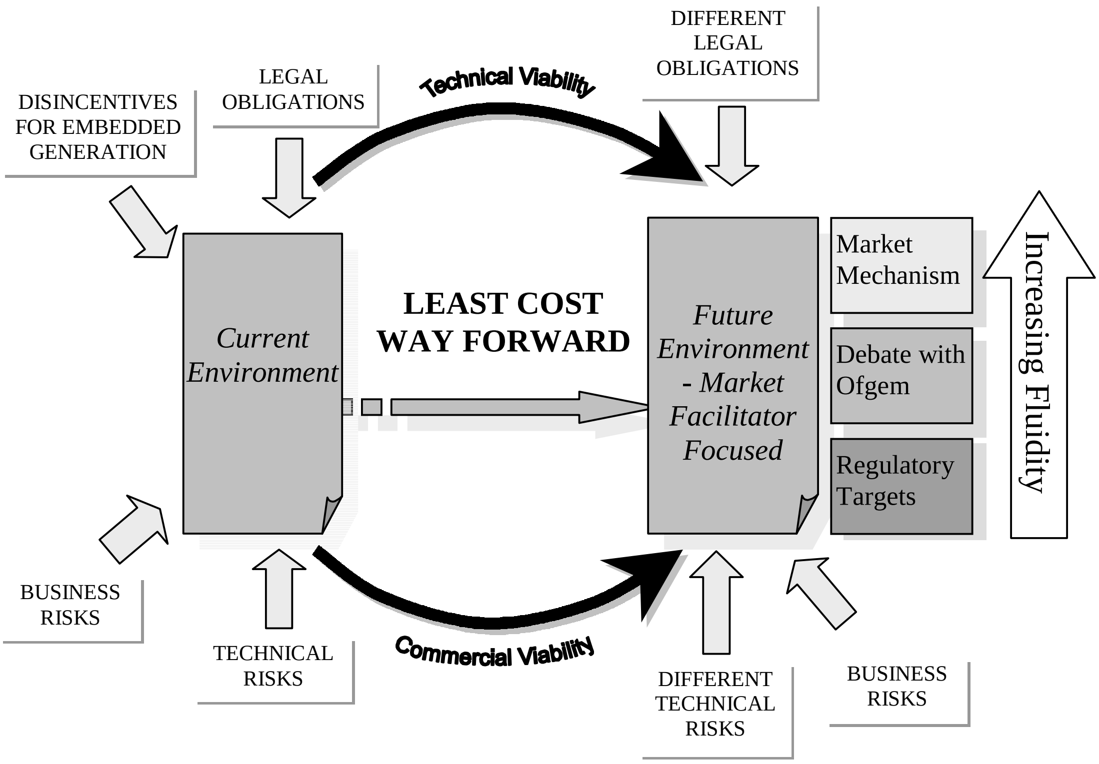
This paper focuses on those changes to the regulatory framework that would be needed in the longer term. There are several possibilities for creating the right business environment to encourage the changes with different degrees of market fluidity. At one end of the spectrum is an open, vibrant market environment with a high degree of fluidity whilst at the other is a rigid regulatory framework with regulatory incentives to connect additional capacity. Sections 5.2.1 and 5.2.2 describes how the opposite ends of this spectrum might look, whilst 5.1.3 recognises that there are an unlimited number of in-between stages.

It should be recognised that a fundamental requirement for each option is ensuring that an appropriate mechanism is in place to allow funds to flow between the businesses that trade in this new environment.

5.2.1 Market based opportunities for resolving these issues

The creation of a market based approach could create the opportunities for resolving these issues. Such a market based approach could co-exist alongside the existing RPI-X regulatory mechanism. The paper identifies a relatively small number of areas that if changed could lead to a creation of the required markets and significantly change DNO behaviour to embedded generators. These issues are generally interrelated and a change in one particular aspect could materially influence a number of key areas.

The diagram over the page illustrates a possible approach of introducing a market-based arrangement.



5.2.1.1 Increasing the certainty of the regulatory process

Investments and decisions affecting how the penetration of embedded generation can be increased in practice need to be considered over a timescale comparable with the government's targets. It would be beneficial if there was a greater understanding between network operators and Ofgem so that an overall long term regulatory strategy could be developed on which to base short and medium term tactics. In particular it would be beneficial to provide DNOs with a clear long term approach to:

- The principles and methods by which Ofgem will measure the relative performance of DNOs in future price control reviews
- The treatment of capital and operational expenditure and the relationship between them
- The development of any move towards increasing the degree of performance based regulation.

5.2.1.2 Creation of a local ancillary services market

To allow the potential network benefits of embedded generation to be properly recognised, a local 'ancillary services' market could be developed which supplements or complements the national ancillary services market. This would allow DNOs to contract directly with embedded generators for these services and introduce economic signals which would assist the DNO to select between conventional and innovative means of providing these services. The development of a marketplace for tradable services would influence DNO capital and operational expenditure requirements.

There are various services that are necessary to provide a secure and reliable electricity supply. At present these services are effectively bundled and are generally provided either intrinsically by the DNO network or from NGC. These costs are currently 'passed through' suppliers which renders DNOs neutral to any opportunities. Therefore there is currently no incentive for DNOs to actively participate in unbundling these services. However unbundling of these services could create markets where these services are traded on a transparent and equitable basis by a range of participants including generators, load customers and network operators. The services as defined in the 'Assessment paper' are:

Security Service
Provision of network capacity
Provision of customer service improvements in terms of CI, CML, Worst served customer and Transient interruptions
Provision of Power Quality improvement in terms of voltage flicker, harmonics and protection operating times
Provision of voltage support

Ancillary Service
Provision of Reactive Power as a tradable commodity (ie not necessarily for voltage support locally)
Provision of Frequency Response
Provision of Reserve
Provision of Black Start

Creating a market in some of all of these services will create opportunities. DNOs would be able to consider alternatives to traditional investment proposals, and offer a service which facilitates others operating in the marketplace. A local ancillary services market which integrated with the current national market could present opportunities for aggregated local services to be traded in the wider market, thereby creating parity between embedded and non embedded generators.

Such a market could provide opportunities for considering embedded generation services as an alternative to NGC connection point development. At present the costs of providing the existing connection point assets are passed through to DNO customers. Reviewing the charging principles for future connection point assets could be considered, as this would influence the alternatives that the DNO considers.

5.2.1.3 Moving towards a more performance based regulatory system

It is recognised that there are merits of moving from an asset based regulatory framework to one which taken output performance into account. In any move to become more asset neutral, it will be essential to ensure that the right performance measures are developed. Each DNO balances the costs of designing and operating a network, with the performance of that network in terms of the current performance measures (currently CI, CML, GO, OS etc.), and network risks. The degree of risk implicit within a network represents the low probability – high consequence situations and represents the longer term stewardship aspects of network management. Measures of such risks are particularly difficult to quantify.

Under Ofgem's IIP scheme the amount of income exposed to performance measures is 2%. At this level, the balance between cost, risk and performance is unlikely to change significantly. However if the percentage of performance incentive were to change substantially network operators would need to change this three-way balance. In itself this should not cause concern, but it emphasises the need for performance measures that accurately measures those aspects of a network that are considered important. There needs to be a balance between the short term performance measures and the longer term stewardship or risk measures which should reflect the changing role of distribution networks. A further that question arises if the DNOs become increasingly exposed to performance based regulation is in relation to the establishing an appropriate cost of capital.

5.2.1.4 Creating opportunities for increasing DNO revenue

The size and nature of the network dominate the costs of operating and maintaining it. Increased levels of embedded generation reduces the validity of the cost and revenue drivers assumed by Ofgem (25% and 50% respectively) and used in the price controls. The present drivers create the perverse situation whereby as the penetration of embedded generation increases, DNO income is reduced and operating costs increase. It may therefore be appropriate to review the application of the 'units' proxy for network capacity costs and consider how the service offered by DNOs could be charged for.

It is in considering the area of service offering, which are described more fully in Section 3.5, that it should be possible to develop incentive schemes that would reward DNOs for doing the 'right' thing.

In addition there may be some services that a network operator could offer which would provide a specific customer, or number of customers with a quality of service over and above that delivered by a distribution system designed and operated in accordance with 'good engineering practice'. Services might include:

a) Extra security
b) Shortening post fault restoration times
c) More stable voltage (reduces fluctuations)
d) Higher fault level (dip reduction)

These services should be valued on the basis of their worth to customers, and it is likely that their value will not be high for customers in general

The DNOs have an existing, albeit relatively small, incentive to reduce losses within the price control formula, however, any losses that are reduced as a result of distributed generation are netted out of the calculation. The existing incentive therefore is to reward DNOs to invest in asset based loss-reducing equipment rather than to consider embedded generation as an option (or to be part of a portfolio of options) to reduce losses. Losses are also impacted by many factors that are outside of the DNOs' control and are particularly complex to calculate on a local scale. It may be appropriate to review the treatment of losses associated with embedded generation in the regulatory formula.

5.2.1.5 Changing the generator connection charging mechanism

It has been recognised in the Charging Principles Paper that there is a need to review the current approach for deep connection charges for embedded generators. Options for moving forward on this issue have been presented in the paper. If there is a move towards a shallower connection charges with some form of DUoS charge for generators, DNO capital expenditure would increase and there would need to be a mechanism for funding this investment which encourages DNOs to optimise both capex and opex by innovation and capital efficiencies. A change in the charging principles could encourage DNOs to implement the technical innovations discussed in Section 4.

An approach that might reduce connection charges is the development of local trading mechanisms which would allow users affected by a network capability restriction to have the choice of paying (or contributing) for the restriction to be removed or to alter their operating regime to work within the restriction. Such an arrangement would be a development of the existing rudimentary rule based system whereby the generator manages his output either by design or be altering his operational regime to match the network capability. The DNO could facilitate the development of such a network access market once the full implications have been investigated.

5.2.2 Imposed regulatory requirement

At the opposite end of the fluidity spectrum to market based options, a regulatory incentive mechanism could be adopted to provide the necessary funds. This would be based upon the regulator taking the place of a free market. Such an approach might be required if the development of a more fluid marketplace does not materialise, or if the level playing field that results from its development proves to be insufficient to meet the government's targets. Two possibilities are presented below which could encourage the required technical changes.

Incentive	Advantages	Disadvantages
Reward for each MW of (Renewable or good quality CHP) generation connected	Incentivises DNOs to implement innovative solutions	Need to establish incentive levels, realistic targets, capability of existing network
	Simple & transparent	
	Incentivise DNOs to attract generators	Reduced locational signals
Reward for each MWh generated	Similar to above and incentivises DNOs to minimise operational constraints	Similar to above but DNO has limited or no influence over the operational regime

5.2.3 Extending the scope of the DPCR process

Whilst the development of a free and open market described above should be the long term vision, the practicalities of moving sufficiently far in that direction within the timescales required to meet the governments targets may prove challenging. Similarly, agreeing specific regulatory targets for embedded generation connections may not deliver the lowest overall cost solutions. In between the two positions described above there is an unlimited number of options. There is also an approach that involves DNOs entering into a dialogue with Ofgem as part of the DPCR process to agree capital and operational expenditure proposals which would facilitate a playing field, and hence pave the way for increased levels of embedded generation.

6 Conclusions

All the parties involved in the delivery of energy to customers have a part to play in facilitating the changes that will be required to meet the governments targets for embedded generation. This paper is focussed on those aspects where network operators can influence, but the role of the other stakeholders including Generators, Suppliers, Customers and Ofgem, should not be forgotten. In particular, Ofgem need to ensure that there is a regulatory regime in place that supports and incentivises DNOs to meet their obligations to facilitate competition in supply and generation.

Changing the way that distribution networks are designed and operated to encourage innovation has the potential to benefit to all customers since, properly managed, it could reduce total costs of operating a distribution network whilst maintaining or enhancing performance. In order to initiate these changes, it is necessary to review certain aspects of the regulatory process that dominates DNO’s business environment. The key areas that should be addressed are:

- generation connection charging principles
- a clear framework on regulation and incentives on DNOs
- development of a local ancillary services market

If the technical possibilities for operating distribution networks more actively are established to any significant extent, the appropriate commercial mechanisms required to support these possibilities will need to be developed.

In addition, for these technical possibilities to become practical options they will need to be developed further. A strategic co-ordinated approach to research and development across all the stakeholders would be essential.

It is recommended that a working group consider the possibilities identified in this document, together with feedback arising from the consultation process. This group would further investigate the issues, assess their materiality in terms of contribution to the government’s targets and impact on stakeholder businesses with a view to preparing a report in Autumn 2001 making detailed recommendations of how to move the key longer term issues forward.

Network operators welcome discussions leading to definite proposals to address these issues. In establishing this dialogue it will be essential that all stakeholders, demonstrate a willingness to be open and have transparent processes. This will create an atmosphere of understanding and trust which is essential if the governments targets are to be met.

7 Contributors to the report

This report has been compiled by the following DTI embedded generation working group members:
Catherine Mitchell and Phil Jones, acting as rapporteurs.

Contributions were received from:
Phil Jones, Alan Laird, Mike Kay and Alan Creighton (on behalf of DNOs)
Lewis Dale (on behalf of NGC)
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Terry Brookshaw (on behalf of Suppliers)
Phil Baker (on behalf of the DTI)
Review comments were provided at the DTI Embedded Generation Working group Meetings.

Appendix - The Current Regulatory Framework

This appendix describes the DNO current regulatory framework as it impacts on embedded generation.

1 Background

Distribution Network Operators (DNOs) have an obligation under the Electricity Act (as modified by the Utility Act) to develop, maintain and operate an efficient, co-ordinated and economic system for the distribution of electricity. As part of the process for ensuring that this obligation is satisfied, a debate is held with Ofgem at each Distribution Price Control Review (DPCR) to agree the Distribution Price Controls used to regulate DNOs.

These controls, which are based on an RPI-X principle, focus on minimising the internal DNO costs of designing and operating a network rather than considering other external factors which, if taken into account, might result in reducing the overall cost of meeting customers requirements.

2 Distribution Price Control Process

The underlying idea behind the DPC review process is simple. At each price control review point the distribution companies are awarded allowable revenue. This provides an allowance for operating costs (which assumes efficiency improvements over time), a depreciation allowance to cover capital expenditure requirements and a return on the asset base. (The value of the asset base was initially set by the market valuation at flotation uplifted by 15%). These elements are brought together in a present value calculation in order to give an appropriate level of price control revenue over the period of the revised price controls.

The allowed revenue over the period is then sculpted by the initial price cut or P_o and annual X factor. The X factor is set at a level to provide sustainable price cuts over time.

Within the price control period allowed regulatory revenue is permitted to vary with changes in volume as well as being linked to RPI. The revenue driver gives a 50% weighting to customer numbers and 50% weighting to units distributed. Regulated revenue excludes the costs of connections and charges to EHV customers.

Having reached an agreement with Ofgem over the allowable revenue for a price control review period, the DNO is able to make expenditures in whatever way they wish, providing they meet their performance measurements. (The required performance measures and stronger links with allowed revenue are currently under discussion as part of Ofgem's Information and Incentives Project). In line with incentive based regulation, if companies spend less then they will make a higher return during the price control period. These benefits will then be returned to customers at the next review point. Conversely if companies legitimately spend more and make a lower rate of return then allowed revenues might be adjusted upwards.

3 Treatment of capital expenditure

There is an expectation that the net capital expenditure by DNOs will be added to their capital asset base so that it will go into the regulatory asset base at the next DPCR. Any operational expenditure, however, will not be added to the asset base and lead to future revenue. DNOs have to balance risk, cost/finance and their performance measurements when considering expenditure. While not always the case, in general, the underlying price control incentive tends to promote expenditure on capital assets rather than operational expenditure. In practice, evidence suggests that a balance is made between the level of capital expenditure within a price control period and future regulatory returns.

Embedded generators are generally required to pay the full costs of connecting to a DNO's network. In this case the connection assets do not become part of the regulated asset base until the asset is replaced by the DNO at the end of its asset life. This, taken with the other incentives discussed below means that embedded generation is rarely considered as an option within the network design process.

4 The 2000 – 2005 price control

In the DPCR that concluded in December 1999, Ofgem considered the treatment of capital and operational expenditure separately.

4.1 Operating expenditure

Two complementary methods were used to assess efficient levels of operating costs for each company.

Firstly, they used regression modelling to introduce the concept of the 'efficiency frontier'. This plotted the operational expenditure by DNO, taking some account of company size (50% customer numbers and 25% for each of units distributed and circuit length). OFGEM drew the frontier in line with their estimate of the fixed costs of a distribution business (with zero size) and the most efficient DNO. They then estimated how much every other DNO was from the frontier and estimated how inefficient each company was relative to a notional 'most efficient' company.

Secondly, Ofgem employed a consultant to assess the efficiency of each company based on the underlying cost reductions achieved since 1994/95, benchmarking of the cost of performing the main distribution activities (e.g. cost per kilometre of network) and also supporting analysis of human resources and IT costs.

Ofgem took the lesser reduction from the consultants' work and the regression analysis in determining operating costs allowances for each company for the next price control period. They also determined that high cost companies should move three quarters of the way to the frontier by 2001/02 and then retain that position relative to the frontier. This means that the incentive on DNOs is to spend as little as possible on operating costs.

4.2 Capital expenditure

Ofgem employed consultants to examine capital expenditure over the previous price control period (1995-2000) and to considering appropriate levels of capital expenditure for the forthcoming period.

The review of expenditure over the previous price control period considered the accuracy of companies' 1993 and 1995 forecasts, whether there was evidence of unnecessary or inappropriate expenditure, to what degree companies had been able to reduce expenditure through increased capital efficiency and whether quality of supply levels had been affected by companies' spending behaviour.

In making projections for the level of capital expenditure for each company for the forthcoming review period Ofgem's overall aims were to ensure appropriate levels of quality of supply at the lowest overall cost to customers; whilst incentivising capital efficiency and hence reductions in overall cost levels.

The capital expenditure allowances made for the current price control period did not include consideration of any increased requirements or costs resulting from the government's renewable generation targets.

4.3 Information and Incentives Project

In the final proposals of the price control review, published in December 1999, Ofgem confirmed its intention to introduce an additional incentive mechanism from April 2002. The objective is to incentivise the delivery of agreed levels of customer service and, for the period 2002 – 2005, it has pegged this incentive at +/- 2% of revenue.

Ofgem has initiated a programme of work to develop and introduce this incentive and also to address some of the weaknesses associated with the existing framework of price regulation. This programme is called the "Information and Incentives Project" (IIP). The objectives of IIP are to:

- strengthen the incentives on PESs to deliver the agreed quality of output and to place a value on changes in the quality of output
- improve the incentives to achieve efficiency savings throughout the control period and in a way which minimises distortion between operating and capital expenditure
- reduce regulatory uncertainty and risk by increasing openness and transparency between reviews as well as at the time of reviews.

5 DNO cost drivers

The DNOs fundamental cost driver is in maintaining sufficient network to meet maximum demand. The number of units delivered is used as a proxy for maximum demand (with a 25% weighting in the regression modelling) when establishing the costs of providing a network. The DNO revenue driver is also based on units delivered, with a 50% weighting.

Since the units delivered are measured at customer exit points, embedded generation as such does not affect application of the units proxy. However if the generation is used to offset a customer’s on site demand, the number of metered units will reduce. In such cases an increase in the amount of embedded generation reduces the linkage between maximum demand and units for both the cost and revenue drivers, and reduces DUoS income.

6 NGC charges

NGC transmission charges cover three cost areas:

6.1 Connection point assets

Connections are required for directly connected generators and Grid Supply Points (GSPs) for large loads or distribution networks. The charges for these connection points mainly comprise an amortisation of the connection asset and are payable whilst the assets are in service. A termination charge is payable if the connection is terminated prior to the end of their life. Connection charges for GSPs are levied on DNOs and passed through to their customers.

6.2 Transmission infrastructure

All customers share the costs of providing the transmission network infrastructure via the Transmission Network Use of system (TNUoS) charge. The TNUoS tariff is locational and seeks to reflect the incremental costs of reinforcement required for use of the transmission system in these areas. They are levied on directly connected and large embedded generator power stations on the basis of their maximum output and on suppliers on the basis of their average half hourly maximum demand on each ‘triad’ days and non half hourly metered energy provided between 1600 and 1900hrs between November and March.

6.3 Provision of balancing services

Balancing costs are those incurred by NGC in its role of system operator. These include the costs of providing ancillary services (frequency response, reserve, reactive power and black start), resolving constraints and balancing between any deficit or surplus between generation and consumption in the wider market. The charge, called Balancing Services Use of System (BSUoS) charge is levied on both generators and suppliers according to the volumes traded in the market.

7 Losses

DNOs have an incentive to reduce losses within the price control formula. This results in companies being rewarded or penalised based on the historic trend in losses on their network. Any losses that are reduced as a result of distributed generation are netted out of the calculation. Losses are also impacted by many factors which are outside of the DNOs' control.