Programme Area: Energy Storage and Distribution

Project: Network Capacity

Title: Barriers to Deployment; and Environmental & Social Impacts of Deployment

Abstract:

This report assesses the barriers to the development and deployment of each of the Flexible AC Transmission System technologies considered, including both technical and supply chain issues, and identifies some potential solutions.

Context:

The Network Capacity research project identified and assessed new technology solutions that could enhance transmission and distribution capacity in the UK. It assessed the feasibility and quantified the benefits of using innovative approaches and novel technologies to provide improved management of power flows and increased capacity, enabling the deployment of low carbon energy sources in the UK. The project was undertaken by the management, engineering and development consultancy Mott MacDonald and completed in 2010.

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The ETI Energy Storage and Distribution Programme

- Network Capacity Project

Work Package 1 Task 4&5 Final Report
Barriers to Development, and Social and Environmental Impacts of FACTS Devices in UK Grid

August 2010
The Energy Technologies Institute (ETI)

Mott MacDonald

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02	5th August 2010	R. Ball RayBall	M. Scutariu	R Ball RayBall	ETI amendments incorporated.

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Content

1. Summary

1.1 Background

Mott MacDonald has been commissioned by the Energy Technologies Institute (ETI) to carry out the ETI's Network Capacity Project. This project is aimed at supporting the ETI's overall goal of accelerating the deployment of technologies that will help reduce greenhouse gas emissions and thus help achieve climate change goals. Specifically the project will assess the feasibility of two potential areas of development to improve the operation and increase the capacity of the UK onshore T&D systems. The outcome will be a thorough, coherent and well presented analysis that will enable the ETI to make informed decisions as to where future work in the programme should be directed.

- The first area of the project is focussed on the feasibility of applying new and existing power electronic technologies to provide enhanced management of network power flows in order to release more capacity within the T&D system.
- The second area concentrates on the technical feasibility of multi-terminal HVDC in the context of operation within the existing UK T&D system.

The work associated with both areas comprises an assessment of the credible options from these technologies in the context of power flow management including the benefits and also associated impediments to their development and deployment, and will provide guidance in respect of technology development opportunities. The work has been structured into two packages;

- Work Package 1 concentrates on the novel technologies with the potential to release capacity in the UK T&D networks. The work in this package comprises a literature review and modelling of the various technologies integrated into the networks to determine their effectiveness and requirements for such integration. It will also include analysis of environmental and social impacts, and of the barriers to development and deployment.
- Work Package 2 concentrates on the use of multi-terminal HVDC transmission and its integration within the existing UK T&D networks. The work in this package will comprise a feasibility assessment and detailed modelling of multi-terminal HVDC to assess its performance, impact and potential interactions arising from its use. It will also include analysis of the requirements for such integration, the benefits case for conversion of existing AC lines, and of the barriers to development and deployment.

1.2 Work Package 1 Task 4 and 5 Final Reports

Mott MacDonald's final report on the barriers to the development of FACTS devices in the UK Grid covered by the Work Package 1 Task 4 Scope of Work is included as Appendix A. Mott MacDonald's report on the Environmental and Social Impacts of FACTS devices in the UK Grid covered by the Work Package 1 Task 5 Scope of Work is included as Appendix B. The reports incorporate amendments that have been made in response to ETI comments received on the draft reports submitted in April 2010.

The reports are provided as separate stand-alone documents at this stage. The final report for the project consolidates and updates the outputs from each of the individual task reports, including that covered by this document, in order to provide a coherent output that represents the integrated output from all of the work carried out.

Appendices

Appendix A. Barriers to Development of FACTS Devices in UK Grid

ETI Network Capacity Project

Work Package 1 Task 4: Barriers to Development of FACTS devices in the UK Grid

August 2010
Energy Technologies Institute (ETI)

ETI Network Capacity Project

Work Package 1 Task 4: Barriers to Development of FACTS devices in the UK Grid

August 2010

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1	30/04/10	Douglas Ramsay	Paul Fletcher / Sarajit Banerjee	Paul Fletcher	Draft Issue for Comment
2	06/08/10	Douglas Ramsay	Ray Ball	Ray Ball	ETI comments incorporated.

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Content

1. Introduction

This report will consider the barriers to developments of FACTS (Flexible AC Transmission Systems) in the UK transmission and distribution network. The FACTS technologies considered in this report are Static Var Compensators (SVC), STATCOMs and Thyristor Controlled Series Compensation (TCSC). For completeness, outline details of the designs and application of these FACTS devices are given in this report. More comprehensive details are given in the Work Package 1: Task 1 (WP1T1) report.

This report will assess the boundaries for utilisation and development of each of these FACTS technologies individually, including:

- the ability of the industry to commercially deliver the technologies,
- any potential supply chain issues,
- barriers to the device rating or widespread use,
- the reasons – if any – for the lack of application in the past,
- any operational issues the technologies may introduce, and
- investigate potential solutions to the issues raised above.

In addition to the FACTS devices, this report will explore the related issues of coordinated control of quadrature (or quad) boosters in a network and the barriers for utilisation and development of active management of the transmission network. Active network management covers a range of subjects including: demand side management dynamic thermal ratings and power flow management (through special protection schemes). These subjects are discussed in detail in the Work Package 1: Task 2 (WP1T2) report.

It should be noted, that this report will not consider any of the barriers for development of HVDC technologies, these will be considered in the Work Package 2: Task 4 (WP2T4) report.

2. Shunt Compensation

Shunt compensation equipment exists in number of forms including; fixed compensation equipment, Static Var Compensator (SVC) and Static Compensator (STATCOM) systems.

Fixed compensation equipment is found in the form of passive elements - such as capacitors or shunt reactors (inductors) - in many applications these can be switched in and out of the network using circuit breakers. These are not FACTS devices but may be combined with STATCOM or SVC devices in cases where full control of output is not required, to reduce costs, footprint and maintenance requirements.

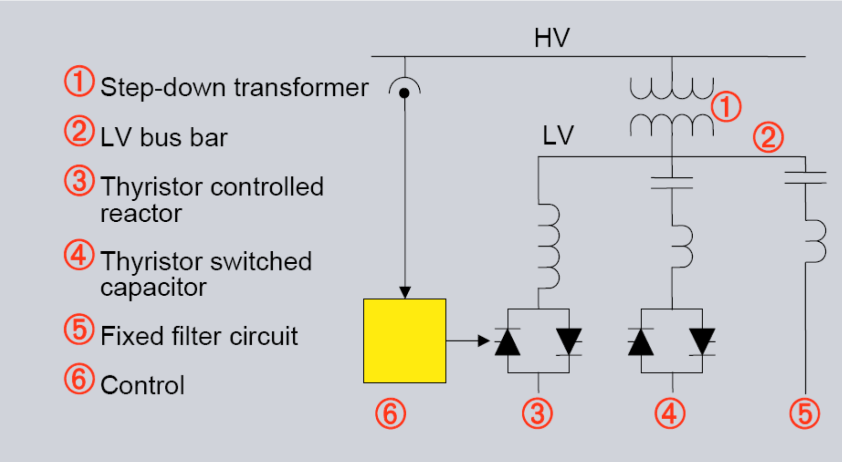
Both capacitors banks and reactors are mature and established technologies that have been applied to all voltages in the UK network; as such there are no major technical barriers to their further deployment.

2.1 Static Var Compensation (SVC)

The Static Var Compensator (SVC) is based on conventional capacitor and reactor modules connected in parallel. These modules can have their output controlled by a thyristor controller, or can be fixed (permanently connected). Fixed elements are often used as harmonic filters. The modules are generally connected to a medium voltage (MV) busbar with a typical operating voltage in the range 13 to 36 kV. The MV busbar can be connected to a higher voltage network using a dedicated transformer or through the third winding of a system transformer. Figure 2.1 and Figure 2.2 show typical configurations of SVCs.

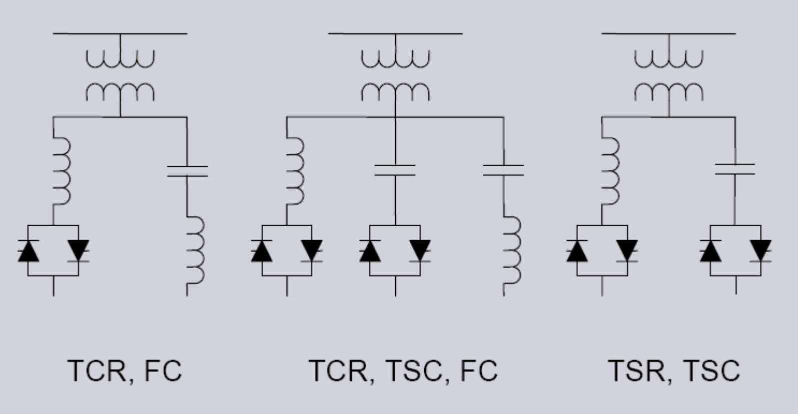
SVCs have been available since the 1970s and have been successfully applied on the UK transmission system for over 20 years providing an output range of up to 225 Mvar per unit. They are considered as conventional technology that has been proven practically.

Figure 2.1: Typical configuration of an SVC



Source: Reynolds, Mark – Siemens – IEEE San Francisco Power Engineering Society (PES), “Application of New Technologies for Power Transmission Systems”, June 2006

Figure 2.2: Common connections of SVCs



Source: Reynolds, Mark – Siemens – IEEE San Francisco Power Engineering Society (PES), "Application of New Technologies for Power Transmission Systems", June 2006

2.1.1 Requirements for SVC

The Work Package 1: Task 3 (WP1T3) study indicated that the size of an SVC required to enhance the UK network capacity would have a controllable output range of up to 900 Mvar (±450). SVCs are shunt devices and as such there should be no major technical barriers to increasing the size of the device, essentially connecting four SVCs rated at 225 Mvar in parallel could provide 900 Mvar. Furthermore very large SVCs such as the 720 Mvar (+575/-145) unit at Black Oak in the USA have been installed outside the UK.

To be utilised in the UK network, a large SVC will be required to connect to voltages up to 400 kV. This is not a technical barrier as a transformer is used to step up the SVC voltage (13 to 36 kV as noted above) to the system voltage.

2.1.2 Technical Barriers to Adoption

The SVC is regarded as a conventional and established technology in the UK and has been used in both EHV (400/275kV) connected applications and at lower voltage ratings.

We do not envisage any significant issues in extending the application of equipment of this type; however the following issues may need to be considered:

2.1.2.1 Control

Where two SVCs (or any combination of shunt connected compensation equipment) are connected in the same area, the output of one device may influence the other. This introduces an issue of coordinating control.

The manufacturers have developed control designs, which have been successfully implemented in the UK where many SVC installations are provided as 'pairs' and operation is coordinated with mechanically switched compensation in the immediate vicinity through Automatic Reactive Switching (ARS) schemes. However, it will be necessary to confirm that the higher levels of compensation envisaged in this study do not result in undesirable control interactions.

2.1.2.2 Transformer Size

The rating of the step-down transformer required for a SVC will be dependent on the SVC operating range (e.g. a 450 Mvar controllable range SVC could be configured to provide +/- 225 Mvar or +450/-0 Mvar) but is not anticipated to present a significant design challenge. However, it should be recognised that single unit ratings in excess of around 500 Mvar may lead to transport problems for three-phase transformers and necessitate the adoption of single phase designs.

2.1.2.3 Footprint

The footprint of SVCs is a particular problem with very large areas required (up to double that of a similarly rated STATCOM). This is likely to remain a major issue, particularly with the large rated SVCs envisaged. However, it should be noted that the land area required is not directly proportional to rating.

It is possible to adopt ‘compact’ design configurations (for example, the +150/-106 Mvar SVCs at St Johns Wood substation occupy a relatively small footprint), however this can be expected to increase costs and may not be appropriate to a rural environment.

2.1.3 Supply Chain Issues

The major European transmission equipment manufacturers (ABB, Areva and Siemens) offer SVCs for transmission applications and have previously all supplied to the UK. Other Suppliers outside Europe have produced SVCs but have a limited UK track record.

The non-active components of SVCs (e.g. capacitor banks, air cored reactors, switchgear, instrument transformers, surge arresters etc) are commonly found in conventional substations and are manufactured in significant volumes around the world. There do not appear to be any major technical barriers to increasing production to meet future demand for SVC technology.

Although the application of SVCs in transmission systems is still relatively uncommon, scaling up the production of thyristor switching modules is also not seen to be a significant issue. The modules are assembled using components supplied from the semiconductor industry, production of which could be readily scaled up. Assembly and testing is on a module basis and does not require significant capital investment in plant. Furthermore, capacity available in other parts of the power electronics industry (e.g. rail traction) could readily be utilised to increase production.

The European manufacturing facilities for large power transformers has been under pressure in recent years (following a long period of rationalisation to address overcapacity in the industry). This has resulted in lead times in excess of two years from order to delivery. We anticipate that this position will ease in the immediate future due to new capacity coming on stream in Europe and transfer of production to other facilities outside Europe. Consequently the availability of transformers is unlikely to be a barrier to adoption of SVCs

In our view, the major supply chain barrier to widespread adoption of SVCs is the limited availability of specialist engineering resources to design, install and commission these equipments. Due to the relatively low order base, scaling up capacity will be challenging and may take some time to deliver results. Furthermore, many of the skills that are relevant to SVC design are liable to be reassigned to HVDC transmission projects to help meet the expected demand in this area.

In addition to increasing the level of specialist engineering resources, the lack of engineering skills could be partly addressed if the UK were to adopt a ‘standard’ SVC design that could be applied anywhere on the system without significant project-specific design. Such an approach has already been adopted by NG, albeit for different reasons, in the procurement of re-locatable SVCs. Rather than being customised to a specific application, these were designed to a worst-case specification allowing them to be relocated in future to other parts of the network without modification. Although equipment costs would be increased by a standardisation policy (since the design would not be optimise for the application), there would be a saving in engineering costs and procurement lead times could be reduced.

2.2 STATCOM

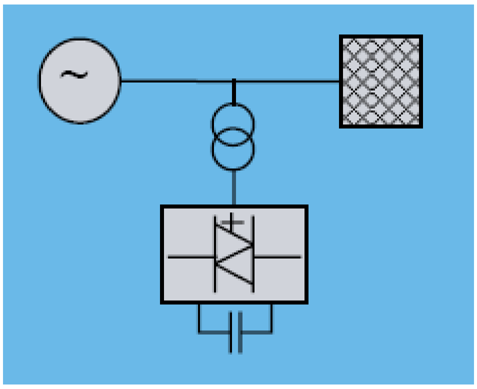
The STATCOM is effectively a static synchronous compensator based on Voltage Source Converter technology (VSC), using power electronic switches to derive an approximately sinusoidal output voltage from a DC source. The switching technique may be based on Insulated Gate Bipolar Transistors (IGBTs) or Gate Turn-Off Thyristor (GTO), although all the manufactures now use IGBTs.

The STATCOM couples to the network through a transformer. The STATCOM can absorb and provide reactive power by varying the device output voltage to be either higher or lower than the system voltage.

STATCOMs have two basic designs, neither of which has yet gained market domination. One uses pulse width modulation and the other uses a multi level switching approach to produce the intended voltage. The pulse width modulation design is used by ABB in their “SVC Light” device while Siemens use the multi level design and call their device “SVC Plus”. Areva (soon to be Alstom) are developing a multi level device.

Figure 2.3 shows a typical configuration of a STATCOM device.

Figure 2.3: Typical configuration of a STATCOM



Source: Reynolds, Mark – Siemens – IEEE San Francisco Power Engineering Society (PES), “Application of New Technologies for Power Transmission Systems”, June 2006

2.2.1 Requirements for STATCOM

Similarly to the SVC technologies, the Work Package 1: Task 3 (WP1T3) study indicated that the maximum size of an STATCOM required for the UK network would be 900 Mvar (±450 Mvar). Again similar to SVC technologies, STATCOMs are shunt devices and capacity can therefore be increased by connecting multiple systems in parallel.

Presently the largest STATCOM installed in the UK is a +225/-0 Mvar device installed at East Claydon. This was designed in the late 1990’s and is based on a multi-level topology and GTO switches. However, the VSC inverters used in a STATCOM are very similar in design to VSC HVDC devices (essentially a STATCOM is the inverter/rectifier end of a VSC HVDC converter connected in shunt to the network). The largest VSC HVDC device order to date in the UK is the East - West interconnector; connecting the Irish network to Wales; which is due to be installed in 2012, and will be rated for ±500 MW.

2.2.2 Technical Barriers to Adoption

STATCOMs have been applied commercially for over 20 years, although the scaling up to transmission power levels has only been achieved relatively recently. It is therefore a less mature technology than that applied in SVCs.

The following issues would have to be addressed if this technology were to be considered for widespread adoption on the UK system:

2.2.2.1 Maturity

The use of STATCOMs is starting to increase with a number units ordered for UK projects, such as London Box wind farm. Nevertheless, with the exception of NG's East Claydon installation, experience with these devices is quite limited. This is particularly true of the higher power ratings that would be required to deliver the increased system power transfers considered by this study.

Further development will be required to achieve a proven ±450 Mvar STATCOM.

2.2.2.2 Losses

Current STATCOM technology incurs higher losses than an equivalent SVC. Whilst this may not represent a barrier if the STATCOMs are to be normally operated close to 'float' condition (0 Mvar output), loss capitalisation would be a significant factor in the commercial evaluation in other situations.

It is anticipated that developments in IGBT devices and commutation schemes will bring down STATCOM losses over time. ABB is for example working on a 4th generation HVDC 'Light' which claims to have lower losses than its current device, and the Siemens MMC (Modular Multi Level) converters avoid the use of high frequency PWM switching schemes, thus reducing losses through a change in commutation scheme. Overall there are strong drivers in general for positive developments in IGBT technology to facilitate wide scale requirements for VSC HVDC (including multi terminal applications).

However even considering the above, IGBT devices (and thus current and near future STATCOMs) can be expected to have higher losses than an equivalent SVC in the short to medium future. This is because switching losses dominate the overall losses, and IGBT devices would always have higher rates of switching than thyristor devices such as SVC (as thyristor devices will only have a switch on operation once per cycle). There is slight counter balancing by the losses incurred in the capacitors and inductors of the SVC, but the overall statement is still expected to remain accurate for the near future.

2.2.2.3 Costs

In addition to loss capitalisation, the cost of a STATCOM is understood to be between 120% and 150% of the cost of a similarly sized SVC device. In the past in the UK STATCOMs have generally only been installed where an SVC device is not practical, such as where the space available is limited. There are also technical motivations to prefer STATCOMs over SVC devices such as the lack of resonant effects, ability to aid fault ride through performance and the higher controllability of output; however, historically in the UK, the main motivation for the use of STATCOM has been the smaller footprint.

The cost of installing a STATCOM may be reduced by the development of higher powered IGBTs which would reduce the number of components and hence project cost. It is likely that the cost of STATCOMs would also be reduced by a more wide spread application of these devices worldwide as this will introduce more economies of scale and competition into the market. This may occur as multi-terminal HVDC is developed.

2.2.2.4 Control

STATCOMs will have the same issues with coordinated control as identified for SVCs; these were discussed in Section 2.1.2.1.

2.2.3 Supply Chain Issues

As mentioned in Section 2.2, ABB and Siemens have commercially available designs “SVC Light” and “SVC Plus” respectively. Areva (soon to be Alstom) are presently developing a STATCOM that is anticipated to be commercially available relatively soon.

STATCOMs have gained some market share in North America where American Superconductor offers a modular STATCOM under the name: “D-VAR”. However, the limited rating of the D-VAR would currently preclude its use in high-power applications.

Other supply chain issues are as for SVCs (see Section 2.1.3).

3. Series Compensation

Series compensation equipment is generally fixed or thyristor controlled/switched.

Fixed compensation equipment is found in the form of passive elements - such as capacitors and reactors. These are not FACTS devices but may be combined with thyristor controlled devices in cases where full control of output is not required, in order to reduce costs, footprint and maintenance requirements.

Both capacitors banks and reactors are mature and established technologies that have been applied to all voltages in the UK network; as such we do not envisage any significant technical barrier to their further deployment.

The only series FACTS device considered in this report is the Thyristor Controlled Series Compensation (TCSC). This device is considered to offer the most potential to allow additional generation to connect.

It should be noted that, there is a high level discussion of small sized Distributed Static Series Capacitors (DSSC) in Work Package 1: Task 2 (WP1T2)

3.1 Thyristor Controlled Series Compensation (TCSC)

Generally, the majority of the series impedance in a transmission line is due to inductive reactance. Thyristor Controlled Series Compensation (TCSC) devices are used to introduce capacitive reactance into the line and hence reduce the overall line series impedance.

TCSCs use a capacitor circuit connected in series with a line. The capacitor is then paralleled with a Thyristor Controlled Reactor (TCR), to provide a smoothly variable series capacitive reactance. This control of the capacitive reactance allows the line impedance to be controlled. This offers the chance to control load flow in a network and hence fully utilise line capacities.

3.1.1 Requirements for TCSCs

TCSCs are generally installed with series capacitors as part of a larger compensation scheme; this means that only a proportion of the series compensation is controllable. The controlled proportion of series compensation is installed not only to offer control of power flow, but also to avoid sub-synchronous resonance.

The TALA transmission scheme in India has two 110 Mvar TCSC devices connected to a line rated for 400 kV, and for a current of 3200 A. It has not been determined if TCSC with larger currents ratings are possible. The TALA transmission scheme is comparable with some high rated lines in the UK and as such there should be no technological barriers to installing similar TCSC devices in the UK network. For lines with higher currents, as is the case with National Grid 400kV 'L6' type lines which can have post-fault continuous ratings of greater than 5000 A, this is an issue that will require further consultation with the manufacturers.

3.1.2 Technical Barriers to Adoption

TCSCs have been applied commercially for 20 years, although the number of developments has been limited. There have been no installations in the UK network. The UK is a relatively small country with a dense population; this has resulted in power stations being located near to one another and relatively near to load centres. This has meant that, by international standards, the UK does not have very long transmission lines and as such there has been no requirement for TCSCs in the UK network. This may change as new generation technologies are sited further from load centres.

The following issues would have to be addressed if this technology were to be considered for widespread adoption on the UK system:

3.1.2.1 Maturity

As mentioned above, there have not yet been any TCSCs installed on the UK network and as such experience with these devices is quite limited. Also mentioned in Section 3.1.1, the highest rated lines in the UK exceed the current ratings of any TCSC currently installed.

3.1.2.2 Control

TCSCs are used to control the power flow in a line. In a complex transmission network, such as the UK, there are many parallel paths for current to travel; TCSCs can be used to control this. Where more than one TCSC is installed it will be necessary to coordinate the control to get the best balance of power flow.

This is not presently a major issue due to the limited application of series compensation devices around the world but this would change if TCSCs were to be installed more widely. The manufacturers have developed control designs but these have only been implemented in the case of two TCSCs connected to parallel lines. There is a lack of experience and willingness on the part of network operators to use more extensive automated coordinated control schemes for post fault (dynamic) conditions. The primary concern of the network operators is that the schemes will not be able to fully factor in all the complexities of the network. There are also concerns over the interaction with control centre staff and their maintaining a clear understanding of how the network and all connected devices will behave.

These barriers could be overcome by initiating pilot schemes for coordinated control in the first TCSCs installed. This would give the network operator experience and confidence in the coordinated control schemes.

3.1.2.3 Cost

Where TCSCs would offer advantages, the lack of application in the UK to date has been due predominantly to the cost and the required footprint. These have generally forced the network operator to select an alternative solution; this could be another parallel line, upgrading a conductor or installing a quad booster.

As with SVCs, the cost of these projects may be reduced by the development of higher voltage thyristors which would reduce the number of components and hence project cost. The development of Silicon Carbide based devices would offer high voltage devices operating at higher temperatures which would further reduce costs. It is likely that the cost of TCSC would also be reduced by a more wide spread application of these devices worldwide as this will introduce more economies of scale and competition into the market.

3.1.3 Supply Chain Issues

ABB and Siemens both offer TCSC devices, while Areva (Alstom) have delivered TCSC devices in partnership with General Electric (GE).

The non-active components of TCSCs are similar to those of the SVCs (e.g. capacitor banks, air cored reactors, switchgear, instrument transformers, surge arresters etc) albeit rated for higher currents. These components are found in conventional substations and are manufactured in significant volumes around the world. There do not appear to be any major technical barriers to increasing production to meet future demand for TCSC technology.

The thyristors used in TCSCs are similar to those used in SVCs. As mentioned in Section 2.1.3, scaling up the production of thyristor switching modules is also not seen to be a significant issue.

In common with SVCs, STATCOMs and other FACTS or HVDC technologies, the major supply chain barrier to widespread adoption of SVCs is the limited availability of specialist engineering resources to design, install and commission the equipment, this is considered further in Section 2.1.3.

3.2 Control of Quadrature Boosters

Quadrature phase shifting transformers – more commonly known as quad boosters – can be used instead of TCSCs to control power flow. Quad boosters control power flow by altering the phase angle of the voltage in a line, this is achieved by injecting a voltage in quadrature (90º) to the series (line) voltage.

A quad booster typically consists of two separate transformers: a shunt unit and a series unit. The shunt unit produces a voltage with a 90° angle to the series voltage. This is then applied to the series unit to provide the injection of voltage in quadrature. The magnitude of the quadrature component is controlled by tap changers connected to the shunt unit.

Quad boosters have been applied in the British network since the 1930s and as such can be considered to be a mature technology. However, the largest circuits in UK are now rated in excess of 3 GW, a rating of this type is problematic to achieve with wound technologies; this can be seen by the lack of transformers of this rating.

Regarding the control of quad boosters, where they are used for steady state voltage and power flow control there appears to be no issues with further deployment. However, there is little experience of coordinated control of post fault (dynamic) conditions. Similarly to TCSCs, network operators are reluctant to apply the technology in this way; this is discussed in Section 3.1.2.2.

4. Active Network Management

A detailed discussion of active network management appears in the Work Package 1: Task 2 (WP1T2) report. That report addressed barriers to the adoption of active network management, and for completeness the relevant content from that report is included in this report on barriers. The WP1T2 report breaks active management into the four categories:

4.1 Power Flow Management

Power flow management is primarily concerned with addressing thermal limits in transmission and distribution networks.

This may involve special protection schemes such as inter-tripping schemes where generation is taken out of service when flows exceed an acceptable level or when a line or transformer goes out of service. Other schemes use a more sophisticated approach where the output of generators is controlled. This represents a much more dynamic solution that requires real-time monitoring and control.

For deployment of power flow management across a transmission and distribution network, the principle barrier to deployment is in agreeing the commercial arrangements governing the curtailment of multiple generators due to multiple network constraints. This may require a reduction or limitation of payments to constrained generators in return for lower connection charges. A consistent approach for dispatching generation in a network using power flow management is required or this will act as an impediment to financing new generation; the rational being that if a generator is going to be subject to curtailment due to network constraints, this must be taken into account when assessing the financial viability of connection.

Generators of different sizes participate in the UK electricity market in different ways, as governed by regulations and industry-agreed frameworks. Active power flow management restricts the ability of a generator to sell its output freely as that output depends on network conditions and resultant constraints at any given time. The transmission and distribution networks in the UK, however, already impose constraints on generators and this is expected to increase as the 'Connect and Manage' philosophy will see more generators connect and a greater degree of constraint management.

The technologies and algorithms used in active power flow management at distribution level could be implemented at the transmission level to provide automatic generator management according to network constraints at any given time. At present ANM at transmission level requires far more measurement and manual supervision than is feasible at distribution level. To overcome this, complex algorithms are required to reduce the requirement for physical measurement and manual control. It is possible that, when these concepts have been proven at distribution level, they may be applied to transmission level.

Power flow management is particularly attractive in providing capacity for new intermittent renewable sources. However, it is likely to prove less attractive to non-intermittent sources looking for connection, as these generators are typically optimised for a specific generation output and will lose efficiency if constrained.

There is also a lack of experience on the part of network operators. The primary concern of the network operators is that the schemes will not be able to fully factor in all the complexities of the network. There are also concerns over the interaction with control centre staff and their maintaining a clear understanding of how the network and all connected devices will behave.

Network protection remains an issue for introduction of ANM, the majority of distribution in the UK is radial with graded O/C and earth fault protection, often with no facility for remote tripping.

The introduction of distributed generation will introduce issues related to detecting fault currents from 'weak' distributed generators, this will be particularly pertinent if the system may be islanded. In order to allow ANM it will be necessary to introduce some form of DG fault behaviour regulation to ensure that faults are detected and islanded operation is possible.

In addition where a fault occurs 'up stream' of a generator in a radial network it would be useful if the closest breaker to the fault tripped before a breaker nearest the generator – this may be difficult to ensure with conventional O/C protection. There are a number of potential solutions such as directional O/C or differential protection on the generator connection or inter-tripping on each feeder circuit and this will need investigation. CIGRE study committee B5 is investigating these issues.

These barriers can be overcome with:
- Pilot projects for providing experience and confidence
- Development and adoption of flexible industry standards and frameworks – particularly with regard to the connect of intermittent generation
- Development of tools for facilitating planning and associated studies

4.2 Dynamic Thermal Ratings

Dynamic thermal ratings covers a group of technologies aimed at monitoring conditions on the network and calculating component ratings in real time. The conventional approach is to calculate component ratings based on conservative assumptions, particularly for environmental conditions. National Grid uses a three season model, with most DNOs using a summer and winter rating.

Real time power system component temperature is measured directly or estimated through the measurement of indirect parameters such as electric resistance or weather conditions. The software used for managing the system can also take into account each component's thermal behaviour, introducing additional flexibility, especially for electric cables and power transformers.

Dynamic ratings allow improvements in asset utilisation, expanding the power flow transfer capacity according to real environmental conditions and component thermal state. Studies carried out at EPRI suggest that dynamic thermal rating could increase component current carrying capacity by an average of 10-15%. This can allow additional generation capacity to connect without having to reinforce or replace the existing network.

The main barrier to the application of dynamic thermal rating is the disruption to existing assumptions and methods in planning and operation of the network. Dynamic ratings introduce variability to a parameter that was previously considered constant and thus complicates system design and control. Wider adoption of the approach would be assisted by the development of a broadly accepted standard for operating the network with dynamically changing capacity.

Specific implementation barriers can arise with technical complications and cost due to the need for monitoring equipment and communications. The precise placement and configuration of measurement points can present considerable challenges.   It should be noted, however, that the sensors, communications and computational technology required for dynamic thermal ratings are available commercially. These difficulties could be mitigated by the further commercial development of dynamic thermal rating solutions integrated with current network technologies (e.g. SCADA, substation relays).

Two UK distribution network operators, E.On Central Networks and Northern Ireland Electricity, have developed their own line temperature monitoring systems.

4.3 Voltage Management

In a distribution networks the maximum acceptable voltage or step change can be a limiting factor on the capacity of generation. There are a number of ways in which voltage management can be improved to facilitate additional generator connections. The methods differ in the way voltages are measured and the way control actions are determined but all depend on modifying one of the following:

- The real power output of the generator, which has overlaps with power flow management
- The reactive power to/from the generator or ancillary equipment, such as reactive compensation
- The tap position of transformers or voltage regulators

Different methods of voltage management employ different types of calculation or logic, with network operators preferring those methods that are simple, easy to understand and robust to all possible conditions.

Generators must provide automatic voltage control as required by the Grid Code and Distribution Code as appropriate. At transmission level this is supplemented by human control in the National Grid control centre and this can be considered to be a mature technology. At distribution level control centre interaction with generators is more limited.

Barriers to deployment of active voltage management at distribution level include:

- The relatively tight range of acceptable voltages and the potentially large impact of generation
- The complexity of the relationship between voltages at different parts of a network and the output of connected generation
- The rate of change of voltage and speed of response required

These barriers have not prevented some voltage management schemes being deployed but restrict the wider adoption of these methods. The barriers can be mitigated with improvements in technologies for measurement, computation and communications.

The level of maturity and market risk depends on the method. Simpler methods based on local measurement and control of a single piece of equipment, such as on-load tap changing transformers, in-line voltage regulators and reactive compensation, are technically mature and readily available. More complex methods based on remote measurements and co-ordinating multiple resources are only at the trial and demonstration stage.

On-load tap changing transformers, in-line voltage regulators and reactive compensation are available from a large number of manufacturers. The capability of generators to alter their reactive power and contribute to voltage control depends on the specific technology but most modern wind turbines, for example, now offer voltage control capabilities.

4.4 Demand Side Management

Demand Side Management (DSM) involves altering or influencing the demand for electricity to achieve a particular objective. That objective might be to shift demand to other times, either to flatten the overall demand profile, make demand coincident with variable supply, or otherwise minimise costs associated with variations in supply and demand. Demand might also be modified to satisfy network constraints such as power flows and voltages.

Reducing congestion on lines and transformers by levelling loads would facilitate the connection of new loads and generators to the network. This would also reduce voltage problems. DSM is already used in frequency control and controlling load in correspondence to available renewable energy could contribute to maximising renewable energy contribution.

DSM requires a contractual agreement between the network operator and the user defining the amount of load that can be removed or assigned to the user, the modality of the control and tariffs and penalties applied.

Currently, there are a number of large DSM participants in system balancing in Great Britain contributing to frequency control and system reserve. DSM of this type is technologically mature and the major barrier for expansion is the limited number of loads available.

There is some scope for expanding DSM to mid-sized loads such as factories and supermarkets. These loads are typically connected to distribution networks at 11 kV. The major barriers for this are the need for a suitable communications and control infrastructure, the acceptance of DSM from customers and the appropriate commercial framework being in place.

The commercial arrangements are particularly problematic, with it being unclear how DSM will be dispatched between the DNO, the energy supplier and the customer. Test schemes may alleviate this issue.

Regarding smaller and domestic loads, the major barriers for this are again the need for a suitable communications and control infrastructure, the acceptance of DSM from customers and the appropriate regulation framework being in place. If these barriers are to be overcome, a wide-scale implementation of equipment with the capability for DSM (potentially smart meters) and also the installation of suitably controllable loads will be necessary. This in turn requires the development and adoption of appliances and industrial processes allowing a degree of flexibility in energy consumption. In addition to this, economic incentives such as tariffs that provide an incentive for customers to accept partially flexible consumption will be required.

DSM as part of the operation of a distribution network and to facilitate the connection of additional generation remains a proposed method and has not been deployed to a significant degree. It has been implemented in a number of island developments (discussed in the Work Package one, Task two (WP1T2) report).

4.5 Barriers to Active Network Management (ANM)

4.5.1 General Barriers

There are some general barriers to development of all the technologies considered above, these include:

- From the network operator's perspective
  - Conflict with established practice and business model
  - Additional work to assess suitability of ANM solution(s)
  - Additional work to offer ANM and reinforcement as alternatives options for generator connection
  - Additional analysis workload
  - Technical and commercial complexity
  - Devolving control of the power system
  - Unproven technology and techniques
- From the generator developer's perspective
  - Reduced energy production and hence revenues
  - Additional inaccuracies in revenue forecasting
  - Commercial complexity
  - Impediment to raising project capital due to perceived risks

These obstacles are not insurmountable but will require the modification of the commercial and regulatory framework of the electricity industry, particularly the business model for network operators. At present the commercial and regulatory framework restricts the development and widespread adoption of ANM. Network operators have little motivation to be early adopters of new technologies as their business model are not designed to take additional risk for additional benefit and the regulated rates of return offer few ways to earn extra money.

4.5.2 Bringing Active Network Management Technologies to Market

In order to advance ANM technologies from unique and infrequent trials to adoption as standard practice it is necessary to ensure ANM achieves the following:

- Offers technical certainty (which means incremental technology change)
- Allows a solution to develop and evolve gradually
- Fits with everyday practises and existing regulation
- Fits with organisation and operational drivers
- Helps fulfil license obligations
- Is commercially sensible
- Allows the network operator to earn additional income (which may be through access to regulated incentives)

This will require further research and development, prototypes, installation, testing and agreement of commercial arrangements for modular solutions.

In the UK, research and development is not part of the core business of network operators. In order to ensure that the research carried out in academic institutes is focused on the concerns of the network operators it is essential that network operators engage in collaborations with the academic institutes; this is what has been happening over the last five years or so.

Prototyping: research establishments rely heavily on modelling and simulation. Technologies must be taken beyond modelling and into prototypes for further development to take place. Prototyping is likely to require some involvement from commercial entities, whether it is manufacturers, suppliers or system integrators. This can present problems with Intellectual Property (IP) transfer as well as the technical challenges of implementing something entirely new and relying on someone who may not have been involved with the work previously.

Installation: installation of new equipment on an electricity network is likely to impose some disruption to the network operator's normal business. In some cases it may require an outage of part of the network. New equipment of some form is installed all the time so this does not present a significant barrier, but it may result in significant delays until the right people and opportunity are available.

Testing: extensive testing in models and laboratories is necessary before new equipment is installed on the network. Most equipment will also be subjected to factory acceptance testing. Depending on the type of equipment involved, testing facilities may be limited, although steps are being taken in the UK to address this limitation in capability.

Commissioning: before a new technology becomes accepted as ready for use by a network operator it will be necessary to go through a full commissioning process. This may involve additional training so personnel are familiar with the new technology and how it will impact on their activities. The new technology will have been designed to deal with a wide range of network conditions, many of which will only occur under unpredictable circumstances that cannot be deliberately introduced without sever disruption, e.g. under fault conditions. Thus, equipment will be installed and there will be an element of waiting to see whether it survives as different conditions arise over time.

Regarding the commercial arrangements, where a new technology has an impact on prevailing and preferred commercial arrangements then these must be settled before deployment can occur. These can take a considerable amount of time to resolve and may involve multiple parties. In extreme cases there may be a need for relaxation or changes to regulations. The developers of new technologies are unlikely to have the skills necessary to derive new commercial arrangements so other assistance may be required.

In addition Intellectual Property (IP) can become a barrier to development when multiple parties are involved and there is reluctance to release IP for use by others. This must be overcome by sensible arrangements between parties and some forward looking to try and understand possible IP issues before they arise. The transfer of technologies from research to implementation requires some sort of commercialisation and there are many models for achieving this.

The Low Carbon Networks Fund has the potential to address a lot of these issues and has the potential to advance the active network management technologies to market.

5. Discussion

The FACTS devices considered in this report; SVCs, STATCOMs and TCSCs, do not appear to have any major technological barriers to further utilisation and development. The major barriers for further utilisation are cost and footprint. Historically in the UK, the advantages offered by the FACTS devices have not, generally, been deemed to merit the high costs and large footprints required. However, this may change as more generation is sited far away from load centres. The requirement to control greater power flows over a larger transmission network will necessitate more voltage and power flow control equipment. It does not appear that cost of the systems will diminish greatly but some of the alternatives, such new lines, are increasingly more expensive and problematic.

These drivers and the likely expansion of HVDC may put a strain on the small core of engineers competent to design FACTS and HVDC devices. This may be mitigated by - increasing the number of competent engineer through training grants and subsidies - or reducing the need for engineers by moving to more modular design solutions. However, this is likely to remain an issue.

Each of the active network management technologies discussed in Section 4 have individual barriers to development but the largest general concern expressed by network operators is that of creating niche pockets of non-standard technology around the network and causing legacy problems. To overcome these issues it will be necessary to develop and demonstrate modular solutions that will allow staff to plan, design, maintain and operate ANM systems across the network in a standard manner, preferably not too dissimilar to current methods.

The use of ANM has the potential to change the operation of the transmission and distribution networks in the UK but it will be necessary to develop and adopt flexible industry standards and frameworks to allow this to occur.

Appendix B. Environmental and Social Impacts of FACTS Devices in UK Grid

ETI Energy Storage and Distribution Programme – Network Capacity Project

Network Capacity Project

Work Package 1 Task 5 Final Report - Environmental and Social Impacts

August 2010
Energy Technologies Institute

ETI Energy Storage and Distribution Programme – Network Capacity Project

Work Package 1 Task 5 Final Report
- Environmental and Social Impacts

August 2010

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Appendices

1. Introduction

1.1 Introduction

The Energy Technologies Institute (ETI) has commissioned Mott MacDonald to conduct a study to assess the feasibility of improving operations and increasing the capacity of the United Kingdom (UK) onshore Transmission and Distribution (T&D) systems by the application of power electronic technologies. The project is aimed at supporting the ETI's overall goal of accelerating the deployment of technologies that will assist in reducing greenhouse gas emissions and thus help achieve climate change goals. This report is focussed on the potential environmental and social impacts associated with the application of FACTS (Flexible AC Transmission Systems) covered by Work Package 1 of the project in the UK transmission and distribution network to provide enhanced network power flows and as a result release more capacity within the T&D systems. Potential impacts of HVdc schemes covered by Work Package 2 are addressed in the Work Package 2 reports.

1.2 Candidate Technology Options.

The technologies listed in Table 1.1 have been identified in earlier work as the preferred options to take forward for review. Options 1 and 2 require the addition of equipment to existing substations whereas Option 3 can be achieved either by placing equipment at either end of the line to be treated or by installing equipment at a new location midway along the line. None of the options being considered will entail remedial work on or along the transmission lines themselves.

Table 1.1: Candidate Technology Options

	Type	Name	Description
Option 1	Shunt Compensation	Static VAR Compensator (SVC)	Applied to specific locations on the grid (and may be applied to several locations in a zone to achieve a co-ordinated response). Requires equipment to be installed at the substation concerned
Option 2	As above	Static Synchronous Compensator (STATCOM)	As above
Option 3a	Series Compensation	Thyristor Controlled Series Compensator (TCSC)	Applied to a single line – Requires equipment to be installed at the substations at either end of the line.
Option 3b	As above	Thyristor Controlled Series Compensator (TCSC)	Applied to a single line – Required equipment to be installed at a new location in the middle of the line.

Although the technologies can be applied at the transmission or distribution level they are likely to be of most benefit at the transmission level. As such the majority of this report focuses on the impacts of adding equipment to existing transmission substations.

1.3 Traditional Capacity Extension

1.3.1 Introduction

The electricity transmission network in the UK is operated by three companies, National Grid (England and Wales), ScottishPower Transmission Ltd (Southern Scotland) and Scottish Hydro Electric Transmission Ltd (Northern Scotland). Apart from a small number of exceptions the electricity transmission network in the UK operates as an alternating current (AC) current system on voltages of 275 kV and 400 kV, and also

132 kV in Scotland. National Grid alone operates over 335 substations, 4500 miles of overhead line and 420 miles of underground cable.

Traditionally an extension to the network transmission capacity has required the construction of new overhead lines or underground cabling along with the associated substations. Projects like this are by their very nature complex as they cross large distances often over open countryside resulting in a large impacted area.

1.3.2 Overhead Line Pylons

High voltage transmission line pylons will be constructed from steel lattice. A variety of pylon designs are used depending on the terrain being crossed. They generally vary from approximately 40 to 50 m in height although they can be taller as is the case for the new Beauly to Denny line in Scotland.

1.3.3 Underground Cables

Underground transmission cables may be considered particularly in urban areas, areas of scenic importance or for other environmental reasons however they use does come with a significant increase in both capital and maintenance costs as well as a reduction in reliability

The trench required for the cable will be of a significant width in order to allow separation between cables to allow heat dissipation and to accommodate enough cables to carry the power. To match overhead line thermal performance for a 400 kV double circuit as many as 12 separate cables in four separate trenches may be needed.

Different technologies are available to provide insulation:

- Fluid impregnated paper insulated cables – most commonly used.
- Cross linked poly ethylene – simple cable construction. Higher voltages (275 and 400kV) installed in tunnels to protect from water penetration or damage by a third party.
- Gas insulated (SF6) – cables filled with nitrogen and sulphur hexafluoride gas (which is a greenhouse gas).

1.3.4 Substations

For technical and environmental reasons, transmission substations are generally located between the power generator and the transmission network or between the transmission and distribution networks.

The footprint of a transmission substation can vary from 2 -8 hectares, depending on the voltage and capacity of the line(s) it serves. Older air insulated substations were significantly larger than modern gas insulated versions and could be up to 20 hectares. Equipment found on site will include a control building, protection and control equipment, bus bars, switchgear (gas or air insulated, indoor or outdoors), transformers and circuit breakers.

1.4 New Technologies

1.4.1 Option 1: Static VAR Compensator (SVC)

The SVC is the oldest and most established technology to be reviewed in this study. Where it is considered that the system voltage requires additional control through the injection of reactive power, SVC equipment would be installed alongside the existing substation. SVC equipment requires a very large footprint which would effectively double the area occupied by the existing station. Visually the equipment would be similar to the existing substation and would reach a height of 6 to 8 metres.

Photo 1.1: -75/+150 Mvar SVC National Grid Lovedean Substation, UK.

Source: Courtesy of Areva

1.4.2 Option 2: Static Synchronous Compensator (STATCOM)

STATCOM systems are relatively new on the market, they are also known as SVC Light or SVC Plus. STATCOM systems also require additional equipment to be installed alongside the existing substation in order to regulate voltage however this option would only require around half the footprint of an SVC. A significant proportion of the STATCOM equipment will likely be contained within a building which would be a less significant visual impact than the SVC described for Option 1.

Photo 1.2: -100/100 Mvar 'Holly' STATCOM, Austin, Texas

Source: Courtesy of ABB

1.4.3 Option 3a and 3b: Thyristor Controlled Series Compensator (TCSC)

A TCSC system would require the smallest additional footprint of the three candidate options. The extra plant items will include capacitor banks and thyristor controlled reactors. The most notable feature, from a visual perspective, is that the equipment will be raised from the ground in order to isolate it. In the case of a 400 kV system the TCSC equipment would be raised a minimum of 3.1 m.

As with the SVC and STATCOM systems, TCSC will work by locating the additional equipment adjacent to the existing substations. This can either be at either end of the line to be controlled or, ideally, the equipment would be positioned in a new location somewhere in the middle of the line. Either option would have the same footprint as locating at either end of the line would only use half of the space (at each end) required for the mid line option.

Photo 1.3: Combined fixed capacitor/TCSC used for Rourkela -Raipur Interconnection (India). 394 Mvar fixed rating, and 71 Mvar for TCSC segment

Source: Courtesy of ABB Inc

2. Planning and Consenting

2.1 Planning for Traditional Capacity Increase

Traditional capacity expansion of the grid has often required major new developments such as a new overhead lines or underground cable along with the associated infrastructure (substations, access roads, pylons/joint bays). Such developments can be controversial meeting opposition from consultees and the general public.

All overhead lines above 20 kV require a Section 37 Consent under the Electricity Act 1989 which would be issued by the Secretary of State in England and Wales; or the Scottish Government in Scotland. A Section 37 consent also acts as deemed planning consent. Since 1 March 2010 all nationally significant infrastructure projects in England and Wales are dealt with by the Infrastructure Planning Commission (IPC) under legislation introduced in the Planning Act 2008. This includes all overhead lines of 132 kV or above. The IPC will issue Development Consent Orders which will replace the previous requirements of the Section 37 consenting regime. In Scotland the Section 37 consent from the Scottish Government will remain the consenting regime.

In addition to this, under the Electricity Works (Environmental Impact Assessment) (England and Wales) Regulations 2000 (or Electricity Works (Environmental Impact Assessment) Scotland Regulations 2000), a new overhead line will require an Environmental Impact Assessment (EIA) to be undertaken if the following conditions are met.

- Schedule 1
  - voltage of 220 kV or more and a length of more than 15 km.
- Schedule 2
  - voltage of 132 kV or more or an overhead electric line installed in a sensitive area,
  - the purpose of the overhead line is to connect to a power station that is itself subject to an EIA (this is a Scottish Requirement only).

An EIA will be required for all Schedule 1 developments and consultation with the Local Planning Authority (LPA) will determine if an EIA is required for a Schedule 2 development.

An underground cable would not require planning permission except potentially for joint bays which would be required approximately every 500 to 800m. Joint bays are not likely to be intrusive and as such would not be likely to attract opposition. As good practice an environmental assessment should be made as part of the route determination process.

2.2 Planning for Candidate Technologies

The candidate technologies being assessed in this report enable the grid operators to increase the line transmission capacity without having to build a new line. All the options require either an extension to existing substations or an additional substation midway along a line (option 3b), none of which require an EIA to be undertaken under UK legislation but all of which will require planning consent. However although an EIA is not a legal requirement, all three transmission network operators have a policy to carry out a degree of environmental assessment, the results of which will accompany the planning consent application. This is discussed further in Section 3.

Planning consent will be granted by the LPA under the Town and Country Planning Act (England and Wales) 1990 as amended by the Planning Act 2008 or in Scotland under the Town and Country Planning Act (Scotland) 1997 as amended by the Planning Etc (Scotland) 2006.

2.3 Designated Sites

Within the UK there are numerous designated areas which have been afforded legal protection in order to preserve their existing character or the ecological systems present within them. Development in designated areas is often guided by the need to preserve any protected features within the area and to support the overall aims of the overarching designation. As such, this does not necessarily preclude development within their boundaries but does discourage it.

Table 2.1 gives a summary of the major site designations that would be considered when determining the location of a substation.

Table 2.1: Designated Sites

Significance	Name	Description
International	World Heritage Site	Highlights the outstanding international importance of the site as a key material consideration to be taken into account by LPAs in determining planning applications, and by the Secretary of State in determining cases on appeal or following call-in.
	Ramsar Site	Designated under the Convention on Wetlands of International Importance for their importance to water birds
	Special Protection Areas (SPAs) and Special Areas of Conservation (SACs)	Designated for their importance to ornithological interests and endangered or vulnerable habitats and species, respectively. These sites form part of a wider network of sites designated under the European Natura 2000 programme and are designed to form a European Union (EU) wide network of protected areas to maintain and restore the abundance of species and habitats of Community interest.
National	National Park	Defined areas of the countryside that have been given strong protection under legislation and the planning system for the conservation and enhancement of their special qualities.
	Site of Special Scientific Interest (SSSI)	Nationally recognised sites providing statutory protection for flora, fauna, or geological or physiographical features.
	Areas of Outstanding Natural Beauty (AONB)	Designation that aims to conserve natural beauty, including wildlife, physiographic features and cultural heritage as well as the more conventional concepts of landscape and scenery. AONBs have equivalent status to National Parks with regards conservation value. They are managed by local authorities, organisations, community groups and the individuals who live and work within them or who value them.
	National Nature Reserves (NNR)	Designated at a national level with the aim of securing protection and appropriate management of the most important areas of wildlife habitat, and to provide a resource for scientific research. All NNRs are also designated SSSIs and therefore afforded an equal protection status.
	Scheduled Ancient Monument (SAM)	Scheduling as an ancient monument represents the only legal protection specifically designed for archaeological sites.

Significance	Name	Description
	Ancient Woodland (AW) and Semi Natural Ancient Woodland (SNAW)	Recognises a valuable biodiversity resource both for its diversity of species and for its longevity as woodland.
	Listed Building	Consent for works which affect a Listed Building must give special regard to certain matters, including the desirability of preserving the setting of the building.
	Gardens and Designated Landscapes (GDL) and Historic Parks and Gardens	Gardens, parks and landscapes that are considered valuable assets at national, regional and local level.
Local	Local Nature Reserves (LNR)	Areas which are locally important for nature conservation, however these are not necessarily of national importance. As such, there is no legal necessity to manage a LNR to any set standard however some form of management agreement often exists.

3. Site Selection Guidelines

3.1 Introduction

The approximate location of a substation is initially determined by transmission networks requirements such as the requirement to connect a new power generating station. When determining the precise location and design, the grid operators are assisted by in-house guidelines. These guidelines are used to design a suitable substation which takes into account technical feasibility, consentability, financial and environmental aspects.

The implementation of these guidelines will ensure that the transmission license holders meet their obligations under Schedule 9 of the Electricity Act 1989 which requires them to:

- have a regard to the desirability of preserving natural beauty, of conserving flora, fauna and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interests; and
- do what they reasonably can to mitigate any effect that the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects.

The following sections outline the guidance used by National Grid (NG), ScottishPower Transmission Ltd (SPTL) and Scottish Hydro Electric Transmission Ltd (SHETL).

3.2 National Grid

3.2.1 Holford Rules – Overhead Line Routing

NG owns the electricity transmission network in England and Wales and operates the electricity transmission system throughout Great Britain.

Broad principles for routing overhead lines were developed by Lord Holford in 1959 and later clarifications added by NG in a 1992 review. These principles, known as the Holford Rules, have been accepted by the all the transmission operators (NG, SPTL and SHETL) as the guiding rules when designing overhead line routes. The rules are as follows:

1. Avoid altogether, if possible, the major areas of highest amenity value, by so planning the general route of the line in the first place, even if the total mileage is somewhat increased in consequence.
2. Avoid smaller areas of high amenity value, or scientific interest by deviation; provided that this can be done without using too many angle towers, ie the more massive structures which are used when lines change direction.
3. Other things being equal, choose the most direct line, with no sharp changes of direction and thus with fewer angle towers.
4. Choose tree and hill backgrounds in preference to sky backgrounds wherever possible; and when the line has to cross a ridge, secure this opaque background as long as possible and cross obliquely when a dip in the ridge provides an opportunity. Where it does not, cross directly, preferably between belts of trees.
5. Prefer moderately open valleys with woods where the apparent height of towers will be reduced, and views of the line will be broken by trees.

6. In country which is fiat and sparsely planted, keep the high voltage lines as far as possible independent of smaller lines, converging routes, distribution poles and other masts, wires and cables, so as to avoid a concatenation or ‘wirescape’.
7. Approach urban areas through industrial zones, where they exist; and when pleasant residential and recreational land intervenes between the approach line and the substation, go carefully into the comparative costs of undergrounding, for lines other than those of the highest voltage.

More detail on the Holford rules can be found in Appendix Appendix A. It should be noted that the Holford Rules that apply to the routing of overhead lines are included here for completeness but are not of direct relevance to this ETI study since its aim is to increase capacity without the construction of new overhead line infrastructure.

The 1992 review of the Holford rules included the addition of the following notes on the siting of substations.

- Respect areas of high amenity value (see Rule 1) and take advantage of the containment of natural features such as woodland and fitting in with the landscape character of the area;
- Take advantage of ground form with the appropriate use of site layout and levels to avoid intrusion into surrounding areas;
- Use space effectively to limit the area required for development, minimising the effects on existing land use and rights of way;
- Alternative designs of substations may also be considered, e.g. ‘enclosed’, rather than ‘open’, where additional cost can be justified;
- Consider the relationship of towers and substation structures with background and foreground features to reduce the prominence of structures from main viewpoints; and
- When siting substations take account of the effects of line connections that will need to be made.

3.2.2 Horlock Rules – Substation Siting

The NG guidelines for substation siting and designing are known as the Horlock Rules. The rules were drawn up to guide those responsible for designing and siting substations, including major extensions and modifications, and to be in keeping with the NG environmental policy statement and the requirements of Schedule 9 of the Electricity Act 1989. The intent of the rules is that the final design should be a balance between technical, economic, and environmental considerations.

An EIA is not a requirement for substation developments, unless they are part of a larger power station development, but in order to achieve the Horlock Rules objectives an environmental assessment is made of key aspects and an environmental report is prepared with the findings. The following issues will be included in the environmental assessment:

- Description of the Development;
- Description of the site including:
  - Flora and Fauna;
  - Soil – agricultural quality and geology;
  - Water courses and land drainage;
  - Climatic factors;
  - Historic culture and archaeological sites;
  - Landscape and topography;
  - Recreational Use;

  - Proximity of population, and
  - Other features of importance.
- Planning Policy including land designations;
- Assessment of impact on:
  - Visual landscape;
  - Flora and fauna;
  - Geology;
  - Land use;
  - Air and climate; and
  - Traffic and infrastructure.
- Proposed mitigation measures for:
  - Site planning;
  - Pollution prevention and control;
  - Waste;
  - Visual; and
  - Ecological.

A full copy of the NG siting guidance is provided in Appendix B.1.

3.3 Scottish and Southern Electric

Scottish and Southern Electric subsidiary SHETL owns and maintains the 132 kV and 275 kV transmission network in the north of Scotland.

SHETL guidelines to siting substations also refer to the supplementary notes found within the Holford Rules as well as their own Engineering and Environmental notes. These are broadly similar to the NG Horlock Rules.

The guidelines also include an assessment methodology to identify a preferred site by scoring the various options against various criteria. The initial scorings are based on the judgement of the specialists involved to reduce the options to two or three sites. The remaining options are taken forward to a more detailed design stage where accurate costing and environmental appraisal can take place.

Site surveys and environmental assessment will be carried out at the short-listed sites and the findings reported in a Site Selection Report. The environmental assessment will include both construction and operational phases and will cover the following aspects:

- Geology / soils;
- Hydrology;
- Ornithology;
- Protected species;
- Habitats;
- Cultural heritage;
- Landscape character;
- Visual impact;
- Land / water use;
- Access and recreation;
- Noise;

- Traffic and transport;
- Socio-economics and
- Carbon balance.

The full site selection methodology for SHETL are provided in Appendix B.2.

3.4 ScottishPower Energy Networks

ScottishPower Energy Network subsidiary SPTL is the transmission licence holder for the south of Scotland operating at 132 kV and above.

Little information is publicly available regarding the assessment process SPTL follow however consultation documents and environmental statements also make reference to the substation siting additional guidance contained within the Holford rules. SPTL have also published a ‘Schedule 9 Statement’ which sets out how they will carry out the duties required by Schedule 9 of the Electricity Act 1989. A copy of this statement is provided in Appendix B.3.

4. Key Assessment Aspects

4.1 Introduction

All the Flexible AC Transmission Systems (FACTS) options under considerations will require additional equipment to be constructed adjacent to existing substations or, in the case of Option 3b, a new site being built midway along the line, between existing substations. Each technology option differs in footprint, physical dimensions and types of equipment and buildings required.

The following sections describe the implications of the new equipment on key environmental aspects during the operational and construction phases however it should be recognised that the information is only indicative at this stage as each substation would have to undergo site specific assessment to get a true picture of the potential impacts.

Section 5.1 contains a summary table comparing each of the candidate technologies against each aspect.

4.2 Ecology

A development of this type will require land take in order to accommodate new equipment. In the case of Option 1, 2 and 3a this land will be adjacent to an existing substation and Option 3b will be a new site located midway along the line of interest. As part of the design process specialist surveys will be undertaken to identify protected species and habitat likely to be impacted. Where reasonably practical the design should take those findings into account and to avoid or reduce major impacts.

Permanent impacts would include the loss of habitat to accommodate the new equipment and potentially changes in site hydrology affecting water dependant habitats. Mitigation measures could include relocating or redesigning the site in order to avoid loss or disturbance of sensitive areas or creating compensatory habitat.

Temporary impacts would occur during the construction period and any future decommissioning phase. Impacts could include, but not be limited to, disturbance of protected species (breeding, foraging, movements), accidental harm to protected species and pollution of ground or water bodies (including sediment pollution). Mitigations may include restricted working hours, programming construction works to avoid breeding seasons, demarcating sensitive areas, traffic speed restriction and operating pollution prevention measures.

4.3 Designated sites

Geographical Information System (GIS) information is readily available on the internet in order to determine if the proposed development would be within or adjacent to a designated area.

Substation siting guidelines for NG, SPTL and SHETL all contain the requirement that, as far as is reasonably practical, they should seek to avoid areas of high amenity value i.e. internationally and nationally designated areas. As Options 1, 2 and 3a would all involve development at existing sites then it is likely that the site will already have taken this requirement into account.

When considering Option 3b, any proposed site should avoid the following areas:

- National Parks;
- AONBs;
- Heritage Coasts;
- World Heritage Sites;
- Ramsar Sites;
- SSSIs;
- NNRs;
- SPAs;
- SACs.

If avoidance of these designated sites is not possible, Option 3a may be preferable.

4.4 Noise

4.4.1 Overhead Lines

High voltage overhead lines and substations can generate noise. The level of noise generated depends principally on the line or substation operating voltage - with more noise being generated as the operating voltage increases.

Noise from overhead lines is a result of a phenomenon known as corona discharge - an electrical discharge which is caused by ionisation of the air around the overhead line conductors. Audible noise from overhead line conductors is only generally expected for lines with an operating voltage in excess of 230 kV. Although conductors are designed and constructed to minimise corona effects, local surface irregularities may enhance the electric field strength sufficiently for corona discharges to occur. This can be caused by damage, insects, raindrops or pollution - for example salt deposits in coastal areas. The noise level generated by a high voltage overhead line is weather-related, with the highest noise levels anticipated to occur during wet weather conditions when water drops collect on the conductors and increase corona activity which can be audible as a “crackling” sound or a low frequency hum. In this instance, the corona discharge is caused by small electrical discharges from the water drops.

Overhead lines are typically quiet during dry weather when audible noise from the line can barely be heard in normal fair weather conditions. However, during long, dry spells noise as a result of corona discharge can occur as a consequence of airborne debris deposits on the conductors and the corona discharge can be heard. The noise occurring as a result of such deposits typically disappears when sufficient rain falls to wash the debris away.

4.4.2 Substations

Within substations there are many potential sources of noise. Whether the noise can be heard outside a substation depends on a number of factors, including equipment types and the level of noise attenuation present (either engineered intentionally or provided by other structures). In particular, high voltage switchgear installations within substations typically take two forms being either air insulated or gas insulated.

Air insulated switchgear (AIS) is generally located outdoors, although indoor installations are also possible, particularly for coastal substation locations where the switchgear is located indoor to minimise conductor pollution. Air insulated switchgear is subject to the same corona discharge effect as overhead lines and therefore has the same associated noise levels for a given operating voltage.

Gas insulated switchgear (GIS) is more compact and is normally located indoors. However, it is not used in preference to AIS by the GB Transmission Operator, National Grid, unless there are clear requirements for its use since the SF6 gas used as an insulating material is a greenhouse gas with a global warming potential many times that of CO_2 and therefore it is used sparingly. GIS equipment therefore does not have the same noise levels associated with AIS substations or overhead lines of the same operating voltage.

Transformers at substations generate a low frequency. Other equipment such as resistors, reactors and capacitors banks may also be installed in substations and similarly contribute to the overall level of noise generated.

Other lesser sources of noise include that due to auxiliary equipment (such as motors and fans). In addition, where compensation equipment is utilised, additional equipment such as the semi conductor device cooling system will also be a source of noise. However, such equipment is usually enclosed within its own building or container. Therefore, in general these noise sources are less likely to have an impact on external receptors.

4.4.3 Mitigation Options

The significance of any impact will be determined by distance to the nearest sensitive receptor. If there are no nearby receptors then it is likely that a full assessment of the operational noise will not be required. A sensitive receptor is normally a residential property but can be other sensitive buildings such as schools or hospitals or can also be an ecological feature.

If operational noise is found to be significant then mitigation measures can be taken such as placing equipment indoors, adding additional acoustic screening to a standard building design or providing screening through appropriate landscaping and planting or the erection of acoustic fencing.

4.4.4 Construction Noise

Activities during the construction phase will result in higher noise levels than the operational phase although these will be of a temporary nature.

The nearest sensitive receptors will be identified as part of the site assessment and a background noise survey will be undertaken. Computer modelling will then predict the noise levels during the construction phase and assess for significance.

Noise sources will include; excavation machinery, dump trucks, cranes, vibrating equipment, and delivery vehicles. Construction noise can be mitigated through a mixture of restricted working hours, use of sound reducing equipment, and maintaining equipment in good working order.

The impact of construction noise will be of a temporary nature and mitigation measures should be sufficient to reduce noise to an acceptable level. The potential for impact is likely to be similar for all the candidate options.

4.5 Landscape and Visual Impact

The impact of a project on the landscape is assessed in terms of how the introduction of the new equipment would alter the landscape character, skyline and quality of scenic views. A specialist landscape architect should be involved during the design stage to advise on the best position for the additional equipment and suggest mitigation measures where appropriate.

The introduction of a new substation would most likely be considered a significantly adverse impact particularly if being built on a previously undeveloped site (Option 3b). In order to make the development more acceptable all sensitive landscapes (i.e. those designated for local, regional or national landscape value) should be avoided and, where possible, the substation should be screened through the use of existing land forms or through sensitive landscaping.

Options 1, 2 and 3a all require additional equipment to be added to existing substations. The impact significance will be dependant on site specific factors however these options may be considered to be preferable to Option 3b as the existing substation will have already influenced the landscape character. Option 3b is likely to be the least preferred option in terms of landscape and visual impact as it will most likely involve building on a previously undeveloped site and therefore be a more significant change to landscape character and scenic views.

Each of the technology options is different in appearance and this will also affect the landscape and visual impact.

- Option 1 (SVC) – To a layman's eyes this equipment will look similar to a traditional substation.
- Option 2 (STATCOMS) – Much of the equipment associated with this option will be indoors and as such may be more acceptable to the general public.
- Options 3a and 3b (TCSC) – This option involves equipment being raised above the ground (3.1 metres for a 400 kv substation). The unusual nature of this equipment and the height may make it less appealing to the general public.

4.6 Air Quality

There will be no emissions to air during the operational phase of the development and as such impacts on air quality will be restricted to vehicle exhaust emissions and dust creation during the construction phase. Management techniques such as water spraying and road sweeping to reduce dust and ensuring all vehicles and equipment are turned off when not in use to reduce exhaust gases would require to be implemented and as such air quality issues are likely to be minimal.

4.7 Cultural Heritage

Impacts on archaeological features are likely to be restricted to within the development footprint. Additional consideration may be given to nearby features which may experience a change to their setting or views although this is more likely to be an issue in the case of a new substation, such as for Option 3b, rather than for an extension to an existing site which will already be part of the setting.

As part of the assessment a desk top study and site visit would be carried out by an Archaeologist to determine if any archaeological or cultural heritage features are likely to be present at the proposed development site. The site should be designed where possible to avoid identified archaeological and cultural heritage features and furthermore any nearby features should be demarcated during construction to prevent damage. An archaeological watching brief may also be required during construction to check any sub surface findings.

4.8 Hydrology

Impacts on surrounding hydrology can be expected during both the construction and operational phases. All water features such as rivers, drinking supplies, ground water levels, ditches and ponds that are likely to be affected by water coming from the site (within the same water catchment area) should be identified.

During the construction phase there will be a risk of water pollution from oil and chemical spills and also surface water run off contaminated with sediment. In order to prevent pollution of ground and surface waters a robust pollution prevention scheme should be put in place which would include controls for the use of oils and chemicals, storage of oils and chemicals and spill containment plan to deal with incidents. It will also be necessary to implement a surface water collection system for the construction and operational phase which may have to include arrangements for settlement of sediment or removal of oil contamination prior to release.

The increase in hard standing associated with the new development will result in a reduction in permeable ground thus leading to an increase in surface water run off. An assessment will be required of the significance of the increase in run off on the existing drainage arrangements. Drainage consents may be in place and may require to be varied. Consideration should also be given to the use of alternative surface coverings such as permeable pavements, permavoids or swales.

Of the three candidates Option 1 has the largest footprint and is therefore likely to create more surface run off and as a result carry a higher risk of water course pollution during construction although this is not likely to be a significantly greater risk than the other options under review.

Depending on the site specific conditions, particularly if it is within fluvial or tidal flood plains, it may be necessary to carry out a flood risk assessment (FRA) for the site. As Options 1, 2 and 3a are adjacent to existing substations a FRA or other study may already have been carried out but Option 3b is unlikely to have been studied.

4.9 Contaminated land

Prior to starting construction a detailed history of the site should be obtained. For Options 1, 2 and 3a in particular it is possible that the ground being used for the new development may have been used before perhaps in an earlier substation layout. The potential for ground contamination should be investigated and appropriate measures taken prior to developing the new site. This may involve removing contaminated soils either voluntarily or as a requirement of the planning consent.

4.10 Land Use

The potential for habitat loss associated with the proposed developments. It may also be the case that the land lost will have commercial value either for property development or as has been discussed previously high grade farm land. Permanent loss of this land should be evaluated in the context of local, regional and national need. Option 1 has the largest footprint and therefore has the greatest potential for impact.

4.11 Waste

It is now a legal requirement in England for all construction projects with an estimated construction cost of over £300,000 to produce a Site Waste Management Plan (SWMP). This is also good practice and should be applied to projects in the rest of the UK both during construction and operational phases. A SWMP will assist in reducing and managing waste produced. Waste steams (hazardous and non hazardous wastes) should be identified and where possible reusing and recycling options put in place.

Where possible spoil excavated during the construction should be reused on site for landscaping.

4.12 Access and Traffic Management

4.12.1 Access

When a substation is first built consideration will have to be given to how the construction vehicles will reach the site. If a substation is to be built near or in a reasonably built up area then site access may not be a major issue however if the new substation is to be built in a remote location, as might be the case with the transmission network in particular, then a new access road may be required. The access road will need to be of sufficient load bearing strength and width to allow plant transport vehicles and construction cranes to access to the site.

Access to transport equipment to install Options 1, 2 and 3a would have already been put in place in order to construct the substation. Some survey work may be required however to assess if any upgrades are required.

In the case of Option 3b a new access road will likely be required. As the remaining candidate options are to be located alongside existing substations it is reasonable to assume that site access will be good although additional access tracks and crane pads may be required to service the new area. However some of the substations were built some time ago and the road network may have undergone significant changes in the intervening years. A specialist access study should be carried out in order to identify potential issues (e.g. tight bends, street furniture to be removed, bridges requiring reinforcement, potential over sailing of private property)

The construction of any new access roads and any required upgrading of the existing road network should be included in any impact assessment, particularly ecology, hydrology, cultural heritage and land use.

When comparing the candidate technologies, Option 3b is considered as having the most potential access impacts.

4.12.2 Traffic

Background traffic data should be used to determine the impact significance of the additional traffic during construction. Where possible, construction vehicle routes should be designed to avoid sensitive areas such as schools.

A traffic management plan should be implemented during the construction phase. The plan would include delivery routes, signage plans, communication plan for general public, delivery schedule and any restrictions on time.

All the options under consideration would have similar traffic impacts, and in all cases the vehicles used at site and to transport equipment and materials to the site would have to comply with legislation concerning acceptable vehicles sizes and weights.

4.13 Socio-economic

Construction of any of the candidate technologies is unlikely to result in a significant impact. Employment opportunities will be created during the construction phase and where possible these jobs should be filled locally to the site however these positions will only be short term and, as the substations are unlikely to be manned, no permanent employment will be created. Some economic benefits would be felt by the local community due to construction personnel spending in local shops, petrol station, restaurants etc and there would likely be opportunities for local hotels to benefit, however this would also be a minor short term gain.

Another aspect to consider is the effect of the area on recreational value. This will be highly site specific and dependant upon the existing use of the land to be developed and the surrounding area, although the presence of the existing substations will most likely already have influenced the surrounding land use. As previously discussed in the landscape and visual section the use of landscape screening can be used to assist in mitigating negative impacts.

4.14 Electro-magnetic Field (EMF)

There are no statutory exposure limits relating to EMF exposure in the UK. UK Government policy is to comply with the 1998 International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines on occupational exposure and the same guidelines for public exposure under the terms of the 1999 EU recommendations on length of exposure. Note that these basic restrictions apply to the central nervous system, not to the whole body. In 2009 ICNIRP issued a draft revision for consultation. Both sets of guidelines can be found in Table 4.1 although as this is only a draft for consultation, it has no force in the UK until such time as it is adopted by ICNIRP, incorporated into EU provisions and in turn implemented in the UK.

Table 4.1: ICNIRP Exposure Guidelines

	Existing ICNIRP 1998	Draft New ICNIRP 2009
Occupational exposure		
Basic Restriction	10 mA/m^2	100 mV/m
Magnetic Field Reference Level / Actual Field Required	500 µT / 1800 µT	
Electric Field Reference Level / Actual Field Required	10 kV/m / 46 kV/m	
General public exposure		
basic restriction	2 mA/m^2	20 mV/m

	Existing ICNIRP 1998	Draft New ICNIRP 2009
Magnetic Field Reference Level / Actual Field Required	100 μT / 360 μT	
Electric Field Reference Level / Actual Field Required	5 kV/m / 9 kV/m	

Issues regarding EMF arising from using FACTS devices are similar to those considered in designing traditional AC substations or transmission lines. The electromagnetic fields that are generated by electrical equipment within a FACTS installation can normally be accounted for in equipment design and installation layouts; practical methods applied to account for EMFs in FACTS installations include:

- Maintaining appropriate magnetic as well as electrical clearances between substation equipment, and between equipment and operationally accessible areas
- Designing to avoid current loops (and therefore circulating currents) within metallic substation components such as earthing grids, metallic reinforcement within concrete foundations and fencelines, e.t.c.
- Magnetic shielding to eliminate fields outside equipment. An example of this is the phase reactor shielding shown in Photo 4.1.
- Design using non-magnetic materials where possible (i.e. substituting magnetic metal joints in equipment such as bushings)

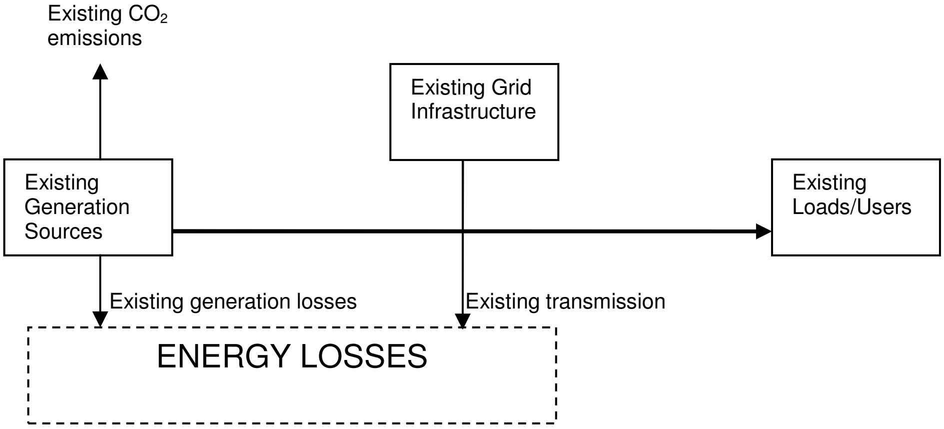
Photo 4.1: Phase reactor magnetic field shielding (on right hand side), applicable to a STATCOM installation

Source: Courtesy of ABB

4.15 Impacts on Carbon Balance

The basic concept diagram below of a generation/transmission system provides a basis for discussing the possible impact of the FACTS devices covered by this report on CO_2 emissions. It can be seen from the diagram that users of electrical energy are connected to the sources of the energy via the grid infrastructure. Energy is lost at the generation source and in the transmission process. CO_2 emissions arise from nowhere else in the system except from any sources that are based on fossil fuels.

Figure 4.1: Generation / Transmission System Concept Drawing



The FACTS devices covered by this report function by modifying the behaviour of elements of the transmission system infrastructure such that the transmission system is potentially able to transmit more power than it would otherwise have been able to. However, it can be seen from the diagram that any such increase in transmission capacity has no direct relationship with CO_2 emissions since these are dependent only on the energy sources that are used to supply the system. It therefore follows that it is not possible to equate any increase in transmission capacity that may arise from FACTS devices with any particular change in CO_2 emissions. Any such changes are determined by the change in generation mix, which is not of itself a function of the grid transmission infrastructure.

The utilisation of FACTS devices would impact on CO_2 emissions as follows;

1. The CO_2 that is emitted as a result of the manufacture and installation of the devices.
2. Any changes to CO_2 emissions that arise as a result of different energy losses from the FACTS devices.

The potential advantage of the application of FACTS devices is that they offer the prospect of increasing the capacity of the existing grid infrastructure, thus avoiding the need to install additional links in the grid. Therefore, from a CO_2 perspective the above considerations become;

1. Is the CO_2 that is emitted as a result of the manufacture and installation of the FACTS devices less than the amount that would be emitted as a result of the manufacture and installation of additional traditional links in the grid?
2. Is the change to the amount of CO_2 that is emitted as a result of different energy losses arising from the application of the FACTS devices less than the losses that would arise as a result of operation of additional traditional links in the grid?

It is not possible to give quantitative answers to the above questions at this stage since they would require a detailed CO_2 analysis to be carried out and this would be specific to the technology concerned, the selected location in the grid, and the selected alternative traditional means of providing the additional capacity (cable or overhead line). However, it is likely that the application of FACTS devices would be advantageous on both counts from a CO_2 point of view for the following reasons;

1. The installation of the FACTS device involves the extension of the substation compound at one end of the transmission line concerned and the installation of the FACTS equipment in the compound. It is unlikely that this would entail more emissions than would be associated with building a new link, since this would require the expansion of two existing substations, the manufacture and installation of the necessary switchgear (and possibly transformers) in these substations, and the construction of a new transmission line between them (or the installation of a new underground cable).
2. The change in losses associated with the application of the FACTS devices would be those associated with the operation of the FACTS device itself plus the marginal change in losses arising from operating the link concerned at a higher power level. This aggregate increase in losses is unlikely to be as high as the losses that would be associated with the operation of a completely new link in the grid system.

It should be noted that the WP2 Task 3 report discusses the CO_2 reductions that could potentially be achieved by the displacement of 1GW of conventional sources of energy by renewable sources.

5. Conclusion

5.1 FACTS Options Comparison

All the options are similar in that they involve an increase in substation size but do not require any retrofit of overhead lines, pylons or insulators. Option 1, 2 and 3a all involve additional equipment to be installed adjacent to existing substations although the footprint of that equipment varies and Option 3b requires an equipment to be installed at a new site to be constructed midway along the line. Table 5.1 provides a summary of the potential impacts associated with each technology type however it should be noted this is provisional on a site specifics being taken into account.

Table 5.1: Options Comparison Summary Table

Aspect	Option 1 SVC	Option 2 STATCOM	Options 3a TCSC	Options 3b TCSC
Ecology, Cultural Heritage, Hydrology, Contaminated Land, Land use,	Largest footprint of options involving substation extensions and therefore the greatest potential to impact on habitats		Smallest footprint and therefore the least potential to impact on habitats	Requires development of previously undeveloped site. Also likely to require new access road in addition to substation site. Overall this is the option with the greatest potential for damage.
Operational Noise	Not Likely to be significant for any of the options under consideration			
Construction Noise	All options under consideration are comparable			
Landscape and Visual	Largest footprint which will require the greatest level of screening	Significant proportion of equipment housed indoors which is preferable visually	Smallest footprint however unusual equipment may be more noticeable by general public if not suitably screened.	As for Option 3a
Air quality	Not Likely to be significant for any of the options under consideration			
Waste	All options under consideration are comparable			
Access	May be some upgrading to existing access	May be some upgrading to existing access	May be some upgrading to existing access	Likely to require a new access road. Access for construction vehicles less certain. Overall this is option has the greatest potential for access issues
Traffic Management	All options under consideration are comparable			
Socio-economics	All options under consideration are comparable			
EMF	Dependant on site configurations but in all situations mitigations would be put in place to ensure public and occupations exposure meets guidelines.			

5.2 FACTS vs Traditional Capacity Expansion

From an environmental perspective FACTS options are significantly preferable to traditional capacity expansion by building a new line. A new line will include a new substation with equivalent impacts to those associated with the FACTS options however there would be also be the construction and operation of the overhead line or underground cable. Table 5.2 gives the differences between the two traditional options, new overhead line and new underground cable compared to the impacts associated with the implementation of a FACTS solution.

Table 5.2: FACTS Vs Traditional Expansion

Aspect	Overhead Line	Underground Cable
Ecology	Additional impacted areas along line route mainly during construction but also impacts on birdlife during operational life.	Additional impacted areas along cable route. Mainly temporary impacts during construction but some permanent on sensitive habitats such as peat or wetlands.
Operational Noise	Some additional impact due to corona hum	Similar to FACTS technology
Construction Noise	Additional impacted areas along line route	Additional impacted areas along cable route
Landscape and Visual	Very significant increase in impacts	Greater potential impacts than FACTS options
Air quality	Larger construction area but not significant	Larger construction area but not significant
Cultural Heritage	Additional potential for impacts along line route	Significantly higher potential for impacts along cable route
Hydrology	Greater impacts due to additional water crossing. Provided pylons are located away from riversides the additional impact should be minimum	Greater impacts due to additional water crossings. Cable crossing have the potential to disturb river and river ecology.
Contaminated Land	Additional potential for impacts along line route	Significantly higher potential for impacts along cable route
Land use	Additional land take for pylon locations.	Additional impacted areas along cable route. Route corridor sterilised from building permanent structures, and restricted planting ie. no trees or shrubs
Waste	Significant increase in excavated spoil volumes during construction	Very significant increase in excavated spoil volumes during construction
Access	Very significant increase in access issues along line route.	Very significant increase in access issues along cable route.
Traffic Management	Very significant increase in access issues along line route.	Very significant increase in access issues along cable route.
Socio-economics	Increase opportunities for job creation during construction and to a lesser extent during maintenance periods	Increase opportunities for job creation during construction and to a lesser extent during maintenance periods
EMF	Potentially more opportunity for exposure along the line route. However exposure limits will be within guidance levels.	Cables are typically buried 1 m below ground and therefore an individual standing directly above would be exposed to higher EMF than an OHL which is significantly further away.

From a planning perspective a new overhead line would also require additional planning consideration as an EIA would be required as well as a Section 37 Consent in Scotland or a Development Consent Order from the IPC in England and Wales.

An underground cable would not require planning consent except potentially for joint bays which would be required approximately every 500 to 800m. As good practice an environmental assessment should be made as part of the route determination process.

5.3 Conclusion

When considering each candidate technology the characteristic that appears to have the most influence on the potential for environmental impacts is the associated footprint. Another important consideration is that all but one of the options would be sited alongside an existing substation while Option 3b requires the development of an entirely new site.

With these factors in mind the two preferred candidate options from an environmental perspective are:
- Option 2 – STATCOMS (a smaller footprint than option 1); and
- Option 3 –TSCS at either end of the selected line.

Appendices

Appendix A. Transmission Operator Sub Station Siting Guidance Horlock Rules

Appendix A. Overhead Line Routing Guidance

A.1. National Grid Holford Rules

Rule 1: Avoid altogether, if possible, the major areas of highest amenity value, by so planning the general route of the line in the first place, even if the total mileage is somewhat increased in consequence.

Note on Rule 1
a Investigate the possibility of alternative routes, avoiding if possible the areas of highest amenity value. The consideration of alternative routes must be an integral feature of environmental statements.
b Areas of highest amenity value are:
Areas of Outstanding Natural Beauty
National Parks
Heritage Coasts
World Heritage Sites

Rule 2: Avoid smaller areas of high amenity value, or scientific interest by deviation; provided that this can be done without using too many angle towers, ie the more massive structures which are used when lines change direction.

Note on Rule 2
a Some areas (e.g. Sites of Special Scientific Interest) may require special considerdtion for potential effects on ecology (e.g. to their flora and fauna).
b Where possible choose routes which minimise the effects on the settings of areas of architectural, historic and archaeological interest including Conservation Areas, Listed Buildings, Listed Parks and Gardens and Ancient Monuments.

Rule 3: Other things being equal, choose the most direct line, with no sharp changes of direction and thus with fewer angle towers.

Note on Rule 3
a Where possible choose inconspicuous locations for angle towers, terminal towers and sealing end compounds.

Rule 4: Choose tree and hill backgrounds in preference to sky **backgrounds wherever possible; and when the line has to cross a ridge, secure this opaque background as long as possible and cross obliquely when a dip in the ridge provides an opportunity.**
Where it does not, cross directly, preferably between belts of trees.

Rule 5: Prefer moderately open valleys with woods where the apparent height of towers will be reduced, and views of the line will be broken by trees.

Note on Rules 4 and 5
a Utilise background and foreground features to reduce the apparent height and domination of towers from main viewpoints.
b Minimise the exposure of numbers of towers on prominent ridges and skylines.
c Where possible avoid cutting extensive swathes through woodland blocks and consider opportunities for skirting edges of copses and woods.
d Protect existing vegetation, including woodland and hedgerows, and safeguard visual and ecological links with the surrounding landscape.

Rule 6: In country which is fiat and sparsely planted, keep the high voltage lines as far as possible independent of smaller lines, converging routes, distribution poles and other masts, wires and cables, so as to avoid a concatenation or 'wirescape'.

Note on Rule 6

a In all locations minimise confusing appearance.
b Arrange wherever practicable that parallel or closely related routes are planned with tower types, spans and conductors forming a coherent appearance; where routes need to diverge, allow where practicable sufficient separation to limit the effects on properties and features between the lines.

Rule 7: Approach urban areas through industrial zones, where they exist; and when pleasant residential and recreational land **intervenes between the approach line and the substation, go carefully into the comparative costs of undergrounding, for lines other than those of the highest voltage.**

Note on Rule 7
a When a line needs to pass through a development area, route it so as to minimise as far as possible the effect on development.
b Alignments should be chosen after consideration of effects on the amenity of existing development and on proposals for new development.
c When siting substations take account of the effects of the terminal towers and line connections that will need to be made and take advantage of screening features such as ground form and vegetation.

Supplementary Notes

(a) Residential Areas

Avoid routeing close to residential areas as far as possible on grounds of general amenity.

(b) Designations of County, District and Local Value

Where possible choose routes which minimise the effect on Special Landscape Areas, Areas of Great Landscape and other similar designations of County, District or local value.

(c) Alternative Tower Designs

In addition to adopting appropriate routeing, evaluate where appropriate the use of alternative tower designs now available where these would be advantageous visually, and where the extra cost can be justified.

Appendix B. Transmission Operator Sub Station Siting Guidance

B.1. National Grid Horlock Rules

Section III GUIDELINES

Overall System Options and Site Selection

1 In the development of system options including new substations, consideration must be given to environmental issues from the earliest stage to balance the technical benefits and capital cost requirements for new developments against the consequential environmental effects in order to keep adverse effects to a reasonably practicable minimum.

Amenity, Cultural or Scientific Value of Sites

2 The siting of new NGC substations, sealing end compounds and line entries should as far as reasonably practicable seek to avoid altogether internationally and nationally designated areas of the highest amenity, cultural or scientific value by the overall planning of the system connections.

Notes:

1 Internationally and nationally designated areas of highest amenity, cultural or scientific value are:

National Parks;
Areas of Outstanding Natural Beauty;
Heritage Coasts;
World Heritage Sites;
Ramsar Sites;
Sites of Special Scientific Interest;
National Nature Reserves;
Special Protection Areas;
Special Areas of Conservation.

2 Care should be taken in relation to all historic sites with statutory protection eg Ancient Monuments, Battlefields and Listed Buildings.

3 Account should be taken of Government Planning Policy Guidance and established codes of practice.

4 Account should be taken of any development plan policies relevant to the siting or design of substations.

3 Areas of local amenity value, important existing habitats and landscape features including ancient woodland, historic hedgerows, surface and ground water sources and nature conservation areas should be protected as far as reasonably practicable.

Local Context. Land Use and Site Planning

4 The siting of substations, extensions and associated proposals should take advantage of the screening provided by land form and existing features and the potential use of site layout and levels to keep intrusion into surrounding areas to a reasonably practicable minimum.

Notes:

1 A preliminary study should be undertaken to identify the extent of land required to meet both operational and environmental needs.

2 In some instances it may be possible to site a substation partially or fully enclosed by existing woodlands.
3 Topographical information should be obtained at an early stage. In some cases a geotechnical survey may be required.

5 The proposals should keep the visual, noise and other environmental effects to a reasonably practicable minimum.

Notes:
1 Allow sufficient space for screening of views by mounding or planting.
2 Consider appropriate noise attenuation measures where necessary.
3 Use security measures which minimise visual intrusion from lighting.
4 Consider appropriate on site water pollution prevention measures.
5 Consider adjoining uses and the amenity of local inhabitants.

6 The land use effects of the proposal should be considered when planning the siting of substations or extensions.

Notes:
1 Issues for consideration include potential sterilisation of nationally important land, eg Grade 1 agricultural land and sites of nationally scarce minerals.
2 Effects on land drainage.

Design

7 In the design of new substations or line entries, early consideration should be given to the options available for terminal towers, equipment, buildings and ancillary development appropriate to individual locations, seeking to keep effects to a reasonably practicable minimum.

Notes:
1 With outdoor equipment, a preference should be given normally to a low profile design with low height structures and silhouettes appropriate to the background.
2 Use lightweight narrow section materials for taller structures especially for gantries over about 6 metres in height.
3 Commission exterior design and colours appropriate to the surroundings.
4 Materials and colours for buildings, equipment and fencing should be chosen to harmonise with local surroundings
5 Where possible avoid the use of prominent insulators by consideration of available colours appropriate to the background.
6 Where possible site buildings to act as visual screens for switch gear.
7 Ensure that the design of high voltage and low voltage substations is coordinated by early consultation between NGC and its customers.
8 Where there are particular technical or environmental constraints, it may be appropriate to consider the use of Gas Insulated Switch gear (GIS) equipment which occupies less space and is usually enclosed within a building.
9 Early consideration should be given to the routing of utility service connections.

8 Space should be used effectively to limit the area required for development consistent with appropriate mitigation measures and to minimise the adverse effects on existing land use and rights of way, whilst also having regard to future extension of the substation.

> *Notes:*
> *1 Assess the benefit of removing redundant substation equipment from existing sites where this would improve their appearance.*

9 The design of access roads, perimeter fencing, earthshaping, planting and ancillary development should form an integral part of the site layout and design to fit in with the surroundings.

Line Entries

10 In open landscape especially, high voltage line entries should be kept, as far as possible, visually separate from low voltage lines and other overhead lines so as to avoid a confusing appearance.

11 The inter-relationship between towers and substation structures and background and foreground features should be studied to reduce the prominence of structures from main viewpoints. Where practicable the exposure of terminal towers on prominent ridges should be minimised by siting towers against a background of trees rather than open skylines.

B.2. Scottish Hydro Electric Transmission Ltd (Edited)

Objective

Schedule 9 of the Electricity Act 1989 which require transmission license holders:

- to have a regard to the desirability of preserving natural beauty, of conserving flora, fauna and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interests; and
- to do what they reasonably can to mitigate any effect that the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects.

Existing Guidance

The only existing published guidance for substation selection is contained within the Holford Rules. These are reproduced below.

SUPPLEMENTARY NOTES ON THE SITING OF SUBSTATIONS

a	Respect areas of high amenity value (see Rule 1) and take advantage of the containment of natural features such as woodland, fitting in with the landscape character of the area.
b	Take advantage of ground form with the appropriate use of site layout and levels to avoid intrusion into surrounding areas.
c	Use space effectively to limit the area required for development, minimising the effects on existing land use and rights of way.
d	Alternative designs of substations may also be considered, e.g. ‘enclosed’, rather than ‘open’, where additional cost can be justified.
e	Consider the relationship of towers and substation structures with background and foreground features, to reduce the prominence of structures from main viewpoints.
f	When siting substations take account of the effects of line connections that will need to be made.

These guidelines are intended to expand upon the notes within the Holford Rules and provide specific engineering guidance.

Use of Guidelines

The guidelines are in two sections: Engineering Notes and Environmental Notes. The Engineering Notes should be considered first. These notes provide guidance on establishing the main features of the substation. The Environmental Notes provide guidance on the attributes required of a substation site. It is unlikely that any site shall possess all of the suggested attributes and that some balance will be necessary. The comparison paper in Appendix B provides guidance on how that balance should be assessed.

Requirements for consultation must be considered and established. Consultation may or may not be statutory depending on the nature and location of the proposed development.

Engineering Notes

3. Consider first the connectivity of the proposed substation. Identify the circuits that require to connect into the substation. Thereafter identify the general geographic area which minimises the overall length of new construction required. There is often a compromise between circuits, where extending one circuit can result in reducing the length of another. Priority should be given to the circuits of the highest voltage and/or capacity. Holford Note f covers the consideration of connectivity.
4. Identify the general size of the substation. Complete a basic design based on a flat, green field site, using standard air insulated equipment and access requirements from the CAD database. At this stage, space should be left for possible future expansion of the substation. The layout drawing should include a cross-section detailing the maximum height of the substation equipment and the indicative height of any terminal towers. Holford Note c states that space must be used effectively to minimise the size of the development. Once sites have been identified, it is important to review the design carefully to optimise the layout. Holford Note d states that alternative designs may be considered and suggests the consideration of enclosed rather than open substations. Enclosed is taken as meaning Gas Insulated Switchgear; although it is entirely possible to enclose an air insulated substation, particularly at lower voltages. SHETL does not have a policy on the use of Gas Insulated Switchgear. Guidance is available in Appendix B1. Once a site has been identified, the layout drawing should be revised and consideration should be given to alternative designs to minimise the environmental impact. Such considerations should include:
    a. Low profile line entries
    b. Bunding and screening, possibly using the buildings to screen the site

   c. Altering profile of substation equipment to maximise backdropping from main viewpoints
   d. Materials and colours for buildings, fences and equipment
5. Identify the access requirements. The access requirements will be driven by the largest indivisible load to be transported into the substation and the volume of construction traffic. The largest indivisible load will generally be the transformer with the highest primary voltage. In the absence of specific information, it should be assumed that the substation should have a surfaced access track from the nearest public road, 5m running width, with a maximum gradient of 1 in 10 and a minimum inner bending radius of 10m. Access tracks should be kept as short as possible. However, given the environmental requirements to screen the site from public roads, it should be expected that an access track will be required. The point of connection of the access track to the public road network should be considered to ensure adequate sightlines are available in accordance with the recommendations of the local/national roads authority. The combination of construction traffic and the largest load may require upgrading to the public road network. Once site options have been identified, a preliminary review of the public roads should be completed to establish whether there are any differences in terms of the necessary reinforcements.

Environmental Notes

The environmental review of the substation site must include an assessment of the connecting circuits, the access track and the necessary earthworks in addition to the substation itself.

1. Avoid, where possible, areas of environmental designation (often regarded as having "high amenity value" as in Holford Note a). However, consideration must be given to Engineering Note 1. There may be no point in avoiding building a substation within a designated area if the result is an increase in overall circuit length through the same designated area. Such designations include National Parks, Special Protection Areas, Special Areas of Conservation, National Scenic Areas, National Nature Reserves, Ramsar Sites, World Heritage Sites and SSSIs.
2. Avoid, where possible, close proximity to other environmental designations. Such designations include Scheduled Ancient Monuments, Battlefields, Listed Buildings, Conservation Areas, Historic Gardens and Designed Landscapes, ancient woodland and protected species or habitats.
3. Protect, as far as possible, areas of local amenity value, local areas of conservation and important landscape features such as stone walls and forestry outcrops.
4. Seek dry and firm ground conditions. It is possible to build a substation in almost any location. However, some ground conditions may be unsuitable and would require major earthworks to establish the site. The costs, and environmental impacts, of such works should not be underestimated. In particular, it is preferable to avoid:
   - areas of standing water or peat or boggy ground. Such areas would need to be permanently drained. It is also likely that the ground material would need to be removed and replaced with suitable soils and aggregate.
   - rock outcrops. These will generally require blasting to remove and are probably indicative of bedrock close to the surface. It may prove very difficult to establish effective earth mats in such areas.
   - areas of flood risk. Areas at flood risk should initially be identified using the 200 year flood maps published by the Scottish Environmental Protection Agency. If a site option is close to the flood area a further assessment should be completed to identify the 1 in 1000 year flood area. It is possible to design substations to accommodate the 1000 year flood risk but better to avoid such areas.
5. Seek areas where the substation may be concealed from view (Holford Notes a and b). Preference should be given to using the landform to screen the substation as this can be considered to be

permanent. Screening by trees or other vegetation is also appropriate but is likely to require the establishment of a formal screening zone, within the control of SHETL, around the substation. This greatly increases the overall landtake for the site. Such a screening zone will require a width of around 30m all around the substation. This allows for 15m width of planting and a 15m gap between the screen planting and the substation. This gap provides protection for the substation against falling trees and fire. It should also be noted that any overhead lines connecting into the substation would require a clearance corridor through any screen planting, possibly opening up views of the substation. Priority should be given to views from properties, transport routes and other places where people are expected to be. In considering such views, preference should be given to sites which would cause terminal towers to be backdropped by the landform or at least partially hidden by other objects in the foreground (Holford Note e).

6. Seek areas which are flat. Substations must be constructed on flat ground. It is possible to establish flat ground using cut and fill techniques. It is equally possible to build a substation on several terraces on a slope. However, slopes within a substation create unusable space. A drop in height of 5m across the length a substation will increase the length by around 15m as a result of unusable space. This can increase cost and environmental impact. It should also be noted that a terraced site may be considerably harder to effectively screen.
7. Avoid close proximity to properties. In addition to visual effects, there will be noise effects from both operation and construction. Operational noise is likely to be a greater issue as it is permanent. In an area with little background noise, a substation may cause a noise nuisance for several hundred metres. If there is another source of background noise, such as a river, the distance will be much reduced. Properties in close proximity are also likely to raise concerns over property prices, health effects and disruption due to construction and may therefore make planning consent harder to obtain.
8. Avoid proximity to areas where children would be expected to congregate. These would include schools, footpaths to and from schools and playing fields. Proximity to such areas increases the risk of vandalism and unauthorised entry to the substation with potentially serious consequences. Reference should be made to risk assessment procedures under the ESQC Regulations. (PR-PS-311). Such a risk assessment may introduce conflicts between screening and security. If the substation location is in a high risk area, it would be preferred that it remains visible; to discourage unauthorised entry.
9. Avoid proximity to watercourses. Substations present a pollution risk. Although standard substation design would include containment and oil interceptors, there is always the risk of a major incident. If possible, such risks should be eliminated by site selection. Sensitive watercourses would include private water supplies, freshwater fisheries, fishing/spawning activities or watercourses supporting vulnerable species and riparian habitat.
10. Avoid, where possible, areas of high land value. Such areas would include high quality agricultural land, prime development land and sources of mineral deposits.
11. Seek sites where the landowner is willing to sell the land and cooperate with the construction of the substation. Although compulsory powers are available to acquire land for electrical infrastructure, the process is complicated, expensive and can be prolonged. In particular, it is necessary to prove that no reasonable alternatives exist.
12. Refer to Local Development Plans and government Planning Policy Guidance and codes of practice. Sites which conflict with such documents should be avoided if possible. Some level of expertise is required to locate and review such documents. It is recommended that a meeting should be held with the Local Planning Authority at an early stage in the site selection process to establish whether such documents may impact on site selection.

Site Selection Process

Assess each option in accordance with the comparison paper in the comparative methodology to provide a score for each site. Depending on the number of options being reviewed, it may be prudent to complete this exercise in two phases. Initially allocating scores based on the judgement of relevant persons to allow two or three sites to be selected for a more detailed design. At this detailed stage, a design should be created for each site to allow an accurate costing and environmental appraisal. It is likely that site surveys will be required to assess landform, geo-technical suitability and to identify environmental issues. The remaining options should then be re-assessed using the comparison paper in the comparative methodology.

The lowest scoring site is the recommended substation site.

Methodology for Comparative Assessment Of Substation Sites

Introduction

SHETL's licence obligations require the company to develop options for electricity transmission that have due regard for the environment, are technically feasible and economically viable. This methodology sets out to provide guidance on achieving a reasonable balance between these three criteria.

The assessment will be set out in the form of a report detailing the survey work that has been undertaken, identifying the assessment for each option under each of the headings and providing an overall conclusion to justify the final decision taken on the preferred site.

Environmental Assessment of the site options

A series of criteria have been developed that will be applied to the different headings against which the sites will be assessed. These rank the level of potential significance of effects, post-mitigation, on a scale from 0 (no effect) to 5 (severe effect), for both the construction and operational phases of the developments. The assessment assumes that generic / best practice mitigation will have been applied to any potential adverse effects. Only direct, residual effects will be considered at this stage.

These criteria are set out in Table 1, below. Greater weight is attached to permanent effects than to temporary effects.

Table 1: Environmental Criteria for Significance Levels

Assigned level of significance	Construction effects	Operational effects
0	Zero effect: no environmental disturbance during construction.	Zero effect: no environmental disturbance during operation.
1	Low temporary effect on receptors of low or moderate sensitivity or medium temporary effect on receptors of low sensitivity, limited to the immediate vicinity of the works. No permanent damage or disturbance. No risk of breach of environmental legislation or of prescribed limits.	Negligible or low permanent effect on receptors of low sensitivity, limited to the immediate vicinity of the works. No risk of breach of environmental legislation or of prescribed limits.
2	Low temporary effect on receptors of high sensitivity, located within the immediate vicinity of the works. High temporary effect on receptors of low sensitivity, within or extending beyond the immediate vicinity of the works. No permanent damage or disturbance. No breach of	Low permanent effect on receptors of moderate sensitivity, or medium permanent effect on receptors of low sensitivity, both within and beyond the immediate vicinity of the works. No risk of breach of environmental

Assigned level of significance	Construction effects	Operational effects
	environmental legislation or of prescribed limits.	legislation or of prescribed limits.
3	Medium temporary effect on receptors of moderate or high sensitivity, within or extending to beyond the immediate vicinity of the works. High temporary effect on receptors of moderate significance, within or extending beyond the immediate vicinity of the works. No long term damage or disturbance. Minor risk of breach of environmental legislation or of prescribed limits.	Low permanent effect on receptors of high sensitivity; medium permanent effect on receptors of moderate sensitivity, both within and beyond the immediate vicinity of the works. No long term damage or disturbance. Minor risk of breach of environmental legislation or of prescribed limits.
4	High temporary effect on receptors of high sensitivity, both within and beyond the immediate vicinity of the works. No long term damage or disturbance. Moderate risk breach of environmental legislation or of prescribed limits.	Medium permanent effect on receptors of high sensitivity; high permanent effect on receptors of moderate sensitivity, both within and beyond the immediate vicinity of the works. Moderate risk of breach of environmental legislation or of prescribed limits.
5	Significant and/or sustained risk of breach of environmental legislation or of prescribed limits.	High permanent effect on receptors of high sensitivity, extending to beyond the immediate vicinity of the works. Significant and/or sustained risk of breach of environmental legislation or of prescribed limits.

The assessment scores will be set out against each of the topics being assessed, as indicated in Table 2, below. These topics have been selected to cover the main areas of likely impact and the weighting afforded to each through legislation and regulation.

These scores will be added together and divided by the number of topics in order to achieve a 'mean' value for each site. Potential beneficial effects are shown as "negative" scores in order to balance out potential adverse effects. The construction and operation scores will be averaged to give a final score for impact. (Although operational impacts are likely to be long term and construction impacts are likely to be shorter term, the criterion identified in Table 1 has been defined/weighted to take account of this).

Table 2: Environmental Scoring Table

	Site 1		Site 2	
Topic	Construction	Operation	Construction	Operation
Geology/soils				
Hydrology				
Ornithology				
Protected species				
Habitats				
Cultural heritage				
Landscape character				
Visual impact				
Land/water use				
Access and recreation				
Noise				
Traffic / transportation				
Socio-economics				

	Site 1		Site 2	
Topic	Construction	Operation	Construction	Operation
Carbon balance				
Total score				
Total combined score				
Mean				
Aspects with potentially significant impacts				

Where particularly high scores are attributed to specific aspects that might prevent the development of that site option (for instance, a significant effect on the integrity of the SPA) these will be highlighted at the end of the table and further discussion provided within the overall report, to enhance the final decision-making process.

If necessary, appendices will be provided to set out baseline data in support of specific assessments.

B.3. ScottishPower Tranmission Ltd Schedule 9 Statement

SP TRANSMISSION’S SCHEDULE 9 GUIDELINES

Where any of our operations or any proposed developments or projects comprise a “relevant proposal” we will observe the following guidelines:

1. Established Need

We will seek to construct new lines or substations only where the existing infrastructure cannot be upgraded to meet security of supply requirements, or where an increase in demand for electricity transportation capacity is foreseen which cannot be satisfied by other means or where new connections to customers are required.

2. Designated Areas for Amenity

We will pay due regard to the need to preserve and maintain amenity, particularly within the areas of the greatest landscape, wildlife or cultural amenity, such as National Parks, National Scenic Areas, Sites of Special Scientific Interest, Scheduled Ancient Monuments and other national or international designated areas.

For new transmission infrastructure we will investigate the possibility of alternative routes or sites outwith the designated area. For existing networks and where there is a requirement for infrastructure inside the designated area we will seek to minimise the impact of its presence through the sensitive routing and siting of structures. In such cases we will consult with those groups most likely to be affected at an early stage.

3. Seek to Minimise the Impact of New Infrastructure

We will seek to minimise the effects of new transmission infrastructure at or near both designated sites and also other sites valued for their general amenity, such as areas of archaeological interest, battlefields, local nature reserves, playing fields and water bodies. We will take into account the significance of sites valued for their amenity through consultation with statutory bodies and local authorities.

4. Mitigate the Adverse Effects of Works

Where works are likely to have an adverse effect on amenity, we will carry out our activities in such a way as to reduce the impact of these activities to the practicable minimum.

Where planned works would have a high impact on amenity, we will consult with statutory bodies, local authorities and relevant landowners to help us identify, assess and carry out measures to mitigate the impact so far as is reasonably practicable.

5. Environmental Assessments

We will carry out environmental assessments in accordance with relevant legislation prior to developing proposals for new lines or plant.

6. Protection of Fisheries

In the preparation of plans and programmes we will seek to avoid, so far as is possible, causing injury to fisheries or to the stock of fish in any waters within our licensed area.

7. Training and Awareness

We will promote environmental awareness amongst staff through appropriate training and dissemination of information. We will also make contractors aware of the relevant parts of this statement, and take steps to audit their compliance with it

8. Review of the Schedule 9 statement

We intend to review our Schedule 9 statement at least every 5 years.