Scottish and Southern Energy
Power Distribution

Date of Submission

December 2013

NIA Project Registration and PEA Document

Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

Project Registration

Project Title		**Project Reference**
Magnetically Controlled Shunt Reactor (MCSR)		NIA_SHET_0012
Project Licensee(s)	**Project Start Date**	**Project Duration**
Scottish Hydro Electric Transmission	Dec 2013	15 Months
Nominated Project Contact(s)		**Project Budget**
David MacLeman		£120,000

Problem(s)

The problem addressed by this project is the high cost of equipment to control reactive power on GB Transmission networks. The problem and the limitations of currently used equipment are explained below.

GB power systems mainly consist of electrical energy which is generated, transmitted and distributed as high voltage three phase alternating current (AC) at a frequency of 50Hz. The current in each phase conductor changes direction to and from its generation source a hundred times in every second. Due to the physical orientation and interaction of the effects of current flow in conductors as well as the nature of connected load, the natural oscillation of AC leads to a phenomenon called reactance. Reactance is another form of opposition to current flow exhibited by the other two basic electrical components (inductors and capacitors) due to their ability to momentarily store energy. During each cycle of AC flow from the source to the load and back, in addition to the energy used in the load, there is a fraction of the energy that is temporarily stored in inductive components as magnetic fields or in capacitive components as electric fields and then returned back to the circuit a little later. This storage and discharge of energy draws additional current in conductors causing flow of reactive power, a component of the total transmitted power which has no contribution to the power actually needed by the connected load for meaningful use.

Reactive power flow results in the oversizing of transmission infrastructure, further losses in form of heat due to flow of extra unnecessary current as well as difficulty in maintaining voltage within acceptable limits under varying load conditions. Inductive circuits are said to absorb reactive power and increased load in such circuits results in lower voltage at the load connection points. Conversely, capacitive circuits are generators of reactive power and during periods of light or no load, voltage at load points can exceed that at the source. Statutory power quality requirements and the growing need for transmission capacity imposed by increasing volumes of renewable generation compel Network operators to seek mitigation for the effects of reactive power flow. The principle behind the mitigation is simple, if reactive power is absorbed in a circuit, a source of reactive power is needed to compensate and vice versa. Generating stations can provide both forms of reactive compensation but it is neither practical nor cost effective to use generation for that purpose. A typical solution involves installation of additional devices called Flexible AC Transmission Systems (FACTS) dispersed throughout the network nearer to the load points. A range of FACTS devices exists to serve as either sources or sinks of reactive power and typical devices include capacitors and reactors connected in various ways on the system and in various combinations depending on reactive compensation needs for each part of the target system.

This project focuses on one inductive FACTS device, the shunt reactor which is connected to limit voltage rise in capacitive circuits which have either nothing connected or have light load. Traditional shunt reactors have a fixed rating and are usually switched into service at times of troughs in load profiles. This implementation means that every time a shunt reactor is energised there is a corresponding big step change in voltage. This “all-or-nothing” response is undesirable thus “tapped” shunt reactors would be more preferable as they provide a range of set points (taps) with finer step changes to respond to a wider range of voltage requirements. However, the mechanical tap position changers on these devices have an inherent time delay when moving between taps resulting in a time lag of several minutes between the minimum and maximum ratings. Since modern networks are increasingly connecting dynamic generation sources such as wind to active loads, the inevitable and usually spontaneous fluctuations in generation output and load characteristics are best addressed by dynamic and fast acting reactive support. Tapped shunt reactors do not adequately address such stringent demands.

The current most optimal solution is to use Static Var Compensators (SVC) which comprise of reactors and capacitors switched by power electronics devices as well as circuit breakers (mechanically) where predetermined step changes are needed. SVCs are complex, costly to install and have high maintenance needs. A simpler means of dynamic reactive support without high capital and operational costs would be the most ideal solution. A Magnetically Controlled Shunt Reactor (MCSR) is a new type of FACTS device made by a Russian firm Zaporozh transformator PJSC (ZTR) which appears to address most of the foregoing concerns.

Method(s)

An MCSR possesses a continuously regulated inductive reactance to counteract circuit capacitance and therefore provides a smooth range of reactive output which keeps voltage within required limits. This is done by energising a control winding by a variable DC voltage which induces a bias magnetic flux in the core of the MCSR. This saturates the core of the reactor which results in the absorption of reactive power from the network. Provision of smooth control of the level of DC bias voltage allows variable reactive power to be drawn and quickly enough for the reactor to go from no load to rated power within 150ms.

This technology has mostly been proven in the Commonwealth of Independent States (CIS) countries (former Soviet Republics) but there are no known installations in other parts of the world or in Western Europe. The intention is to trial this technology in SHE Transmission’s License area in the future. This project is a feasibility study which will allow a detailed analysis of the technology and its implementation before a large scale live trial is attempted.

Scope

The scope of this project is to institute a study aimed at establishing the feasibility of installing a trial MCSR on the SHE Transmission network.

MCSRs have not been installed in GB and several details about the technology and the commercial and operational aspects of its implementation need to be assessed before developing enough confidence to do a trial installation on the network. The following aspects will form the methodology of the feasibility study:

- Best location to perform trial of the MCSR
- System data such as background harmonic levels and impedances
- Specification of the performance required for the MCSR on the basis of the chosen site and data
- Integration of the specified MCSR with filtering equipment and capacitors to achieve functionality equivalent to that of a standard like for like SVC
- Complete electrical and civil designs
- Complete quality and procurement review of the supplier, ZTR
- Risk analysis of the technology and potential impact on the trial
- Establishment of training, operation and maintenance requirements
- Costing of the trial installation project activities including training and harmonisation of procedures to address any potential incompatibilities between Russian and GB systems

The activities will be broken into distinct work packages and a report produced at the end of each work package. This project was initially proposed with a total duration of 9 months. A change has been made to extend duration to 15 months as a result of a delay to a system study, to be carried out by (or under the supervision of) SHE Transmission's transmission planning group.

Objective(s)

- Establish the best location for installing a trial MCSR, its performance specification and the relevant system data for the chosen location
- Utilise results from activities above as input for a detailed design of MCSR with capability to be adapted for the functionality of an SVC and including all associated electrical and civil designs
- Review ZTR's quality and procurement processes
- Perform risk analysis of the technology
- Establish the training, operation and maintenance requirements
- Compile reports with results of the study for use to decide the viability of a trial installation and as the design for the potential trial

Success Criteria

The success of this project is based on completion of the study and reports which can provide a basis for deciding the viability of installing a trial MCSR on SHE Transmission's operational network without compromising safety, health and the environment as enshrined in GB statutes.

Technology Readiness Level at Start	Technology Readiness Level at Completion
6	7

Project Partners and External Funding

All funding will be through NIA

Potential for New Learning

The project will provide new learning about:

- The technical feasibility of integrating an MCSR into GB Networks
- The cost effectiveness of using a combination of MCSR with capacitors as an SVC as opposed to a standard SVC
- The level of planning and training needed to roll out the technology
- The ease of adapting to or harmonising the quality, operational and procurement practices and standards of CIS countries with GB ones

The learning from this project will be disseminated through the online learning portal and also through a workshop.

Scale of Project

This project is a feasibility study which forms part of a detailed plan for the trial installation of an MCSR on the operational network. If successful, the actual trial installation can be commenced on the basis of the results from this project. The trial installation will be a large scale project but whose success is largely based on the results from this project. As a result, the scale of this project is deemed the minimum necessary for assessing all the essential aspects of the MCSR technology and associated activities before commitment to a live trial.

Geographical Area

The study will be based on a location in SHE Transmission's Licence area in Scotland.

Revenue Allowed for in the RIIO Settlement

No savings are expected during project implementation as it is investigating the feasibility of this technology and does not involve deployment. Forthcoming investment in reactive compensation is expected to be funded under Strategic Wider Works.

Indicative Total NIA Project Expenditure

An indicative expenditure of £120k is anticipated of which 90% (£108k) is Allowable NIA Expenditure

Project Eligibility Assessment

Specific Requirements 1

1a. A NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

A specific piece of new (i.e. unproven in GB, or where a Method has been trialled outside GB the Network Licensee must justify repeating it as part of a Project) equipment (including control and communications systems and software)	☒
A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)	☐
A specific novel operational practice directly related to the operation of the Network Licensees System	☒
A specific novel commercial arrangement	☐

Specific Requirements 2

2a. Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees ☒

Please answer one of the following:

i) Please explain how the learning that will be generated could be used by relevant Network Licenses.

If the project is successful in establishing the necessary requirements for integrating this technology into GB power systems, all Network Licencees will be able to make informed decisions about the suitability of the technology for their networks.

ii) Please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the Project.

2b. Is the default IPR position being applied?

Yes ☒

No ☐

If no, please answer i, ii, iii before continuing:

i) Demonstrate how the learning from the Project can be successfully disseminated to Network Licensees and other interested parties

ii) Describe any potential constraints or costs caused or resulting from, the imposed IPR arrangements

iii) Justify why the proposed IPR arrangements provide value for money for customers

2c. Has the Potential to Deliver Net Financial Benefits to Customers ☒

i) Please provide an estimate of the saving if the Problem is solved.

The most efficient FACTS devices currently in use are in the form of standard SVCs which incorporate reactors and capacitors controlled by power electronics as well as circuit breakers. All components are typically connected on the lower voltage side of step down transformers due to usual voltage ratings being circa 13kV. By virtue of their physical architecture, layout and connectivity with other power system components, standard SVCs tend to occupy very large footprints in substations.

In an MCSR based SVC, the MCSR and associated capacitors and filters are connected directly to EHV busbars. This eliminates the need for step-down transformers and numerous discrete reactors with a potential to significantly reduce the footprint needed for installation. The absence of power electronics devices eliminates the usual water cooling requirements associated with SVCs which contribute to the high overall cost and also the onerous maintenance requirements.

Use of MSCR based SVCs could therefore reduce the cost of controlling reactive power to maintain constant voltage on the network.

ii) Please provide a calculation of the expected financial benefits of a Development or Demonstration Project (not required for Research Projects). (Base Cost – Method Cost, Against Agreed Baseline).

Anticipated procurement savings are estimated as shown below. Base case and Method costs per unit of capacity are calculated to enable comparison:

Base case cost

A standard SVC rated for -50/+50 MVar costs approximately £5M.

1 x MVar of capacity in a standard SVC = £50,000 (£5M / 50MVar + 50MVar)

Method cost

A +90MVar MCSR costs approximately £2,6M. It is assumed that the capacitors needed to create a

-90/+90MVar MCSR based SVC will also cost £2,6M.

1 x MVar of capacity in an MCSR based SVC = £29,000 (£2.6M + £2.6M / 90 MVar + 90MVar)

Base case cost – Method cost = Savings

£50,000 - £29,000 = £21,000 per unit of capacity (MVar)

A more precise estimate of the savings achievable from this method will however only be quantifiable as part of the feasibility study based on the configuration decided upon, associated project activities and as a direct comparison with like for like alternatives.

iii) Please provide an estimate of how replicable the Method is across GB in terms of the number of sites, the sort of site the Method could be applied to, or the percentage of the Network Licensees system where it could be rolled-out.

In recent times, sources of renewable generation have increased resulting in voltage control difficulties on the network. These effects are ongoing and are likely to continue or escalate with further wind connections. FACTS devices are already being retrofitted in existing substations where voltage excursions are being identified and also in new substations at the interface with offshore wind generators; MCSR based SVCs could be applied to these types of sites in place of standard SVCs. SHE Transmission system planning has identified an anticipated need for controlled reactive compensation on the central transmission corridor and the eastern transmission corridor. As well as providing compensation to facilitate increased power flow during high transfer conditions, controlled reactive response is required to maintain compliance with voltage step criteria under network upsets. The requirement for at least two devices has been included in SHE Transmission planned reinforcements and ongoing planning studies indicate a potential requirement for a further two devices to cater for onerous contingencies. The estimated total cumulative rating for these four devices is 600 – 900 MVAr.

The diminishing amount of conventional generation is also exacerbating the issue of maintaining the capability of rapid reactive power control, particularly during periods of low load and limited renewable generation leading to high voltage levels and fluctuations. The SHE Transmission 132 kV network is susceptible to these conditions in the region north of Beauly and west of Fort Augustus. SHE Transmission, in conjunction with the System Operator (SO) and Scottish Power Transmission (SPT) are presently undertaking studies investigating the operation of the network under these conditions. The anticipated outcome of this investigation, based on results of some early analysis, is the identification of locations where rapid reactive power control will assist the SO operation of the network. In this instance the potential requirement is estimated at up to 100 MVAr from two or three devices.

A total requirement of 700 – 1000MVAr is therefore indicated in the next few years. This is the most recent appraisal of the potential for applying MCSR technology should it prove to be suitable.

iv) Please provide an outline of the costs of rolling out the Method across GB.

The analysis above provides an indication of the cost per unit of capacity for MCSRs, based on current knowledge, a refined estimation of rolling out costs of this technology will be made as part of the feasibility study when the costs of a typical implementation have been established.

2d. Does Not Lead to Unnecessary Duplication ☒

i) Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

There is no evidence of a similar project having been done in GB. Web searches have been performed, IFI, LCNF, NIA registrations have been studied to ensure the project is unique. The suppliers have also confirmed that the technology is yet to be deployed in Western Europe.

ii) If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.