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.

NIA Project Registration and PEA Document

Date of Submission

Oct 2018

Project Reference Number

NIA_SHET_0025

Project Registration

Project Title

Zero Missing Phenomenon

Project Reference Number

NIA_SHET_0025

Project Licensee(s)

Scottish and Southern Electricity Networks Transmission

Project Start

October 2018

Project Duration

1 year and 9 months

Nominated Project Contact(s)

Joe McNeil

Project Budget

£128,500.00

Summary

The efficient running of high voltage Alternating Current (AC) networks involves, among other things, the management of reactive power flows. Transmission lines and cables tend to generate reactive power which requires to be compensated for to manage voltage profiles and reduce energy losses on the system. During periods of low loading, the voltage on a long transmission line or cable may increase along the circuit with the potential to fall outside the operational limits and equipment voltage design ratings which could result in equipment failure. One effective way to manage system voltages within desired operational limits is the use of shunt reactors where the system is susceptible to high voltages. The transmission networks in GB have several installations with shunt reactors connected in different configurations including, but not limited to, line connected, busbar connected and auto-transformer tertiary connected to manage system voltages.

Nominated Contact Email Address(es)

transmissioninnovation@sse.com

Problem Being Solved

The efficient running of high voltage Alternating Current (AC) networks involves, among other things, the management of reactive power flows. Transmission lines and cables tend to generate reactive power which requires to be compensated for to manage voltage profiles and reduce energy losses on the system. During periods of low loading, the voltage on a long transmission line or cable may increase along the circuit with the potential to fall outside the operational limits and equipment voltage design ratings which could result in equipment failure. One effective way to manage system voltages within desired operational limits is the use of shunt reactors where the system is susceptible to high voltages. The transmission networks in GB have several installations with shunt reactors connected in different configurations including, but not limited to, line connected, busbar connected and auto-transformer tertiary connected to manage system voltages.

A growing challenge in networks is the reduction of reactive power demand due to changing characteristics of the demand seen at the transmission level. This results in increased voltage levels, mainly on the transmission system. The high voltage issue is compounded by the continued closure of conventional generation plant, which is mainly being replaced by low carbon generation which has lower

reactive power capabilities as well as reduced fault level contribution to the system. This necessitates the use of reactive compensation equipment to contain the high system voltages. Shunt reactors are a proven cost-effective solution, among other reactive power compensation devices, for mitigating high voltages and they are in common use on the GB transmission system.
The drop in system fault levels, coupled with the use of shunt reactors for voltage management results in a change to the characteristics of the short circuit currents on the network. It is widely understood that when a short circuit occurs, the total current which flows consists of two components namely; an AC component (or symmetrical current) which varies sinusoidally with time and a DC component which is non-periodic and decays exponentially at a rate determined by the time constant of the system. This system time constant is determined from the ratio of the system reactance to the system resistance (X/R) as seen from the point of fault. The X/R ratio of the system affects the DC component and the peak of the fault current at fault inception by introducing a temporary axis which offsets the point about which the sinusoidal current (AC component) oscillates. The higher the X/R ratio of a circuit, the higher the peak fault current and the longer the time it takes for the DC component to decay. For high system X/R ratios, it is possible that under low system fault level conditions the AC fault current component may not cross the axis due to the high DC current offset. This is known as the Zero Missing Phenomenon (ZMP). The intended function of reactors is to absorb reactive power which necessitates their high reactance values (X) and, in order to minimize active power losses, their resistance values (R) are kept to a minimum. This results in very high X/R ratios in installations with shunt reactors. This makes shunt reactor compensated systems with low fault levels susceptible to ZMP.
AC circuit breaker design is reliant upon current zero crossing within rated time for successful interruption of current. It has however been shown on recent transmission designs that a circuit breaker on a circuit with a shunt reactor may have to interrupt fault currents with high and slowly decaying DC components that result in the ZMP, i.e. the current zero crossing not being realised within the rated time for the circuit breaker to clear the fault. This situation is pronounced where there is low fault current infeed through the circuit breaker attempting to clear the fault. In this case, the lower peaks of the symmetrical current component oscillating about the DC offset remain above zero. This issue raises questions which require further investigation, such as:

- What are the transmission design characteristics that make circuit breakers susceptible to the ZMP?
- What is the likelihood that the circuit breaker will be faced with this situation?
- What are the likely consequences of the ZMP?
- If the circuit breaker successfully chops the current, what happens next?
- Can a switching strategy or some cost-effective mitigation be devised?

This project aims to address the questions above through detailed investigation of the phenomenon and its impacts followed by investigation and development of mitigation options.

Method(s)

This project proposes a technical method that will involve engaging consultants to investigate the ZMP and produce conclusions that can impact the future of circuit breaker design. The investigations will focus on understanding the decaying DC current phenomenon produced through the use of shunt reactors, potential consequences and risks, and the ability of existing equipment to interrupt it. It will also outline any potential mitigation options and test their efficacy through network studies. The planning, training, operation and maintenance requirements of any viable mitigation options will also be established. This information can be used by network companies with similar installations. This problem has not been previously investigated in detail. The shunt reactor DC current problem can pose significant risk to equipment and nearby personnel and merits further investigation.

Scope

This project focuses on investigating the decaying DC current problem. It is a feasibility study only, with its conclusions intended to further collective understanding of the problem while assessing the viability of mitigation strategies and technologies. Future projects can use this information to decide if live trials are suitable.
The following steps will form the methodology of the investigation:

- A thorough literature review to identify previous work in this and similar areas. This will include an overview of the ability of circuit breakers and different circuit breaker technologies to interrupt decaying DC currents.
- Shunt reactor installations on the SPT and SHE Transmission Network will be grouped into a number of typical representative cases. For each representative case, simulations shall be carried out to understand and quantify the reactor DC current problem, its impact and associated risks.
- OEMs will be engaged to establish the capability of available equipment and circuit breaker technologies to interrupt prospective DC currents.

· The likelihood of the problem occurring, the associated risks and mitigation options will be evaluated, and their efficacy tested through further network studies.

· Operational guidance will be developed, and recommendations formulated for future implementation in network companies.
A progress report will be produced upon the completion of each step outlining the results and findings.

Objective(s)

· An investigation into the ZMP DC current problem in detail (cause, consequences and likelihood).

· An investigation into the capability of circuit breakers to interrupt the prospective fault current

· An investigation into mitigation options and strategies (and developing them)

· Risk analysis of any viable mitigation options and strategies

· Establish the planning, training, operation and maintenance requirements of any viable mitigation options

· Compile reports with results of the study for dissemination and to decide the viability of live trials of the mitigation options

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

The success of this project will depend on the completion of the investigation into mitigating the problems caused by the reactor DC current problem. Success criteria for the project are:

· Improved understanding of the ZMP due to shunt reactor switching and the problems associated with it

· Gaining an understanding of the viability of technological and operational mitigation options for these problems

· The dissemination of any learning

· Stakeholder satisfaction

Project Partners and External Funding

Scottish Power Transmission

Potential for New Learning

The project will provide new learning about:

· The ZMP DC current problem and any potential consequences and associated risks

· The capability of circuit breakers to interrupt the prospective fault current

· Mitigation options and strategies for this problem and their viability

· The planning, training, operation and maintenance requirements of any viable mitigation options
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 into the problems caused by the ZMP and possible mitigation solutions. If successful, the learning can be disseminated, and future projects can use this information to decide if live trials are suitable. The scale of this project is deemed the minimum necessary to carry out the essential investigations and simulations required to fully investigate and report upon this problem area.

Technology Readiness at Start

TRL1 Basic Principles

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

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

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£110k, 90% of which is allowable NIA funding

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

n/a

How the Project has potential to benefit consumer in vulnerable situations:

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

Any solutions to the problem learned through this project's investigations will potentially be much more cost-effective than any mitigation options currently employed on the network. There will also be savings through prevented equipment damage.

Please provide a calculation of the expected benefits the Solution

Research Project

Please provide an estimate of how replicable the Method is across GB

The project is looking into a problem that affects all network licensees making any learning highly replicable.

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

Project will not lead to a rollout (feasibility study only).

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 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 system 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

RIIO-2 Projects

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☐ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☐ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

The problem of voltage control exists on every network. With the proliferation of Distributed Energy Resources (DER), we are likely to see more reactive compensation required across Distribution and Transmission Networks. This project will generate learning that will support this change in network composition.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

n/a

☑ Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

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

Checks on ENA Smarter Networks Portal showed no other related projects for this specific problem. There are projects on Direct Current (DC) Circuit Breakers (CBs) but we are hopefully looking for more options than simply adding new (costly) DC CBs to the network.
Internet searches reveal that this problem only has theoretical research conducted into it. The aim of this project is to investigate this problem and any mitigation strategies that may exist and verify them with network studies. Consideration will also be given to the planning, training, operation and maintenance requirements of any viable mitigation options providing additional (new) commercial insights for network companies.

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

n/a

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

The Zero Missing Phenomenon is a new challenge manifesting itself in networks of particular configurations and which is only understood on a rudimentary theoretical basis so far. This project aims to delve deeper into understanding the conditions that create the problem and then using the knowledge gained to investigate potential cost-effective mitigation strategies which do not currently exist.

Relevant Foreground IPR

The “Technical Guidance Note” that was created to be used by Transmission Planners to identify and mitigate the ZMP problem:

This is owned by Mott MacDonald and they provide a licence to the industry partners involved in funding the project (SHET & SPT).

The dissemination of this is subject to a Direct Investment Agreement signed through the “Energy Innovation Centre” in collaboration with Scottish Power Transmission. This DIA grants all ‘Network Licensees’ (i.e. any DNO / GDN licensed by Ofgem) with a license to use ‘Relevant Foreground IPR’ (in line with the requirements of the NIA funding). Therefore, the note cannot be shared publicly but can be made available if requested by one of the other Network Licensees.

Data Access Details

n/a

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

The investigations performed as part of the project are quite innovative, as stated in the previous section and therefore fall outside the scope of routine business activities. There is also a lack of in-house technical expertise and equipment/software within the affected network licensees to undertake the project under normal business as usual activities.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

The project involves a collaborative effort between SHE Transmission and Scottish Power Transmission to establish a potential solution to a problem that is becoming more prevalent on their networks. The learning from the project is likely to have impact not only for other network licensees but also for the entire supply chain since there is potential for recommendations from the project to be considered by switchgear OEMs. Ultimately, that would be expected to deliver value to customers. Although the foregoing makes the business case strong, work of this nature still poses financial risk since the outcome may not always be successful. The fundamental aim of NIA funding makes it possible to carry out such investigative research work. In the event of the project outcome being unsuccessful, the sharing of the learning from the project as required under NIA rules means there will be potential for future cost savings from avoidance of investment into similar investigations.

This project has been approved by a senior member of staff

☑ Yes