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

Jan 2014

Project Reference Number

NIA_NGET0103

Project Registration

Project Title

Modelling the tape corrosion process for oil-filled underground cables

Project Reference Number

NIA_NGET0103

Project Licensee(s)

National Grid Electricity Transmission

Project Start

October 2013

Project Duration

3 years and 1 month

Nominated Project Contact(s)

Fan Li

Project Budget

£637,000.00

Summary

The conventional sampling method (currently adopted by National Grid) is a phenomenological one which is far from optimised. On the other hand, research in mechanics of materials has provided a solid understanding and large amount of data for corrosion fatigue. The factors that control corrosion fatigue of the tin bronze tapes include the oil pressure, temperature and its range of change (caused by change in loading), and the environmental factors of the cable's laying environment, such as the presence of ammonia, chloride, sulphur and moisture. This project will enable National Grid to take these controlling factors into account in the life prediction and sampling strategy. There are five milestones in the proposed project: a) the dominant failure mechanism of the reinforced tape is confirmed; b) the empirical and mechanism-based models for calculating (cross-reading) cable condition and remaining life are identified; at the same time c) a database for nominal input data from literatures including environmental corrections is setup; d) a sampling strategy is established, and e) National Grid's specific data to refine the modelling accuracy is included.

Nominated Contact Email Address(es)

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Problem Being Solved

A particular family of oil-filled transmission cables is vulnerable to failure of the tin bronze reinforcing tapes that provide mechanical support to the lead sheath. An oil leak detected in 1996 was found to have been due to the failure of the reinforcing tapes, causing significant reliability and environmental issues and resulting in the replacement of the cable. More cables have failed since then as a result of this deterioration mechanism. A series of asset management initiatives, including investigations and sampling, have been undertaken over the past 15 years in order to understand and prevent this problem. However it has been recently realised that the reinforcing tape failure may not be as severe as expected by our current understanding. It is in the consumers' interest to avoid premature asset replacement. Due to the long lead time associated with planning cable replacement, accurate condition assessment and deterioration models are needed, as well as effective risk mitigation strategies. The conventional method of taking samples is impractical for underground cables because it is an invasive method which runs the risk of damaging the cable. More importantly sampling without a guiding strategy may not be able to reveal the worst corroded area. Therefore it is difficult to be confident about our current understanding in the cable's conditions. A quantitative mathematical model together with reliable database is required to calculate the asset conditions and remaining life and to guide the sampling strategy. Such condition calculations and sampling strategy are extremely important to manage these assets effectively and to plan their replacement.

Method(s)

Research

The proposed research takes advantage of a “cross-reading” methodology that has been established and used for life prediction of engineering systems in other industrial areas. In this approach, the current conditions and remaining life are “cross-read” (calculated) from case studies of existing failure incidents. A pilot study by Leicester confirms National Grid’s previous studies that the reinforcing tapes failed by corrosion fatigue. The cross-reading will be based on a combination of empirical and mechanism-based models for corrosion fatigue. This approach is particularly useful in life prediction for engineering systems which haven’t yet experienced their full life cycle. The project will consist of three steps: 1) identifying an empirical model as the basis of cross-reading. For example, the crack initiation and crack propagation depend on local stress and corrosive damage (such as Paris’ law). The empirical parameters in those models are material and environmental specific. They can be back-calculated from existing cases studies using finite element models. This leads to step 2): developing a database for environmental correction – the empirical parameters will be modified according to the local chemical environment using mechanism-based models. The input parameters in the mechanism-based models are the electrochemical properties of the material and environment, which are adaptive to individual cables buried in different environments. Step 3) experimental studies to confirm the dominant mechanism for corrosion fatigue assumed by the mechanism-based model. These include SEM studies of the failed cables and corrosion experiments to mimic the chemical conditions at the crack tip.

The biggest risk when calculating the remaining life is that different laying environments of the buried cables can lead to different underlying mechanisms of corrosion fatigue. National Grid’s limited number of failure cases and lack of data for the local environment are the major challenges. In this project, the lack of case studies will be compensated by using mechanism-based models and nominal data in the literature for corrosion fatigue. Using this approach, it is possible to calculate cable conditions and remaining life without further sampling. However further samplings would significantly improve the model accuracy. Balancing the cost of further sampling with the risk of using the current data is essential to National Grid’s decision making in assess management. This project will quantify the risk of using the nominal data and mechanism-based models. This is to be achieved by Monte Carlo simulations on the nominal data and studying the sensitivity of model prediction to the input parameters. The quantified risk, the identified key input parameters and the cross-reading model will then be combined to establish a strategy to determine where, when and how to sample. This project will also actively seek opportunities to take samples from cables that are de-commissioning, being repaired or maintained. However targeted sampling will only be carried out where it is useful and when the risk out balances the sampling cost. The developed sampling strategy will minimise the risk that unnecessary or wrong samples are taken from operating cables and enable National Grid to avoid decommissioning cables prematurely. This sampling strategy will be a key deliverable of the project.

Scope

The conventional sampling method (currently adopted by National Grid) is a phenomenological one which is far from optimised. On the other hand, research in mechanics of materials has provided a solid understanding and large amount of data for corrosion fatigue. The factors that control corrosion fatigue of the tin bronze tapes include the oil pressure, temperature and its range of change (caused by change in loading), and the environmental factors of the cable’s laying environment, such as the presence of ammonia, chloride, sulphur and moisture. This project will enable National Grid to take these controlling factors into account in the life prediction and sampling strategy. There are five milestones in the proposed project: a) the dominant failure mechanism of the reinforced tape is confirmed; b) the empirical and mechanism-based models for calculating (cross-reading) cable condition and remaining life are identified; at the same time c) a database for nominal input data from literatures including environmental corrections is setup; d) a sampling strategy is established, and e) National Grid’s specific data to refine the modelling accuracy is included.

Objective(s)

1. Confirm the dominating mechanism leading to tape failure and consequent oil leak
2. Develop a computational (cross-reading) method for calculating residual life before failure
3. Identify input parameters required by the computational method from data of leak and non-leak case studies, history of oil pressure, temperature and temperature change environmental variables
4. Quantify the risk of using nominal data and mechanism-based models in the life prediction
5. Develop a database of input parameters for the computational model from both the research literature and the National Grid reports and database.
6. Practical risk mitigation recommendations regarding to cable tape corrosion

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

- Quantitative understanding on the mechanisms of tape failure
- Innovative methodology and framework for cable condition assessment
- A deterioration model able to capture the dominant mechanisms of the tape corrosion problem.
- Database which provides key input for the model
- Sampling and decommissioning strategy which will enrich the database
- Risk mitigation recommendations based on understanding the dominant mechanisms of corrosion

Project Partners and External Funding

n/a

Potential for New Learning

n/a

Scale of Project

Tape corrosion vulnerable cable network (~180km/650km) for National Grid

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

Tape corrosion vulnerable cable network (~180km/650km) for National Grid. Majority of cables located in London.

Revenue Allowed for the RIIO Settlement

Zero

Indicative Total NIA Project Expenditure

NGET NIA project expenditure is £637,000

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)

Equivalent of avoided cost benefit of £ ~270K per km of cables (subject to sharing factors) with increased 45 to 55 years.

Please provide a calculation of the expected benefits the Solution

Research Project - Not Required

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

180km/650km in National Grid's transmission network indicatively

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

This learning will be embedded within National Grid and disseminated as part of the project costs.

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

It will contribute to the National Grid's understanding of assets and therefore improved asset management strategies. The knowledge is also available to distribution network owners who might need to tackle similar asset deterioration problems.

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.

n/a

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

n/a

Relevant Foreground IPR

n/a

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

n/a

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

n/a

This project has been approved by a senior member of staff

☑ Yes