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NIA Project Registration and PEA Document

Date of Submission

Sep 2023

Project Reference Number

NIA2_NGET0049

Project Registration

Project Title

Sprayed Metal for Effecting Leaking Transformer Repairs (SMELTeR)

Project Reference Number

NIA2_NGET0049

Project Licensee(s)

National Grid Electricity Transmission

Project Start

October 2023

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Muhammad Shaban

Project Budget

£1,150,000.00

Summary

Rawwater provides leak and defect sealing solutions using low melting point alloys called M3. Rawwater's proprietary technology includes M3Spray in which molten alloy is sprayed directly against a flowing liquid leak to stem it.

Building on the leak sealing feasibility work carried out previously, the project will focus on the testing of Rawwater's M3Spray for sealing realistic transformer leak scenarios, including on decommissioned transformer parts. Deployability of the solution including access nozzle development for manual application and semi-autonomous robotic integration for controlled deployment will be tested. Alloy containment to ensure that metal particulates are contained and controlled will also be tested.

This work will culminate in a pilot deployment on a transformer (TRL7) on the NGET estate. Following an initial period of 3 months, there is the option to extend the project to include further robotic integration and further scenarios to a wider range of leaks.

Nominated Contact Email Address(es)

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Problem Being Solved

Transformers across the asset network leak oil. This requires significant maintenance to keep topping up the oil. In addition, leak paths for oil become ingress paths for moisture and air – both of which affect transformer operation significantly. A solution is needed which works (technical solution), can be easily deployed (practical solution), without the need to remove the oil from the transformer (solution benefit).

There are 3 main areas where transformers are known to commonly leak from: the flanged lid, bushing turrets and the radiator bank. The bushing turrets are known to operate at temperatures exceeding the melting point of Rawwater's current 'in use' alloys. While there are a range of alloys, the M3Spray equipment is currently set up to operate with alloys which have a melting point below 100°C and thus the bushing turrets have been discounted at this time. The focus of the project will be a flanged lid and a radiator.

Last year, in collaboration with EPRI, Rawwater's M3Spray technology was tested against some simulated leaks on a pipe connector

and a flanged connection of dissimilar metals with a gasket. M3Spray was found to perform well, particularly on the flange, including after undergoing pressure and temperature cycles.
Significant leak reduction was able to be achieve with no surface preparation and while oil was dripping, thus the feasibility of the technique was proven.

Method(s)

The pilot transformer and radiator will be chosen by NGET, in collaboration with Rawwater and Createc, towards the start of the project. Up to four sites will be visited for identification of suitable pilot transformer and radiator. Requirements capture will take place in terms of site considerations, success criteria and wider questions which need to be addressed, such as condition of equipment substrate, work at height and accessibility for a MEWP.

Small-scale lab-based tests will be set up and conducted within a bespoke indoor rig which simulates the conditions within a transformer, to establish optimal spray and deposition parameters, based on site requirements and success criteria. This rig will include a sliding mount to simulate robot arm movement such that spray arm movement can be simulated, informing optimal movement speeds, hose span and deposition characteristics. The rig will have capability to heat the specimen to represent site operational temperatures (up to 65°C), and fault conditions (above alloy melting point) and will simulate oil pressures within a transformer. Post-testing, the oil will be filtered and examined, and the test rig/specimen will be dismantled to inspect for alloy ingress. Testing will include heating of the specimen post- spray to observe whether the alloy melts and enters the defect. Should alloy ingress be observed under any conditions, the project will be paused for investigation and discussion before proceeding further.

The M3 equipment will be reviewed and upgraded to ensure suitability of alloy capacity and alloy deposition for these types of use cases, which require alloy 12. Alloy 12 is a higher melting point alloy than used in SF6 National Grid deployments, necessary for the temperature profile of transformers. Alloy 12 was used in the EPRI feasibility project, and is suitable for use at operational temperatures of less than 65°C.

For the purposes of representative testing, Rawwater will prepare a bespoke outdoor test area with hardstanding and weather protection. A decommissioned radiator bank and transformer with flanged lid will be delivered by NGET to Rawwater and installed in this bunded area. The equipment will be prepared for representative tests of both manual and integrated solutions. This may include, where feasible, addition of a monitoring system to gather results on effectiveness of the seal and other aspects identified as key in the small-scale testing. RAMS will be produced.

As informed by lab testing and representative testing, the development and testing of the combined solution for the flanged lid will then take place. For the flanged lid, the testing will focus on refining the following steps initially:
1. 3D scan of a leaking section, covering both straights and corners.
2. Path planning selection, using a basic User Interface.
3. Alloy deposition using the M3Spray and autonomous robotic movement, while containing alloy to design deposition locations only.
Both M3Spray and the robot will be controlled at a short distance from the leak site.

Mechanical interfaces between M3Spray and the robot will be collaboratively designed and commissioned. A secure robotics platform for the equipment to be used on site will be designed and manufactured. The robotic User Interface will be designed and tested, with planning undertaken for how this will be physically utilised onsite. This preparatory work, including two days' training of Rawwater by Createc and three separate weeks of collaborative Rawwater/ Createc testing, followed by up to three months of testing by Rawwater, with remote support from Createc, to finessing of the combined robot/M3 application on decommissioned equipment and ensure a controlled and consistent alloy deposition, even in difficult to access locations.

Createc will provide a correctly specified robotic and MEWP equipment for the testing and deployment duration. This will consider access constraints and safe robotic arm reach from the extended MEWP position. The robotic arm will be securely always attached to the MEWP.

Bespoke hose nozzles and attachments will be developed, manufactured, and tested to optimise spray access for hard-to-reach locations such as between the fins of a radiator bank and to optimise spray deposition pattern. These must be tested to ensure no reduction in M3Spray performance. Once developed, the access nozzles will be used for testing on the decommissioned transformer.

Containment solutions to keep alloy deposition within the prescribed areas, as identified in requirements capture. Containment will be designed and tested on the decommissioned transformer.

For both containment and access nozzles, optioneering will identify candidate designs and chosen solutions will be implemented, as informed by the findings of the representative testing. It is likely that this will involve some heating and related controls. In addition to alloy deposition, this development will consider full lifecycle of onsite operations such as line purging between M3Spray operations. It is possible that a range of options will be required to meet the requirements of a range of access and containment needs. The full test findings will be reviewed and in collaboration with Createc, the final solution for the pilot agreed.

A test report will be produced upon completion of lab testing and will be updated and re-issued on completion of the representative testing. Site RAMS will be produced and signed off by NGET. Any personnel attending site requiring persons training will undergo the training.

Scope

The project will deliver the pilot leak seals but also test and develop the solution for aspects which would inform future wider applications. The major challenges to be overcome to meet the objectives and inform wider application are access and containment, while maintaining M3 sealing capability. The project would take the technology from TRL 4/5 to TRL 7 and provide underpinning for a potential project extension which would further automate the process, resulting in TRL 8. The test candidates will be chosen for their suitability. They will be close to the end of their active service and will be accessible to Rawwater and Createc equipment and personnel. Ideally these test candidates will be at the same site or close enough sites to allow travel between them during the same week's deployment. The radiator seal will be placed using manual M3 spray, with bespoke attachments for improved access. Containment will prevent the alloy spray from being deposited in undesirable locations. The integrated spray application to a transformer lid will be undertaken on site such that the spray is done, by sections, semi-autonomously. Based on current thinking, the process is likely to be:

1. A MEWP, mounting the robot, is driven to the location of M3Spray deployment.
2. The robot arm completes a 3D scan of a short section.
3. A user generates the spray path the robot must follow, using a basic User Interface.
4. Users start the spray process, M3Spray is manually started, robot arm moves autonomously.
5. Repeat 1-4 all around the transformer if feasible.

Testing will be done to confirm and refine the technique.

Containment will be developed to prevent the alloy spray from being deposited in undesirable locations. The resulting spray applications will be monitored by NGET for twelve months. After three months, if performance is satisfactory, there will be an option to proceed with an extension to the project with a greater degree of M3Spray automation to prepare for wider pilots and eventual roll out across the network. This would take the form of a robotically controlled elevated work platform and a robot with enhanced automation capabilities, to cover a wider range of access environments, however, this is outside the scope of this detailed proposal.

Objective(s)

The objectives of this project are to:

- Deliver a pilot to seal or heavily mitigate one oil leak on an in-service radiator bank using manual application of M3Spray with appropriate access and containment.
- Deliver a pilot to seal or heavily mitigate one oil leak on an in-service transformer flange lid using M3Spray with appropriate access via robotics and alloy containment, whilst also proving the concept of integration of M3Spray with a robot allowing semi-automation of the spray application process.
- To test:
  - the effect on the alloy seal of heating the asset
  - the required surface preparation
  - sealing over a failed repair

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

Financial distributional impact:

This project ensures that NGET and the UK energy industry are at the forefront of global developments in asset management of transmission system research, enabling the industry to make decisions that could reduce mineral oil top ups and thus reduce OPEX expenditure and are supported by comprehensive research and experiments. With access to the latest research development in oil leak fixation, NGET will be able to manage transformer oil leaks more efficiently and effectively which could deliver savings. Furthermore, the leveraged funding mechanism ensures that expensive research can be carried out at subsidised rates, thereby ensuring the best value for consumers' money. The project will not restrict benefits delivered to vulnerable consumers based on any vulnerability class.

Technical and wellbeing impact:

There is uncertainty in the technology whether we can use Molten metal spray for fixing oil leaks. Mineral oil is clearly a non-renewable mineral oil and using less mineral oil has obvious environmental benefits.
The outcomes from this research will inform and enable the energy industry to take appropriate measures in the best interest of consumers, particularly in the vulnerable category, as the world transitions to a Net Zero future.

Success Criteria

This project will be considered a success if it will be able to answer following technical questions raised in the previous feasibility project and in SF6 project. These include:

- Could there be ingress of alloy in fault conditions on the flanged lid where it exceeded the temperature of the alloy melting point?
- Can M3Spray can be applied over existing failed repairs?
- What surface preparation should be carried out to maximise the sealing performance?
- How does the M3Spray process of alloy deposition required modification for 2 realistic leak scenarios identified for the pilot (TRL 7) and further radiator and flanged lid scenarios (TRL 8)?

The technical development will include testing on a small-scale rig and a decommissioned transformer.

There are practical aspects of the pilot deployment, and beyond which require a different approach to deployment. These may include:

- Development of the nozzle to allow access to hard-to-reach places such as a distance into the transformer bank.
- Integration with robotic deployment to provide a controlled and consistent alloy deposition, even in difficult to access locations.
- Development of the M3Spray equipment to meet alloy deposition requirements.

Once these development areas are complete, the solution will be tested on a pilot transformer, chosen at the start of the project. The definition of success will be agreed and means of measuring success. Following the pilot deployment, the pilot seals will be monitored for a period of 12 month. Additional development to achieve higher TRL can be developed in parallel to the 12-month monitoring. This will mainly focus on additional practical development to ensure deployments are efficient in the future.
A phased approach with hold points will be used to allow for ‘fail fast’ principles.

Project Partners and External Funding

The following project partners will be supporting the project:
Lab testing facility of Rawwater will be used alongside all other technical services at no extra cost to the project.
NGET is providing all the funding for the project and is the only lead project partner.

Potential for New Learning

- Confirmation whether M3Spray is a suitable technology for use for transformer leak sealing (safety and operational aspects tested and reported on)
- A deployable ‘site ready’ solution for two specific scenarios, and sealing of those scenarios in a pilot deployment (TRL 7 option)
- A deployable ‘site ready’ solution to conduct further pilots on a wider range of leak scenarios (TRL 8 option)

Reports will be provided with the results of testing undertaken and associated analysis.

While outside of the scope of this formal proposal, further scope could explore M3Spray automation to prepare for wider pilots and eventual roll out across the network. This would take the form of a robotically controlled elevated work platform and a robot with enhanced automation capabilities, to cover a wider range of access environments. Detail to be agreed upon project confirmation. This would result in TRL 8 level technology.

Scale of Project

Laboratory testing and investigations will be carried out on a decommissioned transformer provided by NGET. Rawwater will design and plan the testing on the transformer using the molten metal spray. Findings will be shared with NGET and a solution will be deployed to a transformer near end life and observed by NGET for 12-month period. During that 12-month period, if the seal is working as expected after 3 months, other testing will be designed for other different scenarios for a complete deployment of the solution.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL8 Active Commissioning

Geographical Area

Laboratory studies to be performed at Rawwater testing facility at Culcheth Enterprise Centre Withington Avenue Culcheth Cheshire.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£1,035,000

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:

Mineral oil leaks are an issue NGET is facing arising from 250,000 L/Annum a decade ago to 700,000 L/annum in 2022 (1% of total volume). Reduced oil leaks lead to reduced top ups and reduced travel to substations (Scope 1 emissions). Improves early problem fixation reducing the fault risk and managing the outages for oil top ups.

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)

N/A

Please provide a calculation of the expected benefits the Solution

The benefit of this project assumes that NGET will achieve fixation of transformer oil leaks in future. Now 169 assets have leakage issues and if fixed through this innovative solution, the mineral oil top up quantity will be reduced saving costs related to procuring mineral oil, labour cost associated to it, and the travel cost. If this project is successful, over a 20-year period, we assume that the overall asset health will improve, and NGET will be able to save £5.5m arising from savings of mineral oil top up and associated costs.

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

The transformer oil leak is not the issue only NGET faces but all other TOs and DNOs has similar issue in which regular top ups are required. The success of this project will reduce the quantity required for oil top up and the associated labour cost. The technical solution deployment will allow other TOs and DNOs to adopt the solution and reduce the maintenance outages. Other licensees may benefit from employing such solution and reduce the overall cost associated with it.

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

Conservative estimates of costs have been made for the purposes of assessing the value of this project, they are based on the cost of mineral oil which is roughly £1/L, the reduction in such a resource will reduce the cost accordingly. Transformer replacements in RIIO-T2 period is budgeted at over £240M. Savings made due to spend in T1 on asset life extension is £97M. If more transformers can operate longer than currently planned, significant savings can be made, orders of magnitude above the spend of this project, and the end solution.
The solution rolling out cost is dependant on the success of the project whether it reaches TRL 8 or ends at TRL 7.

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 transformer oil leak is the issue every TO and DNO is facing and the project if successful will develop deployable solution which can be used by other Network Licenses without any modifications.

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

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.

A review of ongoing and previous projects has not shown any duplication with regards to this work. Molten metal spray has been applied for SF6 leaks in the past however no application to transformer or other oil containing assets has been reported to date. A systematic search on the ENA portal and the web has been done to avoid any duplication. This is the first NIA project to explore the molten metal spray and the transformer oil leaks. The risk of duplication will be addressed through dissemination of progress with other licensees and being open to co-operate with licensees working in this space.

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

This innovative sealing technique has been invented by Rawwater and its capabilities and operational envelopes are being developed and understood. The focus of development of Rawwater's technology has been for sealing SF6 leaks using M3CollarCast technology. M3Spray is a similar technology in the sense it uses the same alloy, which is low temperature and reversible, but it sprays the alloy rather than injects it into a mould.

M3Spray is a unique technology and has not been tried before on a realistic oil leak scenario, only on a feasibility project. The innovation is to see is M3Spray can be modified to make it suitable for transformer leak sealing, when considering the specific materials, geometries, and access restrictions.

The innovative aspects go beyond the sealing technique itself and includes the access and deployment aspects via the with robotics which will operate semi autonomously, moving through the deployment path automatically. This will be an innovation in approach to maintenance, learning from the nuclear industry, removing the human from the operating face, reducing the risk of deployments, particularly in difficult to access areas.

Relevant Foreground IPR

The foreground IPR will be the learnings gained by the implementation of molten metal on transformer oil leaks. The learning will be brought together in a decision support tool which will also form part of the foreground IPR. A deployable solution might also be a part of solution depending on project success.

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

- A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project and click 'Contact Lead Network'. National Grid already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
- Via our Innovation website at https://www.nationalgrid.com/uk/electricity-transmission/innovation
- Via our managed mailbox box.NG.ETInnovation@nationalgrid.com

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

There is currently significant uncertainty regarding the feasibility and accuracy of the proposed method. The molten metal spray has not been applied to transformer oil leaks because of the low temperature of molten metal and high transformer oil temperature. It is likely that the seal is practical for some leaks and not for all. The technical risks mentioned above needs to be answered first before BAU can use it. Due to the uncertainty of the product, gating process is used in the process in which we can determine depending on the results achieved whether we must move forward with the project or not.

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

There are technical risks associated with any innovation project as the proposed solution may not work. Testing to date suggests that the work will be successful, but it cannot be guaranteed. If the laboratory testing is proven successful, the project will carry on working on deployment of the solution to BAU.

The project is anticipated to generate sufficient benefit to justify the expenditure over 20 years. So, the success of the project will only become truly apparent over a longer period. During that time alternative, currently unforeseeable, solutions may arise that provide greater benefit.

This project has been approved by a senior member of staff

☑ Yes