Low Energy Automated Networks (LEAN)

Project Closedown Report

SDRC 9.8 Knowledge & Dissemination

Scottish and Southern Electricity Networks (SSEN) is the trading name of Scottish and Southern Energy Power Distribution (SSEPD), the parent company of Southern Electricity Power Distribution (SEPD), Scottish Hydro Electricity Power Distribution (SHEPD) and Scottish Hydro Electricity Transmission. SEPD is the contracted delivery body for this LCNF Project.

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Version Control

Version	Date	Authors	Change Description
1.0w	09/01/2020	Sarah Rigby Maciej Fila	Final version for website publication following internal and external peer review and sign-off

SDRC Report Specification

Criterion 9.8 Knowledge & Dissemination	• Project closedown report including 'Network Losses Reduction Tool' analysis. • External workshop to present tool and project outcomes. • Plan produced to integrate the loss saving techniques into the business for a large scale rollout if applicable.
Evidence	Evidence: Produce final report and present to Ofgem.
Date	9th January 2020

Photograph of two 33/11kV primary substation transformers during a visit to a LEAN project trial site

Executive Summary

The Low Energy Automated Networks (LEAN) project has successfully met its objective to develop and apply Transformer Auto Stop Start (TASS) technology to reduce losses at 33/11kV primary substations.

The key principal of TASS is to switch off one of a number of transformers in a primary substation at times of low demand to avoid the fixed iron losses associated with that transformer - akin to turning off a car engine when the vehicle isn't driving anywhere.

The TASS system provides local, automated control within the substation to monitor the loading and control this switching, and to respond to SCADA alarms and status information from other network assets. In addition, commands incorporated into the Distribution Management System (DMS) provide the central network Control Room with remote supervision and management capability. The technology has been deployed in primary substations on the SEPD network since June 2018, and over the formal twelve month trial period achieved energy savings of over 67 MWh in total across the two trial sites, with full operation reducing transformer losses by ~25-30%. No impacts on asset health due to TASS operation have been identified through the suite of testing and monitoring techniques applied.

The system continues to operate as designed, demonstrating the ability to both reduce losses and respond appropriately to different network situations, and the scheme design developed through the project provides a streamlined system for integration with existing assets to deliver the TASS functionality.

A second method evaluated through the project was Alternative Network Topology (ANT), which would make use of existing 11kV feeder automation where available to allow a TASS site to operate in parallel with an adjacent primary substation. Prior to commencing the trial stages of the project, the costs, benefits and risks associated with the application of both technologies were assessed, and this work concluded that it is not considered financially viable to deploy ANT with TASS.

In developing, delivering and demonstrating the TASS system, the LEAN project has moved the Technology Readiness Level (TRL) of this proposed method from TRL 2 to TRL 8[1].

[1] Technology Readiness Levels are used to measure the progress of an innovation from concept to reality - the European Commission applies the following 9 TRL definitions, which are reflected in Ofgem's innovation appraisal processes

1 - basic principles observed
2 - technology concept formulated
3 - experimental proof of concept
4 - technology validated in lab
5 - technology validated in relevant environment
6 - technology demonstrated in relevant environment
7 - system prototype demonstration in operational environment
8 - system complete and qualified
9 - actual system proven in operational environment

source: Horizon 2020 Work Programme 2016-17 (Annex G), European Commission, October 2015

Context

Industry figures indicate that losses account for ~6%[2] of the energy entering the distribution system from transmission networks and distributed generation. Electrical losses are inherent in the physics of how key electricity system components operate, however DNOs have a licence obligation to ensure that distribution losses are as low as reasonably practicable[3]. Strategies to reduce technical losses create a more efficient network which reduces costs to customers and equates to lower carbon emissions.

The technology developed through the LEAN project supports DNOs in meeting the industry challenges identified in the Full Submission:

- Decarbonisation
  - during the transition to Net Zero[4], a reduction in electricity losses brings a reduction in carbon emissions associated with the energy saved
  - where increasing levels of embedded generation are seen, the reduction in demand on a primary substation will decrease transformer utilisation, and the use of TASS to reduce losses at times of low demand will compliment the benefits from distributed generation
  - with increasing uptake of low carbon technologies (LCTs) such as electric vehicles (EVs) and heatpumps, demand will become increasingly diverse with wider contrasts between peaks and low demand levels - networks designed with sufficient capacity for times of high demand may be subject to lower overall transformer utilisation, thereby increasing the savings achievable through TASS
- Integrity of supply
  - the TASS system has been developed to minimise any risks to supply and to maintain compliance with Engineering Recommendations P2/6 (security of supply) and P28 (power quality)
  - the TASS control system has been designed with the ability to respond to a failure on the non-TASS transformer and restore the TASS transformer in less than 5 seconds, within the 3 minute threshold that defines Customer Interruptions and Customer Minutes Lost (CIs/CMLs)
  - the TASS algorithm monitors SCADA data to detect issues or faults with the transformers or other assets within a substation, and respond accordingly to minimise risks to security of supply but to avoid any risk associated with attempting to switch a transformer back in onto a fault

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[2] 'Electricity Distribution Units and Loss Percentages Summary' factsheet, Ofgem, August 2010, provides tables showing the electricity units distributed and loss percentages for each of the DNO licence areas - available at www.ofgem.gov.uk/publications-and-updates/electricity-distribution-units-and-loss-percentages-summary

[3] Condition 49 'Electricity Distribution Losses Management Obligation and Distribution Losses Strategy' of the 'Standard Conditions of the Electricity Distribution Licence', Ofgem, August 2019

[4] 'Net Zero - The UK's Contribution to Stopping Global Warming', Committee on Climate Change, May 2019 - this report responds to a request from the Governments of the UK, Wales and Scotland asking the Committee to reassess the UK's long-term emissions targets - available at www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming

- Safety
  - a ‘safety by design’ approach was promoted throughout development of the technology, and the eleven key Operational Principles established through the requirements capture process governed the design of the system and define how individuals with a range of roles interact with the scheme
  - for safety and operational reasons, the system was designed to align with the expectations and existing activities of all those who may interact with the technology
  - TASS specific notifications and commands are available to Control Engineers via the DMS to provide information on the status of the TASS system together with remote management capability, and these commands allow the Control Room to remotely deactivate TASS when someone wants to enter the substation, if there are reports of a trespasser in the substation, or at times of increased operational pressures, for example during storms
  - training and briefing material, together with substation signage, has been developed to provide an awareness of the equipment installed for the project and the requirements for working on or near this
- Compliance with regulatory and legislative guidance
  - the EU Ecodesign Directive[5] places an obligation on manufacturers of transformers to reduce the energy consumption and minimise the environmental impacts occurring throughout a product’s life, however the end of asset life replacement of existing transformers with more efficient designs will take time and TASS offers an opportunity for DNOs to reduce the losses associated with existing transformer operation, with benefits then continuing beyond transformer replacement

TASS therefore allows DNOs to deliver environmental and social benefits through energy efficiency, and contribute to the aims set out by government in The Carbon Plan[6] and actions required to meet the UK’s 2050 Net Zero target[7], while maintaining a safe, reliable supply to customers.

Project Learning

The learning generated through the project is presented in the published SDRC reports, as summarised below:

- SDRC 9.1 ‘Project Set Up and Review of Related Projects’ - the planned project programme and work structure, together with key recommendations for the LEAN project drawn from a review of GB and international projects related to the reduction of distribution networks losses
- SDRC 9.2 ‘Business Case Validation’ - an evaluation of transformer losses and variations due to design and age, an assessment of the four proposed switching methods for implementing TASS, and a review of the business

[5] the EU Ecodesign Directive for transformers took effect in July 2015 https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/ecodesign/transformers_en

[6] ‘The Carbon Plan’, Department of Energy and Climate Change (DECC), December 2011

[7] the ‘Climate Change Act 2008 (2050 Target Amendment) Order 2019’, which came into force on 27 June 2019, amends legislation to introduce a UK target of at least a 100% reduction of greenhouse gas emissions compared to 1990 levels

cases for TASS and ANT both on the SEPD network and at GB level together with the initial version of a tool developed to provide Cost Benefit Analysis (CBA) on the application of these technologies

- SDRC 9.3 'Phase Two Decision Point' - a description of the stakeholder engagement process used to present the findings from the first phase of the project, and confirmation of the support received from internal and external stakeholders for the business's decision to develop and trial TASS technology
- SDRC 9.4 'Initial Learning from Trial Installation and Integration' - comprehensive information on the technology developed, its integration with existing network assets, and the operational principles designed into the scheme, together with an initial assessment of the performance of TASS
- SDRC 9.5 'Monitoring & Analysis' - an appraisal of the techniques used to monitor the transformers and other substation assets, and analysis of the data acquired to evaluate any potential asset health or power quality implications associated with the application of TASS, and verify that the system operates as designed
- SDRC 9.6 'Site Performance to Date' - a full review of the losses savings achieved through TASS operation, and evaluation of both the benefits of the technology and costs of deployment to refine the business case
- SDRC 9.7 'Network Losses Evaluation Tool' - refinement of the CBA tool developed to assess the benefits of TASS, reflecting experience gained from trial implementation, and a detailed description of the substation assessment process which can be used by DNOs to assess the financial viability and technical feasibility of applying the technology on a site by site basis

The accompanying material developed through the project - including the Risk Mitigation Strategy, TASS algorithm specification, system architecture documentation, training material, substation signage, TASS Evaluation Tool and TASS Technology Substation Assessment Guide - then provides a suite of deliverables available to industry stakeholders, including DNOs, product vendors and the regulator, to support the wider implementation of TASS technology, and to inform the effective development and operation of similar decentralised control systems and automation solutions as we move to a DSO model with increasingly dynamic operation of GB electricity networks.

All LEAN project reports are published both on the dedicated LEAN webpages www.ssen.co.uk/LEAN/Learning and on the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents.

Financial Appraisal

The updated assessment of all SEPD primary substations based on current costs indicates that TASS would be financially viable at around 70 sites under the lowest cost deployment scenario, saving ~3500 MWh per year.

Scaling the assessment of this scenario to GB indicates losses savings over 45 years of ~1,500 GWh, equating to a carbon saving of ~201,400 tCO_2e, and providing a cumulative net benefit of over £65 million. The annual energy savings associated with this would be equivalent to the energy generated each year by ~8,400 typical domestic solar photovoltaic (PV) systems in the south of England[8].

Whilst some components of the other TASS deployment scenarios considered have a high cost at present, factors that will act to reduce the costs and increase the financial viability of these options have also been identified, such as the growing availability of suitable technologies and economies of scale as greater ranges of products are developed.

TASS therefore offers a financially viable, as well as technically feasible, option for reducing losses on electricity distribution networks, and demonstrates a business case for applying TASS at specific sites.

Planned Implementation

SSEN intend to retain the trial installations for ongoing losses reduction, and to evaluate the application of TASS at primary substations scheduled for refurbishment within RIIO-ED1.

For wider roll out, the business will assess the scope for obtaining funding for deployment through the RIIO-ED2 Business Plan. The proposals[9] for the Business Plan Incentive promote the inclusion of plans to roll out proven innovation, and indicate that additional totex allowances may be available where it can be demonstrated that additional funding is needed. It is evident that TASS delivers societal (Non-DNO) benefits through energy efficiency which reduces costs to customers and equates to lower CO_2e emissions, correspondingly TASS may align with the criteria for seeking an additional totex allowance.

Structure of this Report

This document meets the LCNF governance requirements for the Project Closedown Report[10], with the content structured accordingly.

In addition, the 'TASS Evaluation Tool' has been used to provide an analysis of the benefits of applying TASS, with this tool also provided to other DNOs through a collective workshop, and a plan outlining how TASS could be integrated into the business for large scale rollout is presented, in accordance with the Project Direction and to meet the requirements of SDRC 9.8.

Interested parties are very welcome to contact the LEAN project team with any enquiries via lean@sse.com.

[8] the Energy Savings Trust's information on solar panels notes that the "average domestic solar PV system is 4kWp" and a "4kWp system can generate around 4,200 kilowatt hours of electricity a year in the south of England"
[9] 'Open Letter Consultation on approach to setting the next electricity distribution price control (RIIO-ED2)', Ofgem, August 2019
[10] 'LCNF: content and structure of second tier close down reports' letter, Ofgem, June 2013

Contents

Acronyms

ANT	Active Network Topology
BPI	Business Plan Incentive
CBA	Cost Benefit Analysis
CI	Customer Interruption
CML	Customer Minutes Lost
CO_2e	Carbon Dioxide Equivalent
CoP	Crossover Point for TASS
DAMSG	SSEN's Distribution Asset Management Steering Group
DFR	Dielectric Frequency Response tests
DGA	Dissolved Gas Analysis
DER	Distributed Energy Resources
DMS	Distribution Management System
DNO	Distribution Network Operator
DSO	Distribution System Operator
ER	Engineering Recommendation
EV	Electric Vehicle
FAT	Factory Acceptance Test
GB	Great Britain
GSP	Grid Supply Point
HIL	Hardware in the Loop testing
ICT	Information & Communications Technology
IEEE	Institute of Electrical and Electronics Engineers standards organisation
IIS	Interruption Incentive Scheme
LCNF	Low Carbon Networks Fund
LCTs	Low Carbon Technologies
LEAN	Low Energy Automated Networks
NIC	Network Innovation Competition
PD	Partial Discharge
PLC	Programmable Logic Controller
PoW	Point on Wave switching
PR	Protection Relay
PV	Photovoltaic
RIIO	Revenue = Incentives + Innovation + Outputs Ofgem's network price control framework
RTU	Remote Terminal Unit
SAP	Senior Authorised Person
SCADA	Supervisory Control and Data Acquisition
SDRC	Successful Delivery Reward Criteria
SEPD	Southern Electric Power Distribution
SFRA	Sweep Frequency Response Analysis
SGAM	Smart Grid Architecture Model
SSEN	Scottish and Southern Electricity Networks
TASS	Transformer Auto Stop Start
TRL	Technology Readiness Level
TSO	Transmission System Operator

1 Introduction

1.1 Overview of LEAN

The Low Energy Automated Networks (LEAN) project aimed to establish whether it is technically feasible and economically viable to implement the proposed energy efficiency methods at 33/11kV primary substations on the Southern Electric Power Distribution (SEPD) network. This project has been supported by Ofgem's Low Carbon Networks Fund (LCNF) with an approved budget of £3.1m.

The two methods considered within LEAN are:

- Transformer Auto Stop Start (TASS) - this is the automated switching out of one of the transformers in a primary substation at times of low demand to reduce energy losses
- Alternative Network Topology (ANT) - this would make use of existing 11kV feeder automation where available to allow a TASS site to operate in parallel with an adjacent primary substation

Prior to developing and trialling these technologies, the first phase of the project assessed the costs, benefits and risks associated with their application. This work indicated a positive return on investment for the application of TASS at specific primary substations and acceptable mitigation of network risks, and accordingly the decision was taken to proceed with developing and demonstrating TASS technology on the SEPD network[11].

Following detailed requirements capture, technology development, testing, and training for relevant operational teams, the trial equipment was installed and activated in June 2018. The system achieved energy savings of ~67 MWh from two sites over the formal 12 month trial period, and continues to operate as designed, successfully controlling automated switching to reduce losses and respond to different network situations.

The suite of SDRC deliverables present different aspects of the project of relevance to a range of stakeholders, and the accompanying material available to other DNOs is designed to support their appraisal of TASS and adoption of the technology on their own networks.

In addition, the experience gained through the project can be evaluated by product vendors to inform their development of technologies or functionalities relevant to enhanced levels of decentralised control, automation and monitoring as the industry transitions to a DSO model with increasingly dynamic operation of GB electricity networks.

The project concluded on 31 December 2019.

[11] as reported in LEAN SDRC 9.3 'Phase Two Decision Point', July 2016

1.2 Overview of SDRC 9.8

The Successful Delivery Reward Criteria (SDRC) are defined in the LEAN Project Direction.

In accordance with the knowledge dissemination criteria specified for SDRC 9.8, this document presents:

- The formal requirements of the Project Closedown Report
- An analysis of the benefits of applying TASS through assessment using the TASS Evaluation Tool
- Confirmation of the external workshop held to present the TASS Evaluation Tool and project outcomes
- A plan outlining how TASS could be integrated into the business for large scale rollout if applicable

To give context for the scope of SDRC 9.8, the following companion SDRCs relate to the development and trial of the TASS technology:

- SDRC 9.4 ‘Initial Learning from Trial Installation and Integration’ - comprehensive information on the technology developed, its integration with existing network assets, and the operational principles designed into the scheme, together with an initial assessment of the performance of TASS
- SDRC 9.5 ‘Monitoring & Analysis’ - an appraisal of the techniques used to monitor the transformers and other substation assets, and analysis of the data acquired to evaluate any potential asset health or power quality implications associated with the application of TASS, and verify that the system operates as designed
- SDRC 9.6 ‘Site Performance to Date’ - a full review of the losses savings achieved through TASS operation, and evaluation of both the benefits of the technology and costs of deployment to refine the business case
- SDRC 9.7 ‘Network Losses Evaluation Tool’ - refinement of the tool developed to provide cost benefit analysis for the deployment of TASS, and a detailed description of the substation assessment process which can be used by DNOs to assess the financial viability and technical feasibility of applying the technology at individual sites

These SDRCs have been published and are available via the ENA’s Smarter Networks Portal[12], together with this SDRC 9.8 Closedown Report.

[12] www.smarternetworks.org/project/sset207-01/documents

2 Project Description from the Full Submission

The three subsections below present the context and aims of the LEAN project as set out in the Full Submission.

2.1 Project Background

Industry figures indicate that losses account for ~6%[13] of the energy entering the distribution system from transmission networks and distributed generation. Electrical losses are inherent in the physics of how key electricity system components operate, however DNOs have a licence obligation to ensure that distribution losses are as low as reasonably practicable[14]. Strategies to reduce technical losses create a more efficient network which reduces costs to customers and equates to lower CO_2e[15] emissions.

In addition, electricity network operators have clear duties to maintain a safe, reliable supply to customers. The LEAN project was therefore defined to address the broader key industry challenges identified in the Full Submission:

- Decarbonisation
  - during the transition to Net Zero[16], a reduction in electricity losses brings a reduction in carbon emissions associated with the energy saved
  - where increasing levels of embedded generation are seen, the reduction in demand on a primary substation will decrease transformer utilisation, and the reduction of losses at times of low demand will complement the benefits from distributed generation
  - with increasing uptake of low carbon technologies (LCTs) such as electric vehicles (EVs) and heatpumps, demand will become increasingly diverse with wider contrasts between peaks and low demand levels - networks designed with sufficient capacity for times of high demand may be subject to lower overall transformer utilisation, thereby increasing the savings achievable through TASS
- Integrity of supply
  - a core focus for the project was the detailed identification of potential risks and associated mitigation measures for system development to minimise any risks to supply and maintain compliance with Engineering Recommendations P2/6 (security of supply) and P28 (power quality)

[13] 'Electricity Distribution Units and Loss Percentages Summary' factsheet, Ofgem, August 2010, provides tables showing the electricity units distributed and loss percentages for each of the DNO licence areas - available at www.ofgem.gov.uk/publications-and-updates/electricity-distribution-units-and-loss-percentages-summary

[14] Condition 49 'Electricity Distribution Losses Management Obligation and Distribution Losses Strategy' of the 'Standard Conditions of the Electricity Distribution Licence', Ofgem, August 2019

[15] CO_2e is the climate change impact of all greenhouse gases associated with an activity or product expressed as an equivalent amount of carbon dioxide

[16] 'Net Zero - The UK's Contribution to Stopping Global Warming', Committee on Climate Change, May 2019 - this report responds to a request from the Governments of the UK, Wales and Scotland asking the Committee to reassess the UK's long-term emissions targets - available at www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming

- Safety
  - safety and operational requirements remain central to all electricity network activities and the promotion of a ‘safety by design’ approach acted to ensure that the technology, user interfaces and training created through the project align with the expectations and existing activities of all those who may interact with the system trialled
- Compliance with regulatory and legislative guidance
  - the EU Ecodesign Directive[17] places on obligation on manufacturers of transformers to reduce the energy consumption and minimise the environmental impacts occurring throughout a product’s life, however the end of asset life replacement of existing transformers with more efficient designs will take time, and TASS offers an opportunity for DNOs to reduce the losses associated with existing transformer operation

2.2 Scope and Objectives

The objective of the LEAN project was to appraise two innovative methods for reducing losses on 33kV/11kV distribution networks through technologies that can be applied to existing assets.

Where detailed initial studies could demonstrate that any risks to network security or asset health could be managed, and that the proposed methods could provide a positive return on investment, the aim was to then develop technology which delivers the associated functionality and deploy this for demonstration on the SEPD network.

The principal method proposed was Transformer Auto Stop Start (TASS), requiring the development of new technology to automatically control switching out of one of the transformers in a primary substation at times of low demand to reduce energy losses.

The second method to be evaluated was Alternative Network Topology (ANT), which would make use of existing 11kV feeder automation where available to allow a TASS site to operate in parallel with an adjacent primary substation.

The project had three distinct phases:

Phase One comprised the development of a comprehensive understanding of the costs, benefits and risks associated with deployment of the LEAN technologies. The information obtained during this phase supported evaluation of the business case, and a methodology for undertaking Cost Benefit Analysis on a site by site basis was created.
Phase Two focused on validation of the technology through deployment and demonstration at primary substations selected to be representative of SEPD and GB distribution network scenarios, but also ensuring minimal risk of supply interruptions.

[17] the EU Ecodesign Directive for transformers took effect in July 2015 - available at https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/ecodesign/transformers_en

Phase Three encompassed the monitoring of transformers at the substations selected for technology deployment to capture relevant learning over the trial operational period.

A Decision Point was incorporated into the project plan to ensure that there was value in proceeding from Phase One to the trial stages. To inform this decision, the findings from Phase One and the conclusions regarding the business case for the technologies were presented to both internal and external stakeholders, including GB DNOs. The responses received through this consultation supported SEPD's decision to continue the project and develop TASS technology for trial on the SEPD network, recognising that it was not considered to be financially viable to deploy ANT with TASS[18].

Subsequently the project has successfully met its objective to develop and apply TASS technology to reduce losses at 33/11kV primary substations, providing a system which addresses each of the wider industry challenges described above.

2.3 Success Criteria

In addition to evaluating the successful operation of the technology trialled on the network, a suite of formal reporting requirements were identified to ensure that the project delivers learning for dissemination to internal and external stakeholders, including other DNOs, product vendors and Ofgem.

Table 1 presents these Successful Delivery Reward Criteria (SDRC) set out in the Full Submission and incorporated into the LEAN Project Direction. The associated SDRC reports present detailed learning on all aspects of the project, and are available to other DNOs to support their appraisal of TASS and adoption of the technology on their own networks, and to product vendors to inform the development of technologies or functionalities relevant to enhanced levels of decentralised control, automation and monitoring.

All LEAN project reports are published both on the dedicated LEAN webpages www.ssen.co.uk/LEAN/Learning and on the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents.

[18] as reported in LEAN SDRC 9.3 'Phase Two Decision Point', July 2016

Table 1 - LEAN Successful Delivery Reward Criteria

9.1 'Project Set Up and Review of Related Projects'

- Finalise work breakdown structure (WBS).
- Review and complete project programme.
- Produce report on GB and international projects related to reduction of losses in distribution networks including recommendations and key suggestions to improve the project design and implementation.

Evidence: The final WBS and programme submitted to Ofgem and a report detailing the project recommendations.

9.2 'Business Case Validation'

- Completion of transformer losses testing within relevant environment, to facilitate an in-depth review of the business case for Transformer Auto Stop Start (TASS) using measured transformer losses figures and specific SEPD network data.
- Confirm or reject the technical validity of each switching method.
- Present results of Phase One work packages to complete business case for rollout of each TASS option with ANT if applicable.

Evidence: A report detailing the work completed to date and an interim version of the losses evaluation tool which considers in detail the predicted costs for each option against the lifetime benefits.

9.3 'Phase Two Decision Point'

- Internal presentation of results to business representatives.
- External presentation of results with considered stakeholders including GB DNOs.

Evidence: Written confirmation from external stakeholders that the solution proposed in conjunction with the projected benefits is applicable for GB wide rollout. In order to move into Phase Two of the project, the modelling work must show a positive return on investment and acceptably mitigate the risk to network security and asset health.

9.4 'Initial Learning from Trial Installation and Integration'

- Installation of appropriate equipment at multiple sites.
- Appropriate learning captured from the installation and commissioning of equipment on site.
- Details of the system communications and control functionality.
- Initial results of the site performance.

Evidence: A report including lessons learnt on all aspects of the integration and subsequent challenges.

9.5 'Monitoring & Analysis'

- In depth review of the techniques used to monitor transformer health.
- Interim feedback on the performance of the implemented sites.
- Initial assessment of asset health before and after TASS operation.
- Data to quantify the electrical impact on the network in terms of power quality.

Evidence: An interim report provided in conjunction with appropriate evaluation of the various transformer health monitoring techniques employed.

9.6 'Site Performance to Date'

- Full scale review of the site performance in relation to losses.
- Losses compared with asset health to quantify the actual benefits.
- Benefits used to quantify the cost of sites operation and hence prove or disprove the business case.

Evidence: A report detailing the operational benefits / challenges of the system to date. In addition site visits will be offered to Ofgem and appropriate stakeholders, internal and external.

9.7 'Network Losses Evaluation Tool'

- Completion of a Network Losses Reduction Tool so that DNOs can clearly assess cost benefits analysis of LEAN deployment on specific sites within their networks.
- Internal SEPD training for network planning engineers and plan for potential integration into 'Business as Usual' practices.

Evidence: The tool will be presented to Ofgem in final format. A standardised SEPD work instruction / technical guide will be published.

9.8 'Knowledge & Dissemination'

- Project closedown report including 'Network Losses Reduction Tool' analysis.
- External workshop to present tool and project outcomes.
- Plan produced to integrate the loss saving techniques into the business for a large scale rollout if applicable.

Evidence: Produce final report and present to Ofgem.

3 Details of the Work Carried Out

This section describes the work undertaken within each phase of the project to appraise the proposed methods for reducing losses and to develop and trial TASS technology.

The formal SDRCs which document the work, and the accompanying material created for use during the trials and for future appraisal and adoption of TASS, are set out in Section 13 'Key Project Learning Documents'. These provide a suite of deliverables available to industry stakeholders, including DNOs, product vendors and the regulator, to support the wider implementation of TASS technology, and to inform the effective development and operation of similar decentralised control systems and automation solutions.

Phase One - Validation of the Business Case and Appraisal of Risks

The first phase comprised the development of a comprehensive understanding of the benefits, costs and risks associated with implementation of the proposed technologies.

To evaluate the benefits and investigate whether transformer losses change through time, the project team engaged with transformer specialist consultancy Doble PowerTest. The approach taken used on site measurements of transformer impedance and winding resistance to estimate the losses from 33/11kV transformers. The results of this analysis were compared with the original Factory Acceptance Testing (FAT) certificates, indicating that no-load (fixed) and load (variable) losses do not change significantly with time. This conclusion therefore supports the use of the transformer losses figures from the FAT certificates for assessment of the business case for TASS.

Potential risks to security of supply, power quality and network assets from the application of TASS and ANT were then identified through an appraisal commissioned from consultancy Mott MacDonald, with associated mitigation measures proposed. This work also assessed a range of switching options and transformer energisation procedures that would ensure compliance with relevant codes and practices, allowing the requirements for applying TASS and ANT to be established, and the costs to be estimated.

Each aspect of this work informed the development of a stepwise process for assessing the technical feasibility of applying TASS and ANT at primary substations. Correspondingly, a software tool was created to provide site specific Cost Benefit Analysis (CBA) consistent with the RIIO-ED1 CBA approach[19], allowing the business case for potential rollout of the LEAN technologies to be refined.

The conclusions from Phase One are presented in SDRC 9.2 'Business Case Validation'[20].

[19] 'RIIO-ED1 CBA guidance note', Ofgem, January 2014
[20] LEAN SDRC 9.2 'Business Case Validation', March 2016

Phase Two - Technology Development & Deployment

Following the decision to proceed to Phase Two[21], the second stage of the project focused on the development and demonstration of TASS technology on the SEPD network.

Accordingly, the project activities centred on:

- Management of the procurement processes for each element of the project defined in the Scope of Works created for the trials, including selection of and engagement with suitable consultants, service providers and product vendors
- Engagement with relevant areas of the business to capture technical and functional requirements for TASS - this established how the business would apply and interact with the technology to gain full value from the system without compromising our priority to provide a safe and reliable supply of electricity to our customers
- Creation of the Risk Mitigation Strategy governing the deployment of the technology, and business approval for the application of TASS
- Selection of the trial sites, including site surveys for TASS deployment
- Detailed scheme design, including definition of the system architecture and creation of the specification for the TASS algorithm
- Programming and delivery of the TASS control device
- SCADA integration to provide the required data exchanges with existing substation assets and systems
- Incorporation of TASS status information and alarms together with TASS control commands into the Distribution Management System (DMS)
- Completion of a series of factory acceptance and bench testing activities on the TASS control device and its integration with other system components
- Installation and commissioning of the TASS system at the trial sites
- Delivery of training sessions and briefings for operational staff, including field and control teams
- Coordinating the various activities associated with planning and implementing the trials, drawing on colleagues from across the business in addition to project consultants & contractors as necessary
- Activation of the scheme for completion of a 12 month formal trial period

Following a review of the tender responses received, project participants were selected based on knowledge and experience together with cost, and Schneider Electric were appointed to collaborate on the development and delivery of the TASS system, with site support provided by Senior Authorised Persons (SAPs) from SSE Enterprise Contracting as required. The synchronising relay selected for incorporation into the TASS system is Vizimax's SynchroTeq MVX unit, and these were supplied by UK Distributor Enspec Power.

SDRC 9.4 'Initial Learning from Trial Installation and Integration'[22] provides comprehensive information on the technology developed, its integration with existing network assets, and the operational principles designed into the TASS scheme.

[21] as reported in LEAN SDRC 9.3 'Phase Two Decision Point', July 2016

Phase Three - Monitoring & Evaluation

The third phase of the project encompassed the use of a range of monitoring and analysis techniques to obtain data on all relevant aspects of the trials.

The objectives for monitoring different assets and systems were informed by the design considerations identified during Phase One and Phase Two, and comprised:

- tracking the health of the transformers and other assets to assess any potential implications from the application of TASS, and minimise risks to asset health or security of supply
- assessing any potential impacts on network power quality from TASS switching
- evaluating the performance of the TASS technology

Correspondingly the approaches used are summarised below.

Asset Health

TASS interacts with a number of existing primary substation assets to provide the automated switching functionality which reduces network losses. In addition to designing the TASS system and control algorithm to mitigate risks to security of supply and asset health, the following methods have been used to assess any potential implications associated with increased switching due to TASS operation:

- visual inspections of substation assets
- transformer condition assessment tests undertaken pre-, mid- and post-trial to allow comparison of the results:
    - Sweep Frequency Response Analysis (SFRA)
    - Winding Resistance tests
    - Magnetising Current tests
    - Winding Capacitance & Power Factor tests
    - Dielectric Frequency Response (DFR) tests
- Partial Discharge (PD) surveys
- conventional oil samples
- online Dissolved Gas Analysis (DGA) monitoring to provide real time transformer oil quality data over the trials

Specialist consultants, including Doble PowerTest and Kelvatek (Camlin Group), have been engaged with over the course of the project to both undertake testing and provide expertise in interpreting the results and evaluating any potential implications for asset health associated with increased switching due to TASS.

[22] LEAN SDRC 9.4 'Initial Learning from Trial Installation and Integration', September 2018

Quality of Supply

The switching in of power transformers can result in large current and voltage transients which may affect customers' equipment, and may cause electrical or mechanical stress to the transformer itself or to other network assets.

Power quality monitoring has therefore been used to provide information on the magnitude and frequency of inrush currents and voltage variations seen during the trials, both with and without the use of controlled Point on Wave (PoW) switching which acts to minimise inrush currents during transformer energisation. The accompanying analysis then assessed the range of potential impacts on quality of supply to evaluate compliance with Engineering Recommendation P28 (ER P28) Issue 2[23].

Expertise in power systems modelling was also commissioned from Mott MacDonald to undertake a time domain based simulation study using the data obtained, and assess the impact of inrush currents on the networks upstream and downstream of the trial primary substations.

TASS Operation

The processes put in place to review TASS operation at the trial sites were designed to allow the project team and operational staff to:

- monitor the system's response to different operational situations
- identify and resolve any potential issues with TASS operation
- understand the business's interaction with TASS
- quantify the losses savings achieved

These aspects were key to verifying that the system continued to operate as designed, demonstrating the ability to both reduce losses and respond appropriately to different network situations.

SDRC 9.5 'Monitoring & Analysis'[24] describes the application of these monitoring techniques, the data sources used and the conclusions from the analysis undertaken to validate that the system operates as designed to provide an effective, reliable solution for reducing network losses.

SDRC 9.6 'Site Performance to Date'[25] provides a detailed assessment of the performance of TASS with regard to the automated switching activity seen and the associated losses savings achieved.

[23] Engineering Recommendation P28 Issue 2 'Planning limits for voltage fluctuations caused by industrial, commercial and domestic equipment in the UK', Energy Networks Association, published in 2018 and applicable from 23 May 2019 - this replaced ER P28 Issue 1, The Electricity Council, September 1989

[24] LEAN SDRC 9.5 'Monitoring & Analysis', February 2019

[25] LEAN SDRC 9.6 'Site Performance to Date', March 2019

4 The Outcomes of the Project

The LEAN project has developed and implemented TASS technology to reduce losses in 33/11kV primary substations. The system continues to operate on the SEPD network, and has been designed for wider adoption and roll out across distribution networks.

This section sets out the project outcomes created to allow other DNOs to understand how and where to apply this technology on their own networks. Updates on the performance of the system and conclusions from the appraisal of asset health are also provided, together with information on broader outcomes of interest regarding the integration of enhanced automated technologies and use of controlled Point on Wave switching.

In developing, delivering and demonstrating the TASS system, the LEAN project has moved the Technology Readiness Level (TRL) of this proposed method from TRL 2 to TRL 8[26].

Project Deliverables to Support the Application of TASS

The project has developed a comprehensive suite of deliverables to support other DNOs to appraise the application of TASS technology on their own networks.

The SDRC reports detail the work undertaken to develop and implement TASS for trial on the SEPD network, and to validate that the system operates as designed to provide an effective, reliable solution for reducing network losses.

The TASS Evaluation Tool and TASS Technology Substation Assessment Process can be used to determine the benefits of applying TASS at individual substations and identify sites that may be suitable for TASS based on both the financial viability and technical feasibility of deployment.

The accompanying outputs - including the Risk Mitigation Strategy, TASS algorithm specification, system architecture documentation, training material and substation signage - then provide a suite of practical material to support DNOs in deploying the technology on their networks. These have been created with consideration to future use should TASS be rolled out across SSEN's network, and in a way that will allow other DNOs to easily adapt the material for their own use should they also want to implement TASS.

[26] Technology Readiness Levels are used to measure the progress of an innovation from concept to reality - the European Commission applies the following 9 TRL definitions, which are reflected in Ofgem's innovation appraisal processes

1 - basic principles observed
2 - technology concept formulated
3 - experimental proof of concept
4 - technology validated in lab
5 - technology validated in relevant environment
6 - technology demonstrated in relevant environment
7 - system prototype demonstration in operational environment
8 - system complete and qualified
9 - actual system proven in operational environment

source: Horizon 2020 Work Programme 2016-17 (Annex G), European Commission, October 2015

In accordance with LCNF project governance, the following sections of this report provide corresponding information relevant to the outcomes of the project:

- Section 13 ‘Key Project Learning Documents’ signposts the documents and material available to DNOs and other stakeholders
- Section 10 ‘Project Replication’ includes a structured scalability and replicability assessment which identifies all aspects of the technology that would merit detailed consideration to inform any adaptations required for the deployment of TASS across other network areas
- Section 8 ‘Lessons Learnt on the Benefits of the Method Trialled’ provides an update on the potential business case for the application of TASS

All deliverables are available to industry stakeholders, including DNOs, product vendors and the regulator, to support the wider adoption of TASS technology, and to inform the effective development and operation of similar decentralised control systems and automation solutions.

Performance of the TASS System & Losses Savings Achieved

The system developed and trialled through the LEAN project continues to operate as expected to deliver energy savings. At the time of writing, TASS has reduced losses by over 100 MWh in total across the two trial primary substations.

The performance of the system over the formal 12 month trial period has been reported through prior SDRC reports, and a summary of the ongoing TASS operation up to 31 December 2019 is given in Table 2, with further detail provided in the text below.

Table 2 - Summary of TASS operation up to 31 December 2019

TASS Trial Site / TASS Operation	Gillingham	Hedge End
Commencement of Full Automated Operation[27]	22/06/2018	08/06/2018
No. TASS Switching Events		
load based (response to load increasing above the CoP for the evening peak)	0	165
time based (scheduled transformer changeover events)	10	5
switching due to a Control Disable command[28] (TX restored, then alternate TX switched out once TASS Enabled)	37	41
switching due to a comms issue (TX restored, then alternate TX switched out once comms restored)	15	5
'TASS Failed to Operate' alarms	4	13
'TASS Faulty' alarms[29]	4	1
'TASS CoP Error' alarms	0	0
Proportion of time a transformer was switched out	81.1%	75.9%
no. hours one transformer was switched out (h of total h)	10856 of 13393	10415 of 13729
Losses Saved to 31 Dec 2019	48.74 MWh	58.09 MWh
Value of Losses Saved to date [30]	£2,912	£3,470
Associated CO_2 Saving [31]	17.6 tCO_2e	21.0 tCO_2e

At Gillingham, the TASS system has enabled one of the transformers to be switched out for around 81% of the time. This reflects the loading at the substation, with no transformer restoration events seen due to the demand increasing above the Crossover Point, and only time based change over events triggering TASS operation to transfer the load to the alternate transformer following two weeks of continuous operation with one transformer switched out.

At Hedge End, TASS has allowed the site to run on a single transformer for around 76% of the time. At this site, the seasonal increase in electricity demand results in more frequent TASS operation over the winter months, with the system eventually switching a transformer in every day for the evening peak, and then switching back to one transformer when the load drops again later at night.

[27] the TASS system was activated at both trial sites on 8 June 2018, however, a stack overflow issue within the RTU at Gillingham then became apparent, leading to TASS perceiving an issue with comms availability - the RTU configuration was subsequently corrected, with full TASS operation commencing at Gillingham on 22 June 2018

[28] for example when TASS is Disabled by the Control Room due to someone wanting to enter the substation

[29] excludes alarms triggered during site visits to work on the substation comms systems

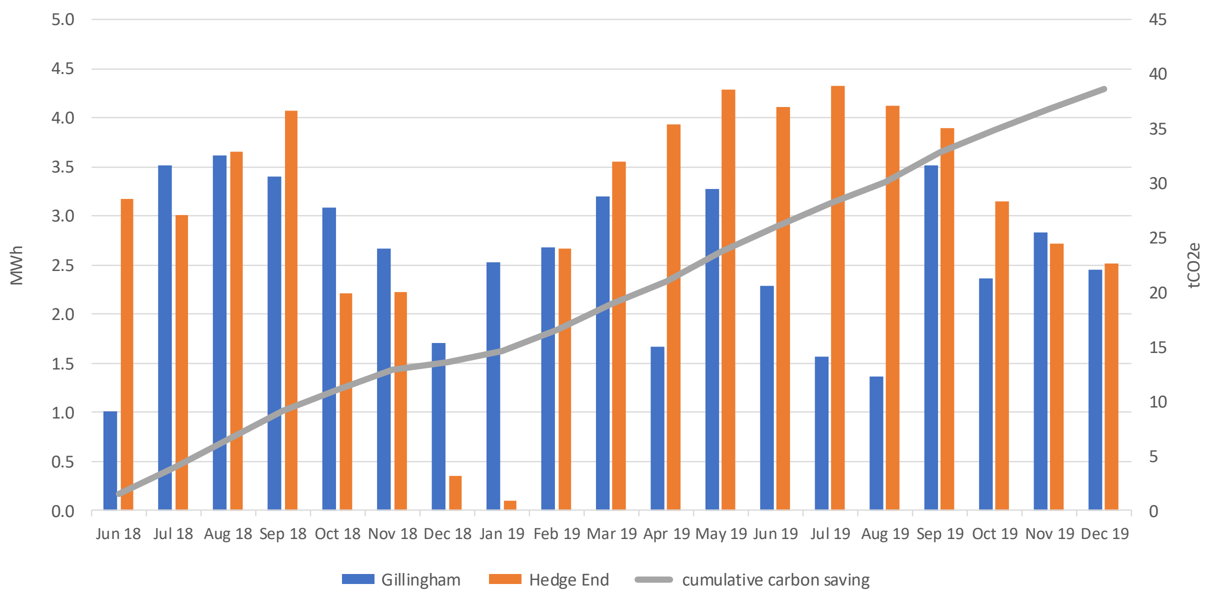
[30] derived using Ofgem's RIIO-ET2 CBA figure for the value of losses of £59.74 per MWh (rounded to the nearest £1) - the RIIO-ET2 Draft CBA value (v1.6) is used as this is more recent than the RIIO-ED1 figure

[31] derived using Ofgem's RIIO-ET2 CBA figure for the 2019 electricity GHG conversion factor of 361.7 g CO_2e per kWh

The 'TASS Failed to Operate' and 'TASS Faulty' alarms from each substation were raised in response to operational situations identified by the TASS control algorithm through SCADA data from other network assets. On each of these occasions the project team suspended operation of the system and investigated to ascertain the cause of the issue and confirm that TASS had operated as necessary to provide an appropriate response. The key issues experienced are described in SDRC 9.6 'Site Performance to Date'[32], and these events provided indispensable live testing of the system to demonstrate that TASS was able to quickly identify a problem, halt operation if needed and raise an appropriate alarm to notify the Control Engineers.

Figure 1 shows the monthly losses savings since system commissioning in June 2018, together with the cumulative associated carbon savings. This indicates the reductions achieved through full operation of TASS over the course of a month, as distinct from the periods when TASS was suspended by the project team.

Figure 1 - Monthly losses savings from TASS operation up to 31 December 2019



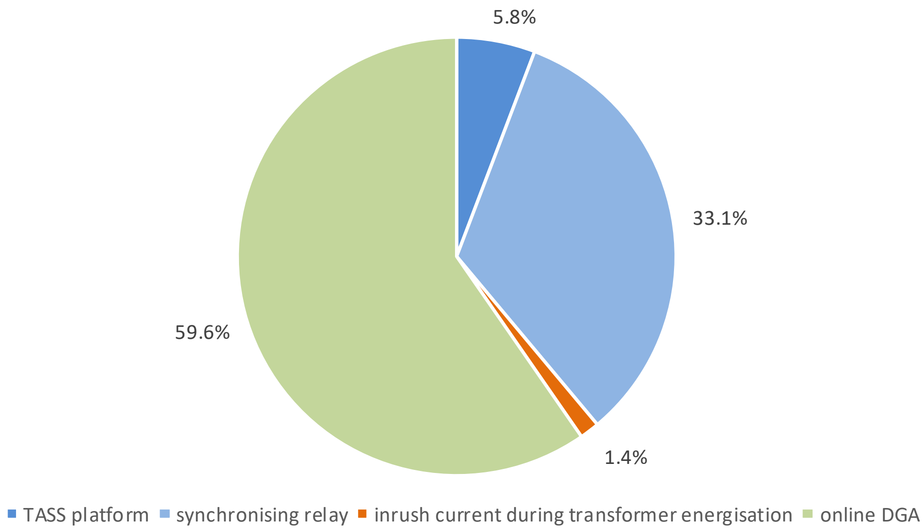
As reported in SDRC 9.6 'Site Performance to Date', the figures show that full TASS operation reduces overall transformer losses by ~25-30% for Gillingham and ~20-30% for Hedge End (reflecting the slightly lower proportional savings over winter months at this site as both transformers operate over the evening peak). The analysis shows that this equates to just under 0.2% of the energy supplied to customers in each case.

Considering the energy used by the equipment installed for the trials, the indicative calculations are that this consumes around 8 kWh per day per site, associated with the TASS platform itself, the synchronising relays, the online DGA monitoring equipment and the inrush currents due to transformer energisation. The energy used equates to an average of 8.5% of the overall energy saving from TASS, however the figure drops to around 3.4% excluding the online

[32] LEAN SDRC 9.6 'Site Performance to Date', March 2019

DGA system being used to monitor the health of the transformers during the trials. The relative proportions of energy used by the different components are shown in Figure 2.

Figure 2 - TASS trials - proportional energy use



The ongoing operation of TASS provides clear evidence of how this system can be used to reduce technical losses on the distribution networks.

Assessment of Asset Health

The approaches used to monitor asset health provide information that has been used to evaluate any potential impacts associated with increased switching due to TASS operation. Interim findings were reported in SDRC 9.5 'Monitoring & Analysis'[33], and the two subsections below present the conclusions updated to incorporate results following completion of the 12 month trial period. No impacts on asset health due to TASS operation have been identified through the suite of testing and monitoring techniques applied.

Transformer Condition Assessment Tests

The specialist condition assessment tests commissioned during the project assess specific elements of a transformer, including the transformer core, windings, insulation, bushings and tap changers.

A pre-trial suite of tests was undertaken on the transformers prior to installation of the TASS equipment. In addition to assessing asset health at that point in time, the results from these tests provided a benchmark against which future results could be compared to identify and assess any changes that may be a consequence of the application of TASS.

[33] LEAN SDRC 9.5 'Monitoring & Analysis', February 2019

Mid-trial tests were then carried out to ascertain whether any impacts were clearly becoming apparent, and a further post-trial suite of tests were run following 12 months of TASS operation.

The results from each round of testing indicated the following:

- pre-trial - no existing issues with any of the transformers
- mid-trial - no changes to transformer condition
- post-trial - transformers remain in good condition, with the results agreeing satisfactorily with those obtained from the pre-trial and mid-trial surveys, therefore no changes due to increased switching operation are identified

A summary of the conclusions from each of the pre-trial and post-trial transformer condition assessment tests is given in Table 3. The full consultants' reports for the post-trial round of tests[34] are provided as Appendix A. The comparison between the pre-trial and mid-trial tests was previously provided in SDRC 9.5 'Monitoring & Analysis', together with the associated reports.

[34] 'Report on Condition Assessment Tests on C1MT and C2MT at SSE Substation Gillingham' and 'Report on Condition Assessment Tests on C1MT and C2MT at Hedge End Substation - Issue 2' reports, Doble, July & August 2019

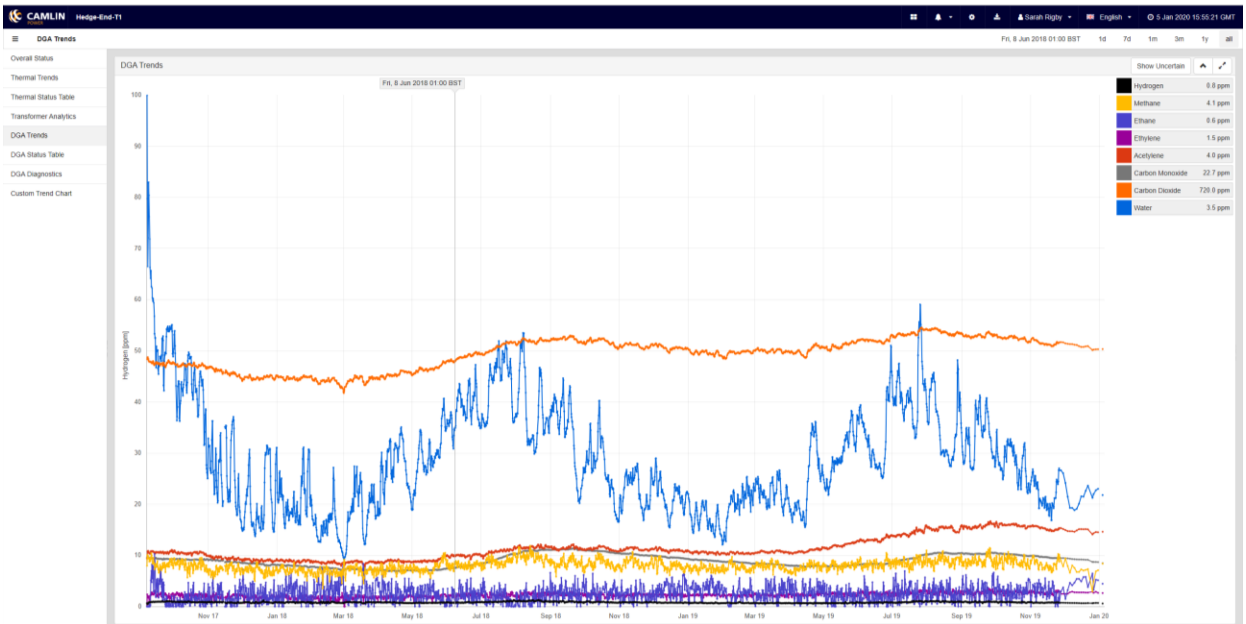
Table 3 - Conclusions from the pre- and post-trial transformer condition assessment tests

	Conclusions from Pre-trial Tests		Conclusions from Post-trial Tests	
Sweep Frequency Response Analysis (SFRA)	no indication of any problem	At both sites the results from the two transformers generally show good agreement across the measured frequency range.	no indication of any changes due to TASS	At both sites the results from the two transformers continue to show good agreement across the measured frequency range. The results compare well with the data from the pre-trial and mid-trial tests, with only minor differences, potentially linked to different practices regarding grounding the test lead screens.
Winding Resistance tests	no indication of any problem	As the transformers at both sites were installed at the same time, and are of the same manufacture and age, measurements were taken on one transformer only at each site - results from different phases agree well and are as expected.	no indication of any changes due to TASS	For the mid-trial and post-trial tests, both transformers at each site were assessed, and measurements on all transformers show good agreement between different phases and consistency across the tap range on the HV side, other than for Gillingham T1 phase A-N tap positions 3 to 5, attributed to deposits on these contacts due to prolonged operation at these tap positions. The results compare well with the data available from the pre-trial tests, with only minor differences.
Magnetising Current tests	no indication of any problem	At one site the results from the two transformers agree closely, and show the expected pattern, at the other site differences in the Magnetising Current results from the two transformers are seen, however this is due to the tests being run on different tap positions.	no indication of any changes due to TASS	At both sites the results from the two transformers indicate good agreement, and show the expected pattern. Comparison with the results from the pre-trial and mid-trial tests shows negligible differences.
Winding Capacitance & Power Factor tests	no indication of any problem	At both sites the results for the two transformers agree well, with all power factor results within the accepted limits.	no indication of any changes due to TASS	At both sites the winding capacitance results agree well with the data from the pre-trial and mid-trial tests. All power factors are within the accepted limits and the results generally agree well, with slightly elevated 'HV to earth' and LV to earth' power factors for one transformer attributable to adverse weather conditions present at the time of testing.
Dielectric Frequency Response (DFR) tests	no indication of any problem	These were carried out at one site only due to the availability of test equipment - the results from the two transformers agree well, and the moisture content in the solid insulation is only slightly above the level that may be expected for a new transformer.	no indication of any changes due to TASS	At both sites the results from the two transformers agree well, and the moisture content in the solid insulation is only slightly above the level that may be expected with a new transformer with the readings considered good for a transformer of this type and age. The results also agree well with the data from the pre-trial (one site) and mid-trial (both sites) DFR tests.

Online DGA Analysis

The online DGA system takes oil samples every few hours to provide readings for 9 fault gases and moisture. The system has been monitoring the trial sites for over two years, with data collected prior to TASS installation providing a benchmark for comparison with readings obtained during the trial period. Figure 3 shows DGA trend data from one of the TASS trial transformers since monitoring commenced, and charts showing the DGA trends for each of the four transformers are given in Appendix B.

Figure 3 - DGA trend chart from the TOTUSPRO system



A review of the trend data from each transformer indicates that all four display similar patterns, and the following observations are made:

- A clear, and expected, seasonal effect can be seen in the water readings as moisture migrates from the solid cellulose insulation to the oil with increased temperatures, however the respective levels are satisfactory and indicate a good oil preservation system. Whilst moisture can be ‘hidden’ from oil DGA readings, advanced analysis undertaken by the SAPIENT team has been used to evaluate and confirm reasonable moisture in cellulose content.
- An increase in the rates of change of Carbon Monoxide and Carbon Dioxide can been seen during the summer as the higher seasonal temperatures act to accelerate degradation, however values remain well within acceptable levels. Further, these gases also migrate between the cellulose and oil, and such patterns are commonly seen in online DGA data.
- A seasonal pattern is also apparent with Acetylene readings, with each transformer displaying an increase in readings over the warmer summer months each year. Whilst all four transformers have relatively high Acetylene levels, as discussed in more detail below, this is in the absence of significant levels of related fault gases which may indicate arcing within the transformer.
- The levels of other gases remain relatively stable with some fluctuations through time.

The SAPIENT analytics service procured with the online DGA system has provided expertise in reviewing the data obtained. The ongoing assessments note no points of concern regarding possible low, medium or high temperature faults within the transformers, and no changes linked to the TASS trials are evident. The latest SAPIENT report[35] based on DGA data to August 2019 is given as Appendix C.

One notable change identified through the online DGA system is the steady, seasonal increase in Acetylene readings. This gas is of significance as its presence may be due to high energy arcing (temperatures >700°C) occurring within a transformer, and this can indicate a high level of risk due to combustibility.

Acetylene readings for each of the trial transformers have always been untypically high relative to the Condition 1 and Condition 2 levels set out in the associated IEEE C57.104-2008[36] standard, attributed initially to the possible use of regenerated oil within the transformer main tanks or tap changers. However, over the summer months the readings for each transformer tend to gradually increase, as can be seen in Figure 3.

This represents a curious observation as the unusual Acetylene levels occur in absence of significant levels of other gases that would typically be produced by high energy faults. At the recommendation of the SAPIENT service and consultants from transformer specialist Doble, therefore, the following activities were undertaken to further examine the issue:

- site inspection of the oil levels and breathers on both the main tank and tap changer to identify anything which may affect the oil pressures and allow deteriorated oil to flow from the tap changer into the main tank
- conventional oil sample analysis
- winding resistance tests - undertaken within the suite of mid-trial transformer condition assessment tests
- tap changer inspections
- consultation with the supplier of the transformers and tap changers

No issues were found through any of these investigations, further, the Acetylene readings tend to stabilise around September time each year, and no changes have been apparent in the levels of other associated gases. Consequently the conclusion drawn is that the high Acetylene readings are attributed to an external cause, and are not linked to any fault activity within the transformers. One proposed mechanism relates to cross contamination from the on-load tap changer, as follows:

- contaminated oil (associated with normal tap changer operation) migrates from the tap changer back to its conservator, which is partitioned from the transformer conservator but shares a breather and air space
- some transference of gases occurs from this oil to the air in the conservator

[35] 'Transformer Condition Report #5 - Gillingham and Hedge End Substations', Kelvatek (Camlin Group), August 2019
[36] IEEE C57.104-2019 'Guide for the Interpretation of Gases Generated in Mineral Oil Immersed Transformers'

- when the ambient temperature rises, increased air movement causes mixing of the air between the tap changer and transformer conservators
- when the temperature drops, part of the mixed air then stays within the transformer conservator, transferring some gases which originated in the tap changer

This explanation corresponds to a seasonal increase in Acetylene potentially linked to daily temperature variations.

Broader Project Outcomes

Integrating Automated Technologies

The TASS system provides local, automated control within a substation to monitor the loading and switch to reduce losses, and to respond to SCADA alarms and status information from other network assets. In addition, commands incorporated into the Distribution Management System (DMS) provide the central network Control Room with information on the status of the system together with remote management capability.

As with many new technologies, the introduction of TASS was not purely focused on development of the equipment - in addition processes were established to ensure that the business can apply and interact with the system to gain full value from the technology without compromising our priority to provide a safe and reliable supply of electricity to our customers.

Consequently, the considerations related to the creation of the TASS control algorithm and deployment of this technology will have relevance to the introduction of a range of decentralised control systems and automation designed to support the increasingly dynamic operation of GB electricity networks.

SDRC 9.4 'Initial Learning from Trial Installation and Integration'[37] details the development of the TASS technology and the work undertaken to install the system for trial on the SEPD network.

Monitoring Asset Health

The combination of approaches used to monitor asset health during the TASS trials provided valuable information on the condition of the substation assets integrated into the TASS scheme to assess any potential impacts from the deployment of TASS.

Further, the online DGA system installed to monitor the transformers at the trial sites has provided increased insight into trends seen in dissolved gas readings. Interest in the data available from this system has been expressed by Asset Management colleagues as a result of project dissemination activities, with access to the system requested to allow consideration of how such technology could be applied to bring benefits to distribution network operation and investment.

[37] LEAN SDRC 9.4 'Initial Learning from Trial Installation and Integration', September 2018

The project has provided a detailed appraisal of the techniques used and data available through these, to inform choices by DNOs or other electricity network stakeholders when monitoring asset health during innovation trials, or to support enhanced risk based asset management in the context of planning of maintenance and replacement activities.

SDRC 9.5 ‘Monitoring & Analysis’ describes the range of techniques used to monitor asset health during the trials.

Use of Controlled Point On Wave Switching

The synchronising relays integrated into the TASS architecture are a relatively new item of equipment with no prior deployment on GB distribution networks, and SSEN had limited experience of the use of Point on Wave (PoW) switching.

Periods of TASS operation both with and without the use of this controlled switching have provided an understanding of the impact of TASS transformer energisation on the quality of supply at the primary substations and within the local distribution network, and allowed the effectiveness of these devices to be assessed.

From the data obtained, it is evident that the PoW functionality delivered by the SynchoTeq relays provides an effective means of ensuring a consistently low level of inrush current during transformer energisation. The analysis also indicates that to maintain best practice compliance with ER P28 Issue 2 voltage fluctuation limits, PoW switching would be necessary at some TASS sites, however other sites may operate acceptably without controlled switching.

SDRC 9.5 ‘Monitoring & Analysis’ presents an evaluation of the effects of TASS switching on power quality together with the assessment of the effectiveness of controlled PoW switching.

5 Performance Compared to the Project Aims, Objectives and Success Criteria

As described in Section 4 'The Outcomes of the Project', LEAN has successfully delivered a new technology which continues to operate on the SEPD network to reduce electricity losses.

This fully meets the key project objective set out in the Full Submission, as presented in Section 2 'Project Description from the Full Submission', and achieves the aim of reducing technical losses to create a more efficient distribution network which reduces costs to customers and equates to lower CO_2e emissions.

Further, the system developed has been designed to support DNOs in addressing the broader industry challenges identified in the Full Submission - decarbonisation, integrity of supply, safety, and compliance with regulatory and legislative guidance. Accordingly:

- the system demonstrated meets the requirements of operational colleagues, without compromising our priority to provide a safe and reliable supply of electricity to our customers
- the architecture provides a streamlined system for integration with existing asset
- the scheme has been designed in a technology neutral way to support wider roll out and application by other DNOs
- all project outputs have been created with a specific focus on the scalability and replicability of the system, with accompanying material created in a way that will allow other DNOs to easily adapt this for their own use
- the experience gained through the project also has relevance to inform the effective development and operation of similar decentralised control systems and automation solutions, and the use of enhanced monitoring, to support increasingly dynamic operation of GB electricity networks

The project SDRCs document the work undertaken to identify requirements, develop and implement the technology, and validate that the system operates as designed to provide an effective, reliable solution for reducing network losses. Correspondingly, these reports have been structured to allow stakeholders, including DNOs and product vendors, to easily find information of relevance to them. All SDRCs and Project Progress Reports have been submitted in accordance with the Project Direction and governance requirements.

6 Modifications to the Planned Approach During the Course of the Project

This section summarises the changes made to the original plans in light of experience and learning over the course of the project.

Application of ANT

As described in Section 2 ‘Project Description from the Full Submission’, LEAN was established to appraise two innovative methods for reducing losses on 33kV/11kV distribution networks - TASS and ANT. Prior to commencing the trial stages of the project, the costs, benefits and risks associated with the application of both technologies was assessed, and this work concluded that it is not considered financially viable to deploy ANT with TASS. Accordingly, it was not deemed appropriate to develop and trial ANT and the decision was taken to proceed with developing and demonstrating TASS technology on the SEPD network.

Evaluating Transformer Losses

To assess whether transformer losses change through time during operation, the project proposed to replicate factory testing on site to provide results which could be compared with the original FAT certificates. However, it became apparent that issues relating to transportation of the required equipment and calibration to maintain the necessary accuracy were challenging, with the quoted cost for on site testing in excess of £120,000 per transformer. Alternative options for assessing losses in operational transformers were therefore investigated, and the project team engaged with Doble PowerTest who proposed a significantly more cost effective technique to estimate losses based on on site measurement of transformer impedance and winding resistance. This approach was found to be suitable for establishing that losses do not change significantly with time, therefore supporting the use of the transformer losses figures from the FAT certificates when assessing the business case for TASS.

Investigating the Effect of Switching on Transformers

Off-network trials had originally been proposed for Phase One of the project to investigate how transformers may react to the increased switching associated with TASS deployment, however this was found to be unfeasible for practical and operational reasons. In place of this, transformer energisation studies were completed to simulate all proposed switching options, providing an effective and efficient alternative to this task. Subsequently, the asset health and power quality monitoring approaches used during the trial stages have obtained detailed data which has been used to further assess any possible implications from TASS switching.

Transformer Switching Options

The Full Submission identified three switching options for applying TASS - using existing switchgear alone; using existing switchgear with advanced controls to minimise inrush currents; and using new advanced switchgear capable of minimising inrush currents. However, no advanced single-pole operated circuit breakers designed specifically for 33kV application were identified, and the cost of deploying equipment rated for higher voltages (e.g. 66kV or 132kV) made the third option of using new advanced switchgear uneconomical for the TASS trials. Accordingly the first two switching options have been assessed through periods of TASS trial operation both with and without the incorporation of synchronising relays to provide controlled Point on Wave switching using existing circuit breakers.

Losses Reduction Introductory Video

A high level, introductory video describing the role of loss reduction in the transition to a low-carbon Britain had originally been proposed, however since preparing the Full Submission two partner DNOs on the ENA's Technical Losses Task Group have created helpful visuals which present the issues:

- Northern Powergrid have created a video introducing the concepts of fixed and variable losses on the distribution network, which can be watched here www.youtube.com/watch?v=M9v_2HDnMLI
- UK Power Networks have created an interactive diagram to explain the different ways in which energy is lost across the electricity system, and this can be found on their website here www.ukpowernetworks.co.uk/losses/#interactive

Consequently it was more appropriate for the LEAN project to make reference to these links in publications such as SDRC 9.4 'Initial Learning from Trial Installation and Integration'[38], rather than assign project expenditure to the creation of an additional video.

Project Timeframes

As noted in Section 9 'Lessons Learnt for Future Innovation Projects', a key challenge at the early stage of trial delivery lay in agreeing terms with the consultants selected for involvement in the development of the TASS technology. The proposed terms and conditions were issued to the consultants in April 2017, however the contract was finally signed in December 2017 following a prolonged negotiation period with their legal team.

Meanwhile, in September 2017 confirmation was received from Ofgem that their clarified definition of what constitutes a Material Change under NIC project governance[39] had been adopted equally to LCNF projects. Consequently, changes to the timing of SDRC submission dates contained within the Project Direction, or a delay to project closedown, of less than one year were no longer considered to be a Material Change requiring formal approval from Ofgem.

In light of this, to allow us to create reports which drew on the right level of experience from the TASS trials and delivered value from project expenditure, it was discussed and agreed with Ofgem that the SDRC submission dates be varied from those specified in the Project Direction and determined in line with project learning, with notice provided to Ofgem prior to submission of each report.

[38] LEAN SDRC 9.4 'Initial Learning from Trial Installation and Integration', September 2018

[39] the clarified definition of a Material Change requiring Ofgem's approval is provided in Appendix 1 and associated Section 8.23 of Ofgem's 'Electricity Network Innovation Competition Governance Document v.3.0', 30 June 2017

Project timeframes were regularly reviewed by the project team, with potential impacts raised and discussed with Ofgem to verify that progress continued to be acceptable with regard to achieving the objectives of the project, fulfilling the SDRC deliverables set out in the Project Direction, and providing useful insight for SSEN and other DNOs.

7 Significant Variance in Expected Costs and Benefits

Project expenditure has remained within the approved budget defined in the Project Direction. Table 4 details expenditure against each line in the Project Budget and compares this with expenditure over the course of the project, which concluded on 31 December 2019. Commentary is also provided below for variances greater than 10%.

At project inception the Ofgem LCNF Funding Direction defined a Funding Awarded figure of £2,669,964.11, with an SSEN DNO contribution of £306,800 together with forecast interest of £91,235.89 then forming the total project budget of £3,068,000. The interest rate achieved over the course of the project has been lower than the assumed rate of return, resulting in interest received of £19,725. Consequently, accounting for this difference in interest, the variance in project expenditure against funds received is £1,408,029.

Table 4 - Project expenditure by category

	Total Project Budget	Expenditure at Project Closedown	Variance against Budget	
			£	%
Labour	£1,197,000	£816,146	£380,854	-32%
Equipment	£544,000	£252,138	£291,862	-54%
Contractors	£722,000	£504,665	£217,335	-30%
IT	£37,000	£0	£37,000	-100%
Travel & Expenses	£283,000	£15,511	£267,489	-95%
Payments to Users	N/A	-	-	-
Decommissioning	£55,000	£0	£55,000	-100%
Other	£230,000	£0	£230,000	-100%
Total	£3,068,000	£1,588,460	£1,479,540	-48%

The internal Labour cost is less than forecast, in part due to the delay in recruitment of the Project Engineer during the earlier stages of the project, however primarily due to ongoing efficiencies in project delivery.

The Equipment cost is lower than the original budget figure, reflecting learning from the work undertaken during Phase One and experience from the subsequent trial stages of the project. Section 6 ‘Modifications to the Planned Approach During the Course of the Project’ describes the adaptations made for efficient and cost effective delivery of the trials, and the key factors which have contributed to this reduced expenditure on equipment are as follows:

- the revised approach to evaluating transformer losses on site based on measurement of transformer impedance and winding resistance, rather than replicating factory testing within the substation

- the completion of transformer energisation studies through modelling and simulation of the different switching options, rather than undertaking off-network trials to assess the effect of TASS switching on transformers
- the conclusions from Phase One and responses to external consultation for the Phase Two Decision Point which supported SEPD's intention to progress only TASS technology for development and trial on the SEPD network, as it is not considered to be financially viable to deploy ANT with TASS
- the subsequent development of the TASS scheme which provides a streamlined system for installation and integration with existing assets, and has provided clarity on the required equipment and associated costs
- the operation of TASS at two initial trial sites, which demonstrated the system's ability both to reduce losses and to respond to the wider network under a range of different situations and resulted in the conclusion that the expenditure for running additional trial sites would outweigh the additional learning that would be gained from those sites, and consequently this would not represent a cost effective use of customers' money for innovation funding in accordance with project governance - the benefit of approach is reflected in the recommendation to plan a staged approach to trial deployment included in Section 9 'Lessons Learnt for Future Innovation Projects'

The Contractor costs are lower than the original budget figure, and this also reflects the increased understanding of the costs associated with delivering the trials. In addition, as noted in Section 6 'Modifications to the Planned Approach During the Course of the Project', the LEAN project was able to reference visual resources prepared by two other DNO Groups to represent the importance of working to reduce network losses, rather than commission the creation of an additional video addressing the same topics.

The IT costs have remained at zero as the design of the scheme developed has resulted in no project specific IT expenditure. General IT costs form part of the business's corporate recharge costs[40] allocated across departments, similarly general DSO & Innovation team costs are apportioned across the teams' activities and projects as overheads assigned to Labour, Contractors and Travel Expenses as applicable.

The Travel & Expenses figure is lower than forecast due to minimal travel requirements and use of teleconferencing facilities wherever possible.

No Decommissioning costs have been incurred since, as reported in Section 11 'Planned Implementation', the decision has been taken by the business to retain the trial installations for ongoing losses reduction beyond the conclusion of the LEAN project.

All costs have been attributed to a specific category, and consequently no expenditure is recorded against Other.

The total figure for funds not spent due to efficiencies during the project is ~£1,411k, and this will be returned to customers in line with project governance procedures.

[40] corporate recharge figures include costs for IT, Finance, HR, Procurement, Risk / Audit / Insurance, Corporate Business Services, Corporate Affairs, Investor Relations & Company Secretary, Health & Safety, Property, Group Change, Legal & Compliance

8 Lessons Learnt on the Benefits of the Method Trialled

This section provides an update on the business case for TASS in light of the benefits and costs established through trial implementation and operation, with acknowledgement given to the factors that will influence the future cost of roll out. The appraisal of SEPD substations using current costs has been scaled to provide a GB assessment for comparison with the preliminary figures outlined in the Full Submission.

Financial Assessment of Deployment on the SEPD Network

The TASS Evaluation Tool has been used to assess 421 SEPD primary substations using load profiles from 2018. This analysis provides site specific figures for annual losses savings together with CBA for TASS deployment. The broader requirements set out in the stepwise Substation Assessment Process have then been considered to indicate the number of SEPD sites at which it would be technically feasible to deploy TASS.

To reflect the architecture applied for the TASS trials, the following three deployment scenarios have been assessed:

- TASS wall box - inc. TASS control device & associated components together with a site survey & protection study
- TASS wall box with a suite of asset health transformer condition assessment tests & PD surveys
- TASS wall box & synchronising relays to provide controlled PoW switching

The indicative current costs for different TASS deployment scenarios are presented in Section 10 ‘Project Replication’.

TASS Evaluation Tool CBA - Step One

In line with Step One of the Substation Assessment Process, Table 5 presents the numbers of sites which indicate a positive CBA using the current cost assumptions associated with the different deployment scenarios.

It is important to note that a range of factors will act to influence the future cost of deployment and potentially increase the financial viability of TASS, such as the growing availability of suitable control technologies and economies of scale as greater ranges of products are developed, and these are identified in Section 10 ‘Project Replication’.

Table 5 - Number of SEPD sites indicating a positive CBA using current cost assumptions - Step One

	Mid-Range Current Costs
Number of sites with positive net benefit up to the transformers' remaining life	
TASS wall box	101 (24%)
TASS wall box, TX tests & PD surveys	38 (9%)
TASS wall box, synch. relays	11 (3%)
Number of sites with positive net benefit up to 14 years	
TASS wall box	101 (24%)
TASS wall box, TX tests & PD surveys	34 (8%)
TASS wall box, synch. relays	7 (2%)

Apportioned CBA - All Steps

In line with the stepwise Substation Assessment Process, it has been identified that 73% of the SEPD sites will have dedicated circuit breakers (Step Two) and 95% of the transformers will be of satisfactory condition (Step Three). Experience from both the development of the system and implementation during the trials indicates that there should be no problems with the protection and control systems, or that these can be readily adjusted to meet the requirements for TASS (Step Four).

Summarising the above assumptions and applying a margin of +/- 5%, the indicative figures for the numbers of sites for which TASS may be technically and economically viable on the SEPD network are shown in Table 6.

Table 6 - Indicative number of SEPD sites indicating a positive CBA using current cost assumptions - All Steps

	Mid-Range Current Costs
Number of sites with positive net benefit up to the transformers' remaining life - taking account of the stepwise assessment process	
TASS wall box	67 - 74 (16%-17%)
TASS wall box, TX tests & PD surveys	25 - 28 (6%-7%)
TASS wall box, synch. relays	7-8 (2%)
Number of sites with positive net benefit up to 14 years - taking account of the stepwise assessment process	
TASS wall box	67 - 74 (16%-17%)
TASS wall box, TX tests & PD surveys	22 - 25 (5%-6%)
TASS wall box, synch. relays	5 (1%)

Using the current cost assumptions, therefore, with the mid-range capex figures, around 2% - 17% (~7 - ~74 sites) of the SEPD primary substations would be viable.

The total cumulative discounted net benefits and energy savings associated with the central point of this range are shown in Table 7.

Table 7 - Cumulative discounted net benefits and energy savings based on current cost assumptions

	Mid-Range Current Costs			
	Total Cumulative Net Benefit	Total Energy Saving	Total Carbon Saving [1]	Energy Saving per Year
Sites with positive net benefit up to the transformers' remaining life - taking account of the stepwise assessment process				
TASS wall box	£1,333,500	48,600 MWh	9100 tCO_2	~3500 MWh
TASS wall box, TX tests & PD surveys	£789,500	36,300 MWh	6100 tCO_2	~2000 MWh
TASS wall box, synch. relays	£284,400	18,200 MWh	3100 tCO_2	~900 MWh
Sites with positive net benefit up to 14 years - taking account of the stepwise assessment process				
TASS wall box	£919,700	25,700 MWh	7500 tCO_2	~3500 MWh
TASS wall box, TX tests & PD surveys	£464,700	15,700 MWh	4500 tCO_2	~2000 MWh
TASS wall box, synch. relays	£159,200	6,800 MWh	2000 tCO_2	~800 MWh

[1] using Ofgem projected figures for decarbonisation of electricity by 2050

Financial Assessment for GB

A high level estimation of the financial benefit from GB wide deployment of the proposed technology was provided in the LEAN Full Submission bid document. That assessment was guided by the findings from an Innovation Funding Incentive (IFI) project carried out by SEPD that studied the impact of losses on the Isle of Wight network. For the bid submission, it was assumed that 90 MWh per annum could be saved by reducing losses at an individual substation using LEAN technology. The financial benefit was then derived based on the RIIO-ED1 losses value of £48.42 per MWh, with the carbon savings based a figure of 428 gCO_2e/kWh for the UK average generation mix.

For comparison with that preliminary assessment, indicative figures for GB application of TASS have been derived based on the current understanding of costs and benefits. In keeping with the approach taken for the Full Submission and SDRC 9.2 'Business Case Validation'[41], this scales the Step One analysis of SEPD sites given above to reflect the total number of GB 33/11kV substations.

[41] LEAN SDRC 9.2 'Business Case Validation', March 2016

The updated evaluation reflects a number of refinements to the appraisal of SEPD substations, as follows:

- annual load duration curves from individual SEPD substations provide more accurate figures for potential losses reductions than the generic load profile previously considered
- costs are based on the equipment and resource assumptions informed through trial application, with the mid-range current cost estimates used for the three deployment scenarios assessed
- in line with the RIIO Cost Benefit Analysis methodology, the TASS Evaluation Tool applies Ofgem projected figures for the level of CO_2e associated with grid electricity and changes in the traded carbon price associated with the decarbonisation of electricity by 2050, rather than applying the same fixed value to each year of the assessment
- the value of losses has been updated in line with the draft RIIO-ET2[42] figure of £59.74

A 45 year assessment period is used in line with the evaluation presented in the Full Submission, and the figures are presented in Table 8 alongside the original estimate for switching Option 2 - controlled switching with existing equipment. This assessment assumes that losses savings continue beyond the remaining life of the current transformers on the basis that these assets will be replaced, allowing TASS operation to continue. However, to reflect the lower inherent losses of more modern transformers, beyond the point of transformer replacement the average annual energy saving is capped at a nominal figure of 29 MWh per year for a site in line with the average saving from substations that currently demonstrate a positive CBA.

Table 8 - Updated GB Financial Benefit Assessment following trial implementation of TASS

	Full Submission	Mid-Range Current Costs [2]		
	Switching Option 2 [1]	TASS wall box	TASS wall box, TX tests & PD surveys	TASS wall box, synch. relays
45 Year Cost Benefit Assessment				
GB total number of sites	4800			
Percentage of sites viable for TASS	24%	24%	9%	3%
GB sites for TASS application - pro-rata	1166	1152	433	125
Total Investment	£21,036,522	£32,128,100	£17,720,100	£9,437,500
45 Year Losses Savings [MWh]	1,432,732	1,582,800	350,400	337,400
45 Year CO_2 Savings [tCO_2e]	288,948	201,400	44,600	42,900
45 Year Indicative Cumulative Net Benefit	£46,207,091	£65,624,600	£22,445,000	£7,573,900

[1] assumed a capex cost of £18,000 per site

[2] extrapolated from 'transformer remaining life' figures on the basis that the TASS technology will still be available for use at a substation following transformer replacement

[42] the RIIO-ET2 Draft CBA value (v1.6) is used as this is more recent than the former RIIO-ED1 figure

To give context to the losses savings presented above, the Energy Saving Trust's information on domestic solar photovoltaic (PV) systems[43] indicates that the range of energy savings would be equivalent to the energy generated each year by ~1,800 to ~8,400 typical domestic PV systems in the south of England. Using the Government's greenhouse gas conversion factors[44], the reduction in carbon emissions associated with these energy savings then equates to around 13 million to 62 million miles travelled by a conventional passenger car, or around 1,300 to 6,200 vehicles each covering 10,000 miles per year.

Section 4 'The Outcomes of the Project' sets out the deliverables created to allow other DNOs to understand how and where to apply TASS technology on their own networks. Section 10 'Project Replication' then presents the key sources of information and knowledge required by DNOs and product vendors to enable them to replicate TASS on other networks, including the Scalability & Replicability Assessment which gives structured guidance to inform any adaptations required for the deployment of this technology across other network areas.

Contribution to UK Policy Aims

By reducing electricity distribution network losses, TASS offers a viable means to deliver environmental and social benefits through energy efficiency while maintaining a safe, reliable supply to customers.

The application of this technology can therefore contribute to the aims set out by government in The Carbon Plan[45] and actions required to meet the UK's 2050 Net Zero target[46] throughout the transition period, as follows:

- in the short term, the energy saved by reducing losses equates to a reduction in carbon emissions associated with the current generation mix, as well as a reduction in the losses component of costs passed on to customers through bills
- in the mid-term, where increasing levels of embedded generation are seen the reduction in demand on a primary substation will decrease transformer utilisation, and the use of TASS to reduce losses at times of low demand will compliment the benefits from distributed generation
- further, with increasing uptake of low carbon technologies (LCTs) such as electric vehicles (EVs) and heatpumps, demand will become increasingly diverse with wider contrasts between peaks and low demand levels - networks designed with sufficient capacity for times of high demand may be subject to lower overall transformer utilisation, thereby increasing the savings achievable through TASS

[43] the Energy Savings Trust's information on solar panels notes that the "average domestic solar PV system is 4kWp" and a "4kWp system can generate around 4,200 kilowatt hours of electricity a year in the south of England" www.energysavingtrust.org.uk/renewable-energy/electricity/solar-panels

[44] calculated based on the passenger vehicle conversion factor for an average car (unknown fuel type) of 0.28502 kg CO_2e per mile taken from the 'Conversion Factors 2018' tables, UK Government, July 2019 www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2019

[45] 'The Carbon Plan', Department of Energy and Climate Change (DECC), December 2011

[46] the 'Climate Change Act 2008 (2050 Target Amendment) Order 2019', which came into force on 27 June 2019, amends legislation to introduce a UK target of at least a 100% reduction of greenhouse gas emissions compared to 1990 levels

- in the longer term, the forecast increase in electricity use due to the electrification of heat and transport anticipated in the Carbon Plan can be expected to increase overall losses, and the reduction of losses through TASS will act to offset the associated impact on customers' bills

Broader Benefits Identified During the Trials

As described in Section 4 'The Outcomes of the Project', the trials have also provided broader learning of benefit beyond the pure application of TASS, as follows:

- the approach taken to design and implement TASS provides learning relevant to the future development of similar innovative automation and control technologies and their integration with existing assets
- information obtained from the range of techniques used to monitor asset health can be used to inform future developments regarding the evaluation of asset health and associated investment decisions
- the power quality monitoring data provides detailed information on the application and benefits of controlled Point on Wave switching

These aspects have proven to be of interest to a range of internal and external stakeholders over the course of the trials.

9 Lessons Learnt for Future Innovation Projects

The arrows in this section summarise key recommendations for the management of future innovation projects and for the development of similar technologies to bring enhanced automated functionality to electricity networks. This guidance is informed by approaches which proved to be effective in delivering the LEAN project, with examples given to illustrate the recommendations.

Engagement with Colleagues & Creation of a Risk Mitigation Strategy

➡ Identifying and engaging with all relevant stakeholders is fundamental to requirements capture, and it is important to promote discussion as necessary to allow all suggestions or concerns to be raised and addressed accordingly, and to reach a consensus where differing view may be held. Innovation teams should aim to manage this thoroughly and in a timely manner as this consultation is of great value for scheme development whilst also strengthening acceptance of the scheme.

➡ A clear and targeted engagement plan supported by a point of focus such as a Risk Mitigation Strategy for guiding the dialogue, recording decisions and demonstrating that all relevant stakeholders have been consulted, is recommended for the development and introduction of all similar network control technologies as a valuable means of informing colleagues and senior managers of the project plans and eliciting their support for a trial.

Experience Drawn on to Inform Recommendations

TASS represents a new way of operating key network assets in primary substations which challenges conventional expectations and judgement. It has therefore been essential to fully communicate the associated risks and mitigation measures to colleagues and senior managers to obtain acceptance from the business of the application of this technology. Accordingly engagement with a range of teams from across the business has been required throughout the LEAN project to:

- support requirements capture
- ensure acceptance of project plans
- coordinate the involvement of specific individuals from different business teams in project activities
- inform operational staff of the trials and the requirements associated with their roles
- raise awareness of the project and disseminate results as relevant to colleagues across the business

The Risk Mitigation Strategy created for the TASS trials provides detail on the principles and responses designed into the system to address safety, operational and data security risks, and sets out the roles and responsibilities of various teams across the business during the different stages of the project. Having this as a focus for all aspects of the trial proved exceptionally useful for guiding this engagement, giving visibility as to who had been consulted, and for building trust in and gaining support for the technology.

SGAM - Smart Grid Architecture Model

➡ The use of SGAM to develop, analyse and communicate new smart grid technologies and associated business structures is recommended for all similar innovation projects and product development work.

Experience Drawn on to Inform Recommendations

A Smart Grid Architecture Model (SGAM)[47] was created for use in developing the systems to be implemented for the TASS trials and in communicating plans and project requirements.

This model was initially used when engaging with third party service providers and product vendors during the procurement process. It was then subsequently used as a working communication tool during discussions with colleagues from different areas of the business, and the model evolved as the system design was refined, with requirements or proposed amendments captured as necessary.

This experience has demonstrated the benefits of using SGAM for:

- System Design

  When designing systems consideration can readily be given to the roles and functions of different systems, the boundaries between these, and the data flows required to provide the relevant information to inform decisions, whether automated or manual. It is possible to see where new equipment will interface with existing assets, and identify synergies to exploit equipment for different smart grid functionalities. Additionally, the complete set of SGAM layers support effective collaboration between all those involved in a system's design to elicit requirements and identify all relevant aspects for consideration (technical, functional, data, communications, etc.).
- Procurement

  Clarity in the specification of complex or interacting systems promotes efficiency in the procurement process, allowing vendors to understand requirements and propose suitable systems or solutions, and supporting the evaluation of proposals by network operators.
- Innovation Rollout

  By using SGAM to share innovative solutions it's possible for other DNOs to analyse and compare solutions, identify and understand aspects suited to centralised or decentralised control on a given network, and assess the adaptations required to replicate a solution on their own networks.

Design Systems from Functions rather than Components

➡ At the start of the design process for new technologies to bring enhanced functionality to networks the focus should be on establishing a clear understanding of the specific functions required from the system, rather than the specific components to be used.

➡ Open engagement with markets and potential collaborators is then recommended to establish the benefits and constraints of a range of proposed system architectures in delivering this functionality.

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[47] SGAM is a three dimensional model that reflects principles applied in well established ICT architecture approaches for designing complex systems in a technology neutral manner, and the SGAM framework encompasses all aspects of a smart grid system, from the electrical infrastructure and ICT technology to required information flows and defined functions

Experience Drawn on to Inform Recommendations

During the tendering process for the trial stages of LEAN a design proposal was sought which could be widely applicable to a range of different substation configurations, with minimal changes required to the architecture or settings for each site. The scheme subsequently implemented, however, is more streamlined than had been envisaged during the early stages of the project.

This highlights the benefit of considering functionality rather than specific components, as this allowed the centralised and decentralised aspects to be appraised, existing systems to be assessed to make use of existing devices and data, and functions to be allocated appropriately to individual components. The relevant information flows and interface requirements could then be ascertained to ensure that the TASS technology integrates well with existing assets and systems.

It also demonstrates the value of presenting ideas to the market to invite solutions and proposals from others, rather than creating a very specific design based on preconceptions of what may be possible.

Structuring the Procurement Process for Developing Technology & Delivering Trials

- Innovation projects seeking to procure services for the development and trial of new technology on a network should assign project requirements to distinct but integrated work packages. This provides flexibility in drawing together and commissioning the different elements of a trial from one or more suitable third parties.

Experience Drawn on to Inform Recommendations

When planning the approach to be taken for delivery of the trial phases of the LEAN project it was clear that a range of skills, expertise and experience would be required in developing and implementing TASS technology. To ensure visibility for potential collaborators and allow the most appropriate mix of capabilities to be accessed, the Scope of Works created for the procurement process therefore detailed all elements of the project but set out the requirements in defined work packages. Specific reference to engagement between the work packages was also made to promote strong communication between all relevant suppliers and product vendors.

The structure of this Scope of Works consequently allowed market capabilities to be explored in an open manner, and ensured that the work was both well aligned to the project requirements and delivered value across all aspects of the development and implementation of the technology.

Timely & Appropriate Stages of Testing

- Progressive stages of detailed testing should be used during the development of technologies that offer enhanced automated control functionality to electricity networks.
- A detailed commissioning plan must also be drawn up to ensure that all relevant aspects are considered during site tests undertaken to confirm the correct operation of the equipment, control algorithms and system communications. This plan must be structured to guide the work and ensure that efficient use is made of the time on site, which is particularly relevant where outages are required for installation or commissioning.

Experience Drawn on to Inform Recommendations

Successive stages of testing were used at appropriate stages during the development and delivery of TASS technology, as follows:

- Factory Acceptance Testing

  Early stage 'Hardware in the Loop' (HIL) testing allowed the interaction of the system and response of the TASS control algorithm to different simulation signals to be tested. The operation of such systems that provide real time control capability can then be refined as necessary to de-risk the move to testing in a real environment with connection to external assets or systems.
- Bench Testing

  Subsequent bench testing in a laboratory equipped with the relevant Information & Communication Technology (ICT) devices to replicate a real network environment was then used to test the communications and data exchanges between the different devices. The TASS control algorithm's responses to different operational scenarios could also be observed, providing a sense check on the design of the scheme and allowing additional potential scenarios and considerations to be identified and addressed at the development stage.

  The TASS test system set up within SSEN's Protection laboratory proved to be invaluable for identifying issues with the TASS algorithm and with its integration to the existing substation SCADA and DMS systems, for example ensuring that the TASS algorithm allowed sufficient time for data exchange between the devices. This could then be rectified prior to site installation, avoiding a time consuming and costly process of arranging additional outages and scheduling resources to complete further testing or commissioning activities on site.
- Commissioning

  For commissioning on site, injection and simulation tests were used to replicate different operational situations and assess the response of the TASS system, prior to enabling the comms link that allowed the TASS control device to issue signals to substation assets. For the final stages of commissioning, full automated control was given to the system allowing it to operate live under the close supervision of the commissioning team.

  The commissioning plan was created with reference to the system design, the existing assets and systems, site specific conditions, and associated risks.

This progression allowed issues to be identified in a timely manner prior to further development or more involved testing activities and full integration with live operational assets.

Staged Deployment of Trial Technology

➡ A staged approach to trial deployment is recommended for the introduction of any innovative technology which represents a radical change to conventional network operation. This supports cost effective delivery of trials by allowing the performance of the system to be assessed prior to committing additional expenditure, and allows those involved with the technology to gain confidence in the system whilst minimising the exposure of the network to potential risks or unknowns associated with the trial nature of the project.

Experience Drawn on to Inform Recommendations

The planned staged deployment of TASS proved to be a pragmatic approach to implementing the trials. Through the experienced gained from installing and operating the TASS system at the two initial trial sites it became apparent that the expenditure for running additional trial sites would outweigh the additional learning that would be gained from those sites. Consequently, our project governance perspective was that this would not represent a cost effective use of customers' money for innovation funding.

This assessment recognised that the TASS system continued to operate as designed under a range of different situations, demonstrating its ability to deliver TASS functionality and respond to the wider network. Consequently, any learning from deployment at further sites would have centred around the installation activity at substations with different configurations, such as two Remote Terminal Units (RTUs) or three or four transformers, however the TASS scheme design and control algorithm have been specifically designed to accommodate this range of configurations, and the same approach to installation and commissioning would be required.

SSEN now incorporates Stage Gate review processes as best practice with Network Innovation Competition (NIC) project submissions.

Present Appropriate Information through Central Data Systems

➡ The information and commands to be available through central data systems should be carefully defined to meet safety and operational requirements and align with the expectations and existing activities of all those who may interact with the technology.

Experience Drawn on to Inform Recommendations

TASS specific information and commands incorporated into the DMS, PowerOn Fusion, provide the network Control Room with real time system status notifications together with remote management capability for the quick identification and resolution of any issues. This data is also recorded and stored in SSEN's data historian system, PI, to provide a record of TASS operation which can be viewed by others within the business who are responsible for monitoring the performance of the system. This information made it possible for the project team to supervise the scheme on a daily basis, and supported investigations to establish the system's response to different operational situations without necessarily requiring a site visit.

More detailed data is then recorded locally by the TASS control device to provide additional information which can be downloaded from site should any investigations into the operation of the system be required.

Automate Regular Analysis Processes

➡ For any analysis that will need to be repeated over the course of a project, or be required for ongoing reporting if system is rolled out across a business, it is recommended that time is taken to automate or semi-automate the process.

Experience Drawn on to Inform Recommendations

Regular updates on the losses saved during the TASS trials were required to meet various reporting obligations. For efficiency and to remove the risk of error to ensure that figures are consistent and comparable, time was taken initially to semi automate the process of obtaining data from central systems and deriving the associated figures.

Communicate the Investigation and Resolution of Issues

- Good levels of communication should be maintained with colleagues or external stakeholders throughout the investigation and resolution of any issues experienced during a trial.

Experience Drawn on to Inform Recommendations

On each occasion that TASS responded to SCADA data from other network assets, the project team investigated to ascertain the cause of the issue and confirm that TASS had operated as necessary to provide an appropriate response. At these times the project team provided updates and explanations to relevant operational staff to build their understanding of the system and promote a sense of engagement with the trials.

Seek Feedback to Evaluate the Implementation of New Systems and Engagement with the Project

- Insight from stakeholders is important to establish whether staff are comfortable with how a system has been implemented, and can be used both to inform the wider roll out of a technology and to shape the implementation of future innovation trials. Tracking the experience of participants can also promote the engagement and cooperation of staff throughout project trials.
- Feedback should also be sought on specific activities, such as the delivery of training, to ensure that the structure and content of the material used is well targeted to its intended audience.

Experience Drawn on to Inform Recommendations

At each of the TASS training sessions run for operational staff, attendees were asked to complete evaluation forms on an anonymous basis. In addition to appraising the training delivered and gauging whether the content covered information relevant to the individuals' roles, the questions provided a valuable opportunity for peer review to verify that relevant factors had been considered and incorporated into the scheme design, and that the system's functionality meets the requirements of our operational colleagues. Positive feedback was received both on the training and the TASS system.

Similarly, six months into the trials a feedback form was issued to Control Engineers seeking views on their experience of interacting with the TASS system, and on the general management of the trials. The responses received indicate that the TASS interface in the DMS meets operational requirements well, and that staff are happy both with how the system has been implemented and their engagement with the project team.

Expectations Regarding Network Modelling

- When defining the scope of any power quality modelling to be undertaken forethought is required on what would constitute useful findings in the event that precise figures cannot be calculated.

Experience Drawn on to Inform Recommendations

The power quality analysis undertaken to simulate the impacts of TASS switching on the upstream and downstream networks illustrated the complexities inherent in translating network models, and in establishing assumptions associated with aspects of the physical network and specific transformer performance which it is not possible to empirically define. Notwithstanding this, as the derived figures can be understood to represent a higher impact than may be expected for the sites, the work was of value in providing a point of reference for the potential worst case switching scenario and level of expected voltage variation across the wider network. For example, the worst case inrush currents calculated within the studies are well within design capabilities for the transformers, thereby supporting the conclusion that inrush currents due to TASS switching present minimal risk of damage which may adversely affect transformer asset life.

Support Appraisal of the Future Scaling or Replication of an Innovation

- Innovation projects should use a structured framework to assess and clearly identify factors that must be considered by others when evaluating the potential application of an innovative technology or methodology to other networks.

Experience Drawn on to Inform Recommendations

Consideration has been given to the scalability and replicability of the TASS system throughout the development and delivery stage of LEAN to support the future potential roll out of this technology.

To give structured guidance to those assessing the feasibility of applying TASS, specific factors have been identified to inform any adaptations required for deployment of TASS across other network areas and highlight where detailed consideration would be of value. These also have relevance to the development of similar automation technologies for application at scale.

These factors are classified using the key circumstances, characteristics or considerations that have an influence on the scalability or replicability of a solution as identified during SSEN's participation in the European collaborative project DISCERN[48].

The scalability and replicability assessment undertaken for the application of TASS is presented in Section 10 'Project Replication'.

Awareness of Network Innovation IPR Requirements

- It is recommended that the Legal and Procurement teams of potential consultants and suppliers interested in becoming involved in any funded innovation projects acquire a good understanding of the associated governance requirements regarding Intellectual Property Rights (IPR), and form a strategic view on how best to benefit from involvement in such projects and gain experience to support ongoing development of the industry and its supply chains.
- A well structured draft agreement, which has been prepared or reviewed by a DNO's legal team prior to issue, is also important as a 'starting point' for discussion on the terms & conditions for procurement.

Experience Drawn on to Inform Recommendations

A key challenge at the early stage of trial delivery lay in agreeing the terms of the contract to be put in place with the consultants selected for involvement in the development of the TASS technology. This included negotiation on the

[48] SSEN partnered in the European Seventh Framework Programme (FP7) project DISCERN (Distributed Intelligence for Cost-Effective and Reliable Distribution Network Operation), which ran from February 2013 to April 2016, and through this the key circumstances, characteristics or considerations that influence the scalability or replicability of a solution were identified to inform a structured appraisal of new technologies - the DISCERN NIA Close Down Report is available on the ENA's Smarter Networks Portal www.smarternetworks.org/project/nia_ssepd_0001/documents

clauses relating to IPR and SSEN’s need to ensure that these were compliant with LCNF requirements. Here, the proposed terms and conditions were issued to the consultants in April 2017, however it took a further 8 months to finalise the procurement agreement with their legal team and confirmation of approval was finally received in December 2017, allowing the Purchase Order to then be issued.

The prolonged negotiation period for agreeing terms with the consultants occurred despite a draft agreement being issued, and despite the Scope of Works specifically referencing the requirement that those expressing an interest in the work must allow the project to adhere to the LCNF Default IPR arrangements, such that the knowledge generated by the project can be disseminated with relevant stakeholders including other GB DNOs.

10 Project Replication

This section presents the key features of the project that provide the information and knowledge required to enable DNOs and product vendors to replicate TASS on other networks, and indicates the costs associated with deployment.

Design for Replication

The technology design process maintained a clear focus on the future scalability and replicability of TASS to ensure that the system trialled is suitable for wider adoption and roll out across distribution networks.

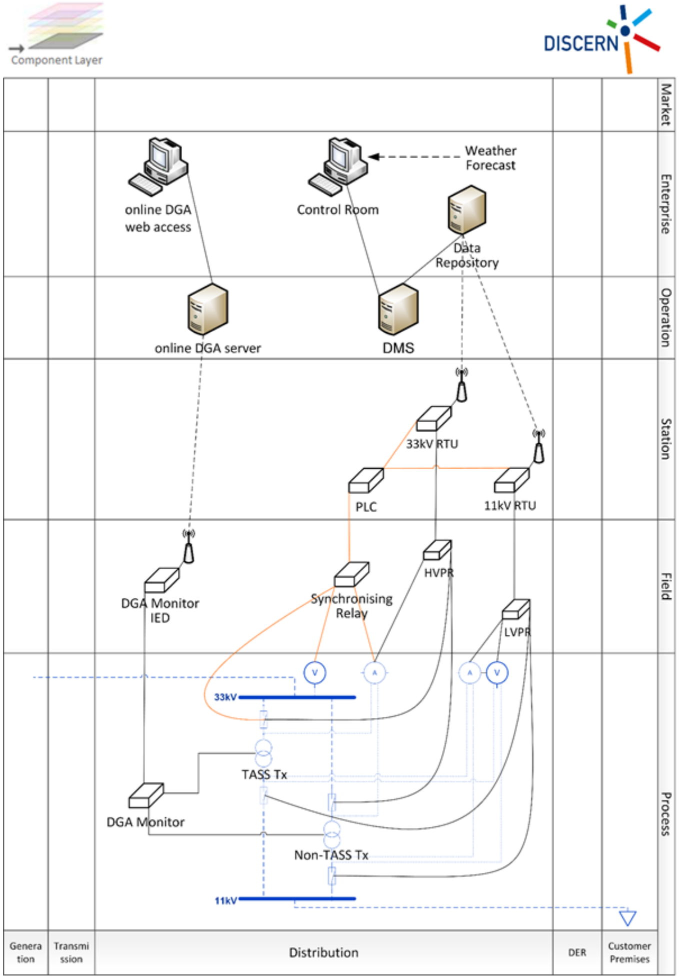
A technology neutral approach has been taken to developing the TASS system architecture and algorithm specification, such that this functionality may be implemented using a range of suitable components and alternative control platforms. In addition to supporting the assessment of TASS for application on other networks or using different devices, this allows the deployment of the technology to be aligned to a DNO's existing procurement frameworks with different suppliers.

The Smart Grid Architecture Model (SGAM)[49] created for use in developing TASS and communicating plans and project requirements then provides an intuitive, technology neutral representation of the system which other DNOs can use to assess the replication of TASS on their own networks. The layers of this model depict the components of TASS together with the communications protocols, information exchanges and functions associated with each element of the system.

The SGAM image in Figure 4 shows the TASS Programmable Logic Controller (PLC) and synchronising relay components of the TASS architecture integrated with the existing substation assets, including the transformers, protection relays (PR) and Remote Terminal Units (RTU) used for SCADA comms, in addition to the online Dissolved Gas Analysis (DGA) system used to monitor the transformers. An overview of SGAM together with the full TASS model is provided in Appendix D.

[49] the TASS SGAM has been created and evolved using the SGAM Visio Template developed through the European FP7 DISCERN project - the DISCERN NIA Close Down Report is available on the ENA's Smarter Networks Portal www.smarternetworks.org/project/nia_ssepd_0001/documents

Figure 4 - TASS SGAM image - component layer



Scalability & Replicability Assessment

To give structured guidance to those evaluating the potential application of TASS, specific factors have been identified which will inform any adaptations required for the deployment of this technology across other network areas. These also have relevance to the development of similar automation technologies for application at scale.

The scalability and replicability assessment undertaken applies a comprehensive framework[50] to evaluate each of the following considerations:

- Interoperability - this relates to the level of tailoring or configuration required to allow a device to interact with an existing system
- Software Design Flexibility
- Interface Design Flexibility
- Economies of Scale
- Cost Effectiveness
- Stakeholder Interaction - this relates to the engagement that new or increased numbers of users or organisations will have with the solution

[50] the TASS scalability and replicability assessment applies the framework created through the European FP7 DISCERN project - this identifies the key circumstances, characteristics or considerations that will influence the scalability or replicability of a solution to inform a structured appraisal of new technologies

- Modularity
- Version Compatibility
- Addition to the Asset (Device/System) Inventory
- Simplicity/Ease of Installation & Integration
- Availability of Alternatives
- Technology Evolution
- Technical Abstraction - this relates to the physical characteristics of the user experience, and how closely people interact with the technology
- Level of Acceptance (amongst all stakeholders)
- Regulatory and Legal Considerations
- External Constraints
- Skills and Training

The factors identified are presented in Appendix E to provide a checklist for reference by DNOs, product vendors or the regulator.

Project Deliverables to Support Replication

The material developed through the project - including the Risk Mitigation Strategy, TASS algorithm specification, system architecture documentation, training material, substation signage, TASS Evaluation Tool and TASS Technology Substation Assessment Guide - provides a suite of deliverables available to DNOs and other industry stakeholders to support the wider application of TASS, and the effective development and operation of further decentralised control systems.

Section 13 'Key Project Learning Documents' signposts the documents and material available through the project which provide detail on the development, implementation and operation of TASS and allow DNOs to understand how and where to deploy TASS on their own networks.

Costs Associated with the Application of TASS

SDRC 9.6 'Site Performance to Date'[51] details the equipment and resource assumptions used to derive current cost estimates for deploying TASS in a primary substation.

The ranges of capex costs for implementation associated with these assumptions are presented in Table 9.

[51] LEAN SDRC 9.6 'Site Performance to Date', March 2019

Table 9 - Summary of current capex cost ranges for TASS deployment at a primary substation by activity/component

	Lower Band	Mid-Range	Higher Band
TASS System Implementation			
Site Survey	£225	£250	£275
Detailed Protection Study	£270	£300	£330
TASS Wall Box	£4,600	£5,400	£6,200
Synchronising Relays	£42,300	£47,350	£47,800
Asset Health Assessment			
Partial Discharge Surveys	£225	£250	£275
Transformer Condition Assessment Tests	£11,460	£12,750	£14,000
Online DGA Monitoring	£51,120	£56,800	£62,480

Regarding the ongoing operation of TASS, at present the business's standard approaches to inspection and maintenance are expected to be sufficient for any substations where TASS is applied, and there is no evidence of any increased risks to asset health due to the deployment of TASS. A nominal figure of £500 per site is therefore assumed for the opex cost associated with TASS. It is not anticipated that online DGA monitoring would be required as part of the wider roll out of TASS, however the indicative operational cost for cloud hosting of data for the fleet of transformers being monitored is around £5,000 per year.

To reflect the options for TASS implementation, Table 10 presents the potential range of current overall capex costs associated with the following deployment scenarios:

- TASS wall box - inc. TASS control device & associated components together with a site survey & protection study
- TASS wall box with a suite of asset health transformer condition assessment tests & PD surveys
- TASS wall box & synchronising relays to provide controlled PoW switching
- TASS wall box & synchronising relays, with asset health tests & surveys
- TASS wall box & synchronising relays, with asset health tests & surveys, and online DGA monitoring

Table 10 - Indicative current capex cost scenarios for TASS deployment at a primary substation

	Lower Band	Mid-Range	Higher Band
TASS wall box	£4,600	£5,400	£6,200
TASS wall box, TX tests & PD surveys	£16,300	£18,400	£20,500
TASS wall box, synch. relays	£46,900	£52,750	£54,000
TASS wall box, synch. relays, TX tests & PD surveys	£58,600	£65,750	£68,300
TASS wall box, synch. relay, TX tests & PD surveys, online DGA	£109,700	£122,500	£130,800
Annual operational costs associated with the application of TASS	£500	£500	£500

Clearly the present costs of some of these deployment scenarios are significant. However, a wide range of factors will act to reduce these costs and increase the financial viability of TASS. These must be also considered by those assessing the implementation of TASS at scale across a network area, and by those developing equipment to provide similar functionalities, to inform thinking on the application of such technology.

Table 11 summarises the key influencing factors. These reflect observations regarding the technical and economic scalability and replicability of TASS, and experience gained during the trials.

Table 11 - Factors that will influence the cost of TASS deployment

Activity / Component	Influencing Factors
TASS System Implementation	
Site Survey	*n/a*
Detailed Protection Study	*n/a*
TASS Wall Box	The TASS algorithm specification was created in a technology neutral manner such that it could be implemented using a range of suitable alternative PLC devices. In addition to supporting application of TASS using different devices, this allows the deployment of the technology to be aligned to a DNO's existing procurement frameworks with different suppliers. The control device used for the TASS trials provided flexibility in the design and development of the system, however for roll out of the technology at scale it may be possible to incorporate the TASS functionality into an existing substation RTU. Similarly, product vendors may choose to provide TASS functionality within their 'off the shelf' RTU devices. In addition, with continued developments in Information & Communications Technology (ICT) and the industry transition to a DSO model with increasingly dynamic operation of electricity networks, it can be expected that in due course new control technologies will become available at lower costs, and these may include additional devices suitable for the implementation of TASS. Installation & commissioning could be completed by in house teams as a regular procedure where TASS is rolled out at scale.
System Integration	The capability to remotely upload new configurations to RTUs would bring efficiencies to the processes of integrating TASS with SCADA and adjusting settings over time as necessary, for example should a different Crossover Point be merited.
Synchronising Relays	The scheme developed & trialled through the project applies TASS to two transformers within each substation, with TASS operation alternating between the transformers to share the switching duty. This principle was designed into the scheme in light of the requirements capture stages of technology development, however for wider roll out the decision may be taken to apply TASS to only one transformer, thereby requiring only one synchronising relay per substation. Product vendors may choose to incorporate Point on Wave functionality into their switchgear, or develop lower cost dedicated Point on Wave switching devices.
Asset Health Assessment	
Partial Discharge Surveys	The cost for PD surveys will be depend on whether there is capability in house to undertake these surveys, or whether they would need to be procured from a specialist third party.
Transformer Condition Assessment Tests	The cost of any transformer condition assessment tests undertaken would be influenced by factors such as the specific combination of tests required; the third party/ies appointed to undertake the tests; the geographical locations of the sites to be tested; and the negotiations held as part of a standard procurement process.
Online DGA Monitoring	A range of online DGA systems are now available on the market to measure specific key gases or provide results for the full suite of fault gases, and with different technologies applied to analyse the oil samples on site and different communications methods used to access the data remotely. The monitoring requirements must therefore be considered to establish the appropriate type of system that would be cost effective for a given application.

General	
Synergies	When introducing any new functionality such as TASS, existing systems should be assessed to identify synergies and make use of existing devices or data transfer routes where possible, to ensure efficient and cost effective deployment. The TASS scheme developed through the project provides a streamlined system for installation and integration with existing assets, and the dissemination material provided will support the assessment of synergies should the technology be rolled out at scale across the business or in other network areas. Similarly, where sophisticated control devices are to be used for the application of TASS, these should be assessed for the opportunity to deliver additional functionality beyond TASS.
Economies of Scale	As with any technology or service, economies can be realised when procuring greater numbers for roll out at scale, and this will apply to the majority of activities and components required for TASS deployment. Economies may also be seen as product vendors adopt technology and manufacture more 'off the shelf' devices to meet an increasing demand for a given functionality. In addition, increasing demand may promote competition between different product vendors, also influencing the price point offered. Installation & commissioning costs can also be expected to reduce when rolling a technology out at scale, due to increased levels of experience and efficiencies in delivery.
Procurement	The use of a standard procurement process or existing procurement framework should ensure visibility and value when sourcing any components or services from third parties.

11 Planned Implementation

TASS offers a financially viable, as well as technically feasible, option for reducing losses on electricity distribution networks, and demonstrates a business case for applying TASS at specific sites.

Following the successful project trials, the Director of Distribution System Operations has become the Sponsor for business adoption of TASS, with recommendations made that the trial installations to continue operating to reduce losses beyond closedown of the LEAN project, and that TASS be accepted as standard practice for application at suitable primary substations.

Accordingly, a paper entitled 'Business Roll Out of TASS' has been presented to the business's Distribution Asset Management Steering Group (DAMSG). This paper is provided as Appendix F, and sets out the strategy for implementing TASS. A decision has subsequently been made to retain the trial installations for ongoing losses reduction, and to evaluate the application of TASS at primary substations in line with the proposed plans for implementation outlined below.

Strategy for Roll Out of TASS

The business case for TASS would be assessed on a site-by site basis in line with the Substation Assessment Process established through the LEAN project. The subsections below indicate the proposed strategy for identifying suitable sites within the RIIO-ED1 and RIIO-ED2 price control periods.

RIIO-ED1

It is recommended that all sites scheduled for 33/11kV transformer and 11kV switchboard refurbishment within ED1, together with planned new primary substations, be assessed for the application of TASS. With current costs, where the system can be deployed without controlled Point on Wave (PoW) switching[52], TASS offers a financially viable and technically feasible option for reducing electricity distribution losses at specific sites, with a typical payback period of <5 yrs for suitable sites. At present, the current costs for a suitable PoW switching device mean that in the short term this deployment scenario is not ordinarily financially viable.

RIIO-ED2

Within ED2 innovation roll out forms part of the Business Plan Incentive proposals, which also indicate that additional totex allowances may be available where it can be demonstrated that additional funding is needed[53]. As TASS delivers societal (Non-DNO) benefits through energy efficiency which reduces costs to customers and equates to lower CO_2e

[52] analysis of the electrical impact of TASS switching on the network indicates that TASS operation with PoW switching would be of benefit for some sites to ensure best practice compliance with ER P28 voltage fluctuation limits, however other sites may operate acceptably without controlled switching

[53] 'Open Letter Consultation on approach to setting the next electricity distribution price control (RIIO-ED2)', Ofgem, August 2019

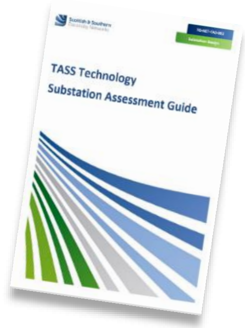
emissions, and would contribute to the aims set out by government in The Carbon Plan[54] and actions required to meet the UK's 2050 Net Zero target[55], TASS may align with the criteria for seeking a totex allowance to fund deployment during that price control period.

The scope for obtaining funding for TASS deployment through the ED2 Business Plan Incentive will therefore be evaluated, with the intention to extend the TASS assessment process to existing substations, not solely those planned for upgrade or refurbishment. A shortlist of sites can be drawn up for incorporation into RIIO-ED2 planning using the TASS Evaluation Tool, and the CBA for each of these sites can be reviewed on a regular basis using updated cost figures through time.

Integration of TASS into the Business

The 'Business Roll Out of TASS' DAMSG paper indicates where each aspect of TASS delivery (including decision making, implementation, supervision and reporting) may best sit within existing business teams. Further, whilst many activities sit within existing business teams, creation of a 'TASS delivery team' would provide a focus for efficiently coordinating activities. It should be noted that at the time of writing this is open to further discussion.

The material developed through the LEAN project - including the Risk Mitigation Strategy, TASS system architecture documentation, TASS algorithm specification, training & briefing material, substation signage, TASS Evaluation Tool and TASS Technology Substation Assessment Guide - provides a suite of deliverables available to the business to support the wider implementation of TASS.



Further Influences that will Promote the Implementation of TASS

Key factors that will act to reduce the future cost of deployment are identified in Section 10 'Project Replication'.

A number of broader technical and regulatory considerations will also influence the potential future application of TASS technology, and these are set out below together with recommended actions for DNOs, product vendors and the regulator.

[54] 'The Carbon Plan', Department of Energy and Climate Change (DECC), December 2011

[55] the 'Climate Change Act 2008 (2050 Target Amendment) Order 2019', which came into force on 27 June 2019, amends legislation to introduce a UK target of at least a 100% reduction of greenhouse gas emissions compared to 1990 levels

Technology

The TASS system specification has been created in a technology neutral manner such that it may be implemented using a range of suitable control devices.

- Product vendors should assess the scope for providing TASS functionality within their 'off the shelf' RTU devices, or consider developing dedicated TASS control units.
- Similarly, product vendors may choose to incorporate Point on Wave functionality into their switchgear, or offer lower cost Point on Wave switching devices designed for application within primary substations.
- When considering the application of TASS, DNOs should assess existing systems or planned new control technologies to identify synergies and make additional use of devices to implement TASS functionality where possible.

Regulatory Considerations

No regulatory barriers to the GB deployment of TASS have been identified, however changes to the following regulatory incentive schemes may positively or negatively influence the potential scope for deployment of TASS.

- RIIO-ED2 proposed Business Plan Incentive (BPI)

  As described above, the proposed ED2 BPI may support the deployment of TASS with funding through additional totex allowances which acknowledge the social and environmental benefits delivered by TASS. This context must be considered by DNOs when assessing the potential roll out of TASS and by Ofgem when seeking to promote the application of technologies to reduce network losses.
- Interruptions Incentive Scheme (IIS)

  The TASS system has been developed to minimise any risks to voltage or security of supply, including CIs & CMLs, and to maintain compliance with Engineering Recommendations P2/6 (security of supply) and P28 (power quality), however, as apparent through the external consultation held during the LEAN project, with any novel and unfamiliar technology perceived risks around CI/CML penalties may shape decisions around the scale of deployment.

  Whilst the IIS remains an important means to maintain a high level of security of supply for our customers, as the industry moves to the world of DSO with increasingly dynamic operation of electricity networks there may be a requirement for Ofgem to review the structure or application of incentives for supply security to ensure that these remain fit for purpose.
- Losses Incentive Mechanism

  Within RIIO-ED1 a discretionary reward is used to incentivise losses reduction on electricity distribution networks. In the absence of alternative mechanisms which recognise the societal value of losses reduction, the creation of a structured, non-discretionary incentive which creates a clear link between losses reduction and reward may support the deployment of TASS and other technologies that reduce network losses. The ongoing Ofgem and wider industry review of the approach to incentivise losses reduction within ED2 continues to consider the appropriate structure and format of the losses incentive.

Additional Use Cases for TASS Technology

Whilst TASS technology has primarily been developed to reduce losses on distribution networks, two further potential use cases for transformer auto stop start functionality have been identified through the stakeholder engagement activities described in Section 12 ‘Learning Dissemination’. These are described below, and a summary of the analysis undertaken to investigate these proposals is provided in Appendix G.

Using TASS to Manage High Voltage Issues on the Transmission Network

National Grid ESO raised the possibility of using TASS on the distribution network to manage high voltage at transmission level by increasing the overall reactance of the network. This reflects measures identified through the ENA's High Volts Working Group[56] regarding the provision of a service to the transmission system operator (TSO), with TASS used to switch out a number of distribution transformers fed from the same Grid Supply Point (GSP)[57] to reduce the voltage at the GSP by temporarily increasing losses.

To investigate this proposal SSEN’s PSS/E[58] network model has been used to assess how the voltage level at a GSP substation changes with increasing numbers of primary transformers switched out.

The conclusions from this analysis indicate that TASS implementation across primary substations can be used to reduce the voltage at the 132kV busbar of a GSP substation, however it may only be possible to achieve this effect at times of medium to high demand. This relates to the key principle of TASS that where substation loading is below the defined Crossover Point, switching out one of the transformers will reduce overall losses[59].

In addition, location specific analysis would be necessary to understand whether TASS functionality may offer a viable solution to meet the technical requirements identified by National Grid ESO for a given network area, such as those set out in their Invitation to Tender for the commercial provision of reactive power services in Mersey[60].

Ongoing consideration will be given to this proposal as the market for ancillary network services continues to develop.

Using TASS to Actively Manage Fault Levels

SP Energy Networks expressed their intention to consider the application of TASS to support the active management of fault levels, with potential benefits for the connection of new Distributed Energy Resources (DER). This concept

[56] ‘High Volts Working Group: Technical Feasibility Report’, ENA, April 2016 - available via the ENA website www.energynetworks.org/assets/files/news/publications/Reports/ENA%20HVWG%20Report%20Final.pdf

[57] a GSP is the point of supply from the transmission network to the distribution network

[58] https://new.siemens.com/global/en/products/energy/services/transmission-distribution-smart-grid/consulting-and-planning/pss-software/pss-e.html

[59] when substation loading is below the defined TASS Crossover Point, switching out one transformer will increase the variable ‘copper losses’ associated with the increased current flowing on the operational transformer (varying with the square of the current flowing through the transformer - I^2R) however this will be lower than the fixed ‘iron losses’ that would occur with all transformers energised

[60] National Grid ESO’s Request for Information, 16 April 2019, and subsequent Invitation to Tender, 14 October 2019, for the commercial provision of reactive power services in Mersey www.nationalgrideso.com/balancing-services/reactive-power-services

may facilitate flexible, non-firm DER connections by using TASS functionality to de-energise or place a transformer on standby when necessary, thereby increasing fault level headroom whilst avoiding the high cost associated with switchgear replacement[61].

The operation of the TASS system delivered through the LEAN project, together with results from additional PSS/E simulation, indicate that TASS can be applied to dynamically control fault levels on distribution networks, under both radial and interconnected configurations. However, for interconnected networks reliable communications between TASS devices in different locations would be required to ensure security of supply.

It is recommended that further analysis is undertaken by DNOs to assess the effectiveness of adopting TASS for active fault level management using their own network models with site specific information. Further discussions regarding this will be held through the ENA's Technical Losses Task Group.

[61] fault levels are reassessed as new possible sources of fault current, such as DER, are to be connected to the network, and fault level constraints occur where the rating of the existing circuit breakers is not sufficient to accommodate the expected fault current

12 Learning Dissemination

Information has been shared with both internal and external stakeholders throughout the course of the project. In addition to presenting key activities and results, the aims of the connections made were to embed knowledge within the business and to inform external stakeholders of the factors relevant to their potential application of TASS.

Knowledge Dissemination

Appendix H describes the dissemination activities undertaken and the outcomes of this engagement. The project team sought to tailor all messages and means of dissemination to the various audiences to maximise the effectiveness and efficiency of this communication.

Section 13 'Key Project Learning Documents' signposts the documents and material available through the project which provide detail on the development, implementation and operation of TASS and allow DNOs to understand how and where to deploy TASS on their own networks.

Stakeholder Consultation

External stakeholders, including each of the other DNO Groups, also closely participated in two key consultation processes during the project, as follows:

- Phase Two Decision Point - June 2016
  The learning from Phase One of LEAN, the conclusions regarding the feasibility and viability of TASS and ANT, and the proposals for the trial stages were presented to external stakeholders, providing the opportunity for questions and discussion on the project. The session was targeted at those working in the areas of losses and innovation from across the industry, and welcomed participants from each of the other GB DNOs.
  ➡ This event was central to informing the decision as to whether SSEN should proceed with the project and trial the technology on the SEPD network.

- Engagement following SDRC 9.4 'Initial Learning from Trial Installation and Integration' - November 2018
  Losses and innovation related colleagues within each of the other DNOs were subsequently invited to give their views on the use of TASS to reduce losses, and on what's being delivered by the LEAN project to support its application. For this purpose, a two-page document was issued to relevant individuals which gave:
  - an introduction to the content of SDRC 9.4 regarding the implementation of TASS
  - a summary of the outputs created through the project to allow DNOs to assess the financial viability and technical feasibility of applying TASS on a site by site basis
  - the scope of future SDRCs, to provide the context for SDRC 9.4

and recipients were invited to consider and comment on:

- whether SDRC 9.4 gives sufficient information for other DNOs to consider the technical application of TASS on their own networks
- what apprehensions they may have on deploying the technology
- what questions or ideas the project raises for them

➡ Pertinent and useful comments were received from each DNO Group, and the project team very much valued the considered thoughts provided by our external colleagues in appraising the application of this technology.

An open session regarding the implementation and operation of TASS was then held with members of the ENA's Technical Losses Task Group in May 2019. This event was used by the project team to address the points raised in the feedback from each of the other DNOs following SDRC 9.4, and to update the group on the TASS trials and the findings reported in SDRCs 9.5 & 9.6. The session was then opened to Q&A on everything of interest to attendees, resulting in an engaging 90 minutes of discussion amongst participants.

These consultations were used to shape plans and inform the direction of the project, and to identify areas of particular interest to the other DNOs. Appendix I presents tables which detail the email responses received on each occasion, describe how the project has acknowledged and responded to the feedback, and set out where associated information has been reported or discussed. Comments and suggestions fall into the following categories:

Asset Health
Security of Supply
Power Quality
Comms
Potential conflicts and/or synergies with other systems
TASS implementation
Site Selection
Training & Signage
Costs
Regulation - incentives
Regulation - perceived CI/CML risk
Changing load profiles with time
Other possible Use Cases

13 Key Project Learning Documents

This section signposts the documents and material available through LEAN which provide detail on the development, implementation and operation of TASS and allow DNOs to understand how and where to deploy TASS on their own networks.

SDRCs

The first phase of the project evaluated the feasibility of TASS and ANT technology and established the benefits, costs and risks associated with deployment. The trial phases of the project then developed and delivered TASS for trial on the SEPD network, providing evidence to validate the findings from Phase One.

The activities over the three phases together with the conclusions and recommendations drawn from the work have been reported in the following sevens SDRCs, in accordance with the requirements set out in the Project Direction:

- SDRC 9.1 'Project Set Up and Review of Related Projects' - the planned project programme and work structure, together with key recommendations for the LEAN project drawn from a review of GB and international projects related to the reduction of distribution networks losses
- SDRC 9.2 'Business Case Validation' - an evaluation of transformer losses and variations due to design and age, an assessment of the four proposed switching methods for implementing TASS, and a review of the business cases for TASS and ANT both on the SEPD network and at GB level together with the initial version of a tool developed to provide Cost Benefit Analysis (CBA) on the application of these technologies
- SDRC 9.3 'Phase Two Decision Point' - a description of the stakeholder engagement process used to present the findings from the first phase of the project, and confirmation of the support received from internal and external stakeholders for the business's decision to develop and trial TASS technology
- SDRC 9.4 'Initial Learning from Trial Installation and Integration' - comprehensive information for those evaluating the potential application of TASS on the technology developed, its integration with existing network assets, and the operational principles designed into the scheme
- SDRC 9.5 'Monitoring & Analysis' - an appraisal of the techniques used to monitor the transformers and other substation assets, to inform the use of these approaches by DNOs or other electricity network stakeholders, and analysis of the data acquired to evaluate any potential asset health or power quality implications associated with the application of TASS, and verify that the system operates as designed
- SDRC 9.6 'Site Performance to Date' - a full review of the losses savings achieved through TASS operation, and evaluation of both the benefits of the technology and costs of deployment to refine the business case
- SDRC 9.7 'Network Losses Evaluation Tool' - refinement of the CBA tool developed to assess the benefits of TASS, reflecting experience gained from trial implementation, and a detailed description of the substation assessment process which can be used by DNOs to assess the financial viability and technical feasibility of applying the technology on a site by site basis

When considering the application of TASS, or the development of other technologies to bring enhanced automation functionality to networks, the primary reporting documents are the four companion SDRCs that relate to the development and trial of TASS technology through Phase Two and Phase Three of the project - SDRCs 9.4 to 9.7. Detail on the structure and content of these four reports is given in Appendix J to allow stakeholders to understand which sections of each report are relevant to their plans and quickly find all information of interest.

The SDRCs have been published and are available both on the dedicated LEAN webpages:

www.ssen.co.uk/LEAN/Learning

and via the ENA's Smarter Networks Portal:

www.smarternetworks.org/project/sset207-01/documents

Accompanying Project Deliverables

To accompany the SDRCs, the range of deliverables created for use during the trials are also available externally to industry stakeholders, including other DNOs and the regulator, as project outputs to support the potential application of TASS. These resources have been developed with consideration to future use if TASS is rolled out across the business, and in a way that will allow other DNOs to easily adapt them for their own use should they also want to implement TASS. The project deliverables have been categorised by 'purpose of use' and are presented in Table 12.

All supporting material is available on request by emailing the project team via lean@sse.com.

Table 12 - Project Deliverables by Purpose of Use

Project Deliverable	Description	Related SDRC
Appraising TASS for Application to Other Networks		
Risk Mitigation Strategy	this set outs the principles designed into the TASS scheme to address safety, operational and data security risks, together with the roles & responsibilities of various teams across the business during different stages of implementation and operation, supporting requirements capture, communication with relevant stakeholders, and acceptance of project plans	SDRC 9.4
TASS Operational Principles	a summary of the eleven key Operational Principles incorporated into the TASS control system and the reasons for adopting the chosen approach	SDRC 9.4
Scalability & Replicability Assessment	the scalability and replicability assessment undertaken to give structured guidance to those evaluating the potential application of TASS and inform any adaptations required for the wider deployment of this technology across other network areas	SDRC 9.8
Design		
SDRC 9.4 - Section 4 'TASS System Design & Integration'	presents the system architecture and control algorithm designed to implement TASS, and gives detail on the data exchanges and physical integration of the scheme with existing assets and systems	
SGAM for TASS Implementation	the SGAM created to communicate plans and project requirements, and support development of the systems to be implemented for the TASS trials	SDRC 9.4
TASS System and Algorithm Technical Specification	the system specification created in a technology neutral manner to support the application of TASS using a range of suitable PLC devices, and allow the deployment of the technology to be aligned to a DNO's existing procurement frameworks with different suppliers	SDRC 9.4
SCADA Data & TASS Responses	details the specific SCADA data items used by the TASS system to monitoring substation loading and switch to reduce losses, and to identify any potential issue with the network or other substation assets and respond accordingly	SDRC 9.4
TASS Algorithm Flow Chart	the detailed TASS algorithm flow chart which represents all the required SCADA data points, tracks their connection from the RTU into the TASS logic, specifies the required TASS settings and timers, and defines the conditions which underlie the TASS decision making process	SDRC 9.4
TASS Wall Box Design Drawings	the detailed design drawings showing the wall box, DIN rails and fixings, and TASS components	SDRC 9.4
Bench Testing		
TASS Algorithm Testing Specification	the testing specification created to guide the testing process, record testing results, note all identified issues, and maintain consistency following modification of any aspects of the TASS algorithm or other component of the system	SDRC 9.4
Site Testing		
Commissioning Plan	an example of the operational commissioning plan created for one of the trial sites to set out all activities required to confirm communications between the TASS PLC and existing RTUs, and correct operation of the TASS equipment and control algorithm	SDRC 9.4
TASS Site Testing Specification	the document created to record the results from the injection and simulation testing and full operational commissioning activities at site	SDRC 9.4

Installation		
SDRC 9.4 - Section 5 'TASS Installation & Commissioning'	describes the installation and commissioning activities associated with the different aspects of the TASS trial system	
Substation Signage	location specific signs created in accordance with the guidance set out in 'Safety Signs and Signals - Health and Safety (Safety Signs and Signals) Regulations 1996' for display on all substation access points (gates and doors) and TASS equipment	SDRC 9.4
Substation Assessment to Identify Suitable Sites		
TASS Evaluation Tool	the tool developed to assess the losses achievable through deploying TASS technology and provide a cost benefit analysis on a site by site basis	SDRC 9.7
TASS Evaluation Tool User Guide	a detailed user guide for the TASS Evaluation Tool	SDRC 9.7
TASS Technology Substation Assessment Guide	a technical guide setting out the process for assessing the financial viability and technical feasibility of TASS application on a site by site basis	SDRC 9.7
Training		
Training & Briefing Material for Operational Staff	the suite of training material developed to support delivery of TASS training and briefings to operational staff, each tailored to specific roles including Control Engineers, Field Staff, and RTS and Protection colleagues - this comprises slides, trainer notes, a set of four handouts for staff to keep for reference, briefing notes for team managers, and substation access 'take-aways' for different levels of authorisation	SDRC 9.4
TASS Evaluation Tool and Site Assessment training session	slides for the training provided to relevant SEPD Asset Management colleagues who would be responsible for identifying sites suitable for TASS	SDRC 9.7
Asset Health Monitoring		
various asset health monitoring reports	a range of reports from specialists and consultants presenting the conclusions from the various techniques used to monitor the health of the substation assets during the trials, inc. • PD Survey reports - SSEN • Transformer Condition Assessment Test reports - Doble • SAPIENT reports - Kelvatek (Camlin Group)	SDRC 9.5
online DGA data from the trial sites	over two years' worth of online DGA data from the TASS trial transformers which comprises readings for 9 fault gases and moisture from oil samples taken every few hours	
Power Quality Assessment		
Transformer Energisation Study report	the report from the study undertaken to model the impacts of switching through time domain based simulation using the power quality data obtained during the trials	SDRC 9.5
power quality data from TASS switching events	the set of power quality monitoring data obtained from TASS switching events with and without the use of controlled Point on Wave Switching	

Innovation Project Management		
LEAN Phase Two & Phase Three Scope of Works	the Scope of Work developed and issued to invite expressions of interest from potential third party contractors and service providers in one or more of the six trial phase work packages	SDRC 9.4
TASS Operational Training Evaluation Form	the course evaluation form completed by Control Engineers and Field Staff to make sure that the content of the training delivered was well pitched and covered information relevant to the individuals' roles	SDRC 9.4
TASS Feedback Form issued to SSEN Control Engineers	the survey form issued to Control Engineers part way through the trial period to evaluate how well the system meets Control Room requirements and seeks individuals' views on their experience of interacting with the system, and engagement with the project team	SDRC 9.5

Project Progress Reports

To provide updates on the planned activities, seven Project Progress Reports have been submitted over the course of the project[62]. These set out the work undertaken over the reporting period, the learning outcomes delivered to meet project objectives, the approaches used to manage challenges and risks, and expenditure against budget.

These documents are also available via the ENA's Smarter Networks Portal:

www.smarternetworks.org/project/sset207-01/documents

14 Contact Details

Interested parties are very welcome to contact the LEAN project team with any enquiries via the contact details below:

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[62] in line with project governance, the project submitted five six monthly Project Progress Reports from June 2015 to June 2017, then two annual Project Progress Reports for June 2018 and June 2019

15 Project Closedown External Workshop and Peer Review

This section describes the external workshop and peer review activities associated with this SDRC 9.8 Project Closedown Report.

External Workshop

As a concluding dissemination activity the project team presented LEAN at a Losses Strategy Consultation event hosted by Western Power Distribution in Birmingham on 9 December 2019.

SSEN's section of the programme was used to provided:

- an overview of TASS and update on how the system has performed during the trials
- descriptions of the outcomes from the project and the suite of material available to other DNOs and product vendors to support the wider implementation of TASS functionality
- an understanding of the approach used to identify primary substations suitable for TASS deployment
- a demonstration of how to use the TASS Evaluation Tool used to provide site specific Cost Benefit Analysis figures for the application of TASS

The invitation email and agenda for the event are given in Appendix K, and the slides presented by SSEN are included as Appendix L. Details of the session together with presentations from the day are also available via the webpage www.westernpower.co.uk/news-and-events/latest-events/wpds-losses-strategy-consultation-event.

Around 30 organisations registered for the event with attendees including product manufacturers, DNOs, consultancies and academic institutions, and this allowed interesting discussion on the application and operation of TASS, together with broader conversations on measures to reduce network losses.

Following the event, the slides were circulated to losses and innovation colleagues from each of the DNO Groups and National Grid ESO, including those who had been involved in previous LEAN external stakeholder engagement activities. Recipients were encouraged to share the presentation with colleagues who may find different aspects of the LEAN project of interest, and invited to request a copy of the TASS Evaluation Tool to assess primary substations on their own networks. The accompanying email is given in Appendix M.

SSEN extend their thanks to Western Power Distribution for this opportunity to speak and present the LEAN project.

External Peer Review

UK Power Networks consented to act as the External Peer Reviewer for this Closedown Report, in accordance with Ofgem's governance requirements for LCNF projects[63].

A draft of the report was issued to UK Power Networks in early December 2019 to invite all feedback and comments on the content and structure of the report. Constructive and considered thoughts were subsequently received, which were very much valued by the project team in contributing to the completion of the report. A copy of the email provided by UK Power Networks which confirms this review is included as Appendix N. All comments were addressed in finalising the report, with feedback also provided to UK Power Networks.

SSEN express sincere thanks to UK Power Networks for undertaking this external peer review.

[63] Section 2.44 of Ofgem's 'Low Carbon Networks Fund Governance Document v.7', 2 April 2015 - available from the Ofgem website www.ofgem.gov.uk/ofgem-publications/94379/lcnfgovdocv7-finalclean-pdf

Appendices

Note that information such as confidential data and contact details have been redacted from these appendices for publication.

Appendix A1 & A2	Post-trial Transformer Condition Assessment Reports - Gillingham & Hedge End, Doble, July & August 2019
Appendix B	DGA Trend Charts for each TASS Trial Transformer
Appendix C	'Transformer Condition Report #5 - Gillingham and Hedge End Substations', Kelvatek (Camlin Group), August 2019
Appendix D	SGAM for TASS Implementation
Appendix E	TASS Scalability & Replicability Assessment
Appendix F	Distribution Asset Management Steering Group paper - Business Roll Out of TASS
Appendix G	Investigating Other Use Cases for TASS
Appendix H	Learning Dissemination
Appendix I	LEAN Response to Consultation
Appendix J	LEAN Project Learning Documents
Appendix K1 & K2	Losses Strategy Event invitation email - *redacted* - and agenda
Appendix L	Losses Strategy Event presentation - SSEN TASS for Losses Reduction - 9 Dec 2019
Appendix M	Update on TASS to Reduce Network Losses - email with accompanying slides circulated to external losses and innovation colleagues - *redacted*
Appendix N	Confirmation of External Peer Review by UKPN - *redacted*

Enquiries regarding these appendices, this SDRC 9.8 Closedown Report or the LEAN project in general are very welcome via lean@sse.com.