Scottish & Southern Electricity Networks

LEAN | Low Energy Automated Networks

Low Energy Automated Networks (LEAN)

SDRC 9.6 Site Performance to Date

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.

Document Ownership

Prepared by	Sarah Rigby LEAN Project Manager - DSO & Innovation, SSEN Maciej Fila LEAN Project Engineer - DSO & Innovation, SSEN
Approved by	Colin Mathieson DSO & Innovation Delivery Manager, SSEN
Approved by	Stewart Reid Head of DSO & Innovation, SSEN

Version Control

Version	Date	Authors	Change Description
1.0	25/03/2019	Sarah Rigby / Maciej Fila	Final version for submission following internal review and sign-off

SDRC Report Specification

Criterion 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	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.
Date	25th March 2019

Executive Summary

The Low Energy Automated Networks (LEAN) project has developed and applied 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 eight months to date has achieved energy savings of over 40 MWh in total across the two trial sites, with full operation reducing transformer losses by ~25%. No impacts on asset health due to TASS operation have been identified through the suite of testing and monitoring techniques applied.

This report presents an assessment of the TASS system to date in terms of the benefits demonstrated during the trials and the costs associated with deploying the technology, allowing the business case to be refined in accordance with the Project Direction and to meet the requirements of SDRC 9.6.

To reflect different choices for implementation, a range of deployment scenarios are considered.

Current costs are presented, however a number of factors will influence the costs of implementing TASS both now and over future years. These are identified accordingly, and must be considered by those assessing the implementation of TASS at scale across a given network, and by those interested in developing technologies to provide similar functionalities.

Clearly the associated costs will influence the proportion of sites at which TASS would be economically viable. Similarly both the costs and values attributed to the resulting benefits will then influence the financial assessment for a given site, and overall cumulative net benefit.

It is evident, however, that TASS offers a financially viable, as well as technically feasible, option for reducing losses on electricity distribution networks, and the assessment demonstrates a business case for applying TASS at specific sites.

An overview of the LEAN project and the context of this SDRC 9.6 report is given in **Section 1**.

Section 2 assesses the performance of the TASS technology to date with reference to the automated switching activity seen and the associated reduction in losses, and provides a review of the operational challenges experienced and refinement of the system during the trials.

➡ It is aimed at those considering the application of TASS at scale across a given network, and those seeking to promote the reduction of technical losses on electricity distribution networks.

Section 3 presents the costs of TASS operation with regard to both the deployment of the TASS technology and the broader considerations related to ongoing operation and asset health, and identifies the factors that will influence these costs.

➡ The content is aimed at those considering the application of TASS or similar automated switching systems at scale across a network area, and those interested in developing equipment to provide similar functionalities.

Section 4 evaluates the business case for TASS in consideration of the benefits and costs assessed during implementation and operation, and considers the wider factors that will influence the scale of future roll out.

➡ This is aimed at those assessing the deployment of TASS at scale across a network area, and those seeking to promote the adoption of technologies to reduce losses on electricity distribution networks, including DNOs, third party organisations and the regulator.

Section 5 describes the site visits offered to external and internal stakeholders, including Ofgem and each of the other DNO Groups, to see the equipment installed for the TASS trials and its integration with other primary substation assets and comms systems.

The next steps for the project are set out in the concluding **Section 6**, and subject to continued successful operation, the system will be trialled for a period of 12 months to assess performance with changing seasonal electricity demands.

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

Contents

Acronyms

ANT	Active Network Topology	IIS	Interruptions Incentive Scheme
AC	Alternating Current	IRM	Innovation Rollout Mechanism
ACO	Automatic Changeover (of LVAC system)	LCNF	Low Carbon Networks Fund
AVC	Automatic Voltage Control	LEAN	Low Energy Automated Networks
BAU	Business as Usual	LVAC	Low Voltage Alternating Current system
CB	Circuit Breaker	MCB	Miniature Circuit Breaker
CBA	Cost Benefit Analysis	NMC	SSEN's Network Management Centre
CBRM	Condition Based Risk Management	PD	Partial Discharge
CI	Customer Interruptions	PDE	Person Day Equivalent
CIS	Control Isolation Switch	PF	Power Factor
CML	Customer Minutes Lost	PLC	Programmable Logic Controller
CoP	Crossover Point for TASS	PoW	Point on Wave switching
DC	Direct Current	PV	Photovoltaic
DFR	Dielectric Frequency Response test	RTS	SSEN's Real Time Systems team
DG	Distributed Generation	RTU	Remote Terminal Unit
DGA	Dissolved Gas Analysis	SCADA	Supervisory Control and Data Acquisition
DMS	Distribution Management System	SD	Secure Digital - SD card
DNO	Distribution Network Operator	SDRC	Successful Delivery Reward Criteria
DSO	Distribution System Operator	SEPD	Southern Electric Power Distribution
EHV	Extra High Voltage	SFRA	Sweep Frequency Response Analysis
ER	Engineering Recommendation	SLC	Standard Licence Condition
GB	Great Britain	SSEN	Scottish and Southern Electricity Networks
GHG	Greenhouse Gas	TASS	Transformer Auto Stop Start
ICT	Information & Communications Technology	TX	Transformer
IFI	Innovation Funding Incentive		

1 Introduction

1.1 Overview of LEAN

The Low Energy Automated Networks (LEAN) project aims 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. It is a £3.1m project supported by Ofgem's Low Carbon Networks Fund (LCNF).

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 11 kV 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.

Within this, the work to validate the business case for the technologies indicated that TASS may be suitable for implementation at around 430 primary substations across the GB distribution network, providing an energy saving in the region of 1,185,000 MWh over 45 years, equating to around 467,000 tonnes of CO_2e. The cumulative discounted net benefit associated with this saving would be in the region of £18 million[1]. This work also concluded that it is not considered financially viable to deploy ANT with TASS[2].

Accordingly, the decision was taken to proceed with developing and demonstrating the TASS technology on the SEPD network[3].

[1] derived using Ofgem's RIIO-ED1 CBA figure for the value of losses and the 2016 Electricity GHG conversion factor and 2016 traded carbon price
[2] as reported in LEAN SDRC 9.2 'Business Case Validation', March 2016 - available via the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents
[3] as reported in LEAN SDRC 9.3 'Phase Two Decision Point', July 2016 - available via the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

1.2 Project Structure

The project has 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 focuses 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 that there is minimal risk of supply interruptions.

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

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 the TASS technology for trial on the SEPD network.

1.3 Overview of SDRC 9.6

This report presents a detailed 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.

The Successful Delivery Reward Criteria (SDRC) are defined in the LEAN Project Direction. In accordance with the SDRC 9.6 evidence requirements, this report provides:

- An assessment of the performance of TASS to date with reference to the automated switching activity seen and the associated reduction in losses
- A review of asset health and ongoing operational considerations related to the application of TASS
- An evaluation of the business case for TASS deployment addressing both the benefits and costs
- A summary of the site visits offered to both internal and external stakeholders

To provide context for the scope of SDRC 9.6, the following companion SDRCs relate to the development and trial of the TASS technology through Phase Two and Phase Three of the project:

- SDRC 9.4 ‘Initial Learning from Trial Installation and Integration’ - comprehensive information on the technology developed, its integration with existing network assets, the operational principles designed into the scheme, and the factors relevant to the scalability and replicability of the system for wider deployment across other network areas, 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 to evaluate both the performance of TASS and any potential asset health or power quality implications associated with its application

- SDRC 9.7 ‘Network Losses Evaluation Tool’ - refinement of the tool developed to allow DNOs to undertake a site by site cost benefit analysis on the deployment of the technology, reflecting experience gained from trial implementation

- SDRC 9.8 ‘Knowledge & Dissemination’ - the project closedown report, including consideration of the wider deployment of the technology across the SEPD network if applicable

SDRC 9.4 was published in September 2018, SDRC 9.5 was published in February 2019, and SDRCs 9.7 & 9.8 are to be published over the course of the project as further experience is gained from trial operation.

2 Assessment of TASS Performance at the Trial Sites

This section assesses the performance of the TASS technology to date with regard to the automated switching activity seen and the associated reduction in losses, and presents a review of the operational challenges experienced and refinement of the system during the trials.

It is aimed at those considering the application of TASS at scale across a given network, and those seeking to promote the adoption of technologies to reduce losses on electricity distribution networks.

Over the 8 months reported TASS has reduced losses by over 40 MWh in total across the two trial primary substations. TASS continues to successfully control automated switching at the trial substations, demonstrating the system's ability to both reduce losses and respond appropriately to different network situations.

Three subsections are presented:

- Review of TASS Performance & Losses Savings Achieved to Date
- Operational Challenges Experienced During the Trials
- Operational Colleagues' Engagement with TASS

A number of data sources are monitored to evaluate the performance of TASS and identify any potential issues with the operation of the scheme, and these are detailed in SDRC 9.5 ‘Monitoring & Analysis’[4].

Review of TASS Performance & Losses Savings Achieved to Date

An initial assessment of TASS performance over the first twelve weeks of operation was presented in SDRC 9.4 ‘Initial Learning from Trial Installation and Integration’[5], with an update following seven months trial operation presented in SDRC 9.5 ‘Monitoring & Analysis’.

The analysis eight months into the TASS trials shows that the system continues to operate as expected and is delivering energy savings. At the time of writing, TASS has reduced losses by over 40 MWh in total across the two trial primary substations.

A summary of TASS operation up to 15 February 2019 is given in Table 1, with further detail on the performance of the system at the two trial sites provided in the text below.

[4] LEAN SDRC 9.5 ‘Monitoring & Analysis’, February 2019 - available via the ENA’s Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

[5] LEAN SDRC 9.4 ‘Initial Learning from Trial Installation and Integration’, September 2018 - available via the ENA’s Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

Table 1 - Summary of TASS trial operation up to 15 February 2019

TASS Trial Site / TASS Operation	Gillingham	Hedge End
Commencement of Full Automated Operation[6]	22/06/2018	08/06/2018
No. of Full Cycle TASS Switching Events[7] (TASS switching out a TX & subsequently reinstating it)	T1 x 19, T2 x 16	T1 x 35, T2 x 33
TASS switching due to substation loading (one TX switched out or switched in to follow demand)	17	108
TASS time based change over events (one TX restored & the other subsequently switched out)	6	2
TASS responses to a comms issue (one TX restored & the other subsequently switched out)	11	1
'TASS Failed to Operate' alarms	3	10
'TASS Faulty' alarms	4	1
'TASS CoP Error' alarms	0	0
Control Room Disable commands issued (TX restored if switched out due to TASS)	14	11
Control Room Lock commands issued	3	2
manual Paused situations	0	1
No. hours one transformer was switched out (h of total h)	5224 of 5737	3634 of 6073
% of time one transformer was switched out	91.1%	59.8%
Losses Saved to date	22.86 MWh	20.17 MWh
Value of Losses Saved to date [8]	£1,106.90	£ 976.50
Associated CO_2 Saving [9]	11.50 tCO_2e	10.14 tCO_2e

At Gillingham, the TASS system has enabled one of the transformers to be switched out for around 91% 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 the seventeen load based switching events noted relating to a transformer being switched out after the system had been Enabled following site access or testing. Six time based change over events have been triggered to transfer TASS operation to the alternate transformer following two weeks of continuous operation with one transformer switched out, and eleven TASS operations were in response to SCADA comms between the substation and NMC being lost for more than 30 minutes due to an RTS issue at the site, as described in the 'Operational Challenges Experienced During the Trials' subsection below. Fourteen switching operations were then due to the Control Room Disabling TASS prior to someone accessing the substation.

[6] 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

[7] reflects a full cycle of TASS switching out a transformer and then subsequently reinstating it, whether due to substation loading, a command from the Control Room, or in response to SCADA data or a loss of comms situation - these figures do not include times when a Control Engineer manually switched a transformer for e.g. outages during transformer condition assessment tests

[8] derived using Ofgem's RIIO-ED1 CBA figure for the value of losses of £48.42 per MWh (rounded to nearest 50p)

[9] derived using Ofgem's RIIO-ED1 CBA figure for the 2016 Electricity GHG conversion factor of 0.503 tonnes per MWh

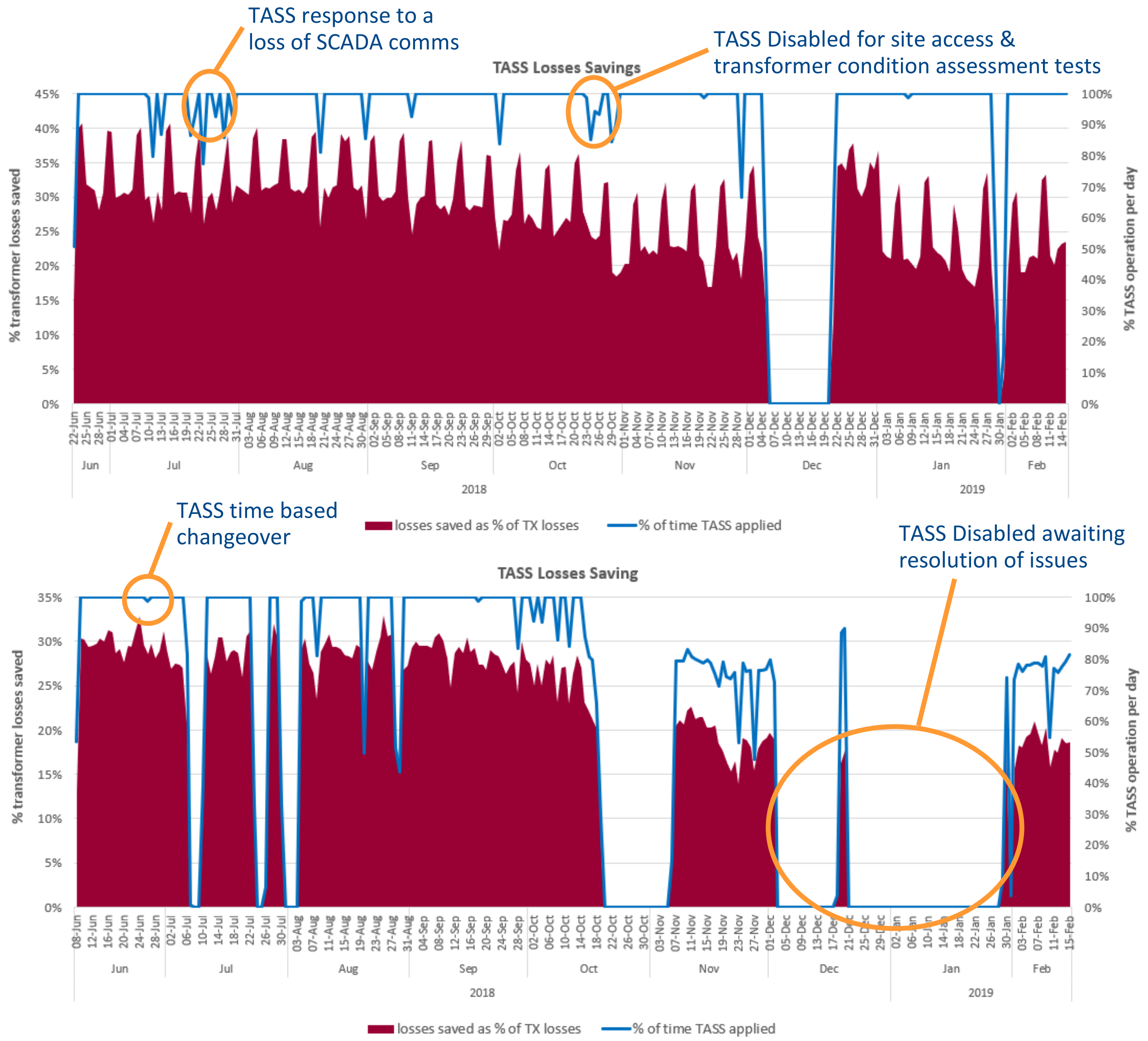
At Hedge End, TASS has allowed the site to run on single transformer for around 60% of the time. This is lower than Gillingham, and lower than the 83% reported in SDRC 9.4 'Initial Learning from Trial Installation and Integration', as TASS was Disabled for 54 days between 2 December and 29 January due to the issues with the LVAC system and the TASS algorithm voltage difference setting also described in the 'Operational Challenges Experienced During the Trials' subsection below. At this site, the seasonal increase in electricity demand has resulted in more frequent TASS operation from around early November, with the system eventually switching a transformer in every day at around 5.30pm for the evening peak, and then switching back to one transformer when the load drops again after around 10.30pm. Consequently there have been a total of 108 load based switching operations. Two time based change over events have been triggered, and one SCADA comms issues has been experienced at this site to date. Additionally, the Control Room Disabled TASS on eleven occasions for site access.

The manual 'Pause' functionality available via the TASS wall box within each substation has been used once at one site, for a period of around 30 minutes. This local non-auto setting provides a back-up option in the event that work must be undertaken within the substation but SCADA comms are lost and it's not possible for the Control Room to remotely Disable TASS, or in the event that someone enters a substation but in error has forgotten to contact the Control Room to request that TASS be Disabled.

The 'TASS Failed to Operate' and 'TASS Faulty' alarms from each substation were raised in response to different operational situations identified by the TASS control algorithm, with some relating to the issues described in the 'Operational Challenges Experienced During the Trials' subsection, and others being in response to situations simulated when testing the software updates applied to refine system operation.

Charts illustrating TASS operation over the course of the trials to date are provided in Figure 1. In these, the blue line shows the percentage of each day during which a transformer is switched out, to indicate the proportion of time that TASS has been acting to reduce losses, and the red area shows the losses savings (after accounting for system energy use) as a proportion of the transformer losses that would have been experienced without the application of TASS. The charts are labelled to indicate examples of a time based change over event occurring, where the system alternates TASS operation between the transformers in the event that one transformer has been switched out for a two week period; the TASS system response to a sustained loss of SCADA comms; TASS being Disabled by the Control Room to allow access to site; and TASS remaining Disabled for a period of time prior to resolution of the issues described in the 'Operational Challenges Experienced During the Trials' subsection.

Figure 1 - TASS operation and losses saved at the two trial sites - Gillingham (top) & Hedge End (bottom)



It can be seen that full TASS operation reduces overall transformer losses by ~25-30% and ~20-30% for the two substations respectively. The analysis shows that this equates to just under 0.2% of the energy supplied to customers in each case.

Table 2 then gives the monthly figures for total losses savings, indicating the reductions achieved through full operation of TASS over the course of a month as distinct from the periods when TASS was Disabled for a period of time.

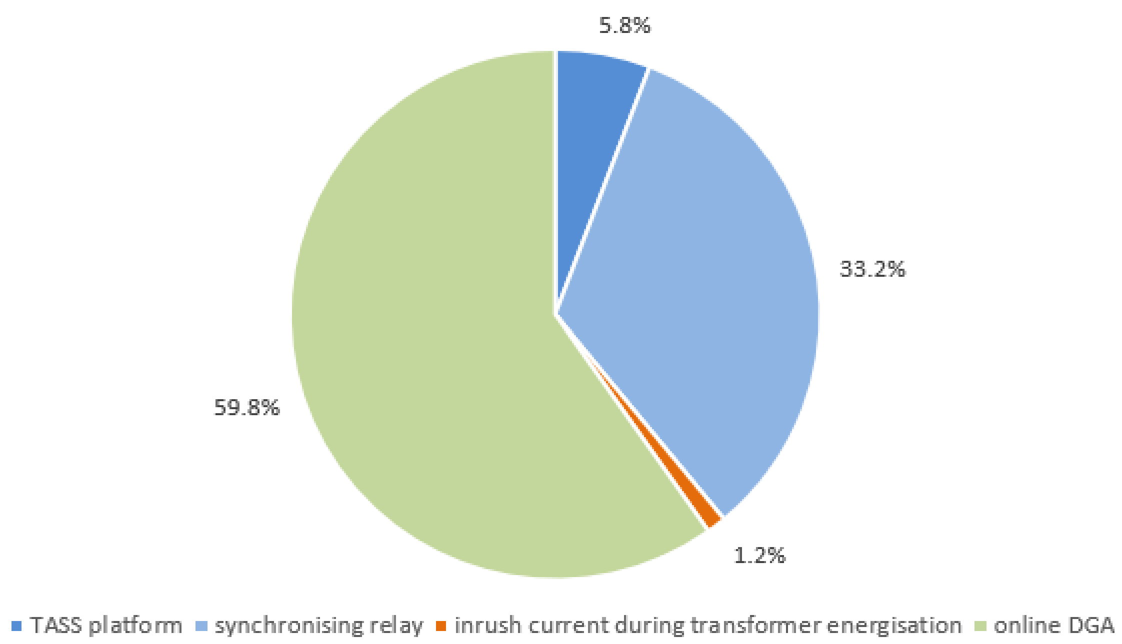
Table 2 - Monthly losses savings from TASS operation up to 15 February 2019

TASS losses savings MWh	June (part month)	July	August	September	October	November	December	January	February (part month)	**total to date**
Gillingham	1.01	3.52	3.61	3.40	3.09	2.67	1.70	2.53	1.33	**22.9**
Hedge End	3.18	3.01	3.66	4.07	2.22	2.22	0.36	0.11	1.35	**20.2**

Comparing the losses savings with the figures forecast by the TASS Tool created during Phase One of the project, the energy savings seen at Gillingham to date are around 8% higher than the 8 month equivalent of the forecast figure (21.3 MWh). Differences are to be expected due to variations in load profiles from year to year, but this higher figure also reflects the fact that at this substation TASS has seen one transformer switched out for the majority of time, with no transformer restoration due to demand increasing above the Crossover Point. The figure for Hedge End is around 37% lower than the 8 month equivalent of the forecast figure (31.9 MWh), primarily reflecting the fact that TASS was Disabled in December and January prior to resolution of the issues described in the 'Operational Challenges Experienced During the Trials' subsection. The TASS Tool will be reviewed to identify any enhancements informed by the development and trial of the technology, and the final version will be presented in SDRC 9.7 'Network Losses Evaluation Tool'.

Considering the energy used by the equipment installed for the TASS trials, the indicative calculations based on seven months of operation are that the system continues to use around 8 kWh energy per day per site. This energy use is associated with the TASS platform itself, the synchronising relay, the online DGA monitoring equipment and the inrush currents due to transformer energisation. The energy used equates to an average of 9.1% of the overall energy saving from TASS, with respective figures of 8.2% for Gillingham and 10.0% for Hedge End where TASS remained Disabled though still monitoring and logging data for a period of time in December and January. The figure for energy use drops to around 3.7% excluding the online DGA system being used to monitor the health of the transformers during the trials, with the figures being 3.3% and 4.0% for Gillingham and Hedge End respectively. The relative proportions of energy used by the different components are shown in Figure 2.

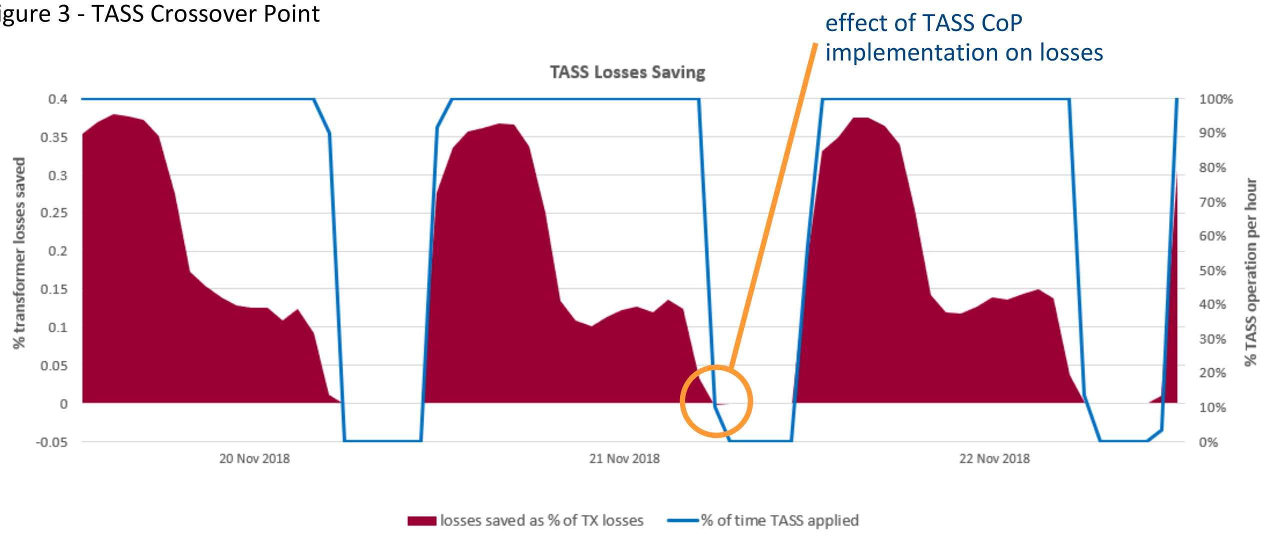
Figure 2 - TASS trials - proportional energy use



The implementation of the Crossover Point (CoP), which specifies the level of demand at which TASS should switch out or restore a transformer for a given substation, also has a minor impact on the losses savings achievable. With one transformer switched out, at a certain point the increase in variable 'copper losses' associated with the increased current flowing on the operational transformer will be greater than the fixed 'iron losses' associated with the magnetisation of the core of a second transformer, and vice versa.

The CoP is applied in the TASS control algorithm with high and low bands of 10% around the defined crossover level, and the algorithm will only initiate switching if the load has been above the higher band or below the lower band for 60 minutes. This fulfils the objective of TASS, but avoids rapid switching in and out when the load fluctuates around the crossover level. These settings may be changed within the algorithm to match the load profiles seen at a given substation, however the data obtained during the trials, as illustrated in Figure 3, suggests that these values are appropriate for the two trial substations and result in minimal additional losses associated with not switching at the precise crossover level.

Figure 3 - TASS Crossover Point



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

Operational Challenges Experienced During the Trials

A key element of any trial is the need to identify challenges with the operation of a new system or device and allow refinements to be made. The processes put in place to review TASS operation at the trial sites are described in SDRC 9.5 'Monitoring & Analysis', and these are designed to allow the project team and operational staff to:

- monitor the system's response to different operational situations
- identify and respond to any potential issues with TASS operation
- understand the business's interaction with TASS

Consequently, this monitoring has allowed all potential issues with the system to be swiftly identified, and has been crucial to ensure that the cause of the issue could be ascertained and confirm that TASS operated as designed to provide an appropriate response.

The issues identified during the trials to date are summarised below, and relate to the following devices/systems:

- the comms modules used with the TASS synchronising relays
- the TASS algorithm voltage difference setting
- substation Low Voltage Alternating Current (LVAC) systems
- substation RTU data
- SCADA communications between the substation & Control Room

In each case TASS responded as designed to the SCADA alarms issued by other substation assets, and a relevant TASS alarm was raised in the DMS which the Control Engineer on duty identified and managed as requested during training. The LEAN project team investigated each situation to establish what had happened, and identify and implement anything needed to resolve the issue.

These events have provided indispensable live testing of the TASS system, and have demonstrated that TASS was able to quickly identify a problem, halt operation if needed and provide notification in the DMS as designed. The operational principles and responses to different network situations designed into the TASS scheme are presented in SDRC 9.4 'Initial Learning from Trial Installation and Integration'.

All challenges experienced to date have been resolved, and none reveal serious adverse implications for the use of TASS. Following site visits on 29 January 2019 to apply updates to both the TASS software, to revise the settings in the control algorithm, and the synchronising relay comms modules, to correct the firmware supporting DNP3 comms, TASS is now operating with controlled Point on Wave switching at both of the trial sites.

TASS Synchronising Relay Signals

As reported in SDRC 9.4 'Initial Learning from Trial Installation and Integration', an intermittent issue was experienced at the trial sites whereby 33 kV circuit breaker operation did not occur when required during TASS switching. This situation occurred once whilst switching a transformer out, and once whilst restoring the transformer that was switched out.

Additional testing verified that the TASS control device and control algorithm were working correctly, and that the issue related to the signal from the synchronising relays incorporated into the scheme to provide controlled Point on Wave switching. Detailed testing by the device manufacturer pin-pointed this to an error in the firmware of the comms module used with the relay to provide DNP3 communications, with a certain combination of logic status flags creating a window of a few milliseconds during which a control signal will not be processed correctly. Updated firmware was provided accordingly, which the project team were then able to upload via SD card onto the comms modules at the trial sites.

Prior to the new firmware being installed, the TASS system bypassed the synchronising relays. As reported in SDRC 9.5 'Monitoring & Analysis', this mode of operation has provided valuable information for use in assessing any potential impacts on power quality without the use of Point on Wave switching.

TASS Algorithm Voltage Difference Setting

The seasonal increase in electricity demand at one trial site has resulted in more frequent TASS operation from around early November onwards, with the system eventually switching a transformer in every day at around 5.30pm for the evening peak, and then switching back to one transformer when the load drops again after 10pm. This switching has not presented any issues for the system, however this changing demand pattern has also resulted in changes to the voltage levels seen during TASS switching, which revealed a problem with one of the check settings applied within the TASS algorithm.

When switching, the algorithm checks the voltage difference between the transformer being switched back in and the 11 kV busbar prior to operating the 11 kV circuit breaker, to ensure that voltages are within acceptable limits. The algorithm is programmed to halt TASS operation and raise a 'TASS Failed to Operate' alarm where this voltage difference exceeds a specified level, and the value was originally set at 300V. In contrast, the Automatic Voltage Control (AVC) settings at the site allow a voltage difference of up to 330V (11kV +/-1.5%) before the AVC scheme operates and the tap changer acts to bring the voltages more in line. Consequently, on five occasions from mid-November TASS halted operation and raised an alarm, even though the voltage difference was within acceptable limits.

To address this and resolve the issue, the voltage difference specified in the TASS control algorithm was revised to 400V (allowing for any issues with accuracy of the readings due to latency in data transfer, etc.), and the new code was tested in SSEN's Protection laboratory, before being uploaded at the two trial sites.

This issue was not seen at the other trial site due to the different characteristics of the load profile at that substation.

Low Voltage Alternating Current (LVAC) System

Primary substations typically have an LVAC system which provides power to auxiliary systems at the site, such as the DC batteries chargers, lighting and heating. The LVAC system takes power from one of the transformers within the substation, and an Automatic Changeover (ACO) scheme transfers the supply to another transformer in the event that the transformer providing the power switches out. Accordingly, ACO operation may be triggered by TASS switching, resulting in increased operation of the scheme and the possibility that where there is an existing issue with the LVAC scheme, TASS operation may bring this to light.

Three issues relating to the LVAC systems have been experienced during the trials, each of which triggered SCADA alarms which TASS identified and responded to as designed. The TASS response was seen by Control Engineers via the DMS and by the LEAN project team via PI ProcessBook, and a review of the event log and fault log date downloaded from the TASS control device on site identified the specific SCADA alarms which TASS had responded to.

Firstly, it was apparent from the TASS fault log and the site log book (used to record site visits by Field Staff) that the Miniature Circuit Breaker (MCB) for one of the battery chargers on site had tripped three times during November 2018. On each occasion TASS had responded to the associated SCADA alarms by Disabling itself and raising a 'TASS Failed to Operate' alarm, as this situation may relate to an emerging fault with the protection scheme. At the site in question there are 3 battery chargers, and these will restart each time the LVAC ACO scheme operates. With the seasonal increase in electricity demand, TASS began to switch more frequently, and so more ACO scheme operations occurred, thereby restarting the battery chargers. A site inspection found that the MCB which kept tripping was a 'Type C' with regard to tripping characteristics[10], when in fact a 'Type D' was required (as used for the two other battery chargers) to accommodate the inverter start-up currents seen on some occasions when the battery charger restarts. A new 'Type D' MCB was sourced and installed by the LEAN project team to address this issue.

Secondly, following another situation where TASS had Disabled itself and raised a 'TASS Failed to Operate' alarm, the TASS fault log data indicated that this was also due to a SCADA alarm from the LVAC system, and a site visit found that a fuse for the LVAC ACO scheme had blown. The 2 amp fuse was replaced by the LEAN project team, and around 20 test operations were run to measure the current drawn by the ACO scheme. The readings were never more than ~0.26 amps, and so it is suspected that the fuse had blown due to being old or faulty rather than experiencing an unacceptably high current, and there have been no further issues with the fuse.

[10] see 'MCB Selection' on https://electrical-engineering-portal.com/what-is-the-difference-between-mcb-mccb-elcb-and-rccb

Thirdly, when commissioning the TASS scheme at one of the sites it was found that the LVAC system was set up in such a way that the comms system saw each LV board independently. Consequently, ‘false’ alarms would have been raised each time the ACO scheme operated even though the two LV boards were operating correctly in combination. To address this the TASS commissioning team added comms links between the two LV boards, allowing TASS to work correctly on commencement of the trials in June 2018.

However, in December a Field Engineer who attended site to deal with a 'defect' logged with the LVAC scheme found these links between the LV boards, and knowing that they are unusual for this site attributed their presence to be the reason that a defect had been raised. The associated record in the site log book notes that removing the links would lead to misleading alarms being raised in PowerOn Fusion, and the Field Engineer had contacted the duty Control Engineer to discuss this, but as both believed this to be a valid defect to be resolved, the links were removed with Control accepting the need to return to using judgement when the associated alarms were raised.

Without these links, when TASS next operated it picked up the SCADA alarms now being raised, and so Disabled itself and restored the transformer that had just been switched out, as it’s designed to.

The TASS response was identified by the project team via the PI ProcessBook, and discussed with the associated Field Engineer and Control Engineer. In tracking the defect back, this was found to have been raised prior to the TASS trials commencing, and indeed may even have been raised due to the fact that ‘false’ alarms were being triggered before the comms links were installed. In addition, these alarms are not necessary for supervision of the substation since many other valid alarms will be raised if there is a true issue, accordingly only a small number of substations are set up in this way and utilise these alarms.

Consequently, it was agreed that the links be reinstated to prevent spurious alarms, and allow TASS to continue operating.

A marker in the DMS schematic for the site was also added to note that the associated alarms will not be raised while the links are in place during the TASS trials. With hindsight, the project team acknowledge that this would have been beneficial directly after the change was made during TASS commissioning.

Remote Terminal Unit (RTU) Data

A situation associated with Control Isolation Switch (CIS) operation on the RTU in one of the substations caused TASS to Lock itself, and then as the RTU was no longer providing substation data to the TASS control device, a 'Faulty' alarm was raised. Here, to minimise the risk of switching in the event that the CIS has been manually operated but in error TASS had not been Disabled prior to staff entering the substation, TASS is designed to Lock thereby suspending operation with no further switching activity. This is in contrast to the TASS Disable functionality which would initiate energisation if a transformer is switched out.

As this event occurred in the evening, however, and there is no record of anyone having accessed the site, it is expected that the RTU had automatically reset itself, rather than this situation being linked with activity at the substation which required manual use of the Control Isolation Switch.

The 'Faulty' alarm then cleared itself when the RTU rebooted, and a Control Engineer subsequently Unlocked TASS.

SCADA Communications between the Substation & Control Room

At one site, a number of transformer switching operations were evident through the daily reviews of PI ProcessBook, and data downloaded during a consequent site visit confirmed that these were in response to TASS identifying a sustained loss of comms between the substation and the DMS. In this situation, where no data transfer has occurred over a period of 30 minutes[11] the algorithm will automatically Disable TASS, restore the transformer that is switched out, and then have no further operational control. This returns the substation to conventional operation over the period that Control Engineers have no visibility of the site, whilst avoiding frequent switching if comms drop out for a fleeting moment. The algorithm will then automatically Enable TASS and resume switching control once comms have been re-established for a period of 30 minutes.

Though the nature of this issue means that the DMS no longer shows real time data, and instead flags warnings that the data shouldn't be trusted, when SCADA comms are returned data is subsequently transferred to PI, and can then be seen via the PI ProcessBook. The RTS comms log for the site was also reviewed by the project team to verify the loss of comms.

As this issue had also, separately, been identified by the RTS team, they worked to resolve the fault and reliable comms have subsequently been maintained.

Operational Colleagues' Engagement with TASS

When developing TASS for trial through the LEAN project, the requirements capture process gave detailed consideration to designing a system which aligns with our colleagues' expectations and existing activities.

Subsequently the project team have maintained dialogue with relevant operational colleagues during the trials to inform them of the conclusions and resolutions of issues identified, thereby supporting their acceptance of the system.

The Control Engineers and Field Staff have remained engaged and cooperative throughout the TASS trials in swiftly identifying and dealing with these issues whilst on duty, in communicating with the project team and in supporting

[11] applied via an algorithm setting such that the value can be altered as appropriate to meet operational requirements

further investigations. Further, as reported in SDRC 9.5 'Monitoring & Analysis' the feedback received indicates that the TASS interface in the DMS meets operational requirements well, and that staff are happy with how the system has been implemented and their level of interaction with the technology.

3 Costs Associated with the Application of TASS

This section presents the costs of TASS operation with regard to both the deployment of the TASS technology and the broader considerations related to ongoing operation and asset health, and identifies the factors that will influence these costs.

The content is aimed at those considering the application of TASS or similar automated switching systems at scale across a network area, and those interested in developing equipment to provide similar functionalities.

Cost considerations are presented under the following subsections:

- Capital Costs for TASS Deployment
- Operational Costs Associated with the Application of TASS
- Comparison with Phase One Capex & Opex Estimates
- Training Resources
- Conclusions & Recommendations

Capital Costs for TASS Deployment

The capex figures presented here reflect the costs associated with the implementation of TASS for trial on the network together with assumptions based on experience gained during the project.

The costs focus on the equipment and activities undertaken to deploy the technology, and omit the development costs for specification and design as the TASS system now under trial is suitable for wider adoption, and supports integration with 1 or 2 RTUs within a substation, with 2 to 4 TASS transformers per primary substation.

Resource Requirements

SDRC 9.4 'Initial Learning from Trial Installation and Integration'[12] presents the resource requirements associated with the deployment of TASS at the two trial sites. The experience gained from implementation at the first site (Gillingham) significantly reduced the time required at the second site (Hedge End), and it can be expected that this would be further reduced should the technology be rolled out across the business. Table 3 summarises the indicative resource requirements in Person Day Equivalents[13] (PDE) for installation and commissioning of the TASS wall box and synchronising relays at the two sites, together with assumptions on resources required for wider roll out.

[12] LEAN SDRC 9.4 'Initial Learning from Trial Installation and Integration', September 2018 - available via the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

[13] Person Day Equivalents being defined as the combined total of days worked by a team of individuals, as distinct from the overall number of days spent on site by the team

Table 3 - Summary of indicative resource requirements for TASS installation & commissioning

	Time on site	Person Day Equivalent	Notes
First Trial Site	10.5 days:	27 days:	
TASS installation TASS commissioning synch. relay installation & commissioning	1.5 days 6 days 3 days	4 PDE 14 PDE 9 PDE	
Second Trial Site	5.5 days:	14 PDE:	
TASS installation TASS commissioning synch. relay installation & commissioning	1 days 3 days 1.5 days	2 PDE 7.5 PDE 4.5 PDE	~50% reduction in time required due to experience gained from installation at the first trial site
Assumptions for Wider Roll Out	2 to 3.5 days:	5 to 9 PDE:	
TASS installation & commissioning synch. relay installation & commissioning	1.5 to 2.5 days 1 to 1.5 days	3.5 to 6 PDE 1.5 to 3 PDE	assumes a further ~25% reduction in typical time & resources required for wider roll out on the basis of further refinement of the process and experience of staff, with ranges applied to reflect varying complexities of site, travel distance, etc.

Current Cost Assumptions

Considering each aspects of the trials, Table 4 presents the assumptions used to derive current cost estimates for TASS deployment in light of project experience.

Table 4 - Assumptions for TASS implementation by trial activity/component

	Indicative Capex Costs - mid-range	No.	Assumptions
TASS System Implementation			
Site Survey	£250 per site	1 per site	mid-range: 2-3 hours per site for a suitably authorised & competent person higher & lower bands: +/-10% to reflect greater travel distances, economies of scale where booking higher numbers of sites, etc.
Detailed Protection Study	£300 per site	1 per site	mid-range: half a day for a Protection Engineer higher & lower bands: +/-10% to reflect varying complexities of site
TASS Wall Box - kit - inst. & comm.	£2,000 per unit £2,850 per site	1 unit per site	mid-range: indicative cost per unit at present 4.75 PDE per site for installation & commissioning by a suitably authorised & competent person higher & lower bands: range of 3.5 to 6 PDE for installation & commissioning to reflect varying complexities of site, greater travel distances, etc. - *see Table 3*
System Integration	minimal cost per site		to integrate the TASS control device with SCADA the RTU configuration at each site is updated to include the minor modifications defined in the RTS 'TASS template', at present this requires the support of the RTS team, however this has minimal time and resource implications, and for wider roll out this task could potentially be carried out by the TASS installation team to incorporate TASS information and commands into the DMS, the PowerOn Fusion template developed during the project must be applied on a site by site basis in line with deployment at specific sites, however minimal time is required for a Cartographer to add this TASS functionality
Synchronising Relays - kit - site support	£23,000 per unit £1,350 per site	1 unit per TX, 2 TXs per site	mid-range: indicative cost per unit at present 2.25 PDE per site for site support from a suitably authorised & competent person higher & lower bands: -10% on kit for economies of scale where purchasing more units range of 1.5 to 3 PDE for site support to reflect varying complexities of site, greater travel distances, etc. - *see Table 3*

Asset Health Assessment			
Partial Discharge Surveys	£250 per site	1 per site	mid-range: 3-4 hours per substation for a suitably authorised & competent person higher & lower bands: +/-10% to reflect greater travel distances, economies of scale where booking greater numbers of sites, etc.
Transformer Condition Assessment Tests - tests - site support	£8,220 per site £4,510 per site	1 per site	mid-range: 4-5 hours per transformer (=> 1 day per site) indicative cost per site at present higher & lower bands: +/-10% to reflect greater travel distances, economies of scale where booking greater numbers of sites, etc.
Online DGA Monitoring	£28,400 per unit	1 unit per TX, 2 TXs per site	mid-range: indicative cost per unit at present including installation on 2 transformers (=> 1.5 days per site) higher & lower bands: +/-10% to reflect greater travel distances, economies of scale where booking greater numbers of sites, etc.

The ranges of capex costs associated with these assumptions are presented in Table 5.

Table 5 - Summary of capex cost ranges 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

As reported in SDRC 9.5 'Monitoring & Analysis'[14], whilst the online DGA system has been fundamental in obtaining data during the trials to evaluate any potential asset health implications associated with the application of TASS, it is not currently anticipated that this monitoring would be required for wider roll out.

Further, the SDRC 9.5 analysis of the electrical impact of TASS switching on the network indicates that TASS operation with controlled Point on Wave (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.

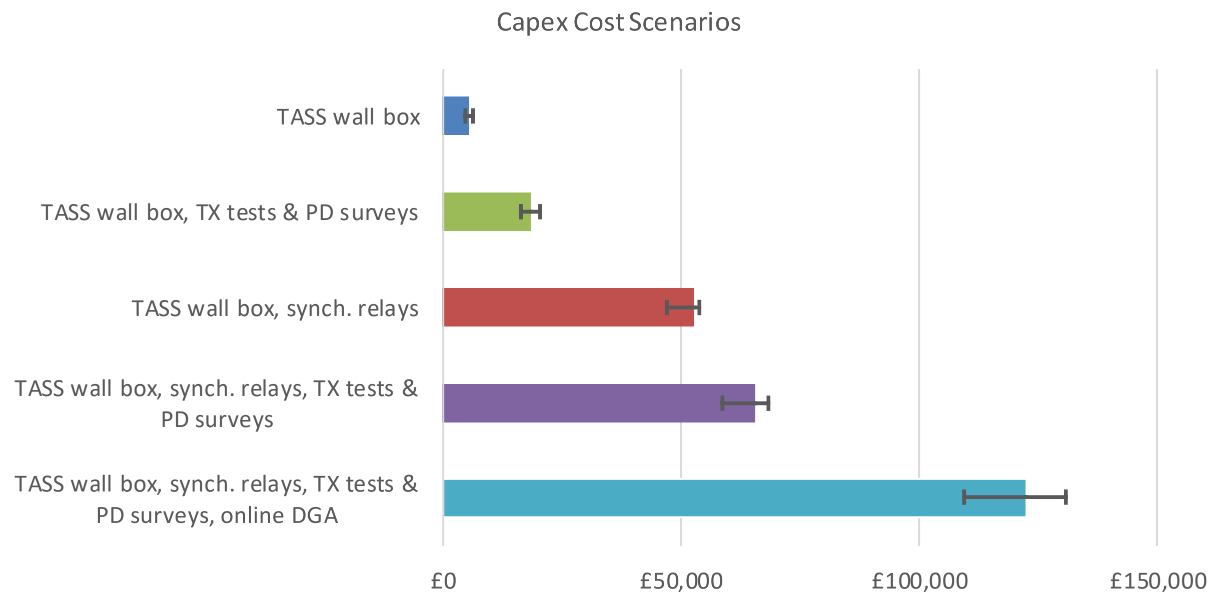
It is, however, recommended that a suite of pre-installation oil samples, PD surveys and/or transformer condition assessment tests be considered as these may be of value to validate that there are no pre-existing issues with the assets, and to provide a set of reference data for any subsequent tests.

To reflect these different options, the following deployment scenarios have been considered:

- 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

Figure 4 illustrates the potential range of overall capex costs associated with these scenarios, with the lower and higher bands indicated around the mid-range assumptions, and the cost figures are presented in Table 8.

Figure 4 - Indicative capex cost scenarios for TASS deployment



[14] LEAN SDRC 9.5 'Monitoring & Analysis', February 2019 - available via the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

Factors that will Influence the Cost of Deployment

Clearly the present costs of some of these deployment scenarios are significant. However, a number of factors will influence the costs of implementing TASS both now and over future years. These must be considered by those assessing the implementation of TASS, or similar systems, at scale across a given network, and by those interested in developing technologies to provide similar functionalities.

Table 6 summarises the key influencing factors. These reflect observations presented in SDRC 9.4 'Initial Learning from Trial Installation and Integration' with regard to the technical and economic scalability and replicability of TASS, in addition to further experience gained during the trials.

Table 6 - 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.

Operational Costs Associated with the Application of TASS

The opex figures presented here reflect the marginal costs associated with the application of TASS with regard to both the TASS control system and the implications of TASS switching for existing substation assets.

Inspection & Maintenance

For the wall box holding the TASS control device and, where used, the synchronising relays, visual inspection can be undertaken as part of the standard substation inspection process with minimal implications for additional resources or time.

With regard to the existing substation assets incorporated into the TASS system, as presented in in Table 7 no implications have been identified to date with regard to asset health, and therefore the business's standard inspection processes are expected to be sufficient for any substations where TASS is applied.

At present, substation inspection and maintenance cycles follow defined timeframes for different assets, of typically 4-8 years, and therefore the additional switching activity due to TASS[15] will not change the maintenance requirements and associated resource costs.

As a future consideration, however, the Condition Based Risk Management (CBRM)[16] process currently used to target refurbishment and replacement activity within SSEN, as well as to report annual Risk Indices throughout RIIO-ED1[17], is being developed for corresponding application in targeting maintenance activity. Once adopted for maintenance planning, the data held within CBRM will be used in line with rules from defined company policies to automatically generate maintenance schedules for individual assets, based on both the probability and consequences of asset failure. Consequently, where information on the number of switching operations is factored into the data assessed for assets such as transformers and circuit breakers, the application of TASS may result in the associated substation assets receiving an increased level of maintenance.

[15] as reported in Section 2 'Assessment of TASS Performance at the Trial Sites', the TASS switching activity seen at the two trial sites represents a range of TASS operation, with switching at one site occurring every day in response to the evening demand peak, and switching at the other site only occurring due to the fortnightly time based changeover events

[16] CBRM was first introduced to GB electricity distribution network operation by EA Technology Ltd and Electricity North West Ltd in 2002, and provides an enhanced approach to asset management which can improve reliability and reduce overall maintenance costs - subsequently, to meet the requirements of Electricity Distribution Standard Licence Condition 51 (SLC 51) for RIIO-ED1 and promote a common approach to the application of CBRM by all DNOs, a methodology has been collaboratively developed by the six GB DNO groups, as presented in 'DNO Common Network Asset Indices Methodology' v1.1, January 2017 - available at www.ofgem.gov.uk/system/files/docs/2017/05/dno_common_network_asset_indices_methodology_v1.1.pdf

[17] RIIO-ED1 is the regulatory price control for electricity DNOs covering the eight year period from 1 April 2015 to 31 March 2023

Refurbishment & Replacement

A range of techniques are being used to provide detailed information on asset health during the trials and monitor for any changes which indicate that TASS operation may have an impact on the health of substation assets, and may therefore result in increased refurbishment or replacement activities.

The approaches used are described in SDRC 9.5 'Monitoring & Analysis', and comprise the following:

- Visual inspections
- Partial Discharge surveys
- Transformer Condition Assessment tests:
  - Sweep Frequency Response Analysis (SFRA)
  - Winding Resistance tests
  - Magnetising Current tests
  - Winding Capacitance & Power Factor tests
  - Dielectric Frequency Response (DFR) tests
- Oil sampling
- Online Dissolved Gas Analysis (DGA) monitoring
- Power Quality monitoring - inrush currents and voltage transients

At this point in time, there is no evidence of any increased risks to asset health due to the deployment of TASS and increased levels of transformer switching. Consequently, no increases in refurbishment or replacement requirements have been identified, with no associated implications for operational resources or materials costs.

A summary of the conclusions regarding the health of substation assets associated with TASS operation is given in Table 7, with detail provided in SDRC 9.5 'Monitoring & Analysis'.

A further suite of transformer condition assessment tests and PD surveys will be undertaken following the conclusion of the trials, and findings will be presented in the project closedown report SDRC 9.8 'Knowledge & Dissemination'.

Table 7 - Summary of the asset health implications for substation assets associated with TASS operation

Asset	Project Conclusions	Cost Implications
Transformers	Results from both the pre-trial and mid-trial transformer condition assessment tests indicate that there are no significant issues with any of the transformers, and no changes due to TASS operation have been identified, even with the majority of switching events over this period being without the use of controlled Point on Wave switching. The online DGA monitoring data shows that the gas levels remain relatively stable for each of the trial transformers, though with natural fluctuations with time. The results therefore raise no concerns regarding possible low, medium or high temperature faults within the transformers, and there is no evidence of any changes linked to the TASS trials. The worst case maximum inrush currents calculated from the power flow analysis (5.2 and 5.7 times the transformer ratings at the two sites) are well within design capabilities for the transformers, thereby supporting the conclusion from Phase One of the project that inrush currents due to TASS switching present minimal risk of winding or mechanical damage to the transformers which may adversely affect transformer asset life.	none identified
Tap Changers	As TASS de-energisation and re-energisation occur at similar low load levels, for the majority of sites that would achieve losses savings due to TASS, the increased overall number of tap changer operations as a consequence of TASS switching should remain within the conventional operational capability of these devices. For example, experience from the trial substations indicates that the application of TASS may result in 1-2 additional tap changes per day over and above an existing low number of operations, whereas substations with high levels of demand may see 7-8 tap changes per day within normal operational duties.	none identified
Circuit Breakers	The major risk to circuit breakers relates to the increased number of switching operations due to TASS. Whilst increased switching will increase mechanical wear on the circuit breakers, the number of additional operations associated with the TASS trials is well within the number of switching operations that circuit breakers are designed to accommodate. In addition, the TASS scheme is designed to switch at times of low substation loading, and consequently the risk of causing damage to the contacts within the circuit breakers is minimised. The conclusions from both Phase One of the project and subsequent conversations with the SSEN Protection team are that TASS presents minimal risk to 11 kV or 33 kV vacuum circuit breakers.	none identified
LVAC ACO schemes	Substation Low Voltage Alternating Current (LVAC) systems and their Automatic Changeover (ACO) schemes comprise standard electrical components designed to operate hundreds of thousands of times. Accordingly, though ACO operation may be triggered by TASS switching, the additional activity should remain within the conventional operational capability of these schemes. As found during the trials, however, where there is an existing issue with the LVAC scheme (such as an incorrect type of Miniature Circuit Breaker (MCB) with unsuitable tripping characteristics), TASS operation may bring this to light. Correspondingly this may allow issues to be identified and addressed prior to failure of the LVAC system during an operational incident.	none identified
RTUs	In contrast to the electrical assets presented above, Remote Terminal Units (RTUs) form part of the substation comms system, and the integration of TASS with these devices has minimal impact on their operation.	none identified

Administration

The LEAN project team's daily reviews of TASS operation via the PI ProcessBook have been necessary during the trials to monitor the operation of the TASS control algorithm and its response to different network situations, however it is not expected that such a close level of observation would be required for wider roll out of the technology. Rather, any issues would be identified by the Control Room, with appropriate operational resources then drawn in as necessary. Here, and subject to further consideration during future decisions on application of this technology across the business, it is anticipated that issues with the TASS control system would be taken on by the RTS team, and issues with the electrical assets would continue to be addressed by the operational Field Staff.

It is expected that the business would continue to monitor the losses saved if TASS is rolled out across the network, with this calculation run annually, or as needed on an adhoc basis, in line with company reporting requirements. Such requirements may relate to environmental reporting, or to the demonstration of a reduction in losses in accordance with our Losses Strategy or any future regulatory Losses Reduction Incentives. Here, the tool for calculating the energy saved at each substation would need to be maintained by the Asset Management & Investment team, with updates made to the transformer specific losses figures in line with any changes to the transformers at a given site, and with the load profiles and TASS switching information applied as relevant to the reporting period in question. Information on the derived savings would then be passed to the Regulatory Reporting team or others within the business as appropriate.

At present, the project team attends site periodically to download the data required for analysis during the trials, and to interact with the TASS system for the purpose of uploading new settings. Beyond the trials, TASS data will only be required for reporting purposes or in the event of an issue with the system, therefore the requirement for a member of staff to attend site may continue to be acceptable for wider roll out of the technology, particularly where this would align with an existing reason to visit site. Alternatively, it may be practicable to establish data transfer for downloading and/or systems updates via the business's SCADA system, or a similar suitable communications medium, should this be considered beneficial and cost effective, and subject to compliance with all relevant secure access and data transfer security requirements.

Opex Cost Assumption

With consideration to the findings presented above, a nominal figure of £500 per site is currently assumed for the opex cost associated with TASS.

It is not currently anticipated that online DGA monitoring would be required as part of the wider roll out of TASS, however should this be required, an indicative operational cost of around £5,000 per year across the fleet of transformers being monitored may be assumed should cloud hosting be required.

Comparison with Phase One Capex & Opex Estimates

Table 8 presents the current cost assumptions for different TASS deployment scenarios together with the estimated costs for Business as Usual (BAU) implementation of TASS derived as part of the technical analysis undertaken during Phase One of the project[18]. It is important to note that these costs do not reflect the factors that will influence the future cost of deployment identified in the 'Capital Costs for TASS Deployment' subsection above.

Table 8 - Comparison of the indicative costs ranges for different TASS deployment scenarios with Phase One estimates

	Phase One*		Phase Two		
	Lower Estimate	Higher Estimate	Lower Band	Mid-Range	Higher Band
Capex					
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	£19,500	£38,000	£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
Opex					
Operational costs associated with the application of TASS			£500	£500	£500

*Phase One cost estimates include a detailed protection study, one TASS control device and one synchronising relay per site

For TASS deployment including controlled switching via synchronising relays, the current lower band is around 2.4 times the Phase One lower estimate, with the current higher band being around 1.4 times greater than the Phase One higher estimate. The key difference in these figures reflects the fact that with the scheme developed for trial implementation, TASS is applied to two transformers within each substation such that TASS operation alternates between the transformers. Consequently, two synchronising relays are required per site, whereas the Phase One work assumed that only one synchronising relay would be required per substation. This principle was designed into the scheme in response to the requirements capture stages of technology development, and shares the switching duty between the transformers to build confidence in the system and provide assurance that the re-energise procedure and transformers operate as expected.

[18] as reported in LEAN SDRC 9.2 'Business Case Validation', March 2016 - available via the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

For the deployment of TASS without the requirement for controlled PoW switching, the costs are less than a third of the lower estimate figure from Phase One.

The full suite of pre-installation oil samples, PD surveys and/or transformer condition assessment tests used during the trials may treble the cost for deployment of TASS without the controlled PoW switching, and the value of using different combinations of these to validate that there are no pre-existing issues with the assets, or to provide a set of reference data for any subsequent tests, would need to be considered for roll out of TASS to other sites.

Training Resources

To indicate the time resources associated with training operational teams who will interact with the system, for the trials each TASS training session lasted 2-3 hours, with typically 4-6 33kV Authorised Field Staff or 1-3 EHV Control Engineers in attendance according to the numbers of staff that could be released from operational duties at any one time. Training was held at the Network Management Centre (for Control Engineers) and the regional depots local to the trial sites (for Field Staff), and if rolled out to the business this training would be provided by the SSEN Training Team to Field Staff within other regions on a similar basis.

For the wider base of operational staff and associated contractors/consultants who may require access to TASS substations, and Control Room staff who may receive a call from someone wishing to enter the substation, briefings to provide awareness of the equipment and the requirements for working with the TASS system and accessing the trial substations can be provided by managers within scheduled Team Meetings.

The training and briefing material created for use during the trials has been developed with consideration to future use should TASS be rolled out across the business, and in a way that will allow other DNOs to easily adapt it for their own use should they also want to implement TASS. Accordingly, this material is available to other DNOs as an output from the LEAN project, and can be requested by emailing the project team via lean@sse.com.

Where the decision is taken to deploy TASS at scale across a network, delivery teams would require installation and commissioning training relevant to the specific equipment used, however the necessary skills and authorisations readily align with current electricity network operation capabilities. This training can be developed with reference to installation guides or work instructions provided by product manufacturers, and be informed by the information presented in SDRC 9.4 ‘Initial Learning from Trial Installation and Integration’.

Conclusions & Recommendations Regarding the Costs Associated with the Application of TASS

Cost assumptions for the implementation and ongoing operation of TASS have been updated to reflect experience gained during the trials.

The figures presented here reflect the current costs for TASS deployment, however consideration is also given to the wide range of external or site specific factors that will act to reduce these costs and 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. It is recommended that these points also be 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.

At present, the business's standard approaches to inspection and maintenance are expected to be sufficient for any substations where TASS is applied, with minimal cost implications. More specialist techniques, such as those used to evaluate asset health throughout the trials, may then be used if any potential issues are identified which merit further investigation.

This position may change with the ongoing progression to targeting maintenance activities using CBRM, according to the evaluation criteria established. Where information on the number of switching operations is factored into the data assessed for assets such as transformers and circuit breakers, the application of TASS may result in the assets within associated substations receiving an increased level of inspection and maintenance. Whilst the CBRM common methodology developed collaboratively by the six GB DNO groups, as defined in the 'DNO Common Network Asset Indices Methodology' document, does not currently specify detail relating to numbers of operations of relevant asset categories, this consideration will need to be reviewed in the context of each DNO's specific implementation of CBRM.

At this point in time, there is no evidence of any increased risks to asset health due to the deployment of TASS with increased levels of transformer switching, consequently no increased refurbishment or replacement costs have been identified.

The capex and opex costs presented here have been used as inputs to the Network Losses Evaluation Tool developed during Phase One of the project to provide an updated Cost Benefit Analysis (CBA) on a site by site basis, with the results then scaled to GB. This assessment is presented in Section 4 'Business Case for TASS Deployment'.

4 Business Case for TASS Deployment

This section presents an evaluation of the business case for TASS in consideration of the benefits and costs assessed through implementation and operation. The approaches developed to appraise the financial viability and technical feasibility of TASS on a site by site basis have been used to demonstrate the wider business case for TASS deployment, and factors that will influence future roll out are considered.

The content is aimed at those considering the application of TASS at scale across a network area, and those seeking to promote the adoption of technologies to reduce losses on electricity distribution networks.

The following subsections are presented:

- Process for Assessing the Business Case for TASS on a Site by Site Basis
- Financial Assessment of Deployment on the SEPD Network
- Financial Assessment for GB
- Further Influences on the Business Case for TASS
- Conclusions & Recommendations

Process for Assessing the Business Case for TASS on a Site by Site Basis

The four work packages in Phase One of LEAN aimed to provide a clear understanding of the benefits, costs and risks associated with implementation of the proposed technology and inform the technical design of the scheme. As part of this work, a 'TASS Tool' was created to provide a Cost Benefit Analysis (CBA) consistent with the RIIO-ED1 CBA approach[19], allowing the business case for deployment of the LEAN technologies to be assessed. Correspondingly, a stepwise process for assessing the technical feasibility of TASS on a site specific basis was developed.

These methodologies have been used to review the CBA for the application of TASS taking into account subsequent experience during the trial stages of the project, and the use of the two approaches is described below.

'TASS Tool' for Assessing Losses Reductions

The TASS Tool was developed to quantify the benefits associated with the application of TASS on a site by site basis.

It comprises an Excel spreadsheet with Python Script which simulates the operation of TASS using half-hourly substation load measurements, in SSEN's case taken from the PI Historian system, and determines the associated reduction in losses over the course of a year. These energy savings are then used in a CBA which considers the capex and opex costs for deploying TASS, the remaining life of the transformers, and the environmental and social benefits in terms of the value of the losses and CO_2 emissions saved.

[19] RIIO-ED1 CBA guidance note, Ofgem, 17 Jan 2014

The cumulative discounted net benefit is calculated for the remaining life of the transformers (not more than 65 years), and for 16 years (to reflect two price review periods of the duration of RIIO-ED1). The tool can be used to provide a list of substations for which a positive cumulative discounted net benefit is derived on the basis of generic cost assumptions, and these shortlisted sites can then be considered in more detail for the application of TASS taking into account site specific technical and cost factors.

As reported in Section 2 'Assessment of TASS Performance at the Trial Sites', with full operation of TASS (as distinct from the periods when TASS was Disabled prior to resolution of the issues described in that section), the energy savings seen at each site are in line with the savings calculated using the TASS Tool, though slightly exceeding the forecasts in each case. Such differences are to be expected due to variations in load profiles from year to year, with higher figures indicating a level of demand that has allowed one transformer to be switched out for a greater period of time than calculated, therefore these results verify the use of the tool to simulate TASS operation.

More detail on the TASS tool is given in SDRC 9.2 'Business Case Validation'[20]. The initial version will be reviewed to identify any enhancements based on project experience, and the final version will be presented for SDRC 9.7 'Network Losses Evaluation Tool' with an accompanying technical guide providing instructions for use.

This tool will be available to other GB DNOs to enable them to assess the potential for deployment of TASS technology on their own networks on a site by site basis. The technical and training material available with SDRC 9.4 'Initial Learning from Trial Installation and Integration'[21] will then support the application and roll out of TASS.

Stepwise Assessment Process

The stepwise assessment process provides a framework around the use of the TASS Tool to evaluate the technical feasibility of applying TASS at the specific substations, and refine the investment cost figures.

The process is described in detail in SDRC 9.2 'Business Case Validation', and comprises the following steps:

- Step One: TASS Tool used with generic cost assumptions for all sites to provide a shortlist of substations
- Step Two: identify which of the shortlisted substations has a dedicated 33 kV circuit breaker
- Step Three: review the transformer and switchgear condition at each of these substations
- Step Four: undertake a detailed control and protection study for TASS implementation
- Step Five: update the TASS Tool cost benefit analysis with site specific costs

[20] LEAN SDRC 9.2 'Business Case Validation', March 2016 - available via the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

[21] LEAN SDRC 9.4 'Initial Learning from Trial Installation and Integration', September 2018 - available via the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

For all sites that are found to be technically feasible, the final stage of the assessment is to apply the site specific capex and opex costs informed by the detailed study for TASS implementation. The resulting CBA can then be used to make decisions on the application of TASS at each viable site.

This process was used when identifying suitable substations for the trial application of TASS, and no changes to these steps are required in light of project experience. However, insight into the process of applying each step has been gained through the Phase Two trial stage of the project, and detail on the use of the stepwise assessment process will be presented in conjunction with the TASS Tool in SDRC 9.7 'Network Losses Evaluation Tool'.

Financial Assessment of Deployment on the SEPD Network

The indicative current costs for different TASS deployment scenarios are presented in Section 3 'Costs Associated with the Application of TASS'.

These have been applied to the losses savings figures derived using the TASS Tool within Phase One of the project to provide an updated high level analysis of the CBA for TASS deployment across all 381 SEPD primary substations.

To reflect the architecture applied for the TASS trials, the business case assessment here considers the costs for 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

Step One - TASS Tool CBA

In line with Step One of the stepwise assessment process described above, Table 9 presents the numbers of sites for which the TASS Tool indicates a positive CBA for the current cost assumptions associated with the different deployment scenarios, alongside the figures from the original business cases assessment for comparison.

Again, it is important to note that these costs do not reflect the factors that will influence the future cost of deployment identified in Section 3.

Table 9 - Comparison of the number of SEPD sites indicating a positive CBA using current cost assumptions - Step One

	Phase One [1]		Phase Two		
	Lower Estimate	Higher Estimate	Lower Band	Mid-Range	Higher Band
Number of sites with positive net benefit up to the transformers' remaining life					
TASS wall box			148 (39%)	142 (37%)	138 (36%)
TASS wall box, TX tests & PD surveys			87 (23%)	82 (22%)	75 (20%)
TASS wall box, synch. relays	63 (16%)	25 (7%)	20 (5%)	16 (4%)	16 (4%)
Number of sites with positive net benefit up to 16 years					
TASS wall box			151 (40%)	145 (38%)	136 (36%)
TASS wall box, TX tests & PD surveys			85 (22%)	78 (20%)	72 (19%)
TASS wall box, synch. relays	60 (15%)	22 (6%)	17 (4%)	13 (3%)	11 (3%)

[1] Phase One cost estimates include a detailed protection study, one TASS control device and one synchronising relay per site

All Steps - Apportioned CBA

The TASS Tool has been used together with knowledge of the associated technical requirements for deployment drawn from experience during the trials to indicate the number of SEPD sites at which it would be technically feasible to deploy TASS.

Following the TASS stepwise 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 10.

Table 10 - Comparison of the number of SEPD sites indicating a positive CBA using current cost assumptions - All Steps

	Phase One		Phase Two		
	Lower Estimate	Higher Estimate	Lower Band	Mid-Range	Higher Band
Number of sites with positive net benefit up to the transformers' remaining life - taking account of the stepwise assessment process					
TASS wall box			98 - 108 (26% - 28%)	94 - 104 (25% - 27%)	91 - 101 (24% - 26%)
TASS wall box, TX tests & PD surveys			58 - 64 (15% - 17%)	54 - 60 (14% - 16%)	49 - 55 (13% - 14%)
TASS wall box, synch. relays	46 (12%)	17 (5%)	13 - 15 (3% - 4%)	10 - 12 (3%)	10 - 12 (3%)
Number of sites with positive net benefit up to 16 years - taking account of the stepwise assessment process					
TASS wall box			100 - 110 (26% - 29%)	96 - 106 (25% - 28%)	89 - 99 (23% - 26%)
TASS wall box, TX tests & PD surveys			56 - 62 (15% - 16%)	51 - 57 (13% - 15%)	48 - 53 (12% - 14%)
TASS wall box, synch. relays	40 (10%)	15 (4%)	10 - 12 (3%)	9 (2%)	8 (2%)

Using these current cost assumptions, therefore, around 3% - 29% of SEPD primary substations would have positive cumulative discounted net benefit results across these TASS deployments scenarios if the lower capex figures can be achieved, or around 2% - 26% if the higher capex figures are used. Accordingly with the mid-range capex figures, around 2% - 28% (~10 - ~100 sites) of the SEPD primary substations would be viable.

The total cumulative discounted net benefits and energy savings associated with the central point of these ranges are shown in Table 11.

Table 11 - Cumulative discounted net benefits and energy savings based on current cost assumptions

	Phase Two						
	Total Cumulative Net Benefit			Total Energy Savings (MWh)			Energy Saving per Year
	Lower Band	Mid-Range	Higher Band	Lower Band	Mid-Range	Higher Band	
Sites with positive net benefit up to the transformers' remaining life - taking account of the stepwise assessment process							
TASS wall box	£1,842,000	£1,779,500	£1,719,000	72,800	71,900	71,400	~3500 MWh
TASS wall box, TX tests & PD surveys	£1,118,500	£1,021,000	£931,000	59,500	58,600	55,900	~2500 MWh
TASS wall box, synch. relays	£316,500	£251,000	£238,000	29,400	27,000	27,000	~800 MWh
Sites with positive net benefit up to 16 years - taking account of the stepwise assessment process							
TASS wall box	£1,409,500	£1,352,500	£1,298,000	44,400	43,900	42,900	~3500 MWh
TASS wall box, TX tests & PD surveys	£770,000	£686,500	£610,500	35,100	33,700	32,200	~2500 MWh
TASS wall box, synch. relays	£132,00	£87,000	£79,000	12,600	10,300	9,000	~800 MWh

To give context to the losses savings presented above, the Energy Saving Trust's information on domestic solar photovoltaic (PV) systems[22] indicates that the range of energy savings per year would be equivalent to the energy generated each year by ~190 to ~830 typical domestic PV systems in the south of England. Using the Government's greenhouse gas conversion factors[23], the reduction in carbon emissions associated with these energy savings then equates to around 1.4 million to 6 million miles travelled by a conventional passenger car, or around 1,000 to 6,000 vehicles each covering 10,000 miles per year.

For comparison with the assessment undertaken during Phase One of the project, SDRC 9.2 'Business Case Validation' indicated that around 9% (34 sites) of the SEPD primary substations would be viable for the application of TASS using the mid-range estimated capex figure of £28,750, with a total cumulative discounted net benefit of £700,000 based on the forecast remaining life for each transformer, or £435,000 over a 16 year timeframe, and with associated energy savings of around 2,090 MWh per year.

[22] 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

[23] calculated based on the passenger vehicle conversion factor for an average car (unknown fuel type) of 0.29072 kg CO_2e per mile taken from the 'Conversion Factors 2018' tables, UK Government, July 2018 www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018

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, equating to a financial saving of nearly £4,500 based on the standard value of losses figure of £48.42 per MWh. A table presenting the resulting figures is given in Appendix A.

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 bid submission and SDRC 9.2 'Business Case Validation', this scales the Step One analysis of SEPD sites given above to reflect the total number of GB 33/11kV substations.

The updated evaluation reflects the mid-range current cost assumptions for the three deployment scenarios assessed in Section 3 'Costs Associated with the Application of TASS'. The reference to annual load duration curves from all SEPD sites then supports a refined calculation of the potential losses reductions, in contrast to the generic load profile previously considered.

A 45 year assessment period is used in line with the original assessment, and the figures are presented in Table 12 alongside the original estimate for switching Option 2 - controlled switching with existing equipment - presented in the bid document.

Table 12 - Updated GB Financial Benefit Assessment following trial implementation of TASS

	Bid Document	Phase Two [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%	38%	20%	3%
GB sites for TASS application - pro-rata	1166	1789	1033	202
Total Investment	£21,036,522	£49,912,400	£42,252,600	£15,168,500
45 Year Losses Savings [MWh]	1,432,732	2,797,200	2,124,400	635,900
45 Year CO_2 Savings [tCO_2e]	288,948	1,102,500	837,300	250,600
45 Year Indicative Cumulative Discounted Net Benefit	£46,207,091	£49,800,200	£46,807,800	£9,329,100

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

[2] based on the mid-range current capex cost assumptions, and 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

Further Influences on the Business Case for TASS

The business case presented above relates to the current costs for TASS deployment. A broad range of technical and regulatory considerations will further influence the business case for applying TASS technology, and these are discussed below.

Prices

As described in Section 3 'Costs Associated with the Application of TASS', a number of factors will influence the future cost of equipment required to implement TASS, and hence the financial viability and marginal costs and benefits associated with deployment of the technology at a given site. These include synergies in applying the TASS functionality via existing equipment, or incorporating PoW functionality into switchgear, in addition to the economies of scale that would be seen with wider deployment, and as a greater range of suitable devices become available from different product vendors.

Retrofitting vs New Build

The above assessment considers the retrofit application of TASS within substations. An alternative would be to incorporate TASS when the control and protection system at a primary substation is scheduled to be updated in line with business processes, or when a new substation is to be constructed. Whilst the overall energy savings and associated costs of this approach have not been considered within the project, it is expected that this approach could result in lower costs for installation of TASS, potentially increasing the financial viability of installing the technology at a given site. It would, however, result in a different set of primary substations at which TASS is deployed, with subsequent implications for the potential overall energy savings and financial benefit.

Changing Load Profiles

With increasing levels of distributed generation and other low carbon technologies such as electric vehicles connected to distribution networks, and with the ongoing roll-out of smart meters, the demand patterns recorded at any primary substation may change through time. Such technologies may result in increasingly extreme highs and lows in demand, less predictable load profiles and potentially lower overall utilisation factors. In the situation where there are lower overall utilisation factors or potential decreases in minimum demands where renewables are connected, the energy savings achievable through the deployment of TASS may significantly increase, thereby increasing the financially viability of TASS. However, it may conversely be the case that for some sites, future changes in energy usage patterns may reduce the financial viability of TASS where the load at the substation falls below the cross over point less often or for shorter periods of time.

Incentives within the RIIO Regulatory Framework

The financial benefits of using TASS to reduce losses relate directly to the societal (Non-DNO) benefits associated with overall energy efficiency which reduces customer bills and equates to lower CO_2e emissions. Consequently, TASS aligns with the criteria contained within the Innovation Roll-out Mechanism (IRM)[24] established by Ofgem to support DNO Licensees in deploying solutions which bring social, environmental or carbon reduction benefits which would not otherwise be recognised within a Licensees' business plan.

Accordingly, referral to the IRM funding mechanism will be of relevance when considering the potential roll-out of TASS.

With regard to incentives for losses reduction, within RIIO-ED1 a discretionary reward is used to incentivise losses reduction on electricity distribution networks[25]. Whilst support for the use of technologies or other approaches to reduce losses is valued, the creation of a structured, non-discretionary losses incentive which creates a clear link between losses reduction and reward would provide increased certainty to an assessment of the business case for TASS. It is recommended that the ongoing review of the approach to incentivise losses reduction within RIIO-ED2 continues to consider the development and application of a non-discretionary losses incentive.

One further consideration regarding the current regulatory framework relates to the perceived risk around Customer Interruptions and Customer Minutes Lost (CI/CML) in the event of a fault on the non-TASS transformer whilst the TASS transformer is switched out, and associated penalties under the Interruptions Incentive Scheme (IIS). This concern was acknowledged at the outset of the LEAN project, and accordingly the TASS system and control algorithm developed and trialled through the project have been designed to minimise risks to security of supply. As described in SDRC 9.4 'Initial Learning from Trial Installation and Integration', the system monitors a wide range of existing SCADA data points to identify network issues, and will act to restore a transformer within 5 seconds when a loss of supply for some or all customers has been detected, to restore the supply as swiftly as possible whilst maintaining safety.

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 need to review the structure or application of incentives for supply security to ensure that these remain fit for purpose.

As noted in Section 5 'Site Visits Offered to Stakeholders', the apprehension about the deployment of TASS expressed by the other DNO Groups through the project's stakeholder engagement activities similarly relate to the context of incentives for losses reduction or the balance of losses savings with the potential consequence of a CI/CML event.

Value of Losses & Carbon

At present prices, the value of the energy saved is predominantly associated with the value assigned to losses, with the CO_2e proportion equating to only 7% of the overall value. Changes to the financial value of both losses and CO_2e, in addition to changes in the energy mix affecting the level of CO_2e associated with grid electricity, will influence these

[24] 'Electricity Distribution Innovation Roll-out Mechanism submission guidance', Ofgem, February 2016, www.ofgem.gov.uk/system/files/docs/2017/02/irm_guidance_template_electricity_distribution.pdf

[25] 'Losses Discretionary Reward Guidance Document', Ofgem, www.ofgem.gov.uk/ofgem-publications/97068/lossesdiscretionaryrewardguidancedocument-pdf

potential savings. At present the RIIO-ED1 Cost Benefit Analysis methodology incorporates forecasts for changes in the electricity GHG (greenhouse gas) conversion factor and traded carbon price, however the value for losses is a set as a fixed figure through time.

Further Use Cases

The application of TASS presented here relates specifically to its use in reducing network losses. Further applications for this automated switching technology may be realised, for example TASS may offer a means to manage high volts issues on the transmission network by increasing the reactance of the network. The project team are exploring this possibility with National Grid ESO and will continue to form thinking on how this may be offered as a service, including considerations regarding commercial and/or technical interfaces needed between the transmission and distribution systems.

Conclusions & Recommendations Regarding the Business Case for TASS

The range of deployment scenarios and cost assumptions used to assess the current business case for TASS demonstrate a positive CBA for deployment at certain sites.

Clearly, however, the varying cost assumptions influence the proportion of sites at which TASS would be economically viable. Both the costs and values attributed to the resulting benefits will then influence the financial assessment for a given site, and overall cumulative net benefit.

Accordingly, the price, technical and regulatory factors that will further influence the business case for applying TASS are identified, and it is recommended that these be considered by those assessing the application of TASS at scale across a network area, and those seeking to promote the adoption of technologies to reduce losses on electricity distribution networks.

The GB appraisal presented above is based on an extrapolation of the findings from SEPD sites scaled to GB level, and equates to Step One of the TASS process. More detailed information from other GB DNOs would be required to assess the later stages of the stepwise assessment process and further refine this analysis. The number of suitable sites is likely to vary between DNOs, however, and it may be expected that the overall figures would reduce as sites are assessed for the technical feasibility of TASS deployment in line with Steps Two to Five of the stepwise assessment process set out in Section 3 ‘Costs Associated with the Application of TASS’.

This analysis indicates that TASS offers a financially viable, as well as technically feasible, option for reducing losses on electricity distribution networks, however further developments in a range of areas will influence the scale of future deployment.

5 Site Visits Offered to Stakeholders

To provide an opportunity for relevant stakeholders to see the equipment installed for the TASS trials, and its integration with other primary substation assets and comms systems, site visits have been offered to internal and external colleagues at various stages of the project, as summarised in Table 13.

Table 13 - Stakeholder site visit invitations

Stakeholders	Invitations Offered During the TASS Trials
Internal - SSEN	
• Protection team	The Protection team were engaged with during the requirements capture and design stages of the project, and subsequently invited to review the operation of the TASS control device within the bench testing environment at SSEN's Protection laboratory. In addition, site visits were made following installation to observe the TASS system integrated within the full substation environment.
• RTS team	Real Time Systems (RTS) colleagues were similarly engaged with during the requirements capture and design stages of the project, and invited to review the system's interaction with conventional RTS devices during bench testing of the TASS control device at SSEN's Protection laboratory. Subsequently, the RTS team attended site during installation & commissioning of the system to provide the comms connection between the TASS control device and existing RTUs.
• Field Staff	As part of the training provided to operational colleagues, 33kV Authorised Field Staff were invited to join the project team on site and see the equipment being installed. A number of colleagues accepted this offer and attended site during the installation & commissioning period. Throughout the course of the trials, Field Staff have also attended site as part of their normal operational duties, and to support project activities.
• Control Engineers	Similarly, during the training sessions for EHV Control Engineers staff were invited to visit the sites during installation & commissioning, however these colleagues expressed the view that the training itself and supporting material provided were sufficient for their operational requirements.
• DSO & Innovation colleagues	A number of immediate colleagues involved with other SSEN innovation activities have accompanied the LEAN project team for site visits on various occasions during the course of the trials.
• Asset Management team	Following project dissemination activities within the wider business, interest has been expressed by Asset Management colleagues in the online DGA system being used to track the health of the transformers during the trials. Accordingly staff have been invited to site to see the installed monitoring equipment, in addition to being provided with login access to the online system to view the information available.

External	
• Ofgem	Site visits have been offered to the Ofgem Project Officer for LEAN, and/or any relevant colleagues, as an opportunity to see the equipment installed for the trials within the context of the primary substation assets that the system interacts with. This invitation was issued in December 2018, however the Project Officer declined on the basis that she is "happy to say that I am satisfied with the standard of evidence so far and photos of the installed kit is sufficient" - the associated emails are provided as Appendix B.
• DNO Groups	Invitations for site visits have also been issued to losses and innovation colleagues from each of the five other GB DNO Groups. This includes individuals who the project team engaged with during the trial decision point for LEAN, as reported in SDRC 9.3 'Phase Two Decision Point'[26], and members of the ENA's Technical Losses Task Group - an example of the email issued, which includes information on the site locations and travel options, is provided as Appendix C. These invitations were circulated in January 2019, and at the time of writing colleagues from one of the DNOs have accepted the offer and are due to confirm a date for meeting with the project team on site, and the team from another DNO have requested the opportunity for a face to face meeting to discuss the application of TASS, however without requiring a site visit.
• National Grid	In conjunction, colleagues from National Grid's system operation and innovation teams have been invited to visit the trial sites, having expressed an interest in the project and TASS system.

In addition to offering site visits to losses and innovation stakeholders from each of the other DNO Groups, following the submission of SDRC 9.4 'Initial Learning from Trial Installation and Integration' the LEAN project team engaged with these colleagues to seek feedback on the TASS technology and what's being delivered through the LEAN project to support its application.

Responses were subsequently received from each of the DNO Groups, and the project team express their sincere thanks to those who responded to provide valuable and considered comments.

Overall, the project itself and the technical application of TASS receive a positive response, however, each of the DNOs have expressed some apprehension about the deployment of TASS in the context of either incentives for losses reduction, or the balance of losses savings with the potential consequence of a CI/CML event.

The project team will continue to discuss these aspects further with our external colleagues over the course of the project, and the responses received and conclusions from this feedback will be reported in detail in the project closedown report, SDRC 9.8 'Knowledge & Dissemination'.

[26] LEAN SDRC 9.4 'Initial Learning from Trial Installation and Integration', September 2018 - available via the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

6 Conclusion & Next Steps

This report provides the evidence that SEPD has met the requirements of SDRC 9.6, as set out in the LEAN Project Direction. In line with those requirements, the key topics presented are as follows:

- An assessment of the performance of TASS to date with reference to the automated switching activity seen and the associated reduction in losses
- A review of asset health and ongoing operational considerations related to the application of TASS
- An evaluation of the business case for TASS deployment addressing both the benefits and costs
- A summary of the site visits offered to both internal and external stakeholders

At the time of writing, TASS has been successfully controlling automated switching events for over eight months. The system continues to operate as designed, demonstrating the ability to both reduce losses and respond appropriately to different network situations. The scheme design developed through the project provides a streamlined system for integration with existing assets to deliver the TASS functionality, and no impacts on asset health due to TASS operation have been identified.

On the basis of current costs, the business case assessment demonstrates that TASS offers a financially viable, as well as technically feasible, option for reducing losses at individual substations.

However, a number of factors will influence the costs of implementing TASS both now and over future years. These are identified within the report to inform their consideration by those assessing or seeking to promote the implementation of TASS at scale across a given network, and by those interested in developing technologies to provide similar functionalities.

Clearly the associated costs will influence the proportion of sites at which TASS would be economically viable. Similarly both the costs and values attributed to the resulting benefits will then influence the financial assessment for a given site, and overall cumulative net benefit.

The TASS Tool used to provide a CBA on a site by site basis will be reviewed taking into account experience gained during the project, and the final version will be presented for SDRC 9.7 'Network Losses Evaluation Tool' with an accompanying technical guide providing instructions for use.

Similarly, SDRC 9.7 will give detail on the use of the stepwise assessment process to evaluate the technical feasibility of applying TASS at the specific substations, drawing on insight gained when applying each step to identify suitable substations for the trial application of TASS.

These methodologies will be available to other GB DNOs to enable them to assess the potential for deployment of TASS technology on their own networks on a site by site basis. The technical and training material available with SDRC 9.4 'Initial Learning from Trial Installation and Integration'[27] will then support the application and roll out of TASS.

Next Steps

Subject to the continued successful operation of TASS, the trial period will continue until May 2019.

The system will continue to be closely monitored to track the operational scenarios experienced and evaluate how the TASS control algorithm has responded, allowing any modifications or enhancements that could improve the system to be identified.

The assets and systems that TASS interacts with, including the transformers and circuit breakers, will also continue to be monitored to evaluate any potential implications associated with the application of TASS. A further suite of transformer condition assessment tests and PD surveys will be undertaken following the conclusion of the trials, and findings will be presented in the project closedown report SDRC 9.8 'Knowledge & Dissemination'.

Knowledge Sharing

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

The following companion SDRCs relate to the development and trial of the TASS technology through Phase Two and Phase Three of the project:

- SDRC 9.4 'Initial Learning from Trial Installation and Integration' - comprehensive information on the technology developed, its integration with existing network assets, the operational principles designed into the scheme, and the factors relevant to the scalability and replicability of the system for wider deployment across other network areas, 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 to evaluate both the performance of TASS and any potential asset health or power quality implications associated with its application
- SDRC 9.7 'Network Losses Evaluation Tool' - refinement of the tool developed to allow DNOs to undertake a site by site cost benefit analysis on the deployment of the technology, reflecting experience gained from trial implementation
- SDRC 9.8 'Knowledge & Dissemination' - the project closedown report, including consideration of the wider deployment of the technology across the SEPD network if applicable

[27] LEAN SDRC 9.4 'Initial Learning from Trial Installation and Integration', September 2018 - available via the ENA's Smarter Networks Portal www.smarternetworks.org/project/sset207-01/documents

SDRC 9.4 was published in September 2018, SDRC 9.5 was published in February 2019, and SDRCs 9.7 & 9.8 are to be published over the course of the project as more experience is gained from trial operation.

Targeted engagement and dissemination activities will continue with both internal and external stakeholders to share information and experience. The 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 or third party service providers to inform their development of technologies or functionalities relevant to enhanced levels of decentralised control, automation and monitoring as the industry transitions to the world of DSO with increasingly dynamic operation of GB electricity networks.

Appendices

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

Appendix A LEAN Full Submission GB Wide Financial Assessment

Appendix B LEAN site visit invitation to Ofgem & response - *redacted*

Appendix C LEAN site visit invitations to other DNO Groups - *redacted*

Enquiries regarding these appendices, this SDRC 9.6 report or the LEAN project in general are very welcome via lean@sse.com.