LV Engine

Project Progress Report

January 2019

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Version History

Author	Revision	Date	Status	Comments
Ali Kazerooni	V0.1	07/01/2018	Draft	Issued for review and comment.
Michael Eves	V0.2	10/01/2018	Draft	Review and update
Michael Eves	V0.5	28/01/2019	Final – Ofgem submission	Accounting for internal comments
Ali Kazerooni	V0.6	22/02/2019	Final	Accounting for Ofgem comments

Approval

Name	Position	Date	Signature
James Yu	Future Networks Manger		
C Taylor	Director of Process & Technology		

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1 Executive Summary

1.1 Background

SP Energy Networks in collaboration with UKPN submitted the proposal for LV Engine under the Network Innovation Competition (NIC) mechanism in 2017. WSP, University of Strathclyde, and University of Kiel have also provided technical support for the proposal preparation. Ofgem approved the proposal and issued the Project Direction on the 16th of January 2018.The project commenced in January 2018 and is due to conclude in December 2022.

The LV Engine innovation project intends to trial Smart Transformers (ST) within secondary substations as the central point of an active and intelligent 11kV and LV distribution network. The Smart Transformers (ST) trialled during the project will bring together sophisticated power electronic hardware with intelligent network monitoring and control to maximise the performance and efficiency of the distribution network.

This is the first in the series of annual progress reports for the LV ENGINE project, covering the project delivery period January 2018 to January 2019, the "reporting period".

The project delivery is in line with the original proposal regarding project programme, resources, budget, risk management, intellectual property rights (IPR) and knowledge sharing. We have delivered our first core deliverable within this period titled "Smart Transformer Technical Specification".

1.2 Project Highlights

The project highlights in this reporting period are as follows:

- Collaboration agreement with UK Power Networks has been signed and is now in place. This was the Ofgem condition for accessing the project fund which has been successfully fulfilled.
- WSP, Strathclyde University and Kiel University have been commissioned to provide technical supports in LV Engine considering specific specialities and technical capabilities they can offer.
- All project set up activities, detailed scopes, communication strategy, roles and responsibilities and deliverables by each project partners were defined.
- The first deliverable of the project, Technical Specification of the Smart Transformer, has been successfully submitted to Ofgem within the deadline specified in the project direction.
- In addition to the main deliverable, the delivery team has also prepared supplementary background studies and conducted literature reviews to inform the design and technical specification requirements of the Smart Transformer.
- A list of potential trial sites in SP Manweb and SP Distribution area have been identified for different LV Engine schemes.

- Several internal and external disseminations activities were conducted. That included presenting aims and objectives of the projects within the SP Distribution and SP Manweb, presentation sessions in LCNI 2018, technical paper submissions to CIRED and Powertech.

1.3 Project issues

The procurement for selecting the SST manufacturing partner has been delayed for around 2 months due to delay occurred in developing the tender evaluation strategy for project partner selection and reviewing the tendering documents. We intend to compensate this delay by applying the following:

- Sharing the full collaboration agreement with potential SST manufacturing partners and allow legal review in parallel with technical evaluation; and
- Communicate the tender evaluation information and process as it is developed with senior management to optimise the time required for the final decision on the contract award.

The effectiveness of these measures will be reported in the next progress report

1.4 Project Risks

There are currently no uncontrolled risks that could impede the achievement of any of the project deliverables outlined in the Project Direction, or which could cause the Project to deviate from the its original aims and objectives. Risks are monitored on a continuous basis with regular review at weekly progress meetings. The key risks are summarised below, with more details in Section 4.

1.4.1 Technical & Commercial Risks

Our key potential technical risks that have been identified by the LV Engine Project Delivery Team have been monitored and controlled during the reporting period. Some risks concerned our immediate tasks, and by applying the control measures identified in the proposal, we have successfully mitigated them. We have outlined the most significant technical and commercial risks identified in Table 1. The mitigation measures applied have been outlined in Section 4.

Table 1: LV Engine Technical and Commercial Risks

Technical Risks	Description
Implementation of trial schemes	Trial schemes cannot be implemented as specified in the Technical Design work package
Reliability of monitoring systems	Monitoring equipment is not fit-for-purpose as becoming unhealthy or providing incorrect information, the communication system to transfer the monitored data is not reliable
LV Voltage Monitoring (or Smart Meters) Installation	Access to customers premises for installation of LV monitoring equipment (Smart Meter) is not

	granted
DC Network Protection	A proven and fit-for-purpose DC network protection scheme is not available
Commercial Risks	**Description**
Limited suppliers of SSTs	Minimal tender returns from suppliers for procurement of SST.
Failure to manufacture fit-for-purpose SST	Supplier cannot manufacture SST as per SPEN specifications
Cost of SST exceeds expectation	Cost to design and manufacturer required prototypes higher than expected due to unforeseen costs not identified during early engagement with manufacturers
Failure to design a fit-for-purpose SST	Our manufacturing project partner is unable to design the SST to the terms set in the Technical Specification and pulls out of the project.

As we move into work package 2, tendering for the project partners, we intend to continue to monitor and update the risks and identify mitigation plans accordingly.

1.4.2 Project Management Risks

The Project Manager at each of the project partners ensure that risks related to project delivery are continuously monitored and managed to ensure the project milestones are not jeopardised. The main project management risks are given in Table 2. Further details of Risk Management can be found in Section 4 of this document.

Table 2: LV Engine Project Management Risks

Project Management Risks	Description
Scope Creep	Possibility of "scope-creep" given inputs from wide audience of stakeholders. With such a ground-breaking project, stakeholder interest is high and task leaders must ensure core deliverables remain the main priority before undertaking additional tasks or deviating from plan.
Project programme delay	Project delivery timescales are a potential risk due to the tight programme to meet site delivery dates.
Increased project cost	The cost for the complete scheme is higher

	than anticipated
Lack of available resources	Resources, especially internal resources, may not be available to deliver the project

2 Project Manager's Report

This section provides an overview on the project progress made in this reporting period (16th January 2019 – 16th January 2019)

2.1 Funding Access Condition

The access to LV Engine fund was subject to signing the contract with UK Power Networks as the project collaborator. This condition has been fulfilled and collaboration agreement with UK Power Networks has been signed and is now in place.

2.2 Project Progress Summary

LV Engine project started in January 2018 following the receipt of Project Direction[1] from Ofgem. The first three months (from January to March 2018) of project included all the activities required for project setup and staff mobilisation with the project. In addition to project set up the main activities within the reporting period were under the following work packages:

Work Package 1 - Technical design: The objectives of this work package were to develop the detailed technical specifications which will be required for manufacturing and implementation of the LV Engine solution and identify trial sites;

Work Package 2 - Partner selection and procurement: The objectives of this work package are to select the manufacturing partner through a competitive tendering process and also procure the equipment required for LV Engine schemes. This work package is still open and under progress; and

Work Package 7 -Dissemination and knowledge sharing: The objectives of this work package are to disseminate the learnings generated and methodologies used within delivery of LV Engine project.

2.3 Project Overview

2.3.1 Project plan [Confidential]

The high level project plan is shown in Figure 1. The project has been progressed as planned based on its milestones and deliverables. The first project deliverable was submitted to Ofgem within its deadline (10/12/2018). This is the only deliverable in this reporting period.

The planned budget within this reporting period is [redacted] for the three active work packages. The total actual expenditure is [redacted] as the breakdown shown in Table 3. There is a [redacted]% deviation (underspent) in the planned expenditure which is within the planned contingency cost [redacted] considered in the initial project costing. The primary deviation from the final submission spend

[1] https://www.ofgem.gov.uk/system/files/docs/2018/01/lve_-_project_direction.pdf

is due to some legal activities being completed more efficiently than expected within the current reporting period.

SPEN can confirm that the project is adequately resourced to deliver the project on time and to the budget proposed during the final submission.

Table 3: The project expenditure in the progress period

	Planned	Actual
Work Package 1	[redacted]	[redacted]
Work Package 2	[redacted]	[redacted]
Work Package 7	[redacted]	[redacted]
Total	[redacted]	[redacted]

The following items have been considered for calculating the cost incurred within this reporting period:

- SPEN staff time including the project management time recorded in the course of project
- The invoices received or under processed from the project collaborators (WSP, University of Strathclyde and Keil University) for the labour cost and expenses incurred during the reporting period.
- The cost incurred by UKPN for technical review during work package 1 – there will be further work and support required during work package 2 for tender evaluation.
- The travel expenses of SPEN staff
- The cost of developing dissemination packages including LV Engine website, leaflets, LV Engine fact card etc.
- Legal costs for reviewing and finalising the collaboration agreements with different parties

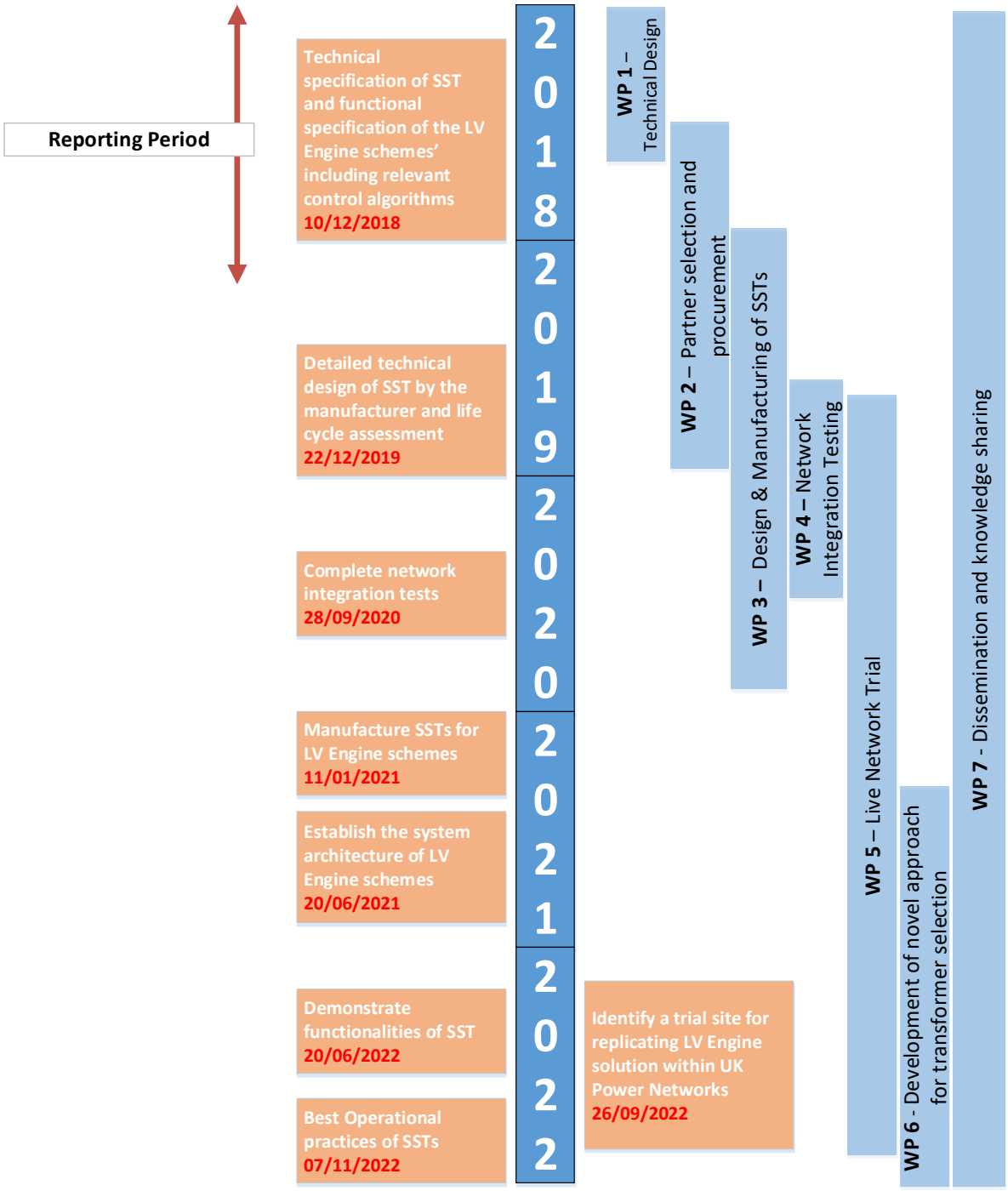

Figure 1 - High-level project programme

2.3.2 Project issues

No major issue has been encountered or identified during this reporting period. There are two minor notes to highlight:

- The project experienced a staff handover during the reporting period; the project manager role was handed over during Q4. There has been no impact to the deliverables or project progress due to this hand over. Moreover, the handover has provided an opportunity to review and strengthen the project management structure.

- We intended to hold a UK DNO workshop within Q4 of the reporting period, however due to the Christmas period and year end, it was decided it would be in the interest of the project to delay this workshop until February 2019. This accounts for the difference between the project and actual spend within Work Package 7, outlined in Table 3.

2.4 Project Progress during the Reporting Period

2.4.1 Project Set up

Following the project start on January 2018, the project setup activities started until March 2018.

- Detailed project structure, Project milestones, project deliverables and sub-deliverables, project partner scopes, roles and responsibilities and breakdown of the tasks were developed in line with LV Engine project direction.
- The LV Engine project was introduced in detail to different stakeholders within SPEN and supporting staff were appointed in different part of SPEN.
- The change control process, documentation formats, shared folders and the communication strategy within the project management structure were established.
- Building on the technical capabilities identified during LV Engine full proposal preparation and technical support required, University of Strathclyde, University of Kiel and WSP were commissioned as project collaborators to provide technical support in various aspects of the project.
- A collaboration agreement with UK Power Networks has also been signed off to allow UK Power Networks support in the course of project. This collaboration agreement was an important milestone to fulfil the project award condition specified by Ofgem.
- A comprehensive kick off meeting and workshop were undertaken with participation of all project collaborators and internal SPEN stakeholders including senior representative from real-time system, IT department, district general managers, design engineers and SCADA team.

The main outcomes of project set up are as follows:

- **Project Initiation Document** – This document provided the details of project management structure and responsibilities of all partners. The document was shared

internally with all the project partner and used as a reference in all the project partner's collaboration agreement.

- **Collaboration Agreements** – Collaboration agreements with LV Engine project partners were signed off and they are now in place after technical and legal process review. Four collaboration agreements have been signed off with UK Power Networks, University of Strathclyde, University of Kiel and WSP.
- **SPEN internal personnel commitments** – As part of internal stakeholder engagement, individuals who support LV Engine identified and their responsibilities and support required defined to ensure LV Engine solution considers the business as usual requirements in terms of operation, process and planning.

2.4.2 Progress under Work package 1 – Technical design

Work package 1 has now been completed and successfully met its aims and objectives. The following activities were conducted within work package 1:

- Conducted multiple workshops and meetings with participation of project collaborators and internal stakeholders for identifying the required technical capabilities of Solid State Transformer that needs to be addressed of specified within Work Package 1;
- Collaborated with UKPN and share the learnings which can inform the technical specification preparation;
- Conducted multiple workshops and meetings with IT and Real Time System to identify the requirements for integration of the control system within SPEN corporate network;
- Developed a through technical specification document that includes the technical and functional requirements for the solid state transformer and intelligent control system;
    - This document is Deliverable 1 of the LV Engine project as specified in the LV Engine project direction by Ofgem. It was supported by the Network Overview describing the electrical network interfaces that the Smart Transformer will encounter, intended to inform an audience with a range of experience with the distribution system itself, ranging from incumbent manufactures for system plant to smaller scale Power Electronic manufacturers perhaps operating within external industries.
- Conducted a thorough manufacturer engagement and a fresh market research to identify the latest technology developments and potential project partners for design and manufacturing the Solid State Transformer and the intelligent control system.
- Conducted trial site selection for LV Engine schemes that included identifying and shortlisting potential for each LV Engine scheme, a report reflecting the methodology used and information from each site was also produced.
- Carried out extensive engagement with potential LV DC customers who may collaborate for trial LV DC network within LV Engine. That included Glasgow City Council, Falkirk Council and several Electric Vehicle (EV) charger manufacturers.
- The delivery team has also conducted, literature reviews, the background studies and research to inform the design and technical specification requirements of the Smart Transformer.

The main outcomes of Work Package 1 are as follows:

- **Technical documents for tendering Smart Transformer –** Three technical documents were produced to inform smart transformer tenderers and specify the technical requirements of Smart Transformer. The three documents are as follows:

    1. **Technical specifications of Smart Transformer:** This document specifies the detailed technical requirements of Smart Transformer and consists of two main parts:

        i. Technical and functional requirements of Solid State Transformer (SST) and Smart Control Systems - This part specifies the core functionalities and technical requirements of SST as a power electronics device interfacing with existing substation plants and network.

        ii. Technical and functional requirements of Smart Control Systems (SCS) - This part specifies the functionalities of the control system and the requirements for interfacing with existing SPEN IT corporate network and Real Time System.

        It should be mentioned that this document is the first deliverable of LV Engine as specified in Project Direction document.

    2. **SPEN Network Overview:** This document is a complementary document to the technical specifications document, and provides more detailed knowledge about SPEN networks design and operation philosophy for High Voltage and Low Voltage networks. This document was produced to provide all the tenders, who have not been exposed to the a UK Distribution Network Operator (DNO), he opportunity to gain UK grid knowledge that can inform their tender response.

    3. **LV Engine trial site selection:** This document describes the methodology and criteria used for shortlisting the trial sites which can be suitable for each LV Engine scheme. This report reflects the outcomes of all the engagement with districts design and operation engineers within SPD and SPM license areas.

- **Literature review and desktop study reports:** In order to inform the development of tendering technical documents and also produce background knowledge on latest development in SST, relevant standards and low voltage DC technical requirements literature reviews and desktop studies conducted by our project partners. The outcomes of those studies are 6 reports as listed below:

    1. **Hardware and control software components of Smart Transformer** – This report provides a review on the potential topologies of Solid State Transformer, the internal control software and the potential specifications of the device. In addition, the pros and cons of each topology were compared and reliability of the device was discussed.

    2. **Tests requirements** – This report review the existing standards and grid codes which need to be considered in test types of the Solid State Transformer.

    3. **Active harmonic filter and resonance damping response** – This report reviews and provides system studies to demonstrate the functionality of a Solid State Transformer as an active harmonic filter and resonance damper.

    4. **Protection and earthing requirements for LV Engine schemes** – This report reviews the challenges for protection and earthing of the LV network where Solid State

Transformer is used. Extensive desktop studies were carried out to demonstrate the requirement under fault conditions.

5. **Technical recommendations on LV DC schemes** – This report reviews the development in LV DC networks and provide recommendations on the requirement for trial of LV DC networks.
6. **Overview of existing LV DC standards** – This report focuses on the existing standards and engineering recommendations that need to be complied with for the design and implementation of LVDC networks.

- **Identified candidate for LV DC network trial [confidential]:** Trial of LV DC networks is one of the innovative aspects of LV Engine project and our delivery team made contacts with potential DC customers who can be our partner for trial of LV DC networks. The main contacts were as follows:

    1. **EV charger manufacturers**: Our team had teleconferences and face to face meetings with some of the EV charger manufacturers including Tritium and Siemens. They confirmed that they are developing new EV charger unites which directly supplied by DC network. The main driver for them was to reduce the weight, volume and cost of EV chargers while the efficiency improves. We continue engaging with EV charger manufacturers to partner the trial of their technology by providing them with LV DC networks.
    2. **Falkirk Council:** As part of Falkirk Stadium Hub, the parking area around Falkirk will be fitted with new low carbon technologies including EV chargers, solar panels, energy storage systems etc. After discussions with Falkirk council it was agreed to reserve an adequate size land within Falkirk Stadium Hub for the Smart Transformer installation.
    3. **Smart Garden Glasgow**: University of Strathclyde is seeking funding for an innovative project aiming to create a smart and future ready environment for students by deploying different low carbon technologies (EV chargers, Street lighting etc) which are primarily supplied by LVDC. SPEN and University of Strathclyde have agreed on collaboration for trial of Smart Transformer in this Smart Garden as an additional point of supply providing LV DC supply point, if University of Strathclyde is successful in securing the funding for the Smart Garden project.

2.4.3 Progress under Work package 2 – Partner selection and procurement

Activities in this work package started in September 2018 and following progress has been made within this reporting period:

- The delivery team conducted pre-qualification questionnaire (PQQ) to identify the capable project partners who can join the project as the SST manufacturing partner and Intelligent Control System partner. The capable manufacturers and suppliers have now been shortlisted.

- The delivery team developed the procurement strategy, documentations and requirements for selection of the Solid State Project Partners. The invitation to tender (ITT) has been recently issued in the end of this reporting period.

The following outcomes to be recognised from the work carried out in this work package to date:

- We have [redacted] capable manufacturers who have passed the PQQ for the SST and, at the time of writing, are currently preparing tenders in response to the ITT released in January. These suppliers have previously carried out R&D in the area of power electronics for grid applications.
- We aim to de-risk the project delivery by considering more than one supplier to deliver the full work (to avoid dependency on a single supplier). We will explore this option upon receiving all supplier tenders and determine the best course of action for the project.
- We have [redacted] suppliers who have passed the PQQ for the SCS tender which we will release in the next reporting period.
- We identified some dependencies upon the SST tender which would not impact the project programme and plan to postpone the SCS tender until the relevant information is made available. We foresee no impact on the project delivery in either delay or costs.

The following manufacturers/suppliers have been shortlisted for the SST and SCS tendering:

Table 4: Prospective LV Engine Suppliers [REDACTED]

2.4.4 Work Package 7 - Dissemination

Project team has conducted internal and external dissemination activities, a summary of these activities are as follows:

Internal dissemination – In order to raise awareness within SPEN, several LV Engine introduction meetings were organised with SPEN in SP Distribution and SP Manweb license and in different districts.

Project website[1] – LV Engine project website was constructed and uploaded to SPEN innovation website. LV Engine website provides a summary of projects, its aims and objectives and a platform for sharing the data and project reports for public access.

Conference papers – Technical papers have been submitted and accepted to different relevant internal conferences including Powertech 2019 and CIRED 2019.

2.5 Outlook to the Next Reporting Period

The following progress is planned in the next reporting period under different work packages:

Work Package 2 – Partner Selection Procurement

[1] https://www.spenergynetworks.co.uk/pages/lv_engine.aspx

- To conduct the tender evaluation and contract award for SST Manufacturing Partner
- To conduct the procurement process for selection of Intelligent Control System

Work Package 3 – Design and Manufacturing of SST

- To review and update the SST technical specification with the SST manufacturing partner where required
- To finalise the detailed design of Solid State Transformer in collaboration with SST manufacturing partner
- To conduct the life cycle assessment of the Solid State Transformer

Work Package 4 – Network Integration testing

- Prepare the network integration testing specifications and test procedure

Work Package 7 – Dissemination

- Organise and hold a UK DNO workshop to share the lessons learnt and obtain feedback on technical specifications of solid state transformer and functional specification of control strategy
- Organise and hold a seminar for wider audiences (Academic, industry etc) to raise awareness about LV Engine progress and technology development
- Prepare technical papers for relevant conferences and articles
- Share lessons learnt in LCNI conference or any other relevant event
- Continue to share the project progress and lessons learnt with stakeholders within SPEN

The main deliverable for the next reporting period is the design of SST by the manufacturer and life cycle assessment report which is planned to be issued by 22/12/2019.

3 Consistency with full submission

At this stage of the project delivery, LV Engine remains consistent with the original Full Project Submission with regards to project schedule, budget, and programme. In terms of resource allocation, we have had one change to the key members within SPEN, however business succession planning ensured a seamless handover.

4 Risk Management [REDACTED]

5 Project deliverables

The project deliverables set out in the Project Direction links with the Project Milestones and the identified targets directly. This project deliverables can be used to check the progress of the project delivery and position the progress against the original proposal.

Within the reporting period, we have successfully delivered our first project deliverable "Technical specification of SST and functional specification of the LV Engine schemes', including relevant control algorithms" on time. This document has been submitted to Ofgem, via email to our project contact.

The document has all evidence as stated in the project direction; moreover, it forms a robust and detailed specification which is a product of thorough collaboration between the project delivery team, our supporting academic and consultancy parties and the wider SPEN business.

In addition to the project deliverable, we have also produced several supporting academic reports which have been a product of research into the field of LVDC and an industrial document which defines the methodology used to identify suitable trial sites for deploying LV Engine schemes.

Table 5: LV Engine project deliverables Table 5 shows a summary of the LV Engine deliverables defined in the Project Direction.

Table 5: LV Engine project deliverables

Reference	Project Deliverable	Deadline	Comment
1	Technical specification of SST and functional specification of the LV Engine schemes' including relevant control algorithms	10/12/2018	**Completed** - This deliverable is now completed and submitted to Ofgem within deadline
2	Detailed technical design of SST by the manufacturer and life cycle assessment	22/12/2019	**Not started** – This deliverable will be prepared in collaboration with SST manufacturing partner
3	Manufacture SSTs for LV Engine schemes	11/01/2021	**Not started** – This deliverable will be prepared in collaboration with SST manufacturing partner
4	Complete network integration tests	28/09/2020	**Not started** – This deliverable will be prepared in collaboration with Network Integration Test Facility provider
5	Establish the system architecture of LV Engine schemes	20/06/2021	**In Progress** – This deliverable will be prepared in collaboration with Intelligent and control system partner and internal SPEN IT & real-time system team
6	Demonstrate the functionalities of SST	20/06/2022	**Not Started**
7	Best operational practices of	07/11/2022	**Not Started**

	SSTs		
8	Identify a trial site for replicating LV Engine solution within UK Power Networks	26/09/2022	**Not Started**
N/A	Comply with knowledge transfer requirements of the Governance Document.	End of project	**Not Started**

SPEN confirm that adequate resources for project management and project delivery have been planned for upcoming deliverables. Resources are available internally in different parts of SPEN organisation and also additional supports will be provided by our project partners.

6 Learning Outcomes

During the reporting period there have been many learning outcomes due to the technical design phase being completed (Work Package 1). Furthermore, we anticipate key learning related to commercial viability and procurement during the forthcoming period as we enter the tender process for our project partners.

Table 8: Learning outcomes

Learning	Description
Source Fault Energy	With the development of the ST, the subsequent downstream fault levels will be reduced in accordance with a multiple of the ST rating to adequately protect the power electronic components of the unit. As a result the project looked to define a range of operation which could adequately interface with incumbent LV protection devices. A range of approaches were considered from academic analysis of typical networks through to fuse link I^2t characteristics.
Project set up	Creation of project initiation document, especially in multi-disciplinary and large scale projects (such as those funded through NIC funding mechanism) can facilitate a robust project between different parties and stakeholders describing the roles and responsibilities, communication strategies, partners scope of works and deliverables.
Manufacturer engagement	Early manufacture engagement is very important when development of a new technologies is intended. This allowed identifying the manufacturing challenges and project risks and clarify SPEN expectation from the project at early stage before procurement
Manufacturer engagement	In order to ensure the LV Engine advances the technology and develop practical solutions that can be adopted for business as usual practices and widely roll out in the network and project fund has been efficiently used for UK Electricity customers. SPEN considered trial of two SST topologies in LV Engine project: • ***Topology 1*** - Topology using a conventional low frequency 50Hz (LF) transformer –This topology uses power electronics devices at the secondary side of conventional LF transformers (11kV/0.4kV). • ***Topology 2*** - Topology using a High Frequency (HF) transformers – Using HF Transformers and power electronics may allow a modular and compact design while delivering the LV Engine Core Functionalities. SPEN see the benefits and applications that both technologies can offer in terms of applications in the existing substations and future developments.
Manufacturer engagement and market research	The experience of deploying Silicon Carbide (Sic) power electronic products is not extensive and most of manufacturers are not confident to deploy them in new projects. Lack of experience in using Sic products may fall into switching control, reliability, performance in different environmental conditions and also supply chain.
LV DC customers engagement	It appeared that some of the EV charger manufacturers propose to use an LV DC networks for supplying their DC chargers as this can reduce the EV charger's volume, weight and cost by eliminating an extra conversation stage from AC to DC. The efficiency of the EV charger units also increases if they are supplied by DC.

	The exact quantified benefits were not shared with LV Engine team due to confidentialities.
Service Conditions	The traditional secondary transformer is specified to facilitate both outdoor and indoor installation. In order to facilitate an outdoor installation during the trial, the project would be imposing onerous restriction on the first manufacture of these units. A project direction to install within existing indoor substations, which was in the first instance realised by overlaying the 11kV switchgear asset modernisation team. Sites with legacy switchgear which took a larger footprint compared with the more modern ring main unit, this provides greater flexibility based on the final footprint of the ST. In addition, the IP rating was developed accordingly.
Power flow control	The Load Sharing function of the SCS shall be capable of determining active power, reactive power, voltage angle and voltage magnitude set points for SSTs. There are dependencies between the aforementioned parameters, therefore changing one parameter may have impact on requirements of the other parameters. It is crucial when an SST operates in a Meshed Network, the Load Sharing and Voltage Control functionalities shall operate coincidently.
Control strategy	The information about LV network topology and electrical parameters of LV circuits are usually not available. The control strategy within LV Engine need to use metering data and relying upon as little the field data collection. In order to provide this functionality, the SCS shall be capable of using AI, machine learning or state estimation techniques together with recent and historic Monitored Data.
EV Interface	EV Charging remains in it's infancy at this time as a technology, and as such there are a number of non-standard interfaces with respect supply voltages. In defining future supplies to EV chargers, a 'cover-all' approach was developed with a band specified for the output of the ST.
SMETS2 Rollout	In order to provide an optimum voltage control strategy for the LV network, it is required to monitor the voltage at different locations along the LV circuits. The monitored voltage data ultimately needs to be received by the Smart Control System in the secondary substation in line with the requirements defined in above. Project direction will continue to focus on the first of the two following mechanisms, the latter retained as a contingency to the SMETS roll out. 1. *Deploying voltage monitoring capability of new smart meter generation (SMETS2) – if possible, this method is expected to be a desirable approach as it is in line with the likely network operation strategy in future which considers the smart meter data. However, the availability and latency of the smart meter data to the network operator, at least within LV Engine project life-time, is still being examined by the LV Engine team* 2. *Deploying independent voltage monitoring equipment at customer premises or link boxes – This can be an alternative approach to Method 1 if the use of smart meter data is proven to be infeasible during LV Engine project. There are commercially available voltage monitoring kits with the capability of communication through 3G/4G networks.*

DC Energy Metering	The ELEXON metering Codes of Practice are entirely silent to DC energy metering (DEM), however the following guiding principles are set out within the Balancing and Settlement Code: • *For the purposes of the Code, the quantities of Active Energy and, where relevant, Reactive Energy Exported or Imported by any Party at a Boundary Point or flowing between Systems at a Systems Connection Point shall be measured and recorded through Metering Equipment installed, commissioned, operated and maintained and otherwise provided for as set out in the BSC.* • *There is no requirement to install, commission, operate and maintain Metering Equipment or measure and record a flow of Active Energy or Reactive Energy through Metering Equipment in respect of any Import relating to an Unmetered Supply; and nothing in this applies in relation to an Unmetered Supply (or any Metering System in respect of an Unmetered Supply).* DEM is still not widely available for DC customers. However, there are already some proprietary products which are not standardised but they have been used for specific applications such as solar PV systems, industrial DC control systems and data centres.
AC/DC Earth Separation	To minimise potential corrosion issues and the level of DC stray currents, the project direction has been developed such that all the metallic surfaces of scheme 4 and scheme 5 with DC outputs to be connected to a functional/structural earthing and not directly to the earth point. The functional earthing conductor is connected to the substation protective earthing conductor through diodes or a combined diode/capacitor solution. This will ensure all the metallic parts are connected to the earth only during pole-to-earth faults, and DC stray currents or DC current leakages flow in the metallic surfaces under normal operation.
Failure modes	Although substation equipment is extremely reliable and the probability of a disruptive failure due to internal arcing is very low, this does have implications for both the design and location of substations, designers are aware that considerable internal overpressure and fireball may be produced when this condition occurs. With respect HV and LV power electronic converters, these are typically housed in a metal-clad enclosure, which is designed to ensure the safety of adjacent personnel. The enclosure will maintain its integrity and contain the arc products in the event of a disruptive failure of the power electronic converters.
Operational Sites	As part of pre-privatisation network development, within some parts of the networks, a number of future proofed substations were established, either as a shell substation or with only LV assets installed. These sites provided potential deployment with minimal interface works to the existing network.

7 Business Case Update

We are not aware of any developments that have taken place since the issue of the Project Direction that affect the business case for the Project.

8 Bank Account [REDACTED]

A dedicated bank account was made available by SPD and SPM to act as the Project Bank Account in to which NGET, as the GBSO, deposited the appropriate project funds through 12 monthly transfers in the Regulatory Year such that the total amount transferred equals the net amount set out in the Funding Direction.

Table 6: LV Engine cost breakdown to date

9 Intellectual Property Rights (IPR) [REDACTED]

10 Other

[This section is currently intentionally blank]

11 Accuracy Assurance Statement

I therefore confirm that processes in place and steps taken to prepare the PPR are sufficiently robust and that the information provided is accurate and complete.

Signature: _____

Name (Print): _____

Title: _____

Date: _____

Signature: _____

Name (Print): _____

Title: _____

Date: _____