Future Networks
4th / May / 2018

Flexible Networks Second Tier Reward Submission.

SP ENERGY NETWORKS

Executive Summary

This document constitutes the application by SP Energy Networks (SPEN) for the Second Tier Reward (STR) for the Flexible Networks for a Low Carbon Future project (Flexible Networks). This project is a Low Carbon Network Fund Tier 2 project. SPEN is applying for the maximum reward available which is limited to the project value of £5.28M.

Flexible Networks has shown exceptional performance in both Criteria A and C. This is evidenced by:

- Significant carbon savings and capacity release for LV connected generation. The Ruabon trial network demonstrated that up to 90% more embedded generation could be connected on the LV network than previously thought. This greatly exceeded the capacity release target of 20%.
- Substantial financial benefits due to innovative techniques with a much lower £/MVA cost of capacity release than those estimated for conventional reinforcements (less than 50%, significantly more so in some cases). These are provided as a flexible toolbox from which to select cost-effective interventions that more holistically address a specific issue and network and can be rapidly deployed.
- For a relatively small LCNF Tier 2 project with a total final value of £5.28M including LCNF funding of £2.85m, a significant network capacity release (20%+) was achieved at all three trial sites and £6.2m conventional reinforcement in the DPCR5 plan for east Fife was deferred. A substantial amount of learning was generated that is widely applicable to industry.
- Learning on LV embedded generation capacity release, voltage optimisation, network security and enhanced thermal ratings for example has major implications for the industry. Flexible Networks has supported the evolution of the industry through provision of recommendations to key industry standards and initiatives (P2/6 review, voltage harmonisation working group).
- SPEN is the first licensee to return innovation funding to the customer through efficiencies in technology, testing and contingency costs, representing a total of £0.75M reduction in LCNF funding returned to electricity customers. This did not impact project success and all the SDRC were still met or exceeded. This demonstrates exceptional value for money.
- Project outcomes are very relevant for SPEN and other DNOs and technologies and techniques trialled are now business ready. This is reflected in SPEN RIIO-ED1 business plans and activities. There has been a strong level of interest and engagement from other DNOs and a number of DNOs and universities have approached SPEN to obtain modelling tools and other learning generated from Flexible Networks. The holistic, DNO-led approach makes the learning highly accessible to other DNOs and deliverables have been focussed on practical tools and guidance for other DNOs to implement into business as usual. The data sets compiled for this project have been made widely available via the SPEN website to organisations and individuals to undertake further research.

1 Description of project and summary of evidence aligned with each Reward Criterion

1.1 Introduction

Flexible Networks for a Low Carbon Future is a Low Carbon Network Fund (LCNF) Tier 2 project. It was successfully bid to Ofgem by SP Energy Networks (SPEN) in 2011 and began in January 2012 and was finalised in October 2015. The University of Strathclyde, TNEI Services Limited, Building Research Establishment and Nortech were involved as key partners in project delivery.

This project has provided network operators with economic, DNO-led solutions to increase and enhance the capability of the networks. These are capable of being quickly implemented and help to ensure that the networks do not impede the transition to a low carbon future. Learning outcomes from Flexible Networks inform intelligent future network change management.

It is recognised that there are some inherent conflicts between the ideal design, operation and management of a distribution network. A significant advantage to applying a more holistic approach, as developed through Flexible Networks is that it facilitates interaction between business functions, planning, operations and asset management, to optimise the tools and techniques developed.

The objectives of the various work packages in Flexible Networks were as follows;

- Develop an enhanced network monitoring methodology and based on this network data, develop and integrate improved DNO planning and operations tools and practices that are optimised for future low carbon networks and use of the innovative techniques being trialled.
- Trial novel technology measures for improved performance of the network such as dynamic thermal ratings of assets, voltage optimisation, and flexible network control.
- Identify the measures by which material improvements in the cost-effectiveness of accommodation of future energy needs can best be demonstrated.
- Develop an investment and future roll-out plan where appropriate cost-benefit exists.
- Disseminate learning to key stakeholders such as customers and other DNOs to ensure sustainable user adoption, through future technical and regulatory policy changes for example.

These objectives were all successfully achieved by the project. In addition to this, Ofgem was satisfied that Flexible Networks met all the Successful Delivery Reward Criteria (SDRC) that were specified in the original project bid and as a result, awarded the full SDRC amount of £515k to SPEN.

For this Second Tier Reward (STR) application, a summary of how the evidence put forward for Flexible Networks aligns with each Reward Criterion is provided below. Flexible Networks has shown exceptional performance in two of the three (STR) criteria as detailed below. The other criterion is not applicable.

Criterion	Summary
A	*Accelerated the development of a low carbon energy sector and has delivered net financial benefits to future and/or existing customers.*
	The Flexible Networks techniques tested for the Ruabon trial network demonstrated that up to 90% more embedded generation could be connected on the LV network than previously thought. This should significantly support development of the low carbon energy sector. The techniques developed can be rapidly deployed, reducing the impact of network interventions on connection of low carbon technology. Flexible Networks has delivered significant financial benefits through: • Deferment of £6.2M of investment originally planned during DPCR5 in east Fife • Developing innovative techniques with a much lower £/MVA cost of capacity release than those estimated for conventional reinforcements (less than 50%, significantly more so in some cases). • Providing a flexible toolbox from which to select cost-effective interventions that address a specific issue and network. • Maximising the value of IP through development of software tools as part of partner contribution and other modelling tools that were shared with other DNOs to maximise learning and more rapidly facilitate rollout into business as usual.
	Value for money provided to distribution customers in the delivery of the Project
	For a relatively small LCNF Tier 2 project with a total final value of £5.28M, (£2.85M LCNF funding) a significant network capacity release (20%+) was achieved at all three trial sites and a substantial amount of learning was generated. Learning on voltage optimisation and enhanced thermal ratings for example has major implications for the industry. SPEN is the first licensee to return innovation funding to the customer through efficiencies in technology, testing and contingency costs, representing a total of £0.75M LCNF funding returned to electricity customers. This did not impact project success and all the SDRC were still met or exceeded. This demonstrates exceptional value for money. Substantial efforts were undertaken to enhance the projects quality. An example of this is the Data Analytics study, outcomes of which provide significant guidance to future planning and operation based on higher volumes of monitoring data and thus, network intelligence.
	Sharing of knowledge amongst all DNOs
	Learning outcomes from Flexible Networks have informed changes to network planning and operations policy and practices within SPEN to support transition to business as usual. These have been disseminated widely to industry. To date, there has been a strong level of interest and engagement from other DNOs and a number of DNOs and universities have approached SPEN to obtain modelling tools and other learning generated from Flexible Networks. The holistic, DNO-led approach makes the learning highly accessible to other DNOs. Flexible Networks has supported the evolution of the industry through provision of recommendations to key industry standards and initiatives (P2/6 review, ENA working group on voltage harmonisation). The data sets compiled for this project have been made widely available via the SPEN website to organisations and individuals to undertake further research. Various partners in this project such as TNEI and the University of Strathclyde continue to extensively draw on their experiences and knowledge gained on the project when working on innovation projects for other DNO's across GB.

	Other Benefits
	A data analytics study, which was not included in the original project scope, was added later due to identification of the additional value that could be provided from running such a pilot study in collaboration with the network monitoring workstream. This has helped to advance the learning outcomes from network monitoring and continues to inform the joint data projects being developed by the ENA working group supporting joint data analytics projects amongst DNOs.
C	*To undertake exceptional effort to ensure the projects exceeds the expected delivery outcomes and the learning from the project is maximised for the good of all DNO customers*
	This project delivered outcomes which have significant implications for industry. For example, the embedded generation capacity release at LV through improved PV characterisation and voltage optimisation. Learning on voltage optimisation is being applied in a dedicated voltage harmonization working group. Given the relatively small LCNF Tier 2 project size with a final total value of £5.28M, the capacity release and learning generated for all technologies and techniques is exceptional. Exceptional efforts to maximise learning for all DNO customers can be demonstrated through the approach to dissemination and involvement in ongoing industry wide initiatives. There has been a lot of interest in outcomes and the data sets compiled for this project have been made freely available for others to use. Deliverables have been focussed on practical tools and guidance for other DNOs to implement into business as usual. By having a collaborative partnership arrangement, where all project partners contributed in kind based on their unique capabilities, resulted in improved outcomes and dissemination of project findings to the wider industry. There was significant cross-working between both SPEN entities, SPM and SPD. In order to maximise learning across licence areas.

	Tier 2 Project name	Licensee	Project summary (2 sentences)	Tier 2 funding £k*	Licensee compulsory contribution £k*	Other contributions £k*	Link to Close-Down Report
1	Flexible Networks for a Low Carbon Future	Scottish Power Distribution (SPD)	Flexible Networks delivered all six successful delivery reward criteria, providing a robust framework within which to select and deploy one or a number of innovative techniques collaboratively to techno-economically release incremental network headroom.	£2850	£2301	£174	Section 2

2 Descriptions and evidence of project compliance with reward criteria

2.1 Reward Criterion A

2.1.1 Aspects of the Carbon Plan and/ or Clean Growth Strategy that have been facilitated

Flexible Networks has delivered a faster, more cost-effective, holistic network management approach that achieves carbon savings through;

- Facilitating higher volumes of low carbon generation and faster connection.
- Facilitating additional demand from the transition to EVs and heat pumps.

The innovative technologies tested in Flexible Networks were trialled in three network locations across the SPD and SPM licence areas. These were selected during the development of the project scope at bidding stage. Evidence of how these show exceptional contribution to the Carbon Plan and/or Clean Growth Strategy is presented below.

Ruabon

The Ruabon distribution network is primarily residential, and many of the domestic properties are local authority-owned. The combination of managing a large housing stock and having social responsibilities in terms of fuel poverty and environmental sustainability led the local council to take a proactive approach in the management of their tenants energy use. As part of their strategy, the council installed solar PV on the roofs of many of their properties. This led to the connection of large “clusters” of PV installations to the local distribution network, sufficient to cause significant voltage rise and therefore potentially affecting the power quality of other, non-PV connected, customers. Restrictions were placed on the amount of PV generation that could be accepted on to each of the LV distributors until the impact could be further understood. The existing generation capacity headroom available in the Ruabon network is limited by the upper voltage statutory limit at LV being exceeded under reverse power flow conditions. Analysis of the baseline generation headroom capacity using existing business as usual techniques indicated that there was no generation capacity available on the Ruabon network.

Based on the detailed secondary substation and LV feeder monitoring data, and development and validation of modelling techniques to improve characterisation of the impact of PV on the LV network, an increase in generation capacity headroom of 38% was achieved [Flexible Networks Closedown Report see page 24]. The application of network voltage optimisation (reduced system voltage) allows further significant PV generation volumes (typically 90% for a 2% voltage reduction) to connect [Flexible Networks Closedown Report see page 30].

This is substantially above the original target of 20% set in the SDRC and illustrates exceptional contribution to the Carbon Plan. This significant increase in low carbon generation capacity supports the further deployment of low carbon generation at LV and provides carbon savings by reducing generation that may otherwise be required from

fossil fuelled generation. The innovative modelling technique trialled and validated is now reflected in the SPEN policy document “ESDD-01-012 Connections for Multiple G83 – Inverter Connected Generation Policy in the SPD Area” . We are using this to facilitate greater PV clusters; both retrofit by social housing landlords, and in new developments by private developers, in Fife and Glasgow for example.

St Andrews and Whitchurch
For both the St Andrews and Whitchurch network trial sites, an increase of demand capacity of around 20% was achieved which is consistent with the SDRC. The exceptional aspect is that the techniques that were developed and trialled in Flexible Networks such as enhanced asset ratings and flexible network control measures can be deployed more easily and quicker than was thought possible at project inception. For flexible network control, this is due to using a seasonal rather than a real-time approach that was initially envisioned. For enhanced transformer ratings, this is due to the straightforward nature of the analysis and the avoidance of any additional automation requirements.

This allows an accelerated and more cost-effective connection of low carbon technologies such as heat pumps or electric vehicles.

2.1.2 Releasing network capacity

The focus and strength of Flexible Networks has been on the total release of capacity from collaboration of innovative technologies rather than capacity release from individual technologies. This provides a flexible toolbox to network planners and operators from which to select the interventions which best address a specific issue and network. It has generated significant learning on how to maximise the holistic capacity from deployment of several technologies and verifying that there is no double counting.

Capacity release from each trial site and for each technology trialled is given below. St Andrews and Whitchurch achieved a capacity release consistent with the SDRC. However, Ruabon achieved a significantly greater capacity release than the SDRC.

It can be seen that enhanced primary transformer ratings provide significant additional capacity at St Andrews but less so at Whitchurch due to differences in ambient temperature and thermal loading curves. For flexible network control, more capacity is released at Whitchurch than St Andrews due to varying network topology.

All technologies have either been implemented already or will be implemented as required due to load increase at these sites. RIIO-ED1 includes plans to deploy these technologies at other specific sites.

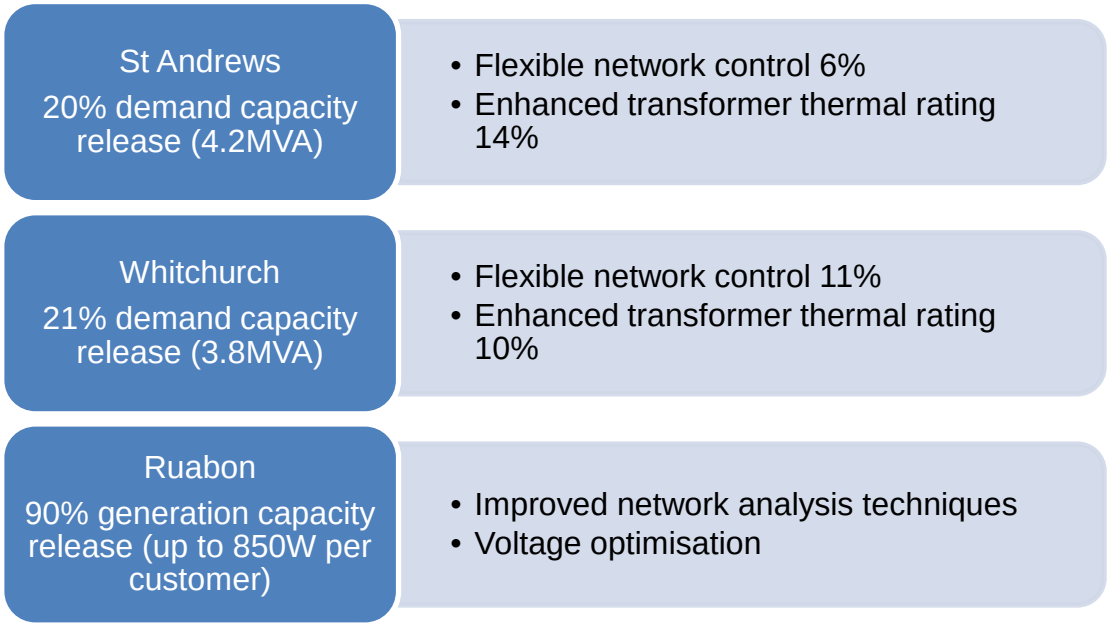


Figure 2-1 Flexible Networks capacity release at three trial sites

2.1.3 Delivering Financial Benefits

Most of the innovative technologies trialled in Flexible Networks represent significant value for money for customers. This can be evidenced by the future method costs for each trialled technology where costs are presented in £ and £/MVA headroom capacity added in Table 2 1 [Flexible Networks Closedown Report, see Section 10 page 45].

Table 2-1: Future Method Costs for Flexible Networks Innovations

Innovation	Future Method Cost (Capital) (£k)	Future Method Cost (£k/MVA)
Enhanced network monitoring	307*	78‡
Enhanced primary transformer thermal rating (based on 2 transformer group)	30	15
33kV Overhead line RTTR system (based on 4 circuit monitoring locations)	90	45
Flexible network control	188	94

Integration of voltage regulators	122	87
Energy efficiency	73	842
Voltage optimisation	31	107

*Total future method cost is for approximately 100 substation sites

‡ Per substation

Financial benefits are assessed on a site by site basis for the three network trial sites in Flexible Networks.

St Andrews
At St Andrews, the lowest cost traditional method would involve reinforcement works including two new 33/11kV transformers to be installed, new 11kV switchgear, 17km of 33 kV overhead line and extensive cable works to reconfigure the 11kV network, providing an additional 21MVA capacity. Due to consents matters across the various land owners, experience has shown that this project would take approximately 3 years to implement and is budgeted at a total cost of circa £6,200k. Our analysis indicates a future method cost for a similar site would be approximately £646k and would provide an additional 4.2MVA. This represents a unit cost estimate of £295k/MVA for traditional method versus £154k/MVA for the future method [Flexible Networks Closedown Report see page 38].

Whitchurch
At Whitchurch, the lowest cost traditional methods would involve reinforcement works and the construction of a green-field primary substation. This would include a 33kV switchboard, one 33/11kV transformer, 11kV switchboard and connecting 33kV and 11kV cables interconnected into the existing networks, providing an additional 10MVA of capacity. This would take approximately 2 years to complete and would be budgeted at £3,100k. Our calculations indicate a future method cost for a similar site would be approximately £612k and would provide an additional 3.8MVA. This represents a unit cost estimate of £310k/MVA for traditional method versus £161k/MVA for the future method [Flexible Networks Closedown Report see page 38].

Ruabon
At Ruabon, traditional methods would require a number of additional 11kV/LV substations to be installed across the network. It can be particularly difficult to establish these substations in mature housing developments where spare land is generally unavailable. Extensive cable works would also be required to integrate these new substations onto the network. This would take approximately 1-2 years to complete and is budgeted at a minimum of £1,200k. For a site similar to Ruabon, the future method cost including monitoring and voltage optimisation would be approximately £337k to allow typically up to 850W per customer on a secondary substation basis compared to 336W per customer currently [Flexible Networks Closedown Report see page 38].

A cost comparison between traditional and future methods for each trial site are presented in Table 2-2 and Table 2-3 [Flexible Networks Closedown Report see Section 8, page 39].

Table 2-2: Comparison between Traditional and Future Methods Costs at trial sites

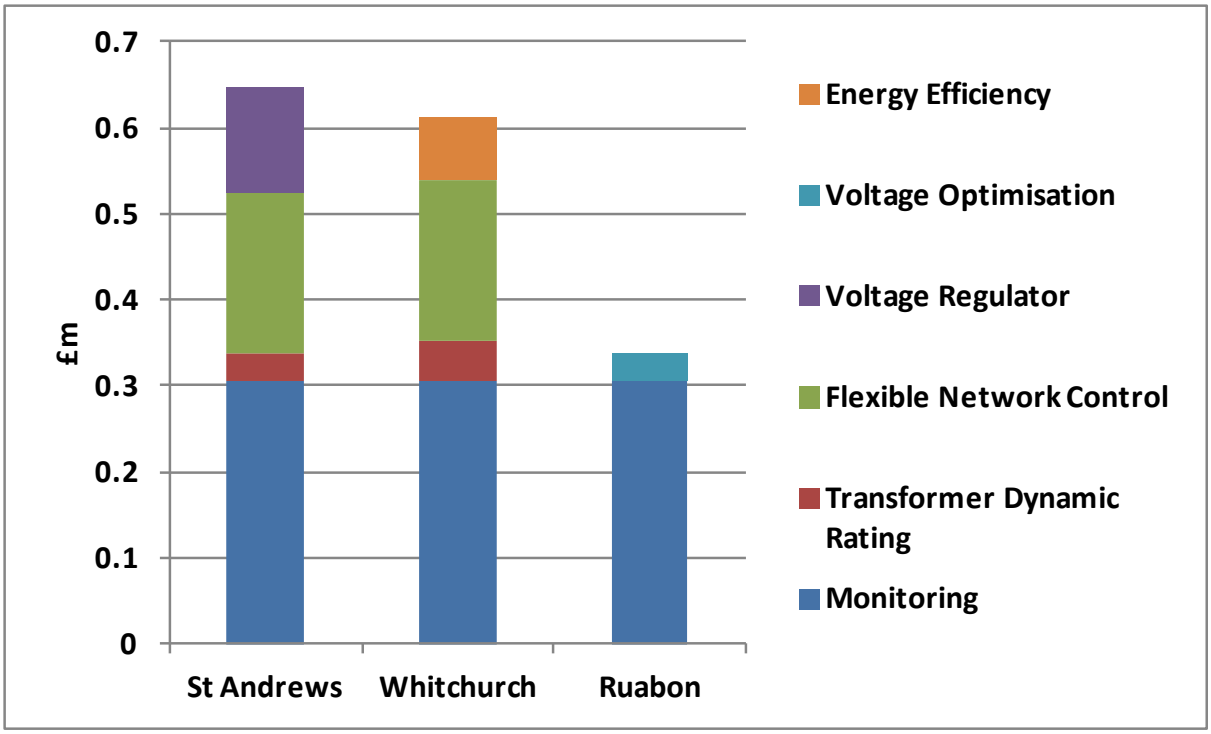
Trial Site	Traditional Method Cost (£k/MVA)	Future Method Cost (£k/MVA)
St Andrews	295	154
Whitchurch	310	161

Table 2-3: Comparison between Traditional and Future Methods Costs at trial sites

Trial Site	Traditional Method Cost (£k)	Future Method Cost (£k)
Ruabon	1200	397

Figure 2-2 summarises the overall future method cost along with the contributions from each of the technologies at each network trial site.

Figure 2-2: Future Method cost of Flexible Networks technologies at three trial sites



Summary
Results of the project demonstrated that significant capacity can be released for low cost using easily applied techniques including: -

- Enhanced transformer rating
- Flexible network control
- Voltage optimisation
- Improved network characterisation (from secondary substation monitoring)

2.1.3.1 Maximising value of intellectual property

A number of software models were developed in the power system software IPSA (background IP) as part of TNEI's partner contribution in kind. These comprised an asset dynamic thermal ratings model, a reliability analysis tool, a ZIP model, rapid input of network load profiles on a half-hourly or hourly basis, a series voltage regulator model, PV generation profile templates and a script for conversion of GIS data to IPSA models. These were made available free to all users of IPSA, most GB DNOs are IPSA users. This partnering strategy helped to maximise the value of IP.

A number of modelling tools were produced for Flexible Networks as foreground IP to facilitate learning and dissemination to other DNOs and more rapidly facilitate rollout into business as usual, providing value for money. An enhanced transformer thermal

rating software tool was jointly developed by TNEI and the University of Strathclyde. An application guide was also produced alongside the software tool.

2.1.4 Rollout across the DNO's system and across GB

Learning outcomes from Flexible Networks have informed material changes to network strategy, planning and operational policy and practices within SPEN as the innovative technologies transition into business as usual. A number of elements of the project were adopted into ED1 proposals and learning from the project is already being transferred into business as usual to become future standard policy as described below. Already, a substation capital investment in the order of £100k was avoided just 3 months after project completion. There is also substantial applicability to other DNOs.

2.1.4.1 Enhanced Network Monitoring

Load forecasting and risk characterisation

The load forecasting and risk characterisation tool is integrated into the existing network planning tool for annual primary network review in SPEN.

Early learning outcomes for Flexible Networks were included in development of the SPEN RIIO-ED1 Network Monitoring Strategy. The significant learning that was generated on monitoring procurement, installation and analysis continues to inform network monitoring strategy and policy going forward.

Improved planning tools

Learning outcomes from the characterisation of PV on the LV network led to recommendations on voltage and PV connection policy and practice changes. These have been adopted by the business and thus, have already been able to release significant generation capacity on the LV network. This is reflected in the policy document "ESDD-01-012 Connections for Multiple G83 – Inverter Connected Generation Policy in the SPD Area" for example.

The data analytics trial in conjunction with IBM has been a first step in data analytics and the technique is not far away from business as usual adoption. Learning from this trial has informed the successful NIA project Network Constraint Early Warning System (NCEWS) and business as usual deployment of an enterprise service bus.

2.1.4.2 Dynamic thermal ratings

Enhanced transformer rating

Beyond the three network trial sites, enhanced transformer thermal ratings will be implemented on a further 10 primary transformers in the RIIO-ED1 period. Health assessments and thermal monitoring are already installed on a number of primary transformers.

Real time thermal ratings (RTTR) were explored in the Northern Powergrid LCNF project Customer Led Network Revolution and require an investment in technology to implement. By comparison, enhanced thermal ratings developed under Flexible

Networks provides a much more cost-effective and business ready approach to achieve substantial capacity release at primary transformers.

Overhead line RTTR

Overhead line RTTR will be investigated as an option for increasing capacity on the 132kV 'PK' route from Barlaston to Crewe in North Wales and on a number of transmission routes in SPT. Overhead line RTTR is also relevant to SPEN's transmission licence through our wider work on this topic with NGET and SSE transmission and Flexible Networks has informed business strategy on this.

This early deployment of RTTR has generated much valuable learning on the issues associated with the installation and maintenance of weather stations, and the potential benefits of RTTR with forecasting in comparison to RTTR alone.

2.1.4.3 Flexible network control

One scheme at Langside in SPD is included in the business plan and we continue to review our reinforcement schemes to identify other schemes which are suitable for the deployment of flexible network control. Increasing focus on reducing customer interruptions and customer minutes lost using greater network automation will benefit significantly from learning on flexible network control.

2.1.4.4 Voltage regulators

An Internal Working Group was set up to get 11kV in-line voltage regulators into business as usual. This has helped to significantly accelerate learning outcomes from Flexible Networks into standard business practice. A scheme to resolve a network voltage issue at RAF Shawbury has been instigated in SPM, using the learning from the project's standardisation of the use of voltage regulators.

2.1.4.5 Voltage optimization

The application of permanent voltage reductions (reduced voltage set point) on the 11kV network is under consideration within SPEN following dissemination of learning outcomes within the business. This will enable significantly increased volumes of generation to connect at 11kV and/or LV in future. This has significantly implications for industry and is being disseminated through an ENA voltage harmonisation working group.

A new standard voltage set-point setting has been applied to Ruabon supported by a software change to the Remote Terminal Unit (RTU). In Glan-yr-afon, Wales, the application of a new voltage set-point is being progressed.

2.1.4.6 Applicability to other GB DNOs

With increasing low carbon technology uptake across the UK, it is forecasted that the technologies and techniques involved in this project will be required to cost-effectively relieve network stress by releasing additional network capacity.

All techniques from Flexible Networks are business ready for roll-out by other GB DNOs. This can be as a collaboration of multiple innovative technologies based on the characteristics of the constrained network. All techniques are relevant to other DNO networks.
We conservatively estimate that benefits will increase to £10M through ED1 for the SPEN licence areas. By extrapolation, a similar conservative benefit for the UK as a whole is £100M.

2.1.4.7 Dissemination of learning for benefit of DNOs' systems across GB

We have provided information to a number of other DNOs on learning outcomes from Flexible Networks. Examples include:

- Providing secondary substation data collected to Western Power Distribution for their LCNF Tier 2 LV Templates project.
- Meeting with Scottish and Southern Energy, Western Power Distribution and Electricity North West to share learning on monitoring installed for various projects.
- Leveraging on our learning from Flexible Networks, we provided comments to Northern Power Grid on the LCNF Tier 2 Customer Led Network Revolution project close down report.
- Providing the Enhanced Transformer Rating Tool to UK Power Networks, updated to facilitate integration to their network.
- Providing the Enhanced Transformer Rating Tool to Western Power Distribution Network.
- Providing the Enhanced Transformer Rating Tool to Aston University, who were WPD's partner in LCNF project FALCON, this supported their RTTR work.
- Providing the developed thermal rating assessment tool upon request by Electricity North West for use in the successful NIC bid Celsius.

Engagement from other DNOs and wider industry has been excellent.

Various partners in this project such as TNEI and the University of Strathclyde continue to extensively draw on their experiences and knowledge gained on the project when working on innovations projects for other DNO's across GB. For example, TNEI supported Electricity North West in development of their business case for the successful Celsius Network Innovation Competition (NIC) bid, a project which explores the use of monitoring and cooling techniques based to increase understanding of thermal behaviour to release capacity at secondary substations.

The data sets compiled for this project have been made widely available via the SPEN website for organisations or individuals to use for further research. This is being used in the projects undertaken by other DNO's and in the research industry, by academics on behalf of other DNO's.

2.1.5 Value for Money to Customers

For a relatively small LCNF Tier 2 project with a total final value of £5.28M including LCNF funding of £2.85M, a significant network capacity release (20%+) was achieved at all three trial sites and £6.2m conventional reinforcement in the DPCR5 plan for east Fife was deferred. A substantial amount of learning was generated. Learning on voltage

optimisation and enhanced thermal ratings for example has major implications for the industry. Flexible Networks has provided exceptional value for money to customers.

2.1.5.1 Project budget

The initial project total value was £6.25M which was later reduced to £5.28M following approval of a change request in 2014. This was driven by:

- Reduced scale of voltage regulator trials;
- Reduced uptake in energy efficiency measures by customers;
- Efficiencies in procurement and delivery of monitoring equipment.

Detailed analysis of enhanced network monitoring data indicated that there was no requirement to install voltage regulators to facilitate flexible network control within Whitchurch and Ruabon trial networks. This may be due in part to the highly interconnected nature of the legacy Manweb network. Therefore, there was no compelling reason or opportunity to deploy voltage regulators at these two sites. Additional learning was however gained from the installation and operation of an 11kV Automatic Voltage Regulator in Ruthin, Wales.

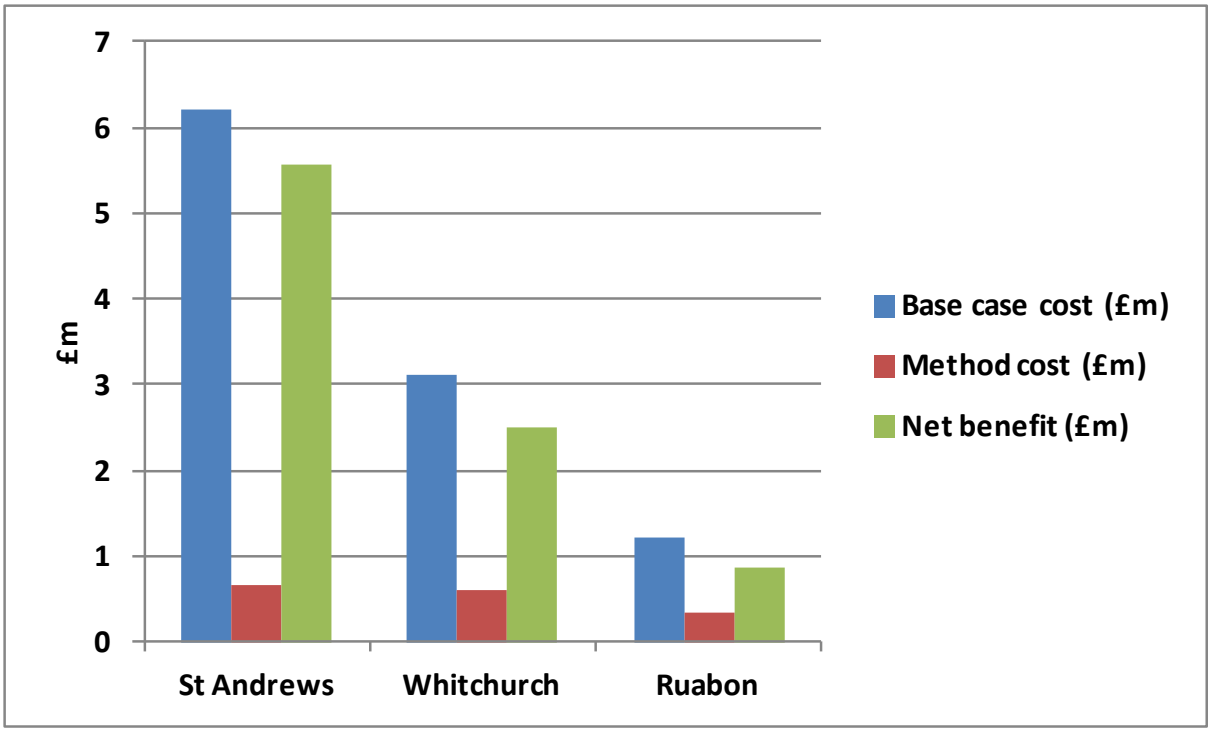
This revised budget (cost reduction) amount represented a total of £0.75M reduction in LCNF funding returned to electricity customers. At completion of the project a further small under-spend of £67k across the overall project was realised. Significantly, SP Energy Networks is the first licensee returning innovation funding to the customer through efficiencies in technology, testing and contingency costs.

Despite the project budget reduction, the SDRC were all met or exceeded and approved by Ofgem.

2.1.5.2 Technology capacity release

Significant value to customers was achieved through substantial release of capacity for the technologies trialled, at low total project cost. Figure 2-3 illustrates the capital cost and net cost benefits of applying the future method at each network trial site as compared to the traditional method.

Figure 2-3: Net benefits for application of Flexible Networks at three trial sites



Traditional methods are around £300k/MVA however innovative techniques trialled in Flexible Networks are generally half of this.

2.1.6 Relevance and timing of project

Not applicable. Whilst the project team worked in an efficient and co-ordinated manner to deliver the exceptional outcomes described in this report we do not wish to include this sub criteria within our case.

2.1.7 Methodology robustness and project readiness

Not applicable. Whilst we believe this project was managed efficiently we do not wish to include this sub criteria in our case.

2.1.8 Other Benefits

Throughout this project, several unexpected lessons learnt were garnered, that are being considered in future innovation projects. These are described below.

2.1.8.1 Data Analytics

A pilot study was undertaken with IBM as part of Flexible Networks to develop a Distribution Grid Analytics tool. This utilised GIS data, NMS network configuration data, co-ordinates of monitoring locations and monitoring data. The current network topology was then visualised through an overlay on Google Maps and analytic tools implemented to enable identification of thermally overloaded substations, voltages outside of statutory limits, and phase imbalance, from analysis of the monitoring data.

The trial has generated significant learning both on the potential power of data analytics to deliver business benefit with increased network monitoring, and in the difficulties of obtaining data from our existing systems in the correct format.

This study was not included in the original project scope. It was added later due to identification of the additional value that could be provided from running such a pilot study in collaboration with the network monitoring workstream. This has helped to advance the learning outcomes from network monitoring in terms of how it could enhance network planning and operation in future. Outcomes have informed our successful NIA projects, DINO and NCEWS and continue to inform the joint data projects being developed by the ENA working group developing joint data analytics projects amongst DNOs.

2.1.8.2 Energy efficiency techniques

While it was initially planned to apply energy efficiency techniques at St Andrews and Whitchurch, this has not proved to be as beneficial as anticipated. The approach adopted was to work with customers and energy suppliers to identify and implement appropriate energy measures that can reduce power demand as well as energy demands without requiring customer behaviour change using energy efficiency devices such as voltage regulators, reactive compensation and low energy appliances. Specific areas served by stressed network assets being targeted rather than a blanket approach.

However, we believe that it may still have potential, perhaps through a different delivery model which may include significant consumer education along with changes in current policy and/or significant financial drivers/incentives.

With decarbonisation of heat being a major future challenge for electricity distribution networks (80% of peak winter heating demand currently met by gas), energy efficiency will be a significant contributor to managing impacts. The Scottish government have targeted a 30% improvement in energy efficiency by 2030. DNOs may need to advise on energy efficiency measures for customers in the future and learning from Flexible Networks would inform our approach.

2.1.8.3 Voltage Optimization

The application of permanent voltage reductions (reduced voltage set point) on the 11kV network was found to significantly increase volumes of generation able to connect at 11kV and/or LV in future. This is a significant learning that we are disseminating this

to industry through the ENA working group on voltage harmonisation, particularly given the industry move towards harmonisation with European voltage ranges.

2.1.8.4 Lessons learnt for FUSION NIC Project

FUSION, a successful 2017 SP Energy Networks Network Innovation Competition (NIC) bid, plans to implement and trial an open and structured flexibility market, as an economic alternative to manage DNO network constraints.
The FUSION trial will be undertaken in East Fife. The Flexible Networks project has informed a detailed understanding of the network in east Fife including detailed monitoring of the primary and secondary substations which remains in place. We developed an understanding of the capability of smart grid techniques to release additional capacity and the associated limits on that capacity. In addition, the Flexible Networks project developed links with important stakeholders including St Andrews University and Fife Council.

2.1.8.5 Field devices

Development of techniques to rapidly identify and resolve issues with large populations of field devices is important. A number of unanticipated communications issues were encountered with the secondary substation monitoring throughout the project. In order to manage this, a system of monitoring the operational status of the monitor population and calculating a data capture metric was developed. This enabled more rapid identification of problem monitors, the specific issue and more efficient resolution which is important with a large number of actively managed field devices (at much larger volumes than in the past with a fit-and-forget LV network).

2.1.8.6 Procurement

Procurement of innovative technology or services is likely to take longer than typical procurement timescales. One practical measure that can be taken to reduce procurement timescales is to issue technical requirements specifications to suppliers ahead of the full tender documentation to allow suppliers more time to address technical requirements.

2.2 Reward Criterion B

Not applicable. We have not provided a response to Reward Criterion B as SPEN did not invest a significant additional contribution in the project.

2.3 Reward Criterion C

2.3.1 Demonstrate where the project has delivered more learning than was expected

For a relatively small LCNF project with a total final value of approximately £5.28M and LCNF funding of £2.85M, there was a significant amount of network capacity release (20%+) and learning generated. A number of valuable lessons were learnt beyond what was expected that have major implications for the industry beyond the project. These are outlined below.

2.3.1.1 Voltage Optimisation

The UK low voltage (LV) limits were partially harmonised with European voltage limits in 1990, when the 240 V +/-6% and 230 V +/-6% voltage limits were harmonised to 230 V +10/-6%. In practice, no physical changes were generally made to actual voltage settings as the old limits were largely captured within the range of the new. There is now a growing consensus within the UK industry for consideration of the full adoption of the European voltage range of 230 V +/-10%. Whilst such a change would require DNOs to make changes to their voltage control policies and settings, the resulting voltage reduction could help create additional network capacity for the connection of embedded generation, as well as reduce energy use for customers.

There is an existing Working Group (ENFG Task Group on Statutory Voltage Limits) dedicated to the European harmonization of the voltages limits (transition to 230 +/-10%). The outcomes of Flexible Networks are invaluable to the investigations of the Working Group and SPEN have a staff member actively participating in this group. Notably, findings of this Working Group will lead to changes to the Electricity Safety, Quality and Continuity Regulations (ESQCR) in the UK.

It is generally recognised that overall system headroom for generation can be increased through better optimisation of voltage set-points and permissible voltage ranges thereby enabling connections of more embedded generation. Results of this project have demonstrated that the voltage optimisation can lead to capacity release much greater than the modest value historically anticipated with a 2% voltage reduction at Ruabon leading to up to 90% capacity being released, in collaboration with improved network characterisation of LV connected embedded generation [Flexible Networks Closedown Report see Section 4, page 30].

Flexible Networks also found that voltage reduction does not provide as much demand load reduction as previously thought [Flexible Networks Closedown Report see Section 4, page 30]. This depends on the voltage dependency of loads connected to the network which can vary depending on load type and electrical characteristics. This suggests that demand reduction through Demand Side Response (DSR) may be a more effective strategy.

2.3.1.2 Distribution Grid Data Analytics

A pilot study was undertaken with IBM as part of Flexible Networks to develop a Distribution Grid Analytics tool. This utilised GIS data, NMS network configuration data, co-ordinates of monitoring locations and monitoring data. The current network topology

was then visualised through an overlay on Google Maps and analytic tools implemented to enable identification of thermally overloaded substations, voltages outside of statutory limits, and phase imbalance, from analysis of the monitoring data [Flexible Networks Closedown Report see Section 4, page 25].

In common with other DNO's, there is an exponential growth in data being collected across the business. Data is an asset, and analysis of the data has the potential to provide information to improve our cost efficiency, improve our asset management techniques, and facilitate new or improved services to customers. However, the area is still largely immature. We carried out a trial of an analytics package, pulling data from different source systems and analysing it to produce visualisations and reports that provide business benefit. We successfully imported the network topology and secondary substation measurement data for 2 of our trial areas into the package which allowed us to use the visualisation and reporting functionality to assess the status of the network.

The trial has generated significant learning both on the potential power of data analytics to deliver business benefit with increased network monitoring, and in the difficulties of obtaining data from our existing systems in the correct format.

This study was not included in the original project scope. It was added later due to identification of the additional value that could be provided from running such a pilot study in collaboration with the network monitoring workstream. This has helped to advance the learning outcomes from network monitoring in terms of how it could enhance network planning and operation in future. Outcomes have informed our successful NIA projects, DINO and NCEWS and continue to inform the joint data projects being developed by the ENA working group developing joint data analytics projects amongst DNOs.

2.3.1.3 Seasonal Approach

Results obtained from this project suggest that it is more cost-effective at this stage to implement a seasonal rather than real-time approach to flexible network control [Flexible Networks Closedown Report see Section 3, page 19]. Whilst we initially envisaged a more real-time approach would be developed, this finding is very valuable, not expected and supports significant value for money.

A real-time approach would require a significant infrastructure upgrade to enable. This could include the installation of permanent onsite monitoring equipment, more complex communication networks and automation schemes for flexible network control. As these technologies continue to evolve, a real-time approach may become more economic in future.

2.3.1.4 Enhanced Primary Transformer Thermal Ratings

The use of the term "enhanced thermal rating" here refers to a fixed enhanced rating rather than a dynamic rating, which is determined through consideration of transformer specific environmental and loading conditions and verified through monitoring of the transformer duty temperature.

The approach of basing the transformer load capability on temperature rather than a definitive manufacturer rating plate figure allows additional capacity to be exploited through existing business-as-usual planning and operational processes, which are designed around fixed transformer ratings. As primary transformers spend the majority of their life at loadings well below nameplate rating (in part due to seasonal as well as daily load cycles), transformer aging is not really an issue for implementation of enhanced thermal ratings. This cost-effective technique reduces costs compared to a real-time approach due to the straightforward nature of the analysis and the avoidance of any additional automation requirements [Flexible Networks Closedown Report see Section 4, page 27].

Additional learning from the project has been maintenance and communications issues associated with weather stations. Localised weather forecasts will probably be used in future for enhanced transformer thermal ratings.

2.3.2 Additional learning as a result of exceptional effort of the DNO

Learning outcomes and success indicators from exceptional efforts in delivering this project have informed the development and delivery of subsequent innovation bids and projects. These are beyond the original knowledge dissemination plans described in the Flexible Networks LCNF Full Submission Pro-forma.

This project involved significant collaboration between both SPEN entities, SPM and SPD. In order to maximise learning across licence areas, exceptional effort was made from the onset to ensure that workstreams were applicable to both areas and that the team consisted of a relatively equal mix of staff from SPM and SPD. This provided excellent value to the project as findings and deliverables including modelling tools, policy and guidance were applicable to both licence areas. Design teams from across the business were engaged with during project delivery, to enable buy-in and use adoption [Flexible Networks Closedown Report see Section 4, page 49].

To ensure representative and replicable outputs, Flexible Networks involved three carefully selected trial areas from both SPM and SPD, covering various network topology and customer demographics: St Andrews in Scotland, Wrexham in Wales and Whitchurch in England [Flexible Networks Closedown Report see Section 12, page 7].

A number of project partners provided in-kind and commercial contributions to various aspects of this project. The approach to project partner interaction with the SPEN project team facilitated a collaborative and collegiate working environment. There was clarity and agreement on the role of each partner including the expectation that a reasonable amount of time would be spent in SPEN offices engaging with the project management and delivery team and wider stakeholders. Partners were engaged at bidding stage which helped to foster a commitment to the project.

Having a close-knit delivery team that involved a range of partners has maximised the learning disseminated to industry through ongoing and future projects developed and delivered by the partners, including a number of network innovation projects.

This project was supported throughout by SPEN executives, management and staff and well-resourced throughout.

2.3.3 Exceptional capture and dissemination of learning in a way that maximises value for all customers

Exceptional capture and dissemination of learning to maximise value to customers can be demonstrated from our approach to deliverables, data dissemination and involvement in ongoing industry wide initiatives.

As part of the Flexible Networks project, a number of stand-alone modelling tools, application guides, practical methodologies and policy and practice recommendations were produced to specifically facilitate ease of rollout and future replication internally and externally (for other DNOs). These cover all workstreams as well as wider, overarching network planning and operation recommendations. The learning was disseminated in a way to make it easily accessible to other DNOs and industry.
A few examples include the enhanced transformer thermal modelling tool, the Good Practice Guide to Monitoring, technical notes on modelling of load and installation, setup and removal guides for monitoring [Flexible Networks Closedown Report see Section 10, page 43].

Learning from the project was disseminated on an individual basis where beneficial to the industry. This included one-to-one discussions with various DNO's to share lessons learnt for the benefit of their ongoing related projects such as a meeting with Electricity North West Limited to discuss the enhanced transformer rating tool which informed the successful Celsius NIC bid. Copies of modelling tools and other deliverables such as the enhanced transformer rating tool were tailored to meet various DNO requirements, such as the version which was provided to UK Power Networks for integration into their network planning processes.

The data sets compiled for this project have been made widely available via the SPEN website for organisations and individuals to use for future research. This data is being used in the projects undertaken by other DNO's and in the research industry, by academics on behalf of other DNO's.

Dissemination of learning on voltage optimisation from Flexible Networks is invaluable to the ENFG Task Group on Statutory Voltage Limits dedicated to consideration of harmonization of voltage limits with European voltages limits. If the outcome of the Working Group is a general lowering of the acceptable voltage limits and based on the large resulting potential network capacity release as was demonstrated on this project, the entire GB network, not only SPEN licence areas stand to greatly benefit with significant network capacity release for generation and potentially demand.