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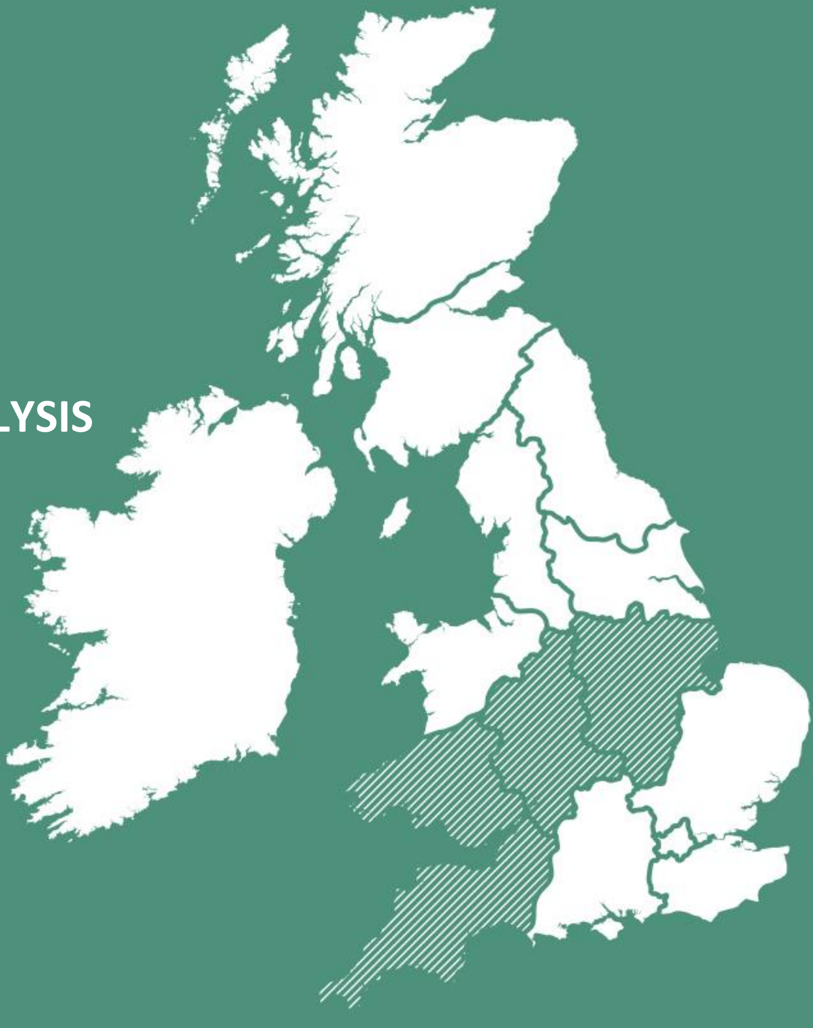
NEXT GENERATION NETWORKS

SMART GRID TELECOMMUNICATIONS ANALYSIS

CLOSEDOWN REPORT



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Contents

Glossary

Abbreviation	Term
AMR	Automatic Meter Reading
BPL	Broadband Power Line
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
DNO	Distribution Network Operator
DSO	Distribution System Operator
EA	Electricity Association
ENEL	National Board for Electricity, Italy
ENISA	European Union Agency for Network and Information Security
ETSI	European Telecommunications Standards Institute
EUTC	European Utilities Telecoms Council
FACTs	Flexible Alternating Current and Transmission Systems
GSM	Global System for Mobile Telecommunications
HAN	Home Area Network
HFC	Hybrid Fibre-Coaxial Cable
LCNI	Low Carbon Network Innovation
GPRS	General Packet Radio Service
IoT	Internet of Things
IT	Information Technology
kbps	kilobytes per second

kHz	kilo Hertz
LPWA	Low Power Wide Area
LV	Low Voltage
Mbps	Megabytes per second
NIA	Network Innovation Allowance
NIC	Networks Innovation Competition
NMO	Network Mobile Operators
NMS	Network Management Systems
OT	Operational Telecommunications
PMU	Phasor Measurement Units
PNDC	Power Networks Demonstration Centre
QoS	Quality of Service
RIIO-ED1	Revenue, Incentives, Innovation, Output – Electricity Distribution
SCADA	Supervisory Control and Data Acquisition
SGAM	Smart Grid Architecture Model
SMIP	Smart Metering Implementation Programme
UK	United Kingdom
V2G	Vehicle to Grid
WAN	Wide Area Network
WPD	Western Power Distribution
xDSL	Digital Subscriber Line
3GPP	Third Generation Partnership Project
4G	Fourth Generation Mobile Networks
5G	Fifth Generation Mobile Networks

Executive Summary

The difficulties of providing communications network services in order to facilitate implementation of smart grid and DSO applications have been identified as an important area of research by WPD and other utilities. This report identifies and documents the communication requirements in respect of the Smart Grid applications which form the basis for the Smart Grid Architecture Model (SGAM) developed jointly by EU standards bodies responsible for power systems and telecommunications – respectively CENELEC and ETSI.
The report also identifies and discusses potential technologies that could be used for various use cases in order to encourage the use and adoption of a smart grid. In this report, the various smart grid applications or use cases are categorised under what is referred to as "Telecoms Templates".

Following WPD's 2015 NIC bid for Telecoms Templates, this project under the NIA sought to undertake an international appraisal of the Telecommunications media deployed to support smart grid adoption within Electricity Distribution Networks.

The project assessed current and planned smart grids implementations at various stages i.e. at trial or laboratory stage as well as those in full scale deployment. Through this assessment, the project was able to identify the overarching smart grid requirements for UK DNOs. The smart grid assessment also considered white papers submitted to industry conferences on the new and emerging applications within smart grids and enabling telecommunications technologies.

From the results of the assessment the following conclusions were established:

- To deliver the complex landscape of smart grid technologies and services, much of which will be central to the implementation of an effective DSO operation, UK DNOs will be required to implement a robust, reliable and highly resilient communications infrastructure which can deliver services across the entirety of a DNO geographic area.
- A number of comprehensive national and regional smart meter deployments have been completed in Spain, Italy, USA and others. Many of these have involved the design, construction and operation of dedicated telecommunications networks. To date, however, there are no large scale examples of smart grid networks and related telecommunications deployments.
- DNOs will have to make a strategic decision to address network ownership i.e. "build or buy". In a low-volume, non-critical scenario, buying in capacity may be more economical than building a network. However, if the traffic is considered highly critical to network services such as reliability and security, then building a network may be necessary to guarantee the DNOs core service responsibilities.

- Similarly, due to the limited availability of radio spectrum for the DNO, strategic choices will need to be made. Mission critical smart grid applications would specifically need licenced communication spectrum against non-mission critical smart grid applications which can utilise unlicensed spectrum for communications.
- Co-ordination of information and responses about cyber security within the UK power utility sector is essential in order to ensure a highly secure network. At present, there is little incident information sharing between power utilities within Europe or the UK.

1 Project Background

Telecommunications Infrastructure will play a pivotal role in enabling DNOs' transition to a smarter electricity network and ultimately a UK-wide low carbon economy. The smart grid will allow greater visibility, control and protection of network assets with enhanced centralised control functions as well as autonomous de-centralised functions. Active and pro-active network management will be essential to optimise the installed assets, whilst meeting the challenges associated with additional distributed generation, storage and consumers changing energy demands.

UK DNO's are well positioned and highly competent at maintaining and augmenting the conventional telecommunications approaches for Remote Monitoring and Control as well as high speed protection of systems and assets. However, with an increased drive towards a Low Carbon economy the operational model for electricity network in the UK is being turned on its head. From a previous operating model (large generator to customer), the proliferation of medium to small scale distributed generation has necessitated a different approach to how the networks are monitored, controlled and protected. Presently, the telecommunications approaches to supporting these new initiatives are adaptions of current systems and bespoke solutions.

This current incremental approach to smart grid telecoms integration can be complicated, costly and undefined in terms of scalability. This project sought to analyse current and proposed smart grid telecommunications solutions and deployments to assess suitability for integration within the UK DNO's, taking a holistic view rather than the current incremental approach.

Through a competitive tender process, WPD appointed Analysys Mason to undertake this review over a period of 12 months, commencing April 2016.

2 Scope & Objectives

The purpose of this project was to complete an analysis of proposed and deployed smart grid telecoms solutions as well as identifying and quantifying the specific architectures, services and data-flows within a future smart grid communications network.

Based on this analysis, the aim was then to identify how DNOs in the UK can deploy and optimise available communications solutions to maintain an effective, efficient and sustainable power distribution system. This must be achieved against the backdrop of significant regulatory and operational change, which will result in distribution systems being required to support increasing levels of smart grid applications and extensive power network intelligence. The project report looked to highlight a range of secondary issues in order to identify the likely scope and scale of the future smart grid communications system.

The project undertook an analysis of global smart grid deployments particularly the telecommunications infrastructure required to support smart grids. The report focused on identifying and quantifying the following:

- Smart Grid Site types
- Smart Grid Layers
- Smart Grid Architecture
- Smart Grid Services
- Smart Grid Data flows
- Smart Grid Security (Physical and Cyber)
- Applicable Telecommunications and IT solutions

By better understanding the smart grid as a whole, informed decisions can be made regarding future deployment of smart grid solutions and how that will interact with or replace legacy communications systems within the UK Distribution Networks.

Below we detail each of the objectives and performance criteria for the project. The project provided some insight and data that has been invaluable in creating a template for future telecommunications connections.

Objective	Performance
Identifying and quantifying site types to be considered for smart grid adaption	✓
Identify and quantify smart grid layers within the DNO	✓
Identify and quantify applicable smart grid architectures	✓

quantifying the specific architectures, services and data-flows within a future smart grid communications network	
Identify and quantify the current and emerging smart grid services	✓
Identify, quantify and characterise the smart grid data flows	✓
Identify and quantify DNO smart grid security – Physical and cyber security	✓
Determine the range of Telecommunications & IT systems	✓
Development of a suite of functional and technical specifications	✓
Development of a suite of smart grid telecoms templates	✓

3 Success Criteria

This has been a very successful project providing a template that can be used across the industry for current and future smart grid applications. Details of the success and measurement criteria are tabled below.

Success Criteria	Status
Site types to be considered for smart grid adaption identified and quantified	✓
Smart grid layers within the DNO identified and quantified	✓
Applicable smart grid architectures identified and quantified	✓
Current and emerging smart grid services identified and quantified	✓
Smart grid data flows identified, quantified and characterized	✓
Physical and cyber security issues identified and quantified	✓
The range of Telecommunications & IT systems identified	✓
Smart grid telecoms templates developed	✓

4 Details of Work Carried Out

The project was developed based on desk research and assessment of various telecoms options available. Project review meetings took place on a rotational basis between WPD and Analysys Mason. The project was delivered in three phases:

- Phase 1 was mainly data gathering - data collection, identifying UK and international projects, and interviews with key stakeholders;
- Phase 2 was data and market analysis - initiating various work streams, and
- Phase 3 was smart grid telecoms design and planning - design of telecommunication templates for smart grids and development of reports.

In order to ensure appropriate utilisation of resources and time some of the activities of phases were run in parallel. The sections below provide some more detail on these aspects.

4.1 Desk Based Research

As part of Phase 1, a desk based research was conducted and focused on assessing the market to determine who was doing what in respect to the development of smart grids, their implementations and most importantly, how these developments are addressing the telecoms requirements to support the deployment of multiple devices and the transfer of increasing volumes of data.

Much of the literature available and reference materials assessed provided scenario views whereby industry players discuss the options and pro and cons, without describing the 'how' and 'what' consequences of physical deployments. Also, much of the market available materials focused heavily on the electrical networks, devices which could/should be deployed and the resulting data, with little or no reference to the telecoms layer.

In order to give a view of the definition of a smart grid, part of the literature review was based on Analysys Mason's intellectually owned telecommunication information hosted on their infrastructure.

4.2 Assessment of Telecoms Options

In parallel with the desk-based research, Analysys Mason assessed the various telecoms options which are currently available, those which are being developed and how they are being deployed or proposed to be deployed. This was aimed at gaining a greater understanding of the functionality and potential applicability to support the projects aims and WPD's goals.

Specifically, reviewing 5G with comparators against 4G and also LPWA; the former has been the subject of specific research within Analysys Mason and is providing a key input in to this area of the review.

4.3 Smart Grids Definition

The project was required to provide a definition of smart grids that could be adopted by WPD. As the reference to smart grids has been around for a reasonable period of time, it has allowed many industry contributors to develop their own definitions, with vendors having a further leaning towards their applications and solutions sets.

Detailed analysis of the many and varied sources defining smart grids was undertaken throughout the project with a particular focus on the EA Technology Transform Model.

Analysys Mason initially accessed a publicly available version of the Transform Model to understand the categories being used within the model and then used these to further develop their views and direction. This enabled Analysys Mason to further progress the smart grids definition with a view of then taking this to identified key stakeholders within WPD for review and input for its final development to reflect WPD's definition of smart grids.

4.4 Conferences and Site Visits

As this project required a review of 'global appraisal of smart grid telecoms', it was important to gain access to key personnel and information across the utility sector. While we could have spent significant time attending the numerous conferences which abound in this space, a focussed number of conferences were considered appropriate. These included:

Event	Location	
EUTC	Frankfurt	27th – 30th Sep 2016
Modernising the UK's Energy network	London	15th Nov 2016
Smart Energy Europe and the Future Utility Summit	London	2nd – 3rd Feb 2017
Energise Workshop	Brussels	16th March – 17th March 2017

4.4.1 EUTC Conference

A member of the project team attended the conference in Frankfurt. The following is a summary of the key themes presented and their relevance to the project.

The three key themes that emerged from the EUTC conference that were identified as having a bearing on and providing some insight and input into the Project were:

- The emergence of 5G and potential impact it could have on utilities
- The discussion and debate on development of private operational communication networks or outsourcing or use of commercially available operator led solutions and
- Cyber Security - There was increased attention and debate around changing operational and business models for DSOs in the future.

4.4.2 Developments in 5G

There is significant hype and attention being placed on 5G with numerous vertical sectors all clamouring for attention and dedicated spectrum based on the increasingly critical nature of communications to each sector driven by digitalisation and frustration with complexity, diversity and cost to operate with existing options. Feature sets and their advent in the 3GPP standards are uncertain in particular some of those that may prove to be the most valuable to the utility sector including the high reliability and low latency aspects and the massive distributed low cost and edge computing capabilities. Primary around the factors that could thwart the usefulness of 5G to utilities is a lack of coherence in terms of requirements and priorities for the sector being provided in a structured way to the 3GPP. Some activity has been seen in other sectors in terms of self-organising and coordination. The EUTC has established a smart grid requirements working group to capture requirements from across the industry and provide coherence and guidance.

4.4.3 Private vs Outsourced Networks

Many different perspectives were presented on the options and opportunities for providing connectivity to expand and diversify the intelligence on the distribution grid, especially at LV. As we already know there is no silver bullet that meets all requirements. What was highlighted is the lack of understanding of the costs related to providing networks that meet the resiliency requirements needed of critical infrastructure as this can most often only be achieved with private networks or hybrids. Telecoms operator's business models and operational processes are simply not aligned to providing utility needs in a productised manner. A number of interesting models were presented, the outcome is clear that more investment, learning and discussion is needed to find a set of solutions that can be considered best industry practice.

4.4.4 2016 LCNI Conference

A number of the project team from Analysys Mason attended this event. WPD and all other DNOs had a major presence and were involved in a series of presentations. Many of the presentations made reference to the numerous innovation projects which are currently underway or recently concluded; while these presentations provided updates on projects progress, limited information was available on the large-scale deployment of successful solutions.

Time will tell to what extent DNOs will now go in transitioning their networks to a smarter, low carbon network.

In addition to the above theme, focus was given at the event to the transition of DNOs to a DSO model, which it would appear all DNOs support but recognise that much work is required before this transition can occur.

4.4.5 Analysys Mason European Summit

This annual event was an 'invite only' attendance of mainly telecoms operators and end users which was held in London in early October, which we attended in conjunction with WPD project members. It provided an opportunity to hear from the wider telecoms industry on activities being undertaken and progress of technologies being deployed or being considered for deployment. 5G was on the agenda and presented some of the findings from previous research as highlighted in a previous section of this report.

4.5 Site Visits

We identified the need to undertake a small number of site visits to gain first-hand experience and evidence of other organisations strategies and developments. The visit to Iberdrola took place in February 2017.

We identified additional local site visits including:

- Surrey University - to understand the status of work and research being undertaken on 5G. This was conducted via telephone and emails.
- PNDC a venture between the University of Strathclyde, Scottish Enterprise, the Scottish Funding Council, Scottish Power and Scottish and Southern Energy aimed at accelerating the adoption of novel research and technologies into the electricity industry.
- Meetings with several DNO's to discuss the Project and gain their inputs to enable further development of the project and its outcomes
- Meetings with various suppliers

4.5.1 Meetings Attended

The project met with Iberdrola to understand the approach they have taken to implementing communications to support their smart metering and smart grids initiatives and to determine the technologies utilised.

An outline of the findings of the visit is included below:

- Iberdrola operate a vertically integrated electricity utility delivering generation to meter services across the north and central region of Spain (in addition to operating other electricity utility businesses around the world)
- Iberdrola have 1000 primary substations and 90,000 secondary substations.
- Iberdrola have a resilient fibre backbone in place and are currently leasing fibre cores to MNOs and other telecommunications operators
- Iberdrola implemented the STAR project in 2007, to develop an integrated smart metering and grid solution

- To-date they have installed 9 million meters, with a target of 10.8 million
- They are utilising a mixture of communications technologies, with the PRIME PLC solution being utilised as their technology of choice for the access network.
- In addition, Iberdrola employ a BPL solution to connect 40% of their secondary substations to their fibre backbone
- In addition, Iberdrola utilise 2G/3G, xDSL and HFC (TV). 4G is not yet seen as a viable option in Spain.
- They operate a single comms network for all parts of the business (corporate, generation, renewables, etc.), with security (firewalls) in place at the applications layer (this includes SCADA)
- They operate a single NMS for telecoms operations and are currently developing a standby facility
- They are divided into 6 regions, each having its own Power NMS with standby facility
- Spectrum is an issue as this is under the ownership of MNOs
- The split of the intermediary comms network (from LV substations to backbone fibre) is 40% BPL, 50% public and 10% a combination of differing comms
- They do not utilise GPRS due to quality of service issues
- They have proven that 3G has limitation for secondary substation applications as service operators prioritise mobile data towards mobile usage
- 10% of their substations are underground
- They operate a design tool for BPL planning, which is an in-house developed tool and utilises an import of the electrical network to base its planning. This is a rules based tool and provides a minimum of 10Mbps between secondary substations
- Each BPL cluster has a fibre backbone connection and have the capability of designing cluster with up to 20 substations; to-date their maximum sized cluster is 8 secondary substations!
- They use only capacitive couplings throughout the network
- Prime is currently being trialled for LV automation
- BPL is not used in overhead instances
- PRIME can repeat up to 64 levels and has the capability of 'auto-evolving'
- Costs of fully installed smart meter is Eur30 (Euro25/meter and Euro5 for installation)
- In the USA, they are trialling a combination of BPL and mesh networks
- The USA has a greater band-width than the UK, up to 500kHZ
- They utilise satellites for remote locations/off-shore and as a back-up for mobile workers
- They do not use GSM
- They have achieved a 97% success rate for installation and first time connection of meters

4.6 Applications Mapping

4.6.1 Transform Model

EA Technology's Transform Model provides electricity distribution companies with a practical tool which enables them to optimise the investments they need to integrate smart grid technologies into existing networks, with the lowest possible amount of new engineering work and maximum cost-efficiency.

4.6.2 SGAM Framework

SGAM framework offers distribution companies a structured architectural aprroach to analyse, design and develop smart grid solutions. This allows for representation of interoperatability in a technology neutral manar.

SGAM is a three dimensional model; merging the dimentions of five interoperatablity layers (business, funtional, Informations, communication and component) with two dimensions of the smart grid plane; zones (representing the hierarchical level of power system management) and domians (covering the electrical energy conversion chain).

The SGAM model allows establishing clear relationships between: the business objectives for the intended solution, the technical functions that will deliver the solution, the information exchanges between the functions, the standard protocols and data models that enable these information exchanges, and the components that implement the technical functions in the system.

4.6.3 Relationship between the EA Transform and SGAM Models

It is important to note that the Transform Model is used to inform strategic, rather than tactical, business decisions. A useful visualisation of this involves the SGAM, which describes a smart grid approach as being made up of several 'layers'. The lower layers deal with the assets installed and the way in which communication occurs between these assets. The Transform Model is not prescriptive regarding the communication medium used, or the level of data warehousing that is employed. Rather, the Transform Model operates at the 'function layer' providing an overall view of the way in which a smart grid should be developed to meet the needs of stakeholders and giving strategic direction to a network operator to help them achieve this.

It was considered appropriate to work with both models in the process of mapping Smart Grid applications.

4.7 Assessment of Telecoms Options

In order to develop a comprehensive matrix of telecommunications options for the various smart grid applications, Analysys Mason referenced the extensive research and investigation that it has been conducted concerning all major available solutions.

4.7.1 5G Status Review

This summary is derived from independent research undertaken by Analysys Mason in 2014 and further updated in early 2016.

Further analysis of the requirements and capabilities of 5G is captured below, this has been derived from independent research undertaken by Analysys Mason in 2014 and further updated in early 2016. It is recognised that 4G has not completed roll-out and it is expected that this roll-out will continue and further evolve which may impact the development and implementation of 5G.

Key messages from this updated research indicated: “The development of 5G standards will be shaped by three main use cases during Phase 1. However, this narrow focus may pull 5G development in diverging directions, which could result in the needs of emerging markets being ignored”.

4.8 Review of Cyber Security

4.8.1 Cyber Security Policy for the European Energy Sector

A very good reference point for this activity was the ENISA report “Communication network interdependencies in smart grids”, which begins its report with the statement ‘one point that has been constantly overlooked and has not received the attention it deserves concerns the interdependencies and communications between all the assets that make up the new power grids. These interdependencies in communications are a fundamental pillar, as they represent the means by which all devices communicate within the smart grid network.’

The report states that connectivity is the foundation for IoT, and the type of access required will depend on the nature of the application. Many IoT devices may well be served by radio technologies that operate on unlicensed spectrum and that are designed for short-range connectivity with limited quality of supply and security requirements, typically applicable for a home or indoor environment.

Analysys Mason has been engaged by the Committee on Industry, Research and Energy of the European Parliament to provide an overview of current legislative and non-legislative cyber security practices in the energy sector and to recommend possible directions for future action.

The report aims to outline current and possible future actions to address the above requirements and concerns by:

- Providing an overview of the present transformation across the energy sector;
- Identifying key developments in cyber security;
- Reviewing the policy and legislation environment; and
- Presenting relevant findings and recommendations.

4.8.2 Summary of Reports on Cyber Security within the EU

The accelerating deployment of smart grids across Europe is fundamentally based upon the implementation of intelligent monitoring and management devices integrated within an expanding communications network.

The digitalisation of the European energy systems within Member States is described in the "Digital Energy System" report by the European Technology Platform for smart grids, which highlights the key use cases that need to be deployed. The report confirms the inevitability of greater digitalisation, noting however that many players have yet to adapt their strategies.

The extent and variety of access points to these more extensive ICT systems mean an increase in the number of potential threat vectors that need to be considered in respect of cyber security.

The framework architecture that defines the future state of the energy continues to evolve, requiring ongoing regulatory action and disruptive research. The CEN-CENELEC-ETSI smart grid co-ordination group has established a significant basis for the transformation of the system with its smart grid reference architecture with the establishment of the SGAM model.

There are numerous additional activities necessary to realise an effective cyber security strategy to address the specific characteristics of the energy sector in Europe. The majority of these should be implemented in legislation and become EU law. Our recommendation is to appoint a central authority with the power and capability to implement all the other recommendations effectively.

4.8.3 Consideration and Impacts of Cyber Security for WPD Smart Grid Communications

We consider there is a need for coordination and sharing of information concerning cyber security within the UK power sector, in order to ensure relevant cyber security solutions and best practices are not outpaced by the growing cyber threats.

4.9 Project Governance, Risk and Issues

4.9.1 Project Governance

Further to the award of the project to Analysys Mason, an initial project workshop was held between the parties which enabled the scope of the assignment to be clarified and the key deliverables to be developed and agreed. An initial phase of the project plan was developed which was followed up with the final and completed project plan.

4.9.2 Risks and Issues

A full RAID log was created, reviewed and maintained. The risks identified were managed by both parties throughout the project lifecycle, with none of these impacting the progress, scope or deliverables of the project.

4.9.3 Project Reviews

Formal bi-weekly project review meetings were held between the parties. From these meetings high level notes were created and actions captured. All actions were reviewed at the following meeting as a standard agenda item.

4.9.4 Communications

Given the importance of this project to WPD and the wider UK DNOs, we jointly considered that it was important to ensure appropriate communications to the utility community was developed.

After a number of iterations, agreement was reached, and appropriate approvals given to publish a formal communication on the Analysys Mason website. The communication was as follows:

"The UK's ambitions for a low-carbon economy are founded upon energy security, sustainability and affordability. The resulting 'transition' of the energy sector will require DNOs to manage the complexity of integrating an increasingly diverse range of new technologies, assets, systems and sub-systems. The telecommunication network necessary to realise the smart grids across the DNO domain will represent the largest single operational and capital investment within the transition to a sustainable smart energy industry".

5 Outcomes

The section that follows gives an overview of projects finding and their relevance to UK DNOs.

5.1 International developments in communications for smart meters and grids

The first step towards large-scale smart systems was the deployment of AMR networks in the early 2000s. The Italian government embarked on the first national implementation of an AMR solution in 2003, ultimately deploying some 32 million meters over a period of seven years.
Spain, France Portugal and certain municipal authorities in areas of Germany have more recently begun to expand the scope of these early smart meter deployments and take the first steps in deploying integrated communications/intelligence in the power distribution networks.

However, these initiatives have been driven by large scale smart meter investments, with the smart grid capabilities representing an incremental addition to the primary metering focused objectives. Furthermore, in most of these cases respective governments have supported the significant cost of these meter rollouts. Critically, as a result of the power utilities involved being vertically integrated; they have been able to leverage this supply side investment within their distribution operations.

This opportunity of course is not available to the UK DNOs. As result of the UK SMIP structure, the UK energy distribution industry cannot leverage or maximise the £billions of infrastructures required to deploy smart meters and in particular the largest investment in any major smart meter deployment - the core telecommunications network and services.

5.2 Components of the communications layer of a Smart Grid

The smart grid is built upon a communications layer which connects and integrates the smart grid technologies, services, applications and participants. This communications infrastructure is similar in form to a traditional telecoms network, and has the following key components, summarised:

- Core network (or backbone) – provides real-time monitoring of the entire grid
- Backhaul network (or WAN) – provides telecoms connectivity between the core and the geographically dispersed distribution segments of the Smart Grid
- Local Access Network – provides connectivity from the WAN to customers' premises where applications such as smart meters are located.

- HAN – the smart devices and applications on customers' premises.

5.3 Selecting the Appropriate Communications Technologies

In order to ensure operational interoperability of the smart grid, its communications network must take into consideration the diversity of data and QoS requirements of all the systems involved. The project assessed communications technologies in terms of how far they meet the individual requirements, both functional and non-functional, of key smart grid applications. It does not consider how these might be deployed in the future, nor propose an integrated communications network design. Issues of local topology, demographics energy profiles, etc. will impact how communications are employed within a smart grid telecommunications network solution and will require further analysis by individual DNOs.

We therefore developed an analytical framework ('Smart Grid Communications Templates') based upon standard Use Cases which have been formulated from a combination of two smart grid development models: the UK EA Transform Model and the SGAM Model developed by CENELEC and ETSI.

5.4 Strategic issues impacting Smart Grid Telecommunications decisions

5.4.1 IT and OT convergence

The advent of smart grid will require DNOs to integrate new types of assets and information systems across the power distribution network taking into consideration all the complexities of operating an increasingly fragmented but fully interconnected public power system.

This will in turn require the DNO to manage the resulting huge quantities of diverse data, much in near real time which will fundamentally impact every operations and business function. The DNO will therefore be required for the first time to build an enterprise-wide data management strategy, based upon the necessity for the previously separate domains of DNO back office IT and network systems OT to become fully integrated.

5.4.2 Spectrum Issues

There are concerns about the availability of spectrum for the DNO industry, when considering the extensive national service level requirements of the smart grid telecommunications network. Unlicensed spectrum may offer options in narrow specific applications areas; however these cannot be employed to support many "critical infrastructure" applications, such as load balancing and substation monitoring and control, which form essential foundations of the smart grid. Issues related to spectrum can be split into those related to licensed spectrum and those related to unlicensed spectrum.

5.4.3 Cyber Security

The expansion of smart grid connected devices throughout the energy distribution system, together with the supporting integrated communications networks, creates a requirement for a co-ordinated energy cyber security planning and strategy initiative.

Analysys Mason therefore recommend a co-ordinated UK industry-wide review of cyber security threats to the future smart grid networks, in order to plan for implementation of effective solutions and responses.

6 Performance Compared to Original Aims, Objectives and Success Criteria

Objective	Performance
Identifying and quantifying site types to be considered for smart grid adaption	Project achieved its aims in this regard
Identifying and quantifying smart grid layers within the DNO	Addressing the smart grid layers in adopting the EA Transform Model and SGAM provided a clear view of how smart grid applications will influence DNO operations in the future
Identifying and quantifying applicable smart grid architectures quantifying the specific architectures, services and data-flows within a future smart grid communications network	As above, utilising available industry models enabled an effective and future proofed analysis of effective architecture
Identifying and quantifying current and emerging smart grid services	A review of the global activities enabled the project to determine the options and potential solutions for WPD and UK DNOs to adopt
Identifying, quantifying and characterising smart grid data flows	Through the development of use-cases to influence the development of telecoms templates the project was able to identify the relevant data flows
Identifying and quantifying DNO smart grid security – physical and cyber security	Through other related activities, Analysys Mason were able to provide evidence and influence into the debate relating to security requirements for the future operations of a DNO
Identifying a wide range of Telecommunications & IT systems	Interacting with various vendors, the project was able

	to identify specific solutions which would be available to the DNO community
Development of a suite of functional and technical specifications	In the development of telecoms templates, the project has been able to identify the technical components relevant to the telecoms requirements to support smart grids
Development of a suite of smart grid telecoms templates	Telecoms templates have been developed and are available for immediate deployment into WPD processes

One of the original objectives was to deliver an assessment of international experience in deploying smart grid communications solutions. To this end Analysys Mason proposed a number of visits to utilities who had deployed large scale smart grid systems. It wasn't possible to attend all events, although an extremely productive visit to the Iberdrola deployments in Madrid was completed.

From the research, telephone discussions and experiences related by Analysys Mason it also became clear that the majority of large scale communications systems deployed by utilities around the world were in fact primarily designed to deliver smart meter communications. Whilst some of these had also been designed to deliver some limited substation and network monitoring functionality there does not appear at this time to be any large scale communications systems deployed that support a broad range of smart grid applications.

From literature reviews and site visits conducted, it was interesting to note that a number of European power utilities that began the smart grid journey much earlier than DNOs in the UK are years ahead in their development of smart grid. For example, ENEL, which started its smart metering implementation about 10 years ago have a much more developed and well thought through view of its future smart grid strategy. This has been due to learnings from smart metering implementations. Similarly, Iberdrola is probably two to three years ahead of it counterparts in the UK in terms of its implementation of smart grid.

7 Required Modifications to the planned approach during the course of the project

Throughout the lifecycle of the Smart Grid Telecommunication Analysis project, no modifications to the planned project approach were raised and therefore no change requests were issued for the project.

8 Significant Variance to Cost and Benefits

Activity	Budget (£)	Actual (£)	Variance (%)
WPD Project Management	51,345	47,954	-7
Consultancy	195,000	188,810	-3
Contingency	27,372	0	100
Total	273,717	236,764	-14

The total project was delivered approximately 14% under the project budget. This is due to the contingency budget not being spent.

9 Lessons Learnt

A number of lessons were learnt in addition to the findings set out in section 5 above. These are grouped by project management, commencement of project, dissemination, future developments and other.

9.1 Project Management

A number of lessons were learnt around project management. The initial project plan was based upon a traditional water-fall delivered against activities and milestones. As the project progressed it became evident that an agile approach was more appropriate due to the iterative nature of research and analysis.

9.2 Commencement of Project

As the work on the project did not commence immediately after signing the agreement, it was recognised that strategy and direction of the project would need to be adapted, therefore an improved interaction with the project sponsor and key stakeholders would ensure the project activities, direction and aims are effectively managed and communicated to ensure the project team adapt to changing needs and objectives of WPD.

9.3. Dissemination

The key messaging required from the project and by WPD may have been missed in the early stages of the project. This became apparent at the project dissemination held in Gloucester on the 5th of April resulting in additional time spent on articulating some key messages required as part of the deliverables. This misunderstanding could have been avoided with improved interaction and communication.

9.4. Future Developments

In the course of project delivery, there were three key events that occurred during the life of the project that will have significant implications for development of smart grids in the UK. These include:

- WPD's formal commitment to becoming a DSO will have huge implications on its operating model;
- Focus on cyber security within the utility sector due to experiences from other utilities worldwide; and
- The Brexit vote for the UK to leave the European Union which has created much uncertainty especially in the case of collaborations amongst utilities with the EU once the UK finally departs.

Notwithstanding these issues, the recommendations and insights raised by the project report should serve as a beacon to guide UK DNOs in addressing issues related to smart grids and telecommunication.

9.5 Other

In the process of organising and arranging meetings and interviews with other international utilities, it was interesting to note the level of enthusiasm shown for the project and ease of arranging meeting; companies were very keen to meet with Analysys Mason and WPD. It is important for WPD to leverage these contacts as these could be employed beyond this project.

10 Planned Implementation

The outputs of the analysis from this project will be used to inform the decision making of those responsible for smart grid strategy and policy within WPD as well as act as a reference to guide and inform those from beyond the DNO environs as to the criticality of smart grid communications. Due consideration should be given to the current smart grid infrastructure deployment and its ability to support accelerated demand for electric vehicle infrastructure. As such meeting the requirements of a smart grid system will likely mean large investments into a complex and far-reaching telecoms network. A strategic technical, operational and economic assessment of the existing telecoms assets and capabilities and future smart grid telecoms system requirements is recommended to plan appropriate business and investment plans.

Deployment of telecoms solutions across MV and LV networks to connect new generations of distributed energy sources, support multi-directional power flows and enable ubiquitous commercial interactions is required. For these solutions, several communications technologies are available for consideration. However, a hybrid of wired technologies integrated with other wireless technologies appears to be a favoured solution amongst many major European utilities. It is therefore recommended that testing of the technical and economic capabilities of technology choices be undertaken within the UK's MV and LV operational environment.

In addition, a collaborative approach will benefit UK DNOs when engaging Ofcom on the need for additional licensed and un-licensed radio spectrum.

From the project, a set of functional engineering templates will be identified for use by network planners. Similarly, a set of technical telecoms templates will be developed which will be used to source telecommunications services by our SURF Telecoms team. The engineering and telecoms templates which have been developed will be written into WPD policy before being deployed. Depending on criticality, technology tests will be carried against the technical telecoms templates before the end of current RIIO- ED1 period.
A co-ordination of information and responses concerning cyber security amongst power utilities in the UK is recommended.

The analysis found that considerable investment and effort is being committed by the UK power utility sector to the better understanding, specification and implementation of smart grid functionality and the resulting transition to a DSO operational model. Relatively little however is understood regarding the considerable investment required to provide the underlying essential telecommunications solutions.

The analysis therefore recommended that the UK DNOs should implement technical and economic assessments of the available smart grid telecommunications network and service options in order to prepare strategic operational / investment plans. This activity should include the following:

- Economic and technical model of smart grid telecommunications requirements
- Assessment of existing DNO telecommunications / data assets and capabilities in relation to future smart grid system requirements
- Comparative quantitative assessment of telecommunications options / scenarios incorporating
    - Specific geographic and topology impacts
    - Projections of applications demand / densities
    - Phased network build scenarios
    - Evaluation of DNO build and operate against third party operator options
- Assessment of options for co-ordinated multi utility / vector telecommunications build and investment
- Design and scoping of relevant systems trials in order to validate model assumptions and outputs

These activities would provide the basis for effective internal business preparations and in turn will allow for informed discussion with regulators and government regarding how smart grids can be effectively and efficiently deployed.

11 Facilitate Replications

The objectives of this project have been subject for discussion throughout the power sector for some time now. WPD have taken the opportunity, through NIA to begin the journey of addressing this significant issue. Without a concerted and integrated approach between DNO's, we will continue to see focussed and non-cost-effective solutions to be applied on a case by case basis.

From insights gained through desk studies, interviews, conference and site visit smart grid have only been deployed on small scale particularly with reference to smart metering on the LV side of the network and network monitoring on the MV portion of the network. Significant deployments of smart grid on a wide scale are yet to be deployed by utilities around the globe. It is therefore of particular interest for the DNOs within the UK power sector to start exploring the development of communication framework and standards for smart grid communication systems such as SGAM. Once these are in place they have the potential of delivering huge benefits to the UK's power sector. Additionally and of significant importance is for DNOs to begin investigation of recommendations made by the report on cyber security and impacts of cyber threats on the UK's future smart grid networks.

The report for this work will also be available in the public domain on the ENA website.

12 Contact

Further details on replicating the project can be made available from the following points of contact:

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