PETERBOROUGH INTEGRATED RENEWABLES INFRASTRUCTURE

SUMMARY REPORT

Distributed Energy Resource Management System Design Specification

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DER Management System Design Specification
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Refer to full report for full details.

Executive summary

Smarter Grid Solutions (SGS) is working with Peterborough City Council (PCC) to support the Peterborough Integrated Renewables Infrastructure (PIRI) innovation project along with other project partners. SGS is establishing the requirements for delivery of project functions through Distributed Energy Resource Management System (DERMS) technology that includes forecasting and dispatching to deliver low carbon multi vector energy financial benefits to customers participating in the PIRI trial. The role of SGS, as a PIRI partner, is to ensure the architecture, use cases and techniques being deployed in PIRI for Distributed Energy Resource (DER) management will support the PIRI smart energy system objectives and the transferability to other UK cities.

The PIRI project centres on a whole systems approach to electricity, heat, and mobility (transport), all linked by a smart energy management system. The smart local electricity system will use supply and demand balancing technology to better meet the needs of the city's homes and businesses. The PIRI project would see some of the steam used to generate electricity at the existing Peterborough Energy Recovery Facility (PERF) put through a heat exchanger to derive heat for a heat distribution network. The project will also explore the electrification of buses and council vehicles, as well as providing charge points for public and private use. Energy from waste, solar power and wind will be harnessed to help support the city as it grows.

This report summarises SGS's design specification report that aimed to provide a design specification for the proposed PIRI DERMS which can be used for system procurement purposes. This summary report includes overview information on the overall design and operating principles, the high-level proposed architecture, the functional and non-functional requirements, functional uses cases and the high-level test strategy. Full details are included in the SGS **DER Management System Design Specification.**

List of abbreviations

ANM	Active Network Management
BESS	Battery Energy Storage System
CHP	Combined Heat and Power Plant
DER	Distributed Energy Resource
DERMS	Distributed Energy Resource Management System
DNO	Distribution Network Operator
HH	Half-hourly
P	Real Electrical Power
PCC	Peterborough City Council
PERF	Peterborough Energy Recovery Facility
PV	Photo-voltaic solar energy electricity generation technology
PW	Private Wire
PWN	Private Wire Network
Q	Reactive Electrical Power
SCADA	Supervisory Control and Data Acquisition
SGS	Smarter Grid Solutions
UI	User Interface

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1. Introduction

Smarter Grid Solutions (SGS) is working with Peterborough City Council (PCC) to support the Peterborough Integrated Renewables Infrastructure (PIRI) innovation project along with other project partners including SSE Enterprise, Element Energy, Cranfield University and Sweco. SGS is establishing the requirements for delivery of project functions through Distributed Energy Resource Management System (DERMS) technology that includes forecasting and dispatching to deliver low carbon multi vector energy financial benefits to customers participating in the PIRI trial. The role of SGS, as a PIRI partner, is to ensure the architecture, use cases and techniques being deployed in PIRI for Distributed Energy Resource (DER) management will support the PIRI smart energy system objectives and the transferability to other UK cities.

The PIRI project centres on a whole systems approach to electricity, heat, and mobility (transport), all linked by a smart energy management system. The smart local electricity system will use supply and demand balancing technology to better meet the needs of the city's homes and businesses. By creating a local electricity network, the project aims to reduce strain on the main UKPN distribution grid and meet local electricity demand with electricity production in Peterborough. The existing Peterborough Energy Recovery Facility (PERF) turns unwanted waste into steam which is then converted to electricity using a steam turbine which is presently sold on the wholesale electricity market. The PIRI project would see some of the steam used to generate electricity used through a heat exchanger to derive heat for a heat distribution network. The project will also explore the electrification of buses and council vehicles, as well as providing charge points for public and private use. Energy from waste, solar power and wind will be harnessed to help support the city as it grows.

At this design stage, the potential assets being considered for PIRI and how they will be utilised have been documented in an Element Energy report which considers the PIRI Concept design and outline feasibility, techno-economic feasibility (TEF) assessment for electricity and transport (Confidential Draft Report for PIRI Consortium, July 2021). It has been agreed with the PIRI partners that Design 2 outlined in the Element Energy feasibility study will be developed. Design 2 includes the Peterborough Energy Recovery Facility (PERF) and the private wire (PW) network to connect customers and provide them with electric power from the PERF and also a proposed new greenfield site PV facility connected to the PW network. The design also includes a proposed new PW Battery Energy Storage System (BESS) facility connected directly to the PW network. As customers are added to the PW network, the PERF electricity production will need to be managed at peak wholesale electricity price times to reduce the cost of residual top ups from the grid, the PW BESS would be used for this as well as potential value stacking through trading in other markets.

During SGS's engagement on the PIRI project, interest in energy proof of origin has been expressed by one of the project partners – this seeks to maximise alignment of aggregated client loads to named generation through demand and energy storage control. This would facilitate the alignment of demand with clean energy sources and in reporting and managing the carbon content and origin of each unit of energy consumed and demonstrate the level of energy system decarbonising achieved accurately. This has been translated into a role for the DERMS scheme to recognise the carbon intensity of each main PIRI Private Wire Network (PWN) electricity source and use this to estimate and forecast the average carbon intensity within the PWN. This information will be accessible to PWN connected customers allowing them to make decisions on when to alter demand, for example, when to charge electric vehicles.

This report summarises SGS's design specification report that aimed to provide a design specification for the proposed PIRI DERMS which can be used for system procurement purposes.

2. Control solution overall design and operating principles

The DERMS control solution is based on the following design and operating principles:

1. To minimise the volume and cost of wholesale market electricity required to top up PWN supplies.
2. To ensure the PWN operates within its thermal limits at all times as PWN connected customer numbers, demand import and generation export increase, the DERMS will include active network management (ANM) functionality to control flexible demand and generation connected to the PWN.
3. To use historical data, weather forecasts and other influencing factors (e.g. time of day) to forecast PWN demand, generation, and grid supply top up requirements on a half hourly granularity. Forecasts to be up to 7 days ahead. By using third-party day ahead wholesale market price forecasts, the DERMS will optimise charging and discharging of the PWN Central BESS to minimise wholesale market energy costs for grid supply top up supplies to the PWN.
4. To monitor and report on the overall estimated carbon intensity of the electricity entering the PWN including electricity imported from the UKPN grid connection, export from the PERF, PWN central PV plant, PWN central BESS and any future PWN connections.
5. To forecast the half-hourly (HH) PWN electricity carbon intensity, up to 2 days ahead and make these forecasts available to PWN customers.
6. To be expandable in order to add new demand and generation.
7. To ensure that communication failures to DER will not result in damage to the PWN, persons or a major loss of supply to customers through cascade tripping of PWN protection devices.

3. High-level proposed architecture

The architecture design covers the interfaces between the actors set out in the context diagram (Figure 1). A number of central multi EV charging facilities have been identified by the PIRI development team. It is assumed that each of these EV facilities would have their own EV charging management system that would manage the overall facility electricity demand within the supply connection capacity agreement. In the future EV charging facilities could provide flexible demand services, where connected to the PWN, managed by the PIRI DERMS, see “Other Future PW DER” in the context diagram.

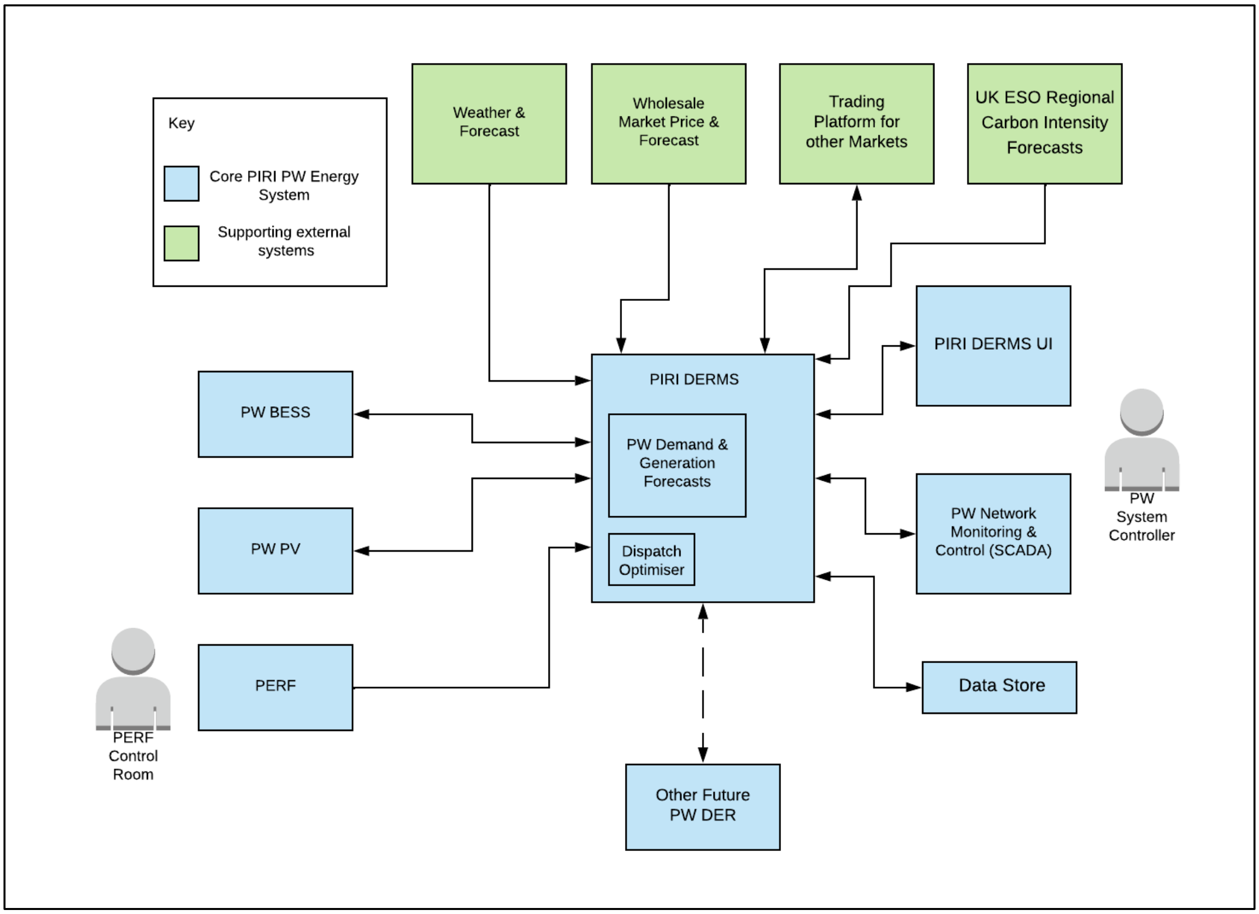

Figure 1 PIRI DERMS context diagram

3.1 System Actors

The system actors in the context diagram are briefly described in the **Table 1**.

Table 1 – System Actors

Actor	Type*	Description
PIRI DERMS	S	Central control system to monitor power flows and issue import/export schedules and set points to DER to manage the PIRI system to minimise electricity charges to customers, minimise carbon and ensure secure and safe operations. Demand and generation forecasting using third party system weather forecasts and, external wholesale price forecasts, to optimise BESS.
PIRI DERMS UI	S	Controlled access to Graphical User Interface via user accounts with different access rights: e.g. Viewer, Controller, and Admin.
PW System Controller	O/P	This is taken to be the organisation/persons responsible for the operations of the PW Network.
PW Network Monitoring & Control (SCADA)	S	A combination of hardware and software installed as part of the PIRI PW network design. This would be used by the PW System Controller.
Data Store	S	Will record all measurement data and DERMS system actions. The stored data can be used for settlement purposes, to support forecasting and for post event analysis.
PW BESS	S	To manage peak demands and minimise the cost of electricity top ups from wholesale market, potential value stacking through trading in other markets. The PIRI DERMS will use forecasts of wholesale electricity prices and PW network demand and generation forecasts to optimise dispatching of the PW BESS.
PW PV	S	A PCC planned greenfield PV generation facility which will be connected to the PW network
PERF	S	Although there is no scope for the PIRI DERMS to influence PERF electricity output, the PERF will provide generation forecasts to assist the PIRI DERMS manage the cost of grid top ups to the PWN
PERF Control Room	O/P	Manages heat and electricity production from the PERF. It would assist the PIRI DERMS by forecasting available PERF electricity.
Other Future PW DER	S	This allows the provision for other as yet unknown future PW network connected DER to be considered in the DERMS design.
Wholesale Market Price Forecast	S	External system that provides day ahead forecast wholesale market prices for electricity.
Weather Forecast	S	External third-party system that provides weather forecast data (week, day, intra-day) used by PIRI DERMS in the forecasting of demand and generation on the PW network.
Third Party Trading platform for markets	S	A trading platform into electricity markets including wholesale, Balancing Mechanism, and other ancillary service markets. This allows the trading of forecast excess PW network electricity or available demand flexibility into other markets.
UK ESO Regional Carbon Intensity Forecasts	S	Third-party system to forecast regional electricity supply carbon intensity through an API. Guidance on the available Carbon Intensity API is provided at **https://www.carbonintensity.org.uk/**

*S = System, O/P = Organisation/Person

3.2 Architecture overview

The PIRI DERMS proposed high level architecture is illustrated in **Figure 2**. The DERMS Central Controller required functionality is fully detailed in the SGS **DER Management System Design Specification,** with summary details provided in this document.

DER to be managed will include PW central DER assets including the planned PW BESS and PW PV facilities and any future PW central DER assets. DER to be managed could also include:

- Customers with generation such as PV, wind, CHP, BESS etc.
- Customers with flexible demand such as EV charge points and BESS.

The PW Local DER Interface would provide the control interface with the customer DER control systems or PW central DER control systems, monitor power flows at each DER site and provide fail-to-safe functionality should communications be lost, or DER assets not responding to DERMS issued P, Q set points. Measurement information at each PW customer connection, and at measurement points on the PW network required by the DERMS would be provided from the PW network SCADA system. For customer sites with managed DER, measurement data and DERMS issued control signals would be via the SCADA communications system.

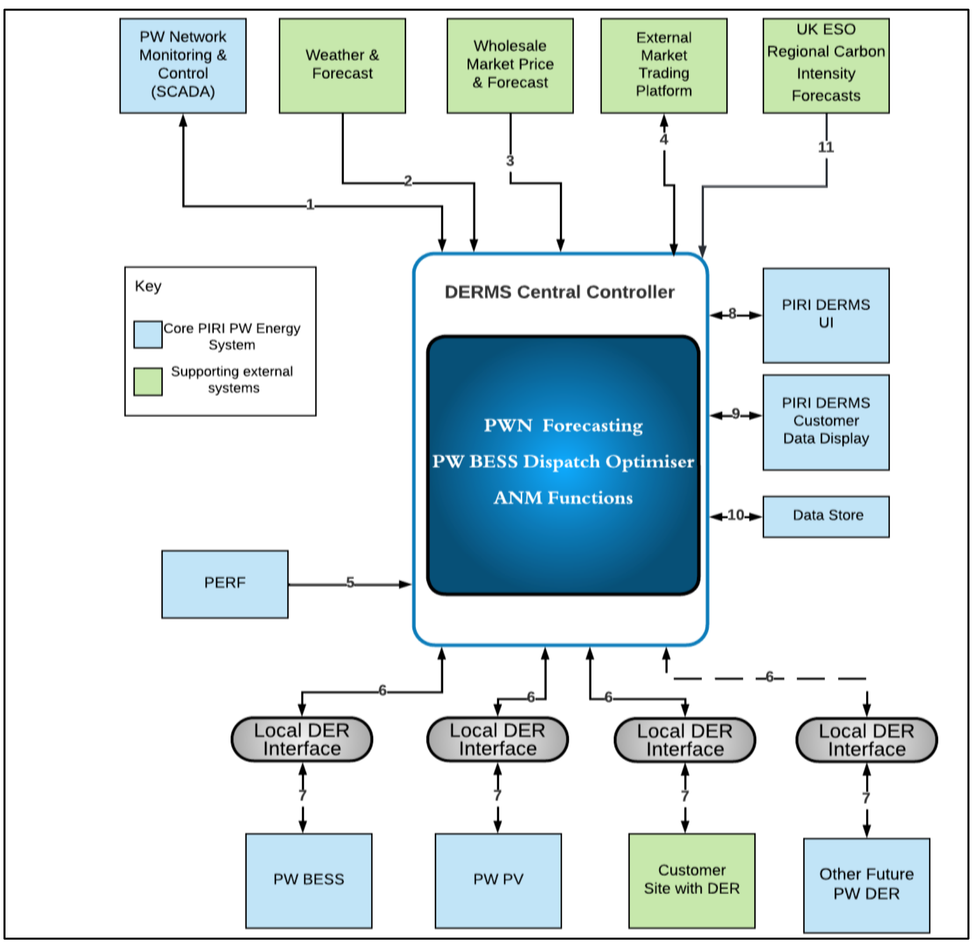

Figure 2 PIRI DERMS Proposed Physical Architecture

3.3 Architecture Interfaces

A representation of the proposed PIRI DERMS architecture interfaces is illustrated in Figure 3.

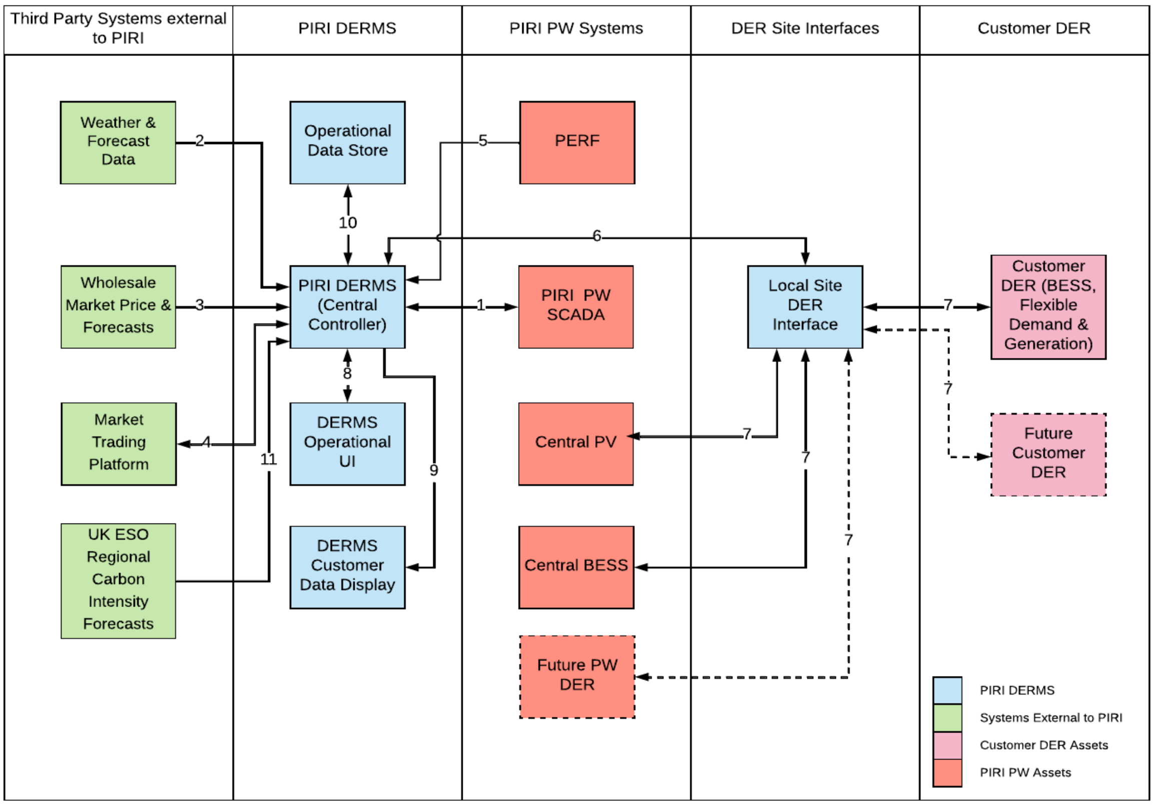

Figure 3 PIRI DERMS Proposed Logical Architecture

3.4 PIRI DERMS Functions

The PIRI DER Management system has two primary functions:

1. Minimise the cost of electricity top ups to the PW network from the wholesale electricity market via the utility grid connection.
2. Ensure the PW Network is operated within its thermal capacity limits or other agreed capacity limits e.g. the connection capacity limit agreed with UKPN for the PW network grid supply connection.

The first primary function envisaged for the PIRI DERMS is to minimise the cost of grid supply top ups when wholesale market prices are forecast to be highest when demand on the PW network is high. The PIRI DERMS will achieve this by forecasting PW demand and sources of electricity supply (PW PV, PW BESS, PERF electricity export). Combining this with forecast wholesale electricity market prices will allow the PIRI DERMS to optimise the dispatching of flexible generation (PW BESS) to minimise the cost of grid supply top ups. The PIRI DERMS will also optimise the recharging of the PW BESS either when there is an excess of PW generation sources above PW demand or when wholesale electricity prices are low or when both conditions exist. Where there is an excess of PW generation and forecast wholesale market prices are high, there may be a case for exporting generation to the utility grid rather than charging the PW BESS. Forecasting PW network demand and generation will utilise sources of metered customer net demand and PW generation export data. This data is assumed to be available to the PIRI DERMS via the PW SCADA system.

The PW network will be designed with both technical design limits and contractual agreement limits that will limit the flow of power in, out and through the PW network.

- There will be contractual agreements with UKPN on the power import and export relating to the PW Network connection to UKPN's network. The connection agreement will place limits on both real and reactive power, there will also be technical limits which will ultimately result in protection system operation when violated, tripping connections to the UKPN network.
- There will be contractual agreements with customers connecting to the PW network which are expected to place limits on real and reactive power taken from the PW network and exported onto the PW network (where export capability is required). This will include demand, generation and mixed demand and generation customers.
- The PW network will have technical design limits e.g. thermal capacity, statutory voltage limits, frequency, harmonics, fault level and faut duration and others. Exceeding technical limits may ultimately result in protection system operation and causing a loss of supply to PW customers.

3.5 PIRI DERMS Further Architecture Detail

A key element of the PIRI DER Management system will be the need for the DERMS Central Controller to communicate with the Local DER Interface device at each managed DER site. This will allow the DERMS Central Controller to receive status information for each DER being managed. There is also a need to communicate with the distribution network SCADA system to receive status information on distribution network circuit breakers and measurement data for key circuits of interest as well as allow the PW network control engineers to issue manual commands where required.

The preferred option for PIRI DERMS communications with DER and the PW SCADA system would be a **fibre optic network** with sufficient bandwidth, low latency and high reliability. DERMS can also be implemented with lower bandwidth, higher latency and less reliable communication infrastructure but will have slower and less reliable performance requiring larger safety margins for ANM applications. Where the PIRI PW design does not include fibre optic communications to manage DER customer sites, **cellular 4/5G communications may offer an alternative solution** assuming cellular services are sufficiently reliable in the Peterborough city centre area associated with the PW network.

3.6 Carbon Intensity

The PIRI DER Management system high level use cases introduced PW network carbon intensity forecasting. The carbon intensity of generation assets can be established when devices are registered onto the PIRI DERMS. The PW BESS and any other future PIRI DERMS managed BESS would require monitoring of the charge cycles to establish the BESS generation export carbon intensity (i.e. you need to estimate the carbon intensity of electricity going into the BESS to estimate the carbon intensity of the BESS export).

Grid supplied top up carbon intensity will use half-hourly carbon intensity published by the UK ESO. It is expected that the PIRI DERMS could provide a 2-day ahead forecast of estimated carbon intensity within the PW network along with historic carbon intensity profiles to assist customers plan their electricity usage to minimise their own carbon footprint e.g. Peterborough City Council can plan when best to charge their own fleets of electric vehicles.

4. Functional and Non-functional requirements

The functional requirements for the PIRI DER Management System cover several grouped themes:

- Network and DER observation
- Data inputs
- Forecasting
- Dispatching
- Performance Monitoring
- Failsafe
- Operating profile
- Graphical User Interface (UI)
- Configuration

The non-functional requirements for the PIRI DER Management System cover several grouped themes:

- Overall requirements
- Local DER Interface (DERMS Outstation) requirements
- Interface requirements
- Cyber security requirements
- Events and data logging

The PIRI DERMS functional and non-functional themes and numbered requirements are set out in the SGS DER Management System Design Specification.5. Functional Use Cases

The following high-level use cases have been identified for the PIRI DERMS which are supported by the PIRI DERMS architecture, and the functional and non-functional requirements. The use cases include those from the earlier SGS design document "DER Management System High Level Requirements and Use Cases" and additional use cases identified in the SGS DER Management System Design Specification.

These high-level use cases are set out in further detail using a standard use case template in the SGS DER Management System Design Specification.

- Obtain wholesale electricity price data.
- Forecast PW network demand from customer sites
- Forecast PW network generation levels
- Forecast PW network electricity top ups from the DNO grid connection
- Forecast PW network carbon intensity
- Forecast PW network constraints
- Optimise PW BESS dispatching
- Performance Monitoring, demand, generation, grid top ups, carbon intensity and DER constraining actions
- Fail-to-safe actions.

6. PIRI DERMS High Level Test Strategy

The test strategy for the PIRI DERMS is to ensure that all functional requirements and use cases are safely and adequately tested prior to the system going live on the PWN. This is to include testing in suitable environments at suitable stages before, during and post system integration with the required

PWN systems ensuring coordination with the PWN project installation programme including the integration and testing programme of other PWN systems related to PIRI DERMS including PWN SCADA/NMS, PW BESS, PW PV, other Local DER, and the other supporting third-party systems (Wholesale price, weather forecast, market trading and NG ESO carbon intensity systems).

Hence there will be a need to agree and establish suitable test stages and environments with the PIRI project delivery management team (yet to be established), including:

1. Factory Acceptance Testing (FAT)
2. Pre-Production Testing (PPT)
3. Site Acceptance Testing (SAT)