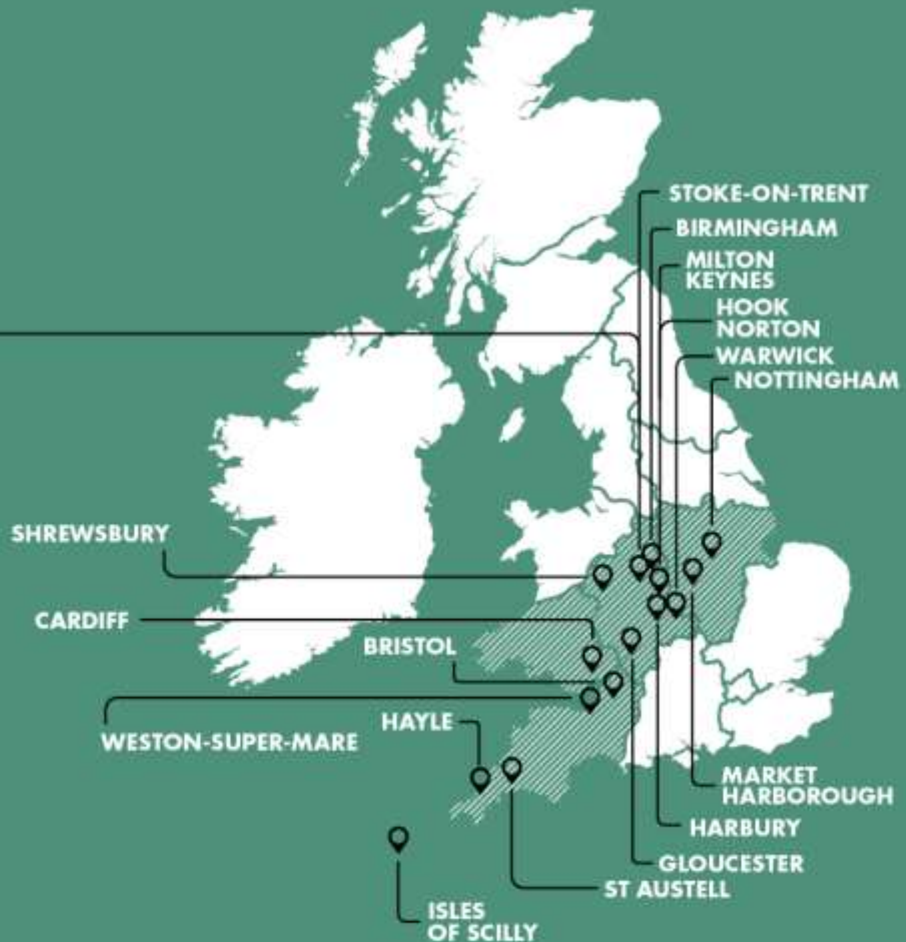
WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS



Distribution Networks: A Balancing Act

Thursday 20th November 2014

Roger Hey

Future Networks Manager

Agenda

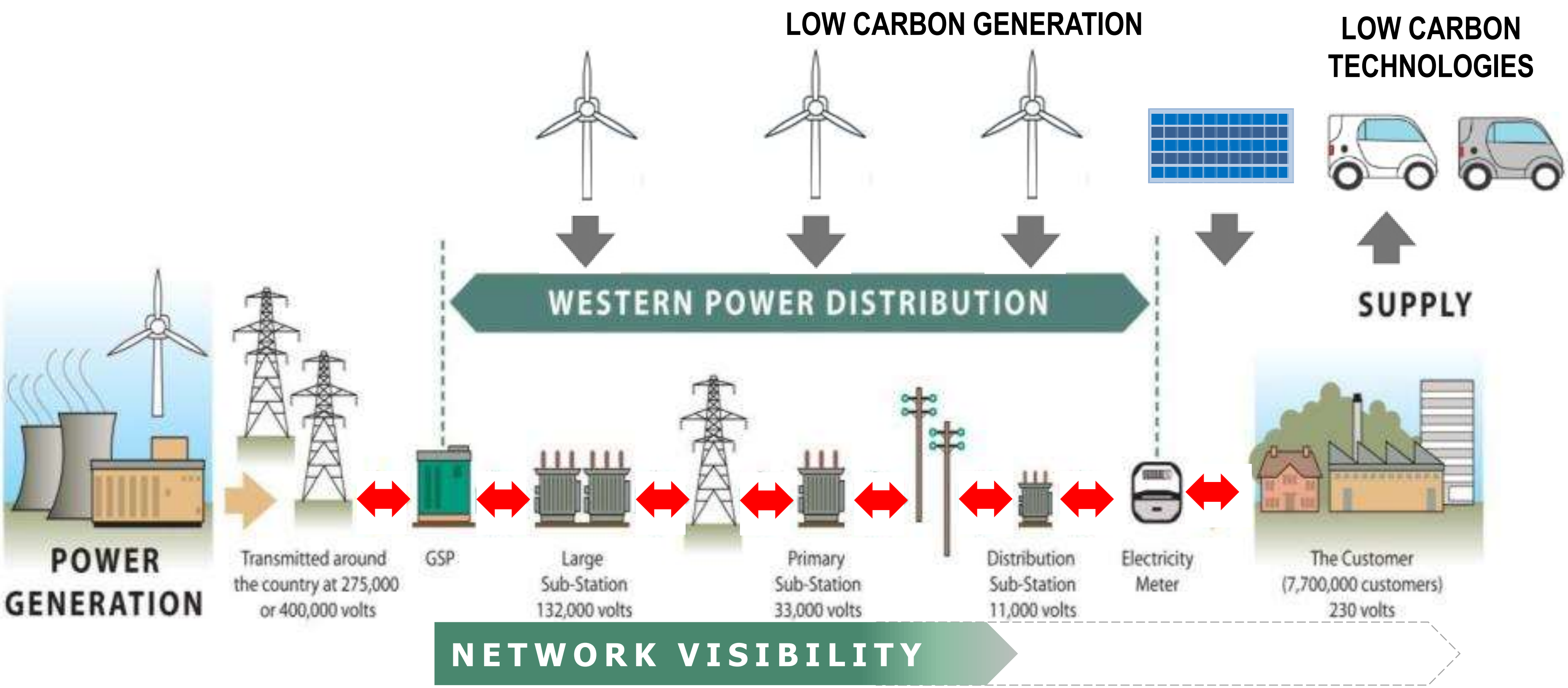
Session 1 Alternative Connection Agreements	**10:20-12:00**
Alternative Connections Agreements – DG viewpoints	
Coffee Break	
Network planning, constraints and Alternative Connections	
Lunch & Networking	**12:00-13:00**
Session 2 – Demand Side Response (DSR)	**13:00-13:45**
Demand Side Response	
Session 3 – Energy Storage	**13:45-15:15**
Learning from Energy Storage Projects	
Customer Slot – How they are going to trial Energy Storage	
Identifying energy storage opportunities - distribution network	
Wrap up and panel session questions	
End of Dissemination Event conversations	**15:15-16:00**

WESTERN POWER DISTRIBUTION

KEY FACTS:

- Wholly owned by Pennsylvania Power & Light
  (PPL - NYSE listed)
- 4 UK Distribution Licences
- 7.7 million customers
- 55,000 sq km area
- Largest length UK network
  216,000 kms of overhead lines and underground cables, and 184,000 substations

The Evolving Electricity Network



- Limited capacity
- Passive design / operation
- Centralised Generation
- Limited Visibility
- One-way power flow
- Load centric design

- Reduced headroom
- Increased Intelligence / Active Management
- Distributed Generation
- Need for increased visibility
- Two-way power flows
- Utilisation centric design

- WESTERN POWER DISTRIBUTION LOW CARBON HUB
- WESTERN POWER DISTRIBUTION NETWORK TEMPLATES
- WESTERN POWER DISTRIBUTION SOLA BRISTOL
- WESTERN POWER DISTRIBUTION FALCON
- WESTERN POWER DISTRIBUTION FLEXDGRID
- WESTERN POWER DISTRIBUTION SOLAR STORAGE
- WESTERN POWER DISTRIBUTION ISLES OF SCILLY SMART GRID

Innovation Strategy

Networks

Demonstrating alternative investment strategies to facilitate the UK's Low Carbon Transition

Customers

Testing innovative solutions to make it simple for customers to connect Low Carbon Technologies

Performance

Developing new solutions to improve network and business performance

Stakeholder Engagement and Knowledge Management

- WESTERN POWER DISTRIBUTION ECHO
- WESTERN POWER DISTRIBUTION HV VOLTAGE CONTROL
- WESTERN POWER DISTRIBUTION LV SENSORS
- WESTERN POWER DISTRIBUTION SMART HOOKY
- WESTERN POWER DISTRIBUTION COMMUNITY ENERGY ACTION
- WESTERN POWER DISTRIBUTION ELECTRIC BOULEVARDS

- Super Conducting Fault Current Limiter (energy technologies)
- Isentropic Energy Storage (energy technologies)
- Carbon Tracing
- WESTERN POWER DISTRIBUTION CONTROL CENTRE LINKS
- WESTERN POWER DISTRIBUTION EARLY LEARNING
- WESTERN POWER DISTRIBUTION SEASONAL GENERATION
- WESTERN POWER DISTRIBUTION SUBURBAN PV IMPACT

Benefits from previous R&D projects

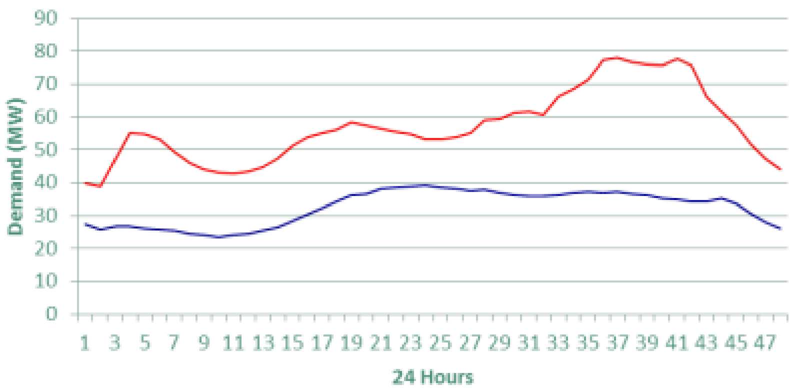
The following projects have been fully implemented across WPD since 2005:

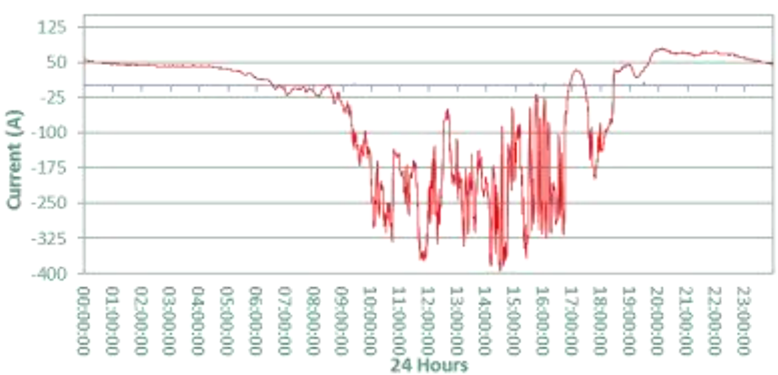
- **Reference Model Network** – Improved Network planning and study techniques
- **Helicopter Inspection Techniques** – Better condition assessment and post-fault restoration
- **Understanding High Penetrations of Distributed Generation**– Modification to conventional network design assumptions
- **Climate Change and Weather Analysis** – New methodologies and probability based predictions to assess network impacts of climate change
- **Non-intrusive testing of tower foundations** – New testing techniques implemented to improve accuracy and speed of response
- **Control system automation algorithm** – Development of reliable and secure protocols for self-healing networks leading to improved network performance
- **11kV Voltage Optimisation project** - Demonstrated of wide scale voltage reduction without adverse impact on customers
- **Electric Vehicles** – Investigation into the impact of charging electric vehicles on Low Voltage networks. Learning incorporated into IET wiring regulations and DNO standards.
- **Harmonic issues on distribution networks** – Investigation into potential harmonic problems caused by converter plant. Learning influenced ENA planning guidelines.
- **Condition Based Risk Management (CBRM)** - Delivered a tool that determines optimum replacement triggers for network assets.
- **Alternative Connections** – Offering Timed, Soft Intertrip and Active Network Management (ANM) generation connections





Innovation for future networks





Our LCNF and IFI projects indicate that there are some smarter solutions which could be used to complement conventional network reinforcement.

We have already started to actively balance generation export with demand profiles, unlocking additional network capacity.

Most innovative solutions require further development and/or cost reduction before they can be applied in the normal course of business.

Being discussed at today's dissemination event:

- Alternative Connections
- Demand Side Response
- Energy Storage

Session 1

Alternative Connections

Alternative Connections Agreements – DG viewpoints

20.11.2014

Outline

- Introduction
- Low Carbon UK – Solar PV
- Challenges
  - Grid connection
    - Conventional connection
    - Alternate connection

juwi at a Glance

Established: 1996 (two-man office)

Employees: more than 1,100 (worldwide)


Headquarters in Wörrstadt, Rhineland-Palatinate

Project development of regenerative power plants

- planning
- construction
- financing
- technical consulting


50 MW wind farm Guanacaste in Costa Rica

Our vision: **100% renewable energy**

Our claim: **Energy is here**


53 MW solar park Lieberose

→ Let's work together to implement renewable energies economically and reliably with passion.

Juwi‘s Sources of Energy

Wind Energy

- more than 252 wind turbines (at 85 locations)
- more than 1000 MW of installed capacity
- total investment: approx. € 1,35 billion
- annual energy production: approx. 2,3 billion kWh

Plouguin wind farm, Bretagne

Solar Energy

- more than 1,500 PV installations
- more than 1200 MW of installed capacity
- total investment: approx. € 2,7 billion
- annual energy production: approx. 950 mio kWh

PV-free-field installation Drama, Greece

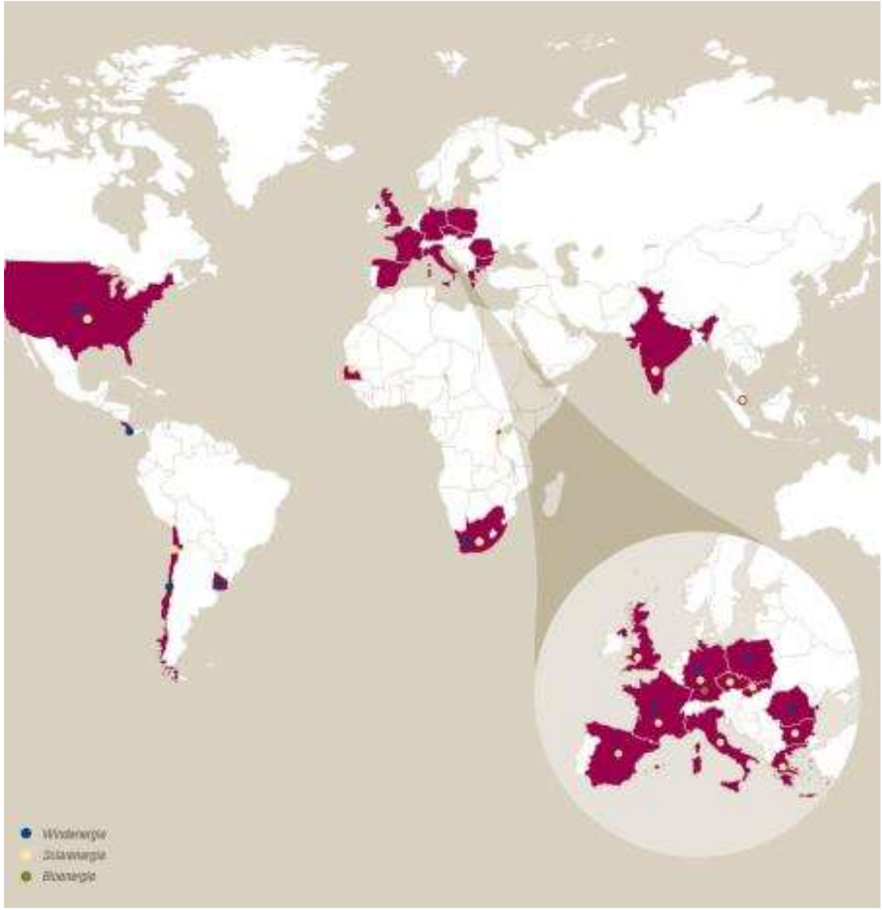
Solar-Hydrogen

- 1 green hydrogen production plant
- TSB funded project: approx. £ 130k

Solar-H2: Green hydrogen production, UK

Offices, Projects and Markets

Projects and Markets



Offices

- **Europe**

  Germany, France, UK, Italy, Greece

- **Americas**

  USA, Chile

- **Asia**

  India, Singapore, Japan, Thailand

- **Africa**

  South Africa

juwi - UK

Hollies solar farm, Skegness, Total capacity: 8605 kWp

Ninnis solar farm, Cornwall, Total capacity: 3880 kWp

King's Lynn Solar farm, King's Lynn, Total capacity: 1332 kWp

Outline

- Introduction
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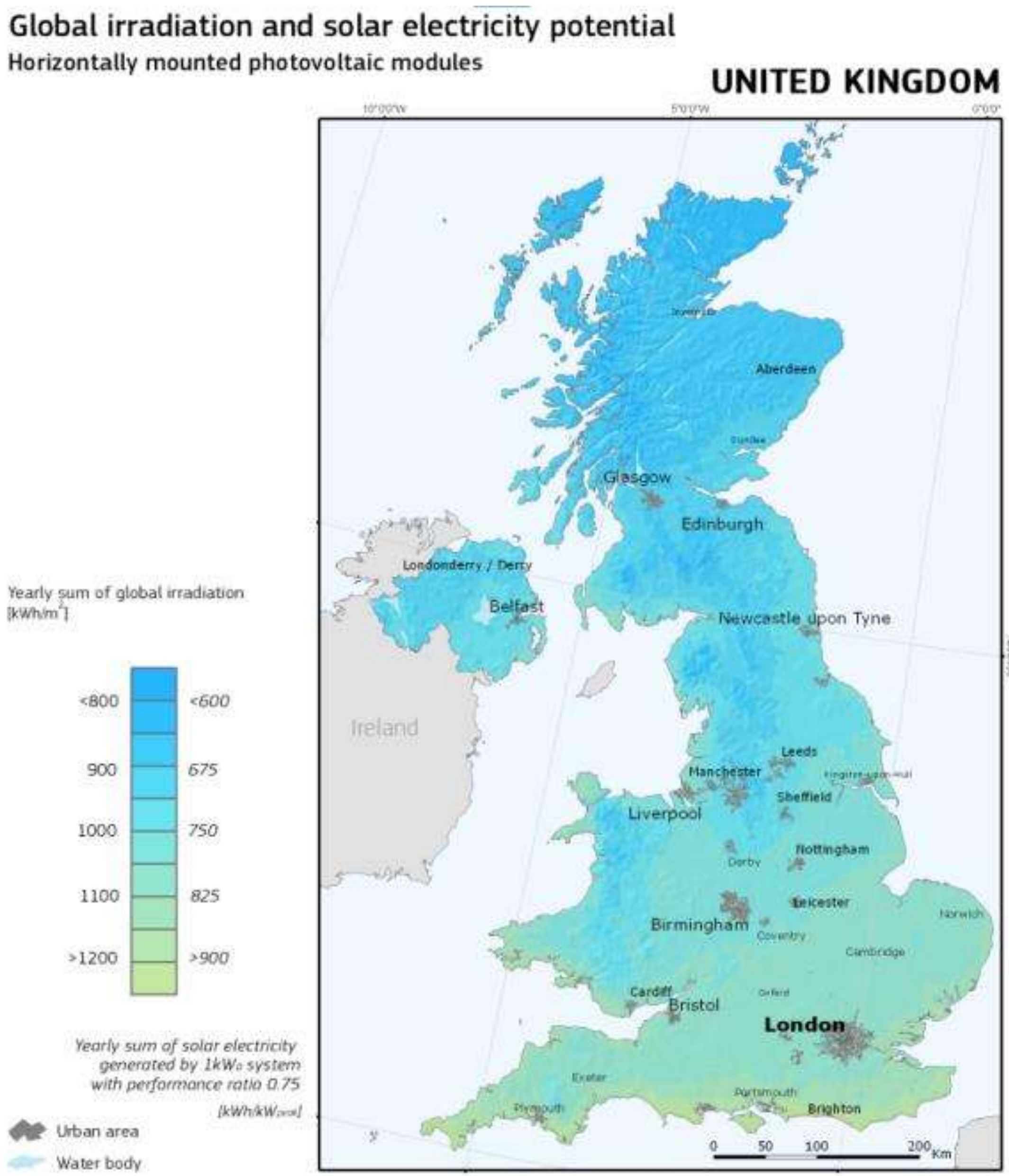
Low Carbon UK – Solar PV

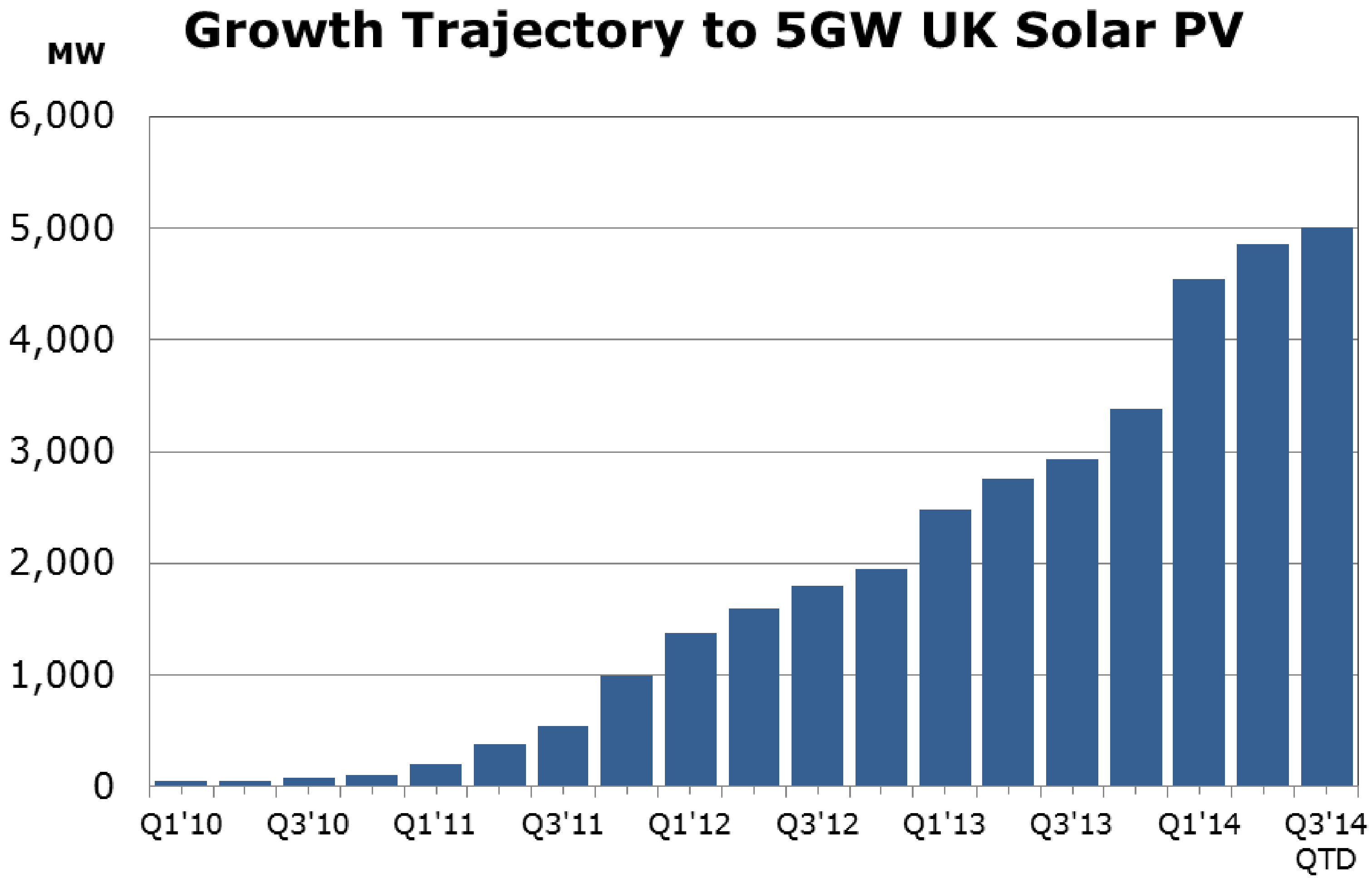


Ref: PVGIS – CM SAF

Incentive Schemes

- **Feed in Tariff (FIT):**
  - Started in April 2010 @ 29p/kWh (250kWp - 5MWp)
  - ~70% reduction within 1 years
- **Renewable obligation Certificate (RoC)**
  - Started with no capacity constraint
  - No RoC for > 5MWp after March 2015
- **CFD bidding process**
  - Started in Oct-Nov 2014
  - Uncertainty ??

Installed capacity – the biggest solar market in Europe



Source: NPD Solarbuzz UK Deal Tracker report, July 2014 & NPD Solarbuzz European PV Markets Quarterly, July 2014.
QTD: Quarter-to-Date

Outline

- Introduction
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    - Alternate connection

Solar PV development challenges

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- FIT in April 2010 vs FIT in September 2011

miscalculation → Tariff was too high

miscalculation → Tariff was too low → Only considered module price reduction and Missed the grid connection change

- EU anti dumping tariff on module
- Digression of RoC vs increasing grid connection charge
- Rate of deployment of PV is faster than up gradation of grid network

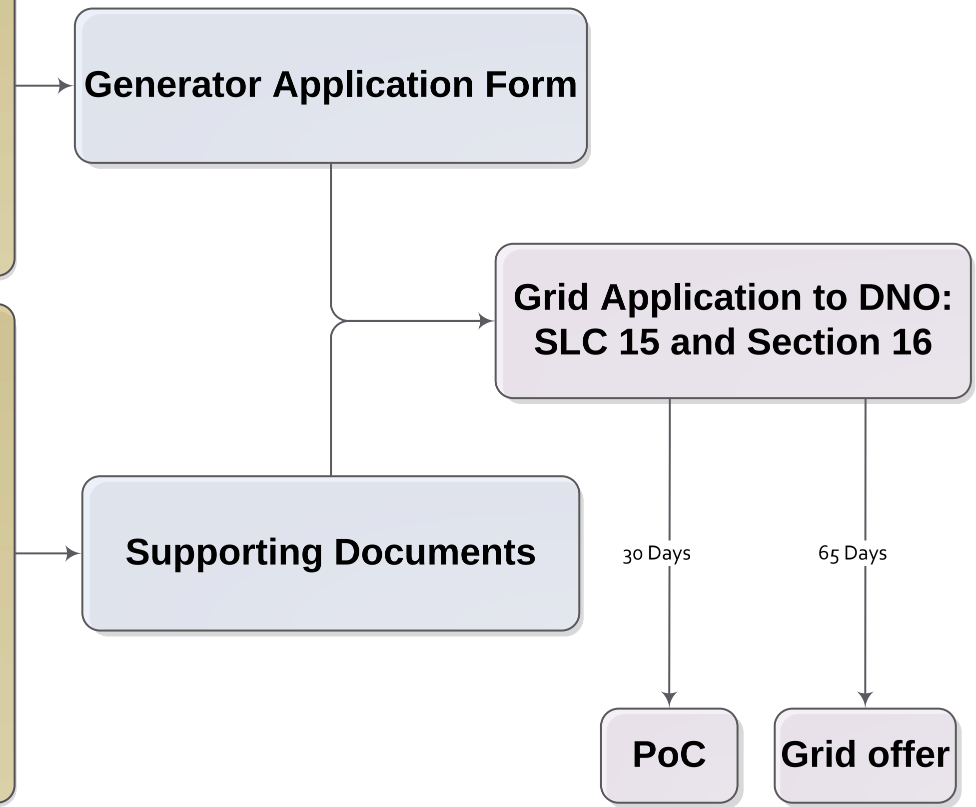
Conventional grid connection

Type of offer	What is this?
Budget Estimate	A basic desk top estimate without any system studies. It is an indicative offer.
Feasibility Study	A chargeable electricity system study to give a more detailed view of likely connection costs for various options.
S16 Connection Offer	DNO will quote for undertaking all the contestable and non-contestable works.
SLC15 CIC Connection Offer	If you want to arrange to do the contestable works yourself (ICP), DNO will quote for the non-contestable works only.

Full Grid Application Process

1. Site details
2. Number of generation sets
3. Power station export and import requirements
4. Power station maximum fault current
5. Generation set active & reactive power capacity
6. etc

1. Site location and Module layout
2. Proposed Metering / substation Location
3. AC Single Line Diagram (SLD)
4. Datasheet / Technical specification of Transformer
5. Datasheet / Technical specification of Inverter
6. Short circuit current details of inverter
7. Harmonics of inverter
8. Letter of authority from land owner



http://www.energynetworks.org/electricity/engineering/distributed-generation/distributed-generation.html

Grid Connection - is there any challenges?

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- Available **Capacity**:

  speed of PV deployment exceeds speed of grid upgrades –

  developers are competing for best connections

- Process difficulties:
  - budget offer – **is it reliable?**
  - increasing **interactivity**
  - different approaches from different DNOs
- **Connection charge???**
- **Increasing connection charge even after accepting the binding offer**
- Outage booking: 'winter Clock Change period' vs Regulation
- Approved switchgear lead time vs project completion date
- Grid maintenance and system generation loss (kWh)

Outline

- **Introduction**
- **Low Carbon UK – Solar PV**
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  - Grid connection
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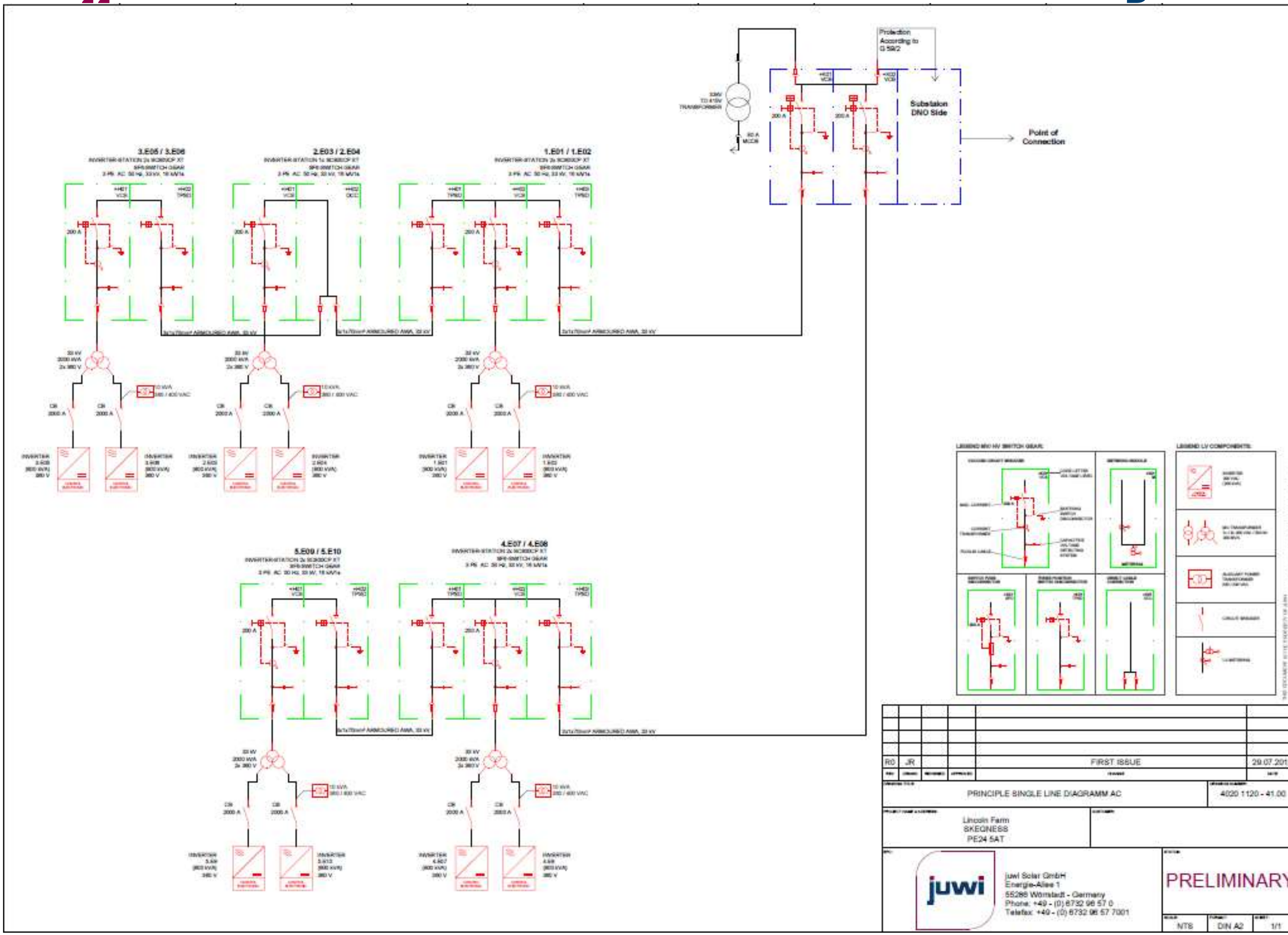
Case Study - Conventional connection



Highlights of the offer

Notice of Interactivity

Please note that this Connection Offer is deemed to be an **Interactive Connection Offer** and WPD is notifying you of the fact in accordance with paragraph 2.24 of our Statement of Methodology and Charges for Connection.

This means that WPD has received a separate application for a connection that makes use of the same part of WPD's **Existing Network**, or **Committed Network**, or otherwise has a material effect on the operation of WPD's Distribution System.

Your Connection Offer is fourth in the **Interactive Queue.**

4 Connection Charge

4.1 The contribution required for providing an electricity connection to the Customer's Premises is:

£ 11,654,352.14 including VAT which shall be payable at the appropriate rate (the **"Connection Charge"**).

Outline

- **Introduction**
- **Low Carbon UK – Solar PV**
- **Challenges**
  - Grid connection
    - Conventional connection
    - Alternate connection

Case Study – Alternate connection offer

2 Basis of the Alternative Connection Offer

2.1 Customer's Installation

2.1.1 WPD understands that the proposed Customer's Installation will comprise the following:-

- 10 x 0.88MVA (0.88MW), 360V solar inverters; and
- 5 x 2MVA, 33/0.36/0.36kV transformers

2.2 Connection and Supply Specification

2.2.1 The characteristics of the new connections will be:

Nominal Voltage at Connection Point: 33,000 V
No of Phases: 3
Nominal Frequency: 50 Hz
Maximum Export Capacity: 8,800 kVA @ Unity Power Factor
Maximum Import Capacity: 80 kVA @ 0.95 Power Factor
Acceptable Power Factor Bandwidth for Export Capacity: Unity with transient excursions to 0.95 lagging and leading power factor being accepted (subject to agreement of National Grid Electricity Transmission plc (NGET).
Acceptable Power Factor Bandwidth for Import Capacity: 0.95 lag to 0.95 lead

Highlights of the offer

juwi

Last In, First Out Position (LIFO)

Where more than one connection within a given section of network needs to be curtailed then the connections shall be curtailed in order, with the last comer being curtailed first and the first comer being curtailed last. When the network limitation is lifted then the connections are restored to normal in the opposite order, i.e. the first comer is restored first and the last comer is restored last. This principle is known as Last In First Out (LIFO). Where a group of connections are handled in this way they are known as a LIFO stack.

The LIFO position number indicates the number of generators connected through alternative connections ahead of you in the LIFO queue.

Your generator will hold the following LIFO position: [5]

The following generation is above you in the LIFO queue:

Generation Type	Generation Capacity (MW)	Number of Connections
Wind	10	1
Solar	24.32	3
Synchronous/Other	0	0

Highlights of the offer - original

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Curtailment under normal running conditions

A study has been completed to assess the level of curtailment of this connection under normal running conditions. This study is based on recent historic trends and predicted generation output. Further details on the assumptions can be made available on request.

Estimated worst case with all generation at maximum output and a reduction in current demand by 25%	Estimated 87.7% Energy constrained from 115,493.6 MWh output over 18 months
Estimated current scenario with no smart grid technology	Estimated 15.8% Energy constrained from 19,789.2 MWh output over 18 months
Estimated current scenario with smart grid technology	Estimated 16.7% Energy constrained from 19,789.2 MWh output over 18 months

Connection Charge

The contribution required for providing an electricity connection to the Customer's Premises is:

£ 453,494.17 excluding VAT which shall be payable at the appropriate rate (the **"Connection Charge"**).

Highlights of the offer - current

Generation Type	Generation Capacity (MW)	Number of Connections
Wind	10	1
Solar	24.32	3
Synchronous/Other	0	0

Table 1

Generation Type	Generation Capacity (MW)	Number of Connections
Wind	10	1
Solar	12	2
Synchronous/Other	0	0

Table 2

Estimated worst case with all generation at maximum output and a reduction in current demand by 25%	Estimated 50.8% Energy constrained from 115,494 MWh output over 18 months
Estimated current scenario with no smart grid technology	Estimated 0.2% Energy constrained from 19,789 MWh output over 18 months
Estimated current scenario with smart grid technology	Estimated 0.2% Energy constrained from 19,789.2 MWh output over 18 months

£ 453,494.17 excluding VAT which shall be payable at the appropriate rate (the "Connection Charge").

Alternate connection – at a glance

- New connection scheme and nervousness within the stakeholders
- Awareness required – potential option for DG depending on the LIFO position
- Constrain analysis considered the extreme worse case scenario – more realistic scenario can allow more limited curtail connection
- Energy curtailed model need to considerer the DC/AC ratio
- Security on the level of curtailment – allows investor’s confidence

Innovative connection

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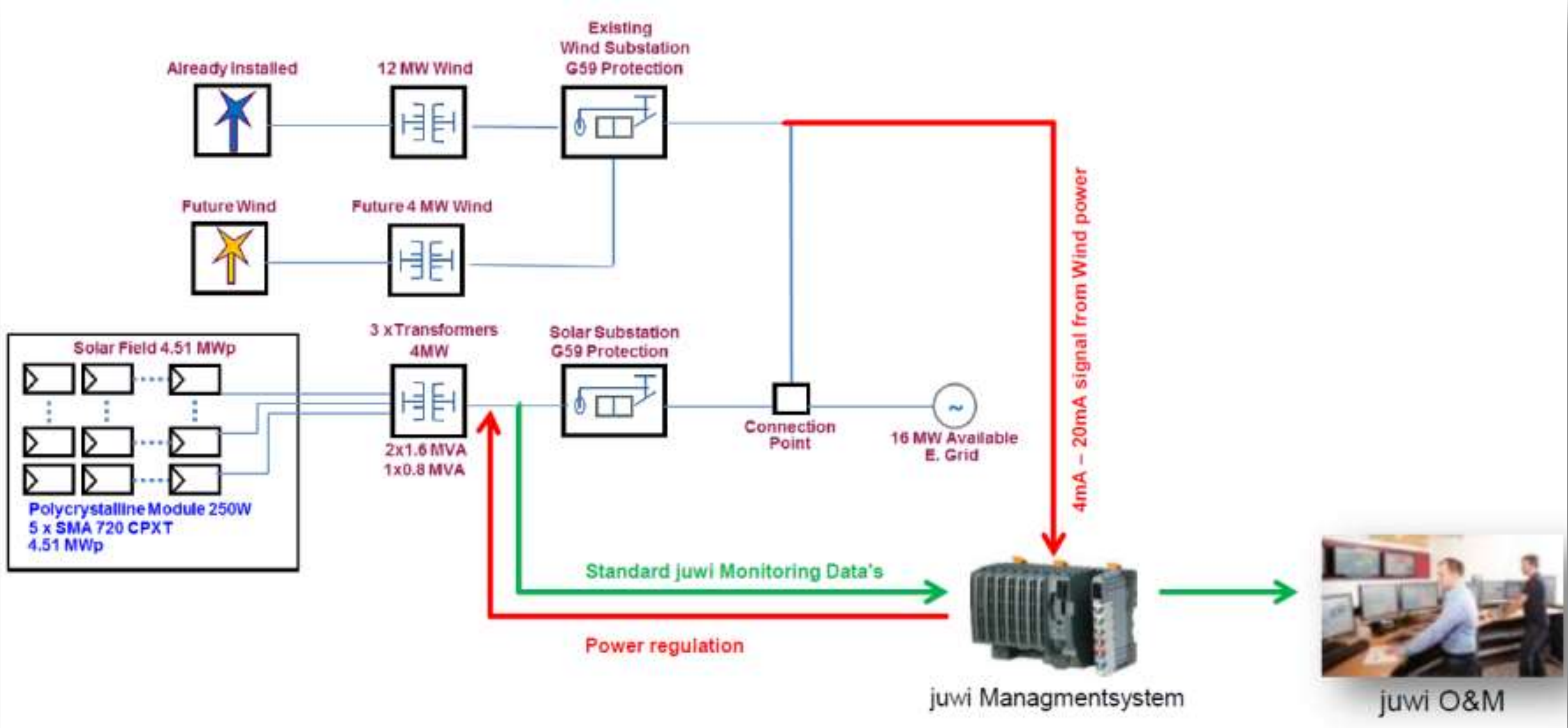
- Wind – Solar or Solar – Wind integration

Spare grid capacity > Shared grid connection > Power controller



Conclusions

Key Factors – how to overcome challenges

- **Extend the alternate connection network (when, where, how to be notified)**
- **Other innovative connections**
- **Different AM & PM tariffs can help maximum utilisation of the available grid and help demand management to match with the base load**
- **Active and reactive power managements of the inverters in the constrained networks**
- **Collaborative approach with DNOs & DGs**

Thank You for Your Attention

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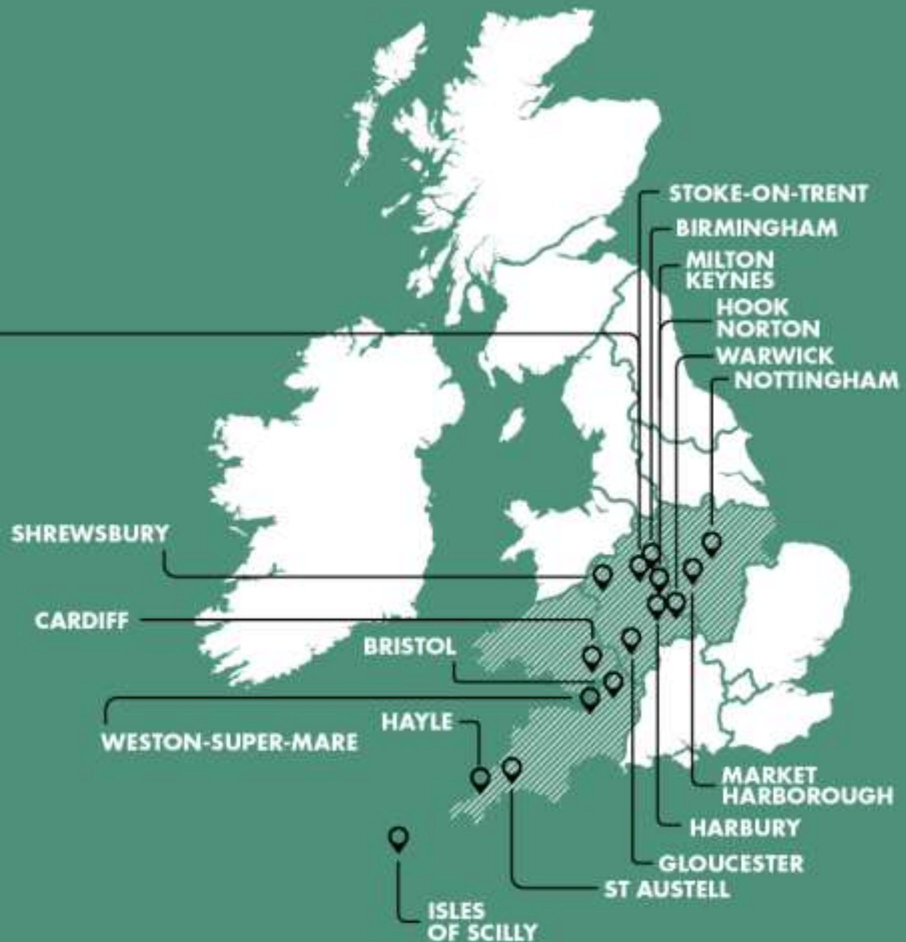
Coffee Break

WESTERN POWER DISTRIBUTION
INNOVATION

NEXT GENERATION NETWORKS



Distribution Networks: A Balancing Act

Network planning, constraints and Alternative Connections

Ben Godfrey

Innovation & Low Carbon Networks Engineer

Agenda

1) Introducing Network Planning and Constraints
   - Limitations influencing Generation
   - Security of Supply
2) Alternative Connections
   - Timed
   - Soft-Intertrip
   - Active Network Management
3) Roll Out
4) Consortia - shared conventional reinforcement

Western Power Distribution DG Levels

Western Power Distribution DG Levels

- 7.8 Million Customers
- 55,000 sq km area
- 216,000 kms of linear assets
- 184,000 substations

- DG Capacity Connected up to Q3 2014 – **4,100** MVA
- DG Connected March to September 2014 – **640** MVA
- DG Capacity Offered and Accepted – **8,800** MVA

What Influences Generation Connections?

Main technical barriers:

I. Power flow, thermal rating and losses
II. Voltage management (static and dynamic)
III. Fault level
IV. Power quality
V. Protection
VI. System issues for National Grid
   Transient stability
   exporting Grid Supply Points
   balancing, etc.
VII. Security of Supply – ENA Engineering Recommendation P2/6

Curtailment for Standard Connections?

Generation connected under firm arrangements will have a resilient supply, however the majority of DG is connected under non-firm arrangements, so when the network is running abnormally, the generation may need to be switched off.

Typically this occurs due to:

- Unplanned faults (transient, short-term and long term)
- Planned maintenance
- Planned new construction works
- Planned asset replacement

The duration of the abnormal running depends on the criticality of the event and will range from milliseconds to months

Alternative Connections

TIMED

- **Generation curtailed within specific times**

- Sub 1MVA
- Modelled seasonal capacity variations
- Localised control only
- No comms
  - May have for voltage constraint
- Non-optimised

SOFT-INTERTRIP

- **Releases pre-fault capacity with trip facility**

- 11kV and 33kV
- Real-time monitored values
- Small clusters of generation or simple pinch points
- Existing monitoring with localised control

ACTIVE NETWORK MANAGEMENT

1010
1011
0100

- **Fully optimises capacity based on all constraints**

- Management of generation using LIFO principles
- Real-time granular control of output
- Requires new Active Network Management control and monitoring systems

Costs, Complexity & Network Optimisation

Alternative Connections

Traditionally all connection agreements have been in a single format.

Standard Connection	Conventional connection (with CAF, where applicable)

Alternative Connections can also be connected under three additional commercial arrangements.

Enduring Alternative Connection	Alternative connection (no CAF)
Interim Alternative Connection	Alternative until reinforcement complete (CAF)
Part Standard, Part Alternative	Increase capacity of existing standard connection with additional Alternative capacity 'top up'

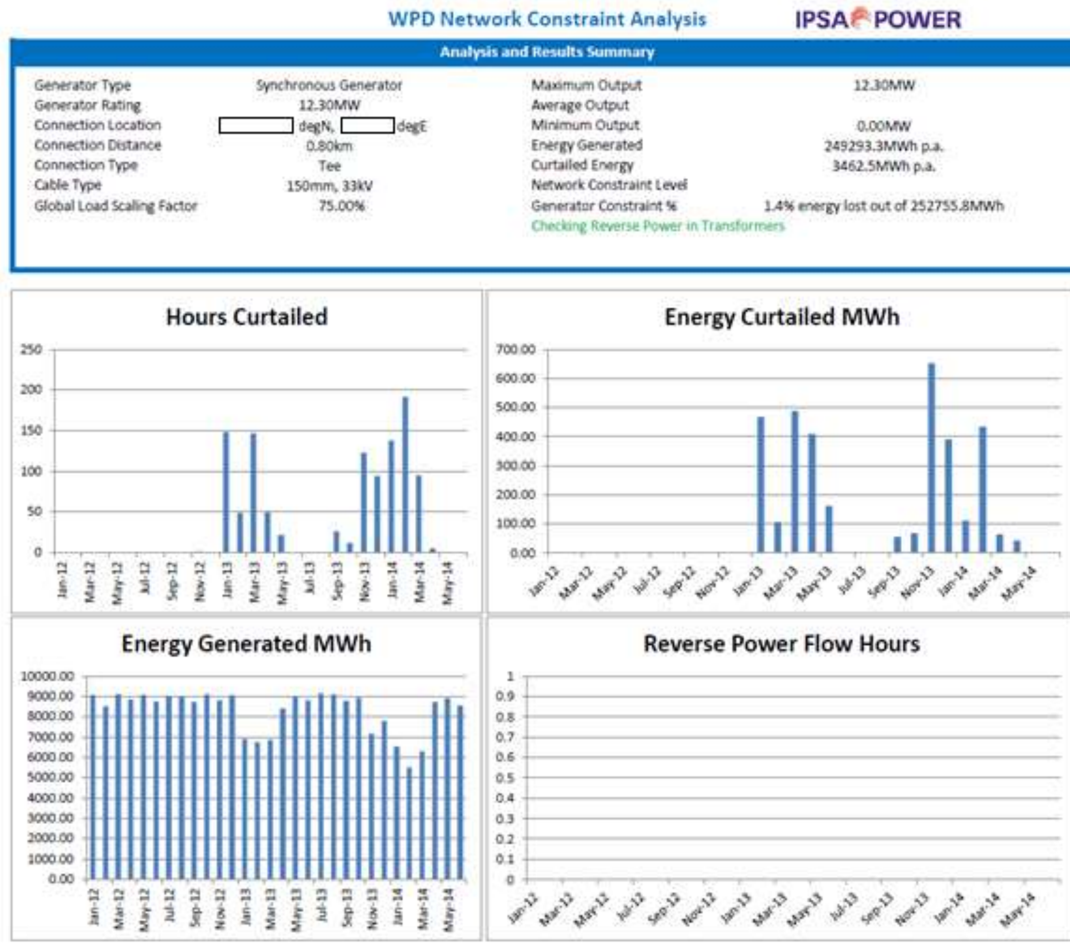
Trade-offs between Alternative Connections and Conventional Reinforcement

	Up Front Cost	Ongoing Cost
Timed connections	Low	Curtailment (fixed by timed restrictions, i.e. 11.3%)
Soft Intertrip	Medium	Curtailment (depending on network conditions, and "sub-optimal")
ANM	Medium	Curtailment (depending on network conditions, "optimal" curtailment) Capacity-based subscription fee
Conventional Reinforcement	High / Medium / Low	None

All connections designed as 'non-firm' will be switched off for abnormal running

Estimating Curtailment

WPD uses historical load data on its network models and superimposes idealised generation profiles to estimate the level of curtailment experienced by the connections



What Influences Curtailment?

Increase

- Outages for maintenance
- Unplanned Faults
- Load loss
- Net demand transfers out
- Net generation transfers in
- Small scale generation
- Communications loss

Decrease

- New load connections
- Load increases
- Net demand transfers in
- Net generation transfers out
- Generation outages
- Reinforcement
- Accepted generation not materialising

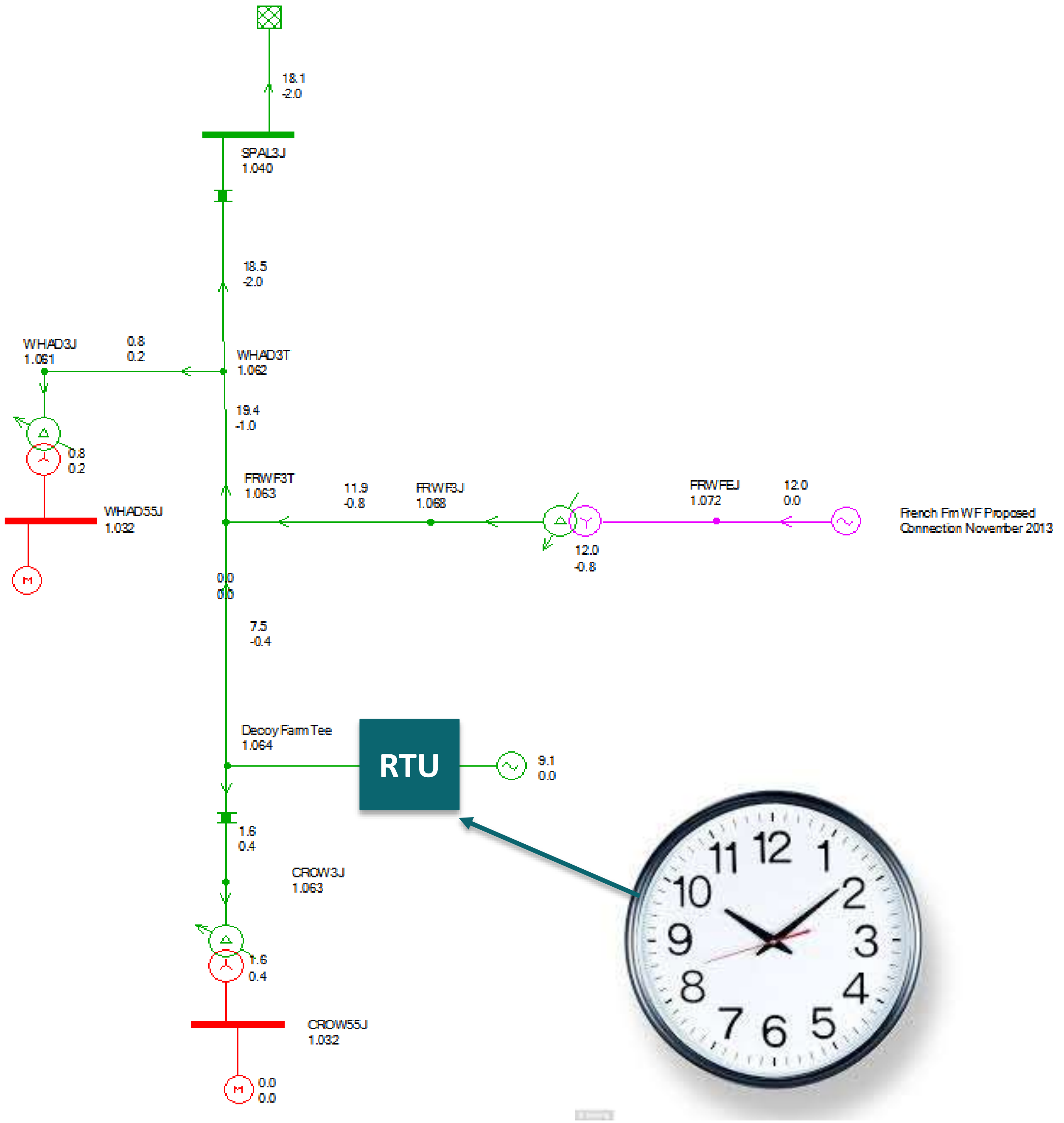
WESTERN POWER DISTRIBUTION INNOVATION

Timed Connection

No comms

Local control

Single generator

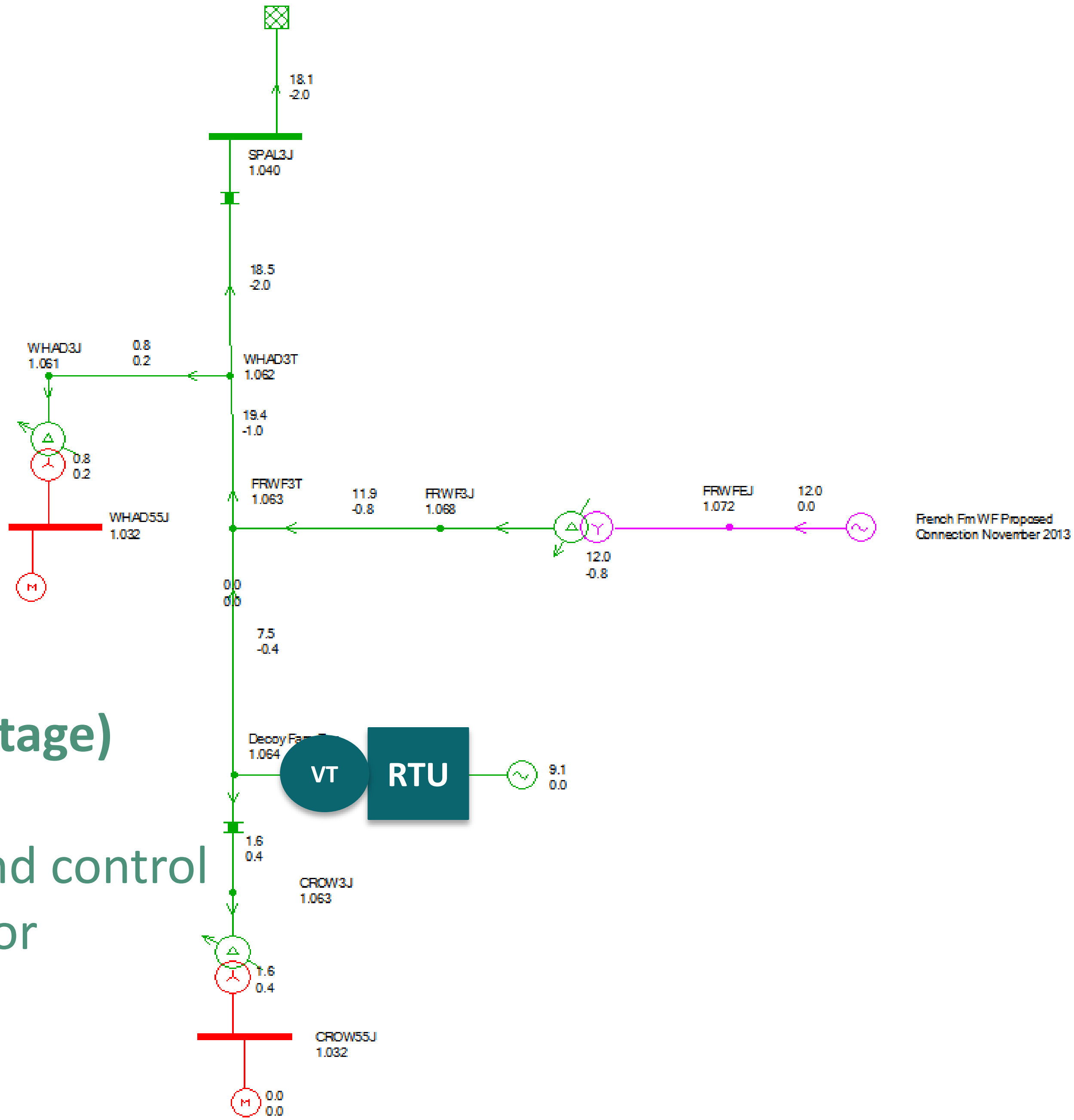


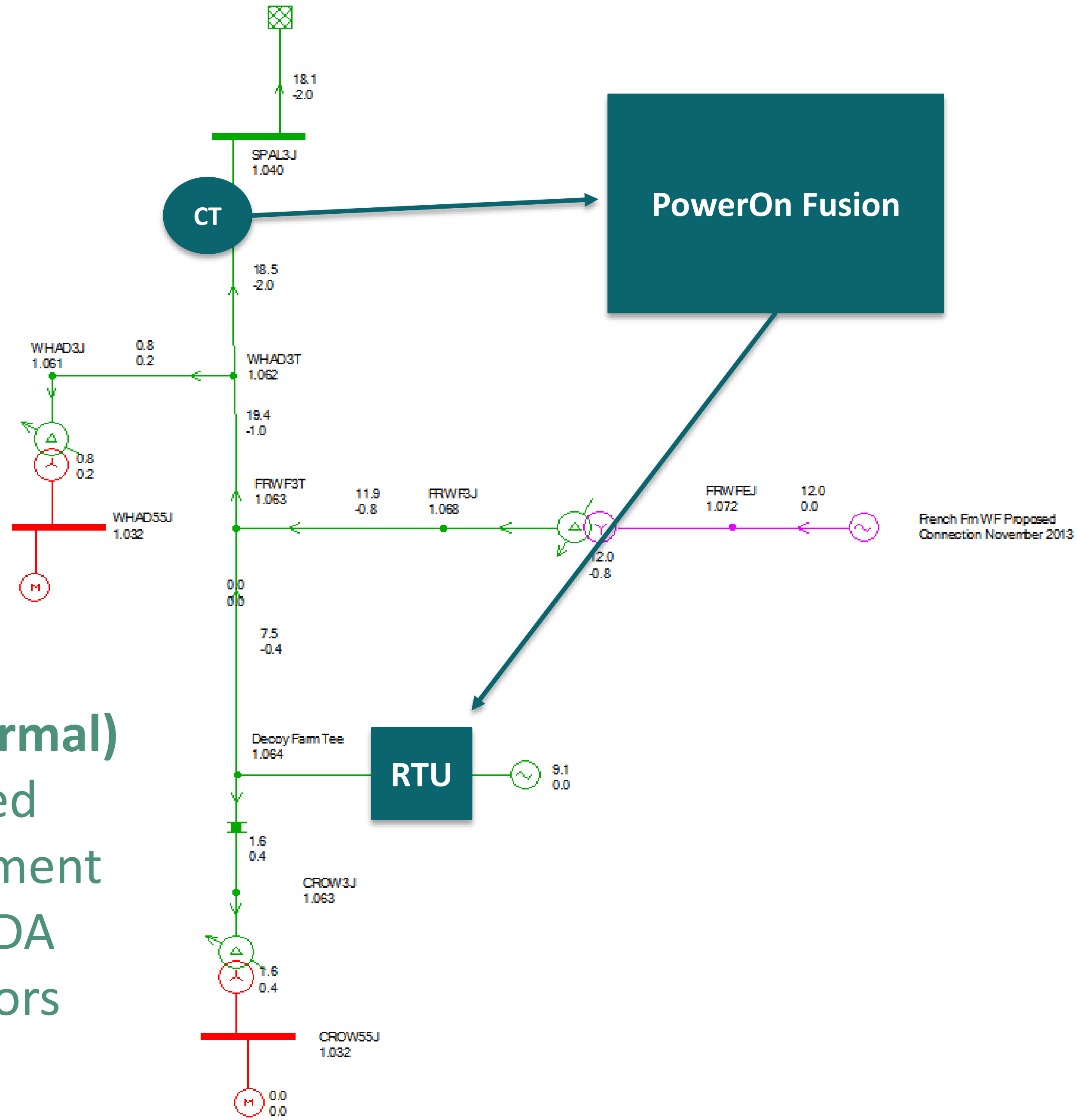
Soft Intertrip (Voltage)

No comms

Local measurement and control

Single generator





Soft Intertrip (Thermal)

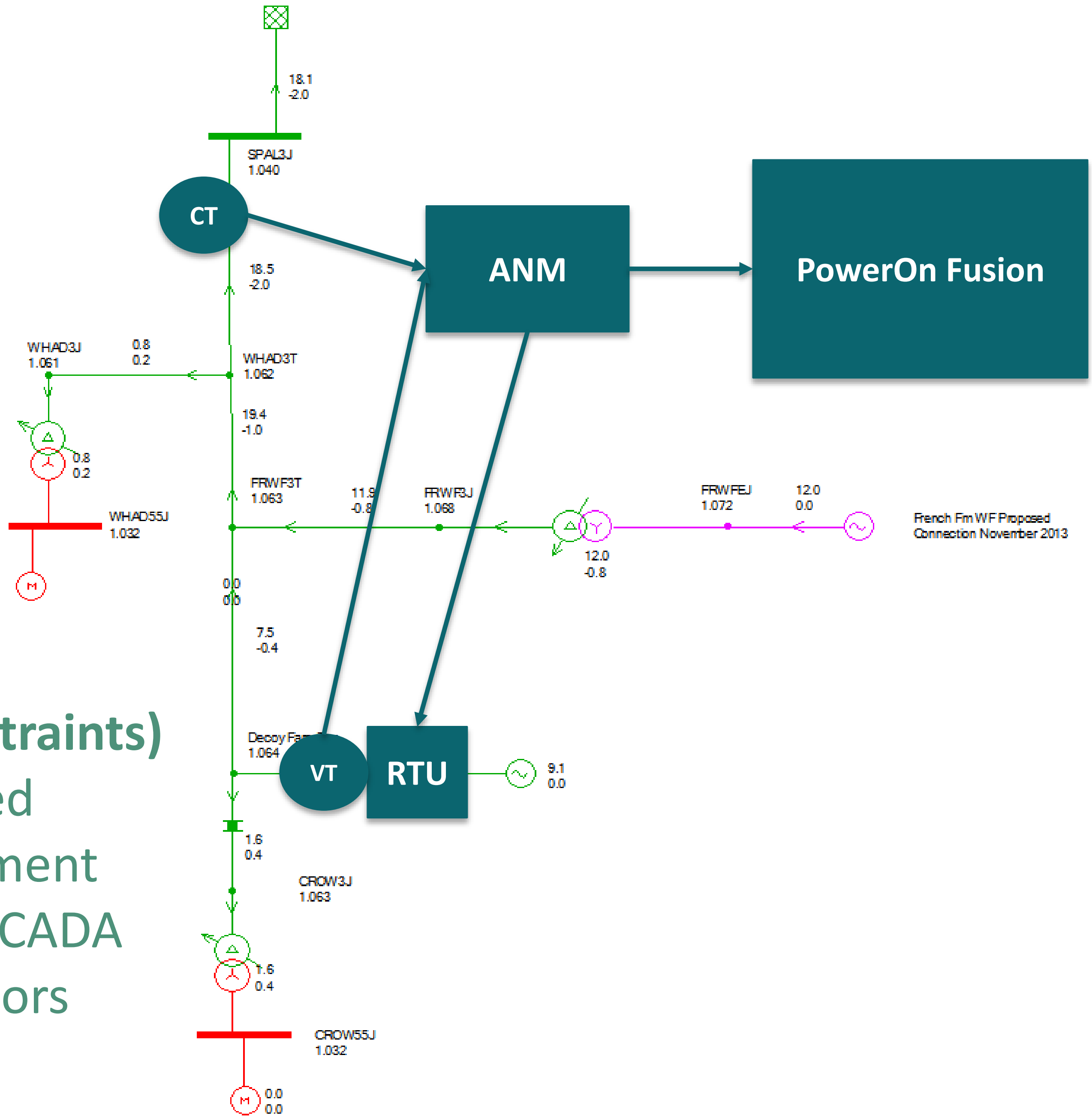
Comms required

Remote measurement

Control via SCADA

Up to 3 generators

WESTERN POWER DISTRIBUTION INNOVATION



ANM (Multiple Constraints)

Comms required

Remote measurement

ANM interface to SCADA

Multiple generators

Where, When and How?

All areas are now issuing basic Alternative Connections, with the most complex types being rolled out in phases.

- **Timed**
  - Available in all areas for non-PV, sub 1MW connections where there is sufficient installed PV to diversify against
- **Soft Intertrip**
  - Available in all areas for generators restricted by a single constraint
  - Maximum of three connections per constraint
- **ANM**
  - Being rolled out in phases to the most complex and oversubscribed areas
  - Active in Skegness (November '13) and Corby (April '14)
  - Due for 9 other areas – Bridgewater/Street (November '14), Horncastle (April '15), Truro (November '15)

Applications are accepted through the normal enquiry process

Consortia Approach

- **Sharing Reinforcement**
  - Allows for consortia application
  - Common reinforcement costs shared
  - Avoids £200/kW capping
- **Developing consortia/agreements**
  - Assessing viability of trial location
  - Seeking options to bring developers together
- **Facilitating sharing of information**
  - Allowing potential partners visibility of other interest

Questions

Lunch

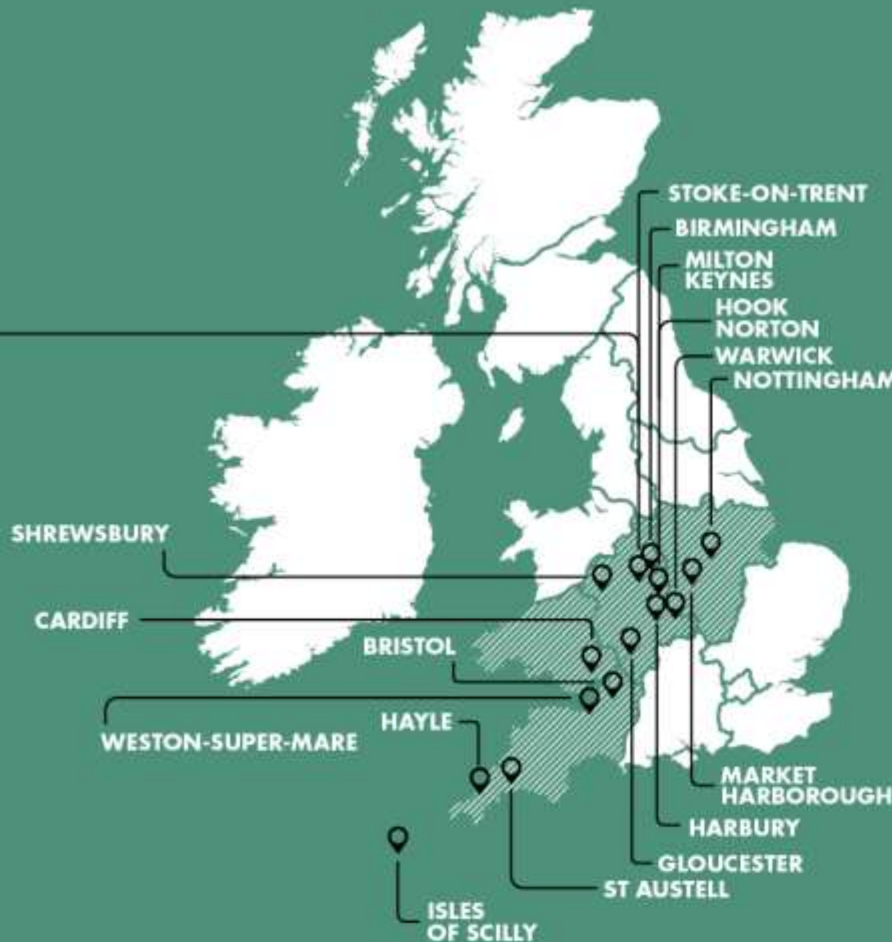
Session 2

Demand Side Response

WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS



Distribution Networks: A Balancing Act

Demand Side Response

Gary Swandells

Agenda

- What is DSR ?
- WPD's trials and results
- What are the UK's other Network Operators doing
- Business as Usual
- What's Next

Demand Side Response

What is DSR ?

It has many names –

- Demand Response (DR)
- Load or Peak Shifting
- Load Curtailment
- Peak Avoidance
- (VPP) Virtual Power Plant

How is DSR provided?

When Instructed -

- Shift or avoid energy consumption

  And / Or

- Start or increase the output of local generation.

What can DSR be used for ?

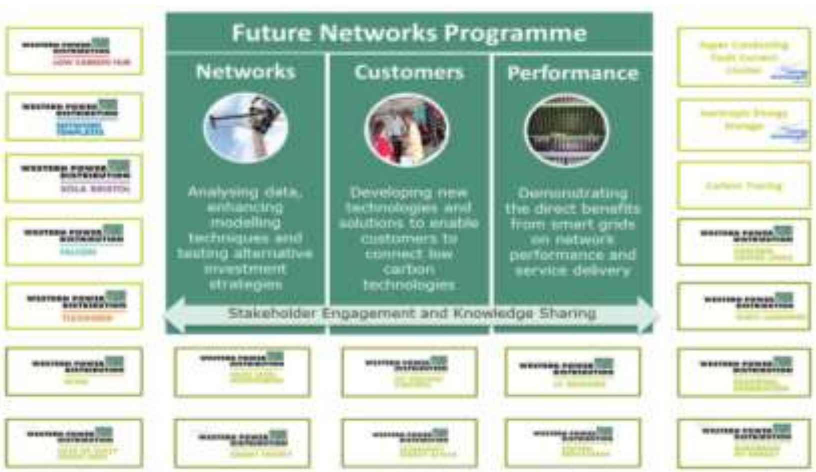
- Support system balancing
- Reduce stress on networks
- Energy trading / arbitrage
- Avoidance of high cost periods
- Local and National capacity issues
- Emergency mitigation
- Replace older, low efficiency and marginal power plants

What benefit is it to a DNO ?

- Temporary or transient faults
- Brief or occasional capacity issues
- Ensuring improved network security
- Avoiding or deferring capital investment costs
- Reducing interruptions and durations of outages
- Increasing existing asset utilisation
- Improving value for money to consumers

WPD's trials of DSR

- Seasonal Generation Deployment
- Project FALCON
- SoLa Bristol
- ECHO



WPD's trials of non-domestic DSR

Seasonal Generation Deployment

aggreko

flexitricity
Unlocking smart grid revenue

Creation of a generator storage facility at WPD substation.

Generator hire company to leave summer event generators during winter periods.

Operated by an aggregator who would manage service delivery

- STOR
- Triad
- DNO peak lopping

Objective:

Develop and deploy the engineering interface

Establish commercial arrangement

Create an economic generation control methodology.

WPD's trials of non-domestic DSR

aggreko

flexitricity
Unlocking smart grid revenue

Seasonal Generation Deployment Results

Engineering objectives met.

Physical plinth & connections built.

Control interface developed.

Control strategy agreed.

Commercial arrangements identified programme conflicts between National Grid and DNO requirements.

Insufficient incentive for project partners.

Project FALCON

Flexible Approaches to Low Carbon Optimised Networks

Testing new smart engineering methods as an alternative to conventional reinforcement.

Create new commercial intervention alternatives.

Develop new advanced communications system to operate local 'Smart' network.

Create new network planning tool that intelligently selects the best and most economic method to upgrade networks.

Project FALCON

http://www.youtube.com/watch?v=2QAbon85yrk

Project FALCON

- New resources and processes to engage with customers.
- Author and approve new ‘performance based’ contracts
- Engage control room in development of ‘use case’
- Financial approval of business proposition
- Control room dispatch arrangements
- Performance assessment software
- Back office systems for settlement processes
- Detail the market conflicts and propose any potential solutions
- Learning (statistical & attitudinal)

Project FALCON

Commercial trials season 1 completed

FALCON met all recruitment objectives for **Distributed Generation** trials

- Direct and third party contracts
- Participation of six aggregators, three of which successfully recruited trialist
- In excess of 10MW of capacity from 11 participants
- Small, medium & large capacity generators
- Stand by and CHP
- Diesel & Gas engines

ESP The Energy Services Partnership | flexitricity Unlocking smart grid revenue | KiWiPOWER demand management | Negawatt Energy | npower | STOR GENERATION LTD

Project FALCON

Commercial trials season 1 completed

Despite several prospects there were no Load Reduction participants

This was not unexpected as it broadly reflected across the majority of DSR programmes and trials

Project FALCON

Commercial trials season 1 results

- 181 potential availability windows
- 61 declaration unavailable
- 66.3% reliability factor

site	04-Nov	11-Nov	18-Nov	25-Nov	02-Dec	09-Dec	16-Dec	23-Dec	30-Dec	06-Jan	13-Jan	20-Jan	27-Jan	03-Feb	10-Feb	17-Feb	24-Feb
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	n	n	n	n	y	y	n	n	n	y	y	y	y	y	y	y	y
2	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	y	y
3	n	n	y	n	y	y	n	n	n	y	y	y	y	y	y	y	y
4	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
5	n	n	n	y	y	y	n	n	n	y	y	y	y	y	y	y	y
6	n/a	n/a	n/a	n/a	n/a	n/a	n	y	y	y	y	y	y	y	y	y	y
7	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
8	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
9	y	y	y	y	y	y	y	y	y	y	y	y	y	n	n	y	y
10	y	y	y	y	n	n	n	n	n	n	n	n	y	y	y	y	y
11	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y

Commercial trials season 1 results

- 18 Events called between 27th November & 28th February
- Approximately ¼ GWh of generation for purposes of trial
- Relatively small number of incidents of delivery failure
- DNO DSR programme conflicts with National Grid Balancing Service

DSR Shared Services Group

- Without sharing framework its unlikely DNO will use DSR as conflicts inflate cost beyond justifiable levels.

- Representation by National Grid & all UK DNOs
- Identify any conflicts and synergies between likely services
  - Contractual arrangements
  - Operation
  - Systems
- Propose a high level sharing framework
- Publish a consultation with findings and proposals

DSR Shared Services Group Highlights

- Primary conflicts contractual based on STOR exclusivity
- Asset sharing presents better value to consumers
- Increases choice to participants without mandating multi-use
- Addresses the risk of unnecessary inflation resulting from exclusive access
- National Grid's requirement is 'non-geographic' and in majority of circumstances have multiple options with only marginal cost impact.
- Geographical sensitivity can make DNO requirement more acute with little or no redundancy for low voltage constraints
- Access rights to assets determined by time separation

Project FALCON

Season 2

- Week ahead notification of operating schedule
- Capped consumption target based on previous year's peaks
- New back office systems
- Increased incentive for load reduction
- Additional aggregator involvement
- Data from new Smart Meter solution

Post Trial - Business as Usual

DSR justified on the bases of managing;

- Transient and temporary pre-fault constraints
- Post-fault restoration of supplies
- Reduction of risk while establishing investment case or awaiting planned capital upgrades

WPD will seek to develop services during 2015 for use during ED1

- Where we might want these services?
- How often we would want these services?
- How long we might want these services?
- How much it could be worth?
- What is our offer going to look like, how will we select these services?
- What could count as DSR?
- Methods of dispatch of DSM/DSR?

Questions

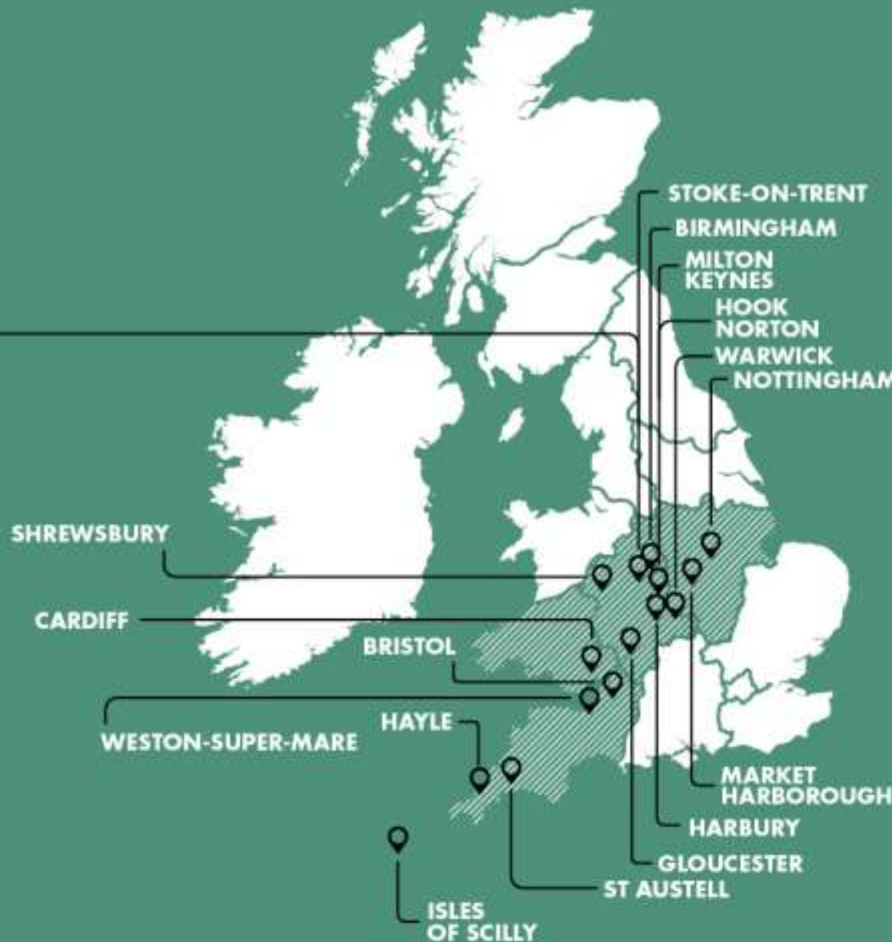
WESTERN POWER DISTRIBUTION
INNOVATION

Session 3

Energy Storage

WESTERN POWER DISTRIBUTION
INNOVATION

NEXT GENERATION NETWORKS



Distribution Networks: A Balancing Act

Learning from Energy Storage Projects

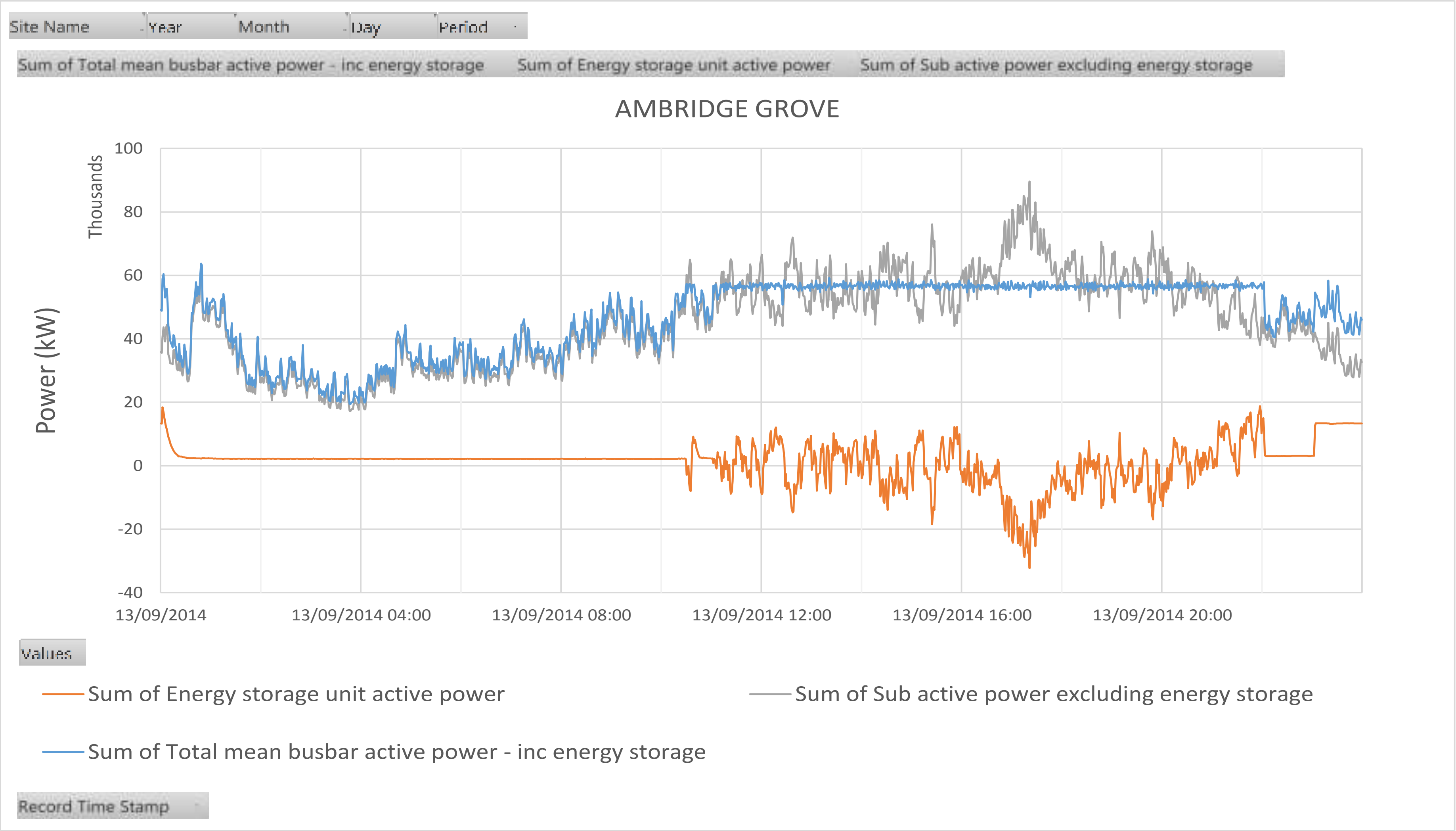
Mark Dale

Innovation & Low Carbon
Networks Engineer

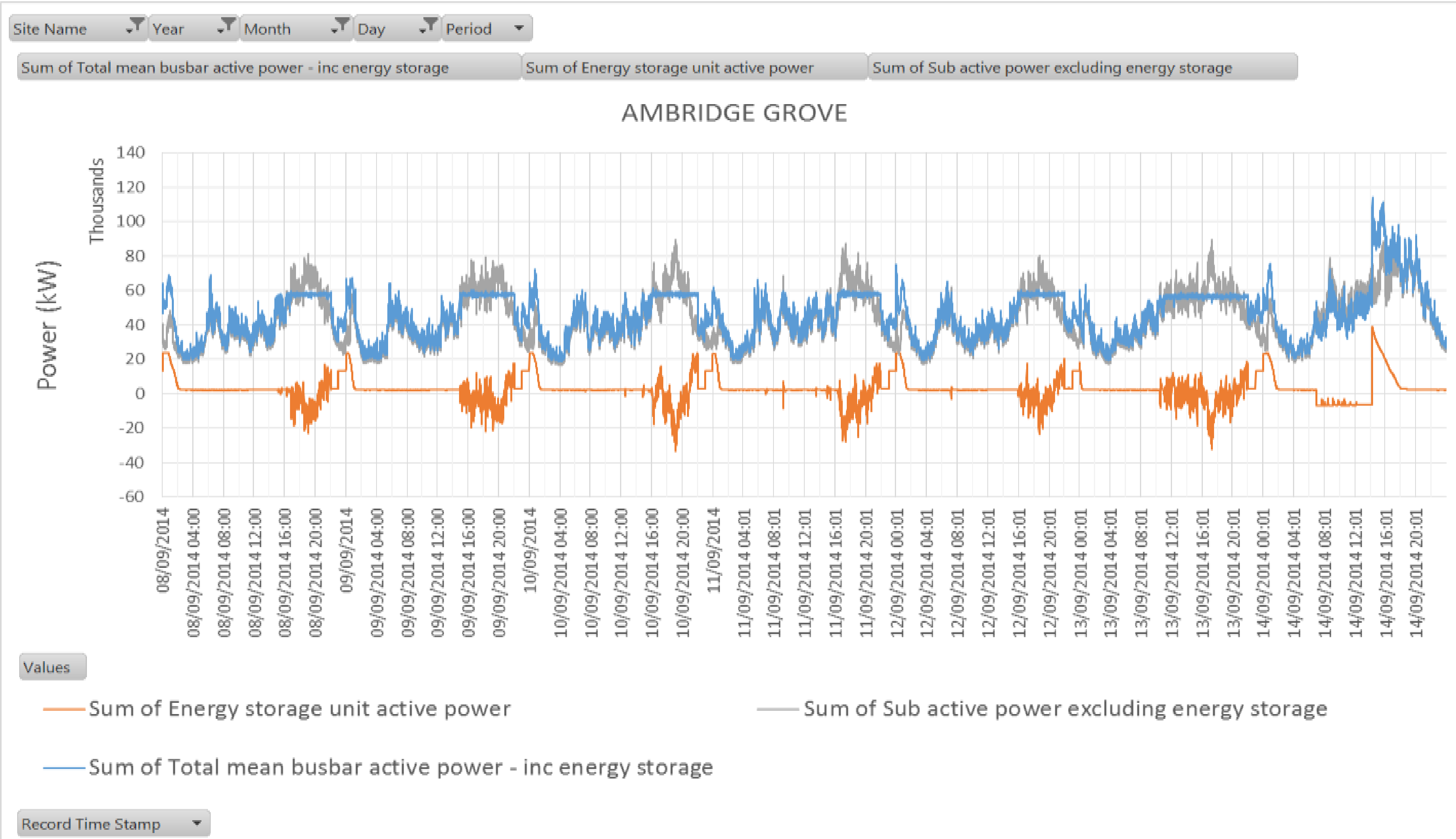
Project FALCON Energy Storage Findings

- Optimum locations on a DNO system and locating sites
- Supply, delivery and installation challenges
- Integration of the system and controls
- Acoustic protection and monitoring
- Charging regime and discharge triggers
- Peak shaving
- Potential commercial opportunities for asset owners

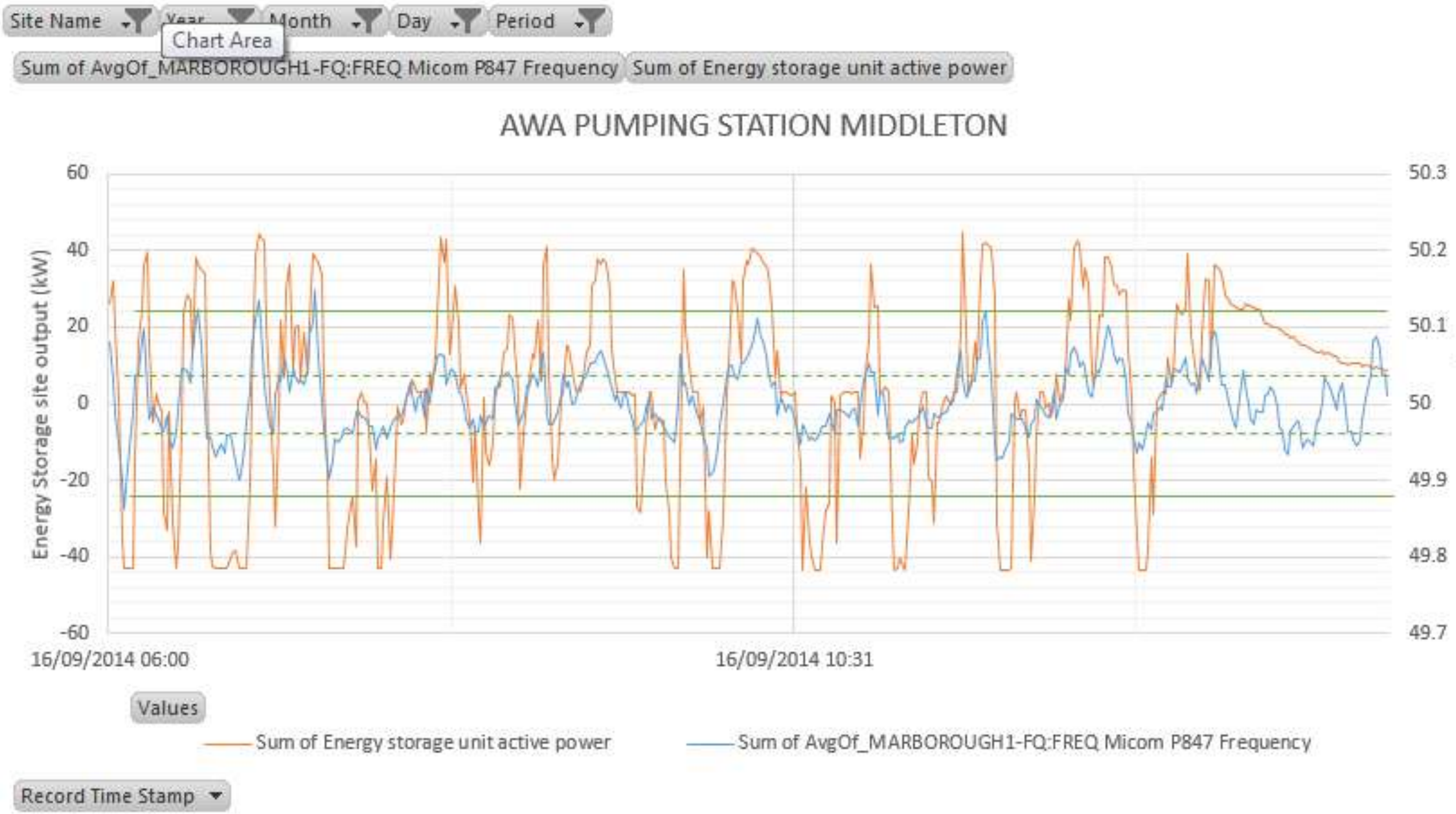
Initial Learning – peak shaving (24 hours)



Initial Learning – peak shaving (week)



Initial Learning – frequency regulation (9 hours)



Presentation Outline

- Brief Overview of Sola Bristol
- Time of use Tariff
- Charging Envelopes
- Customer Engagement

Project Aims

- To solve the network problems which arise when a number of customers in a local area connect PV solar panels to their house
- Investigate how a battery installed in the home can help customers to manage their energy usage and save money on their bills
- Test how consumers respond when offered different electricity tariffs throughout the day
- Explore the benefits of supplying electricity by direct current (DC), rather than the traditional alternating current (AC) and the impact on power quality.

Project Partners

Bristol City Council

Deploying technology at their sites, engaging with schools and offices

Knowle West Media Centre

Leading the domestic properties engagement

Siemens

Designing and providing technology for the project

University of Bath

Academic partner, Knowledge dissemination, tariffs and design

What we are capturing

- Bath Repository

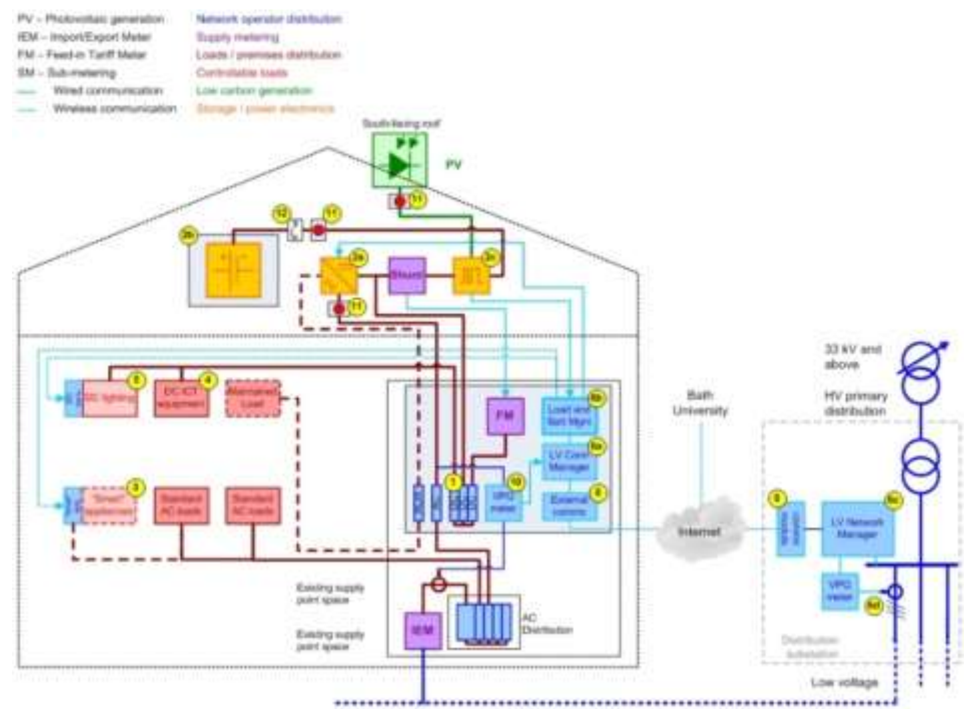
- Sub-Stations 11

LV Network Manager

- Domestics 26

LV Connection Manager

- Schools 5
- Commercials 1
- DC Load types
  - LED lighting
  - Laptop/Desktop



Integrating

- Distributed Solar-PV
- DC storage / DC micro-grid

Enabling

- On-demand export to grid (Tariff/Voltage/Thermal/Surplus)
- Load shifting from AC to DC
- DC lighting & computing
- Partial grid independence
- Sub-station monitoring

SoLa Bristol Domestic Variable Tariffs

Lessons learnt

1. The vast majority of our project participants find electricity concepts complex, including the term kWh.
2. The more effective the variable tariff, the more complex it is to both explan and operate.

Selection of variable tariffs

All popular types of variable tariffs reviewed,

A Real-Time Pricing (RTP) tariff was selected as the basis for the SoLa Bristol domestic Variable Tariff,

It was noted that such tariffs are difficult for customers to understand,

The total benefit obtained from PV generation and battery charging will be expressed to customers as a discount on a fixed tariff, which could be as much as 2.5p/kWh. The greater the benefits of peak lopping and avoided network reinforcement, the bigger the discount could be.

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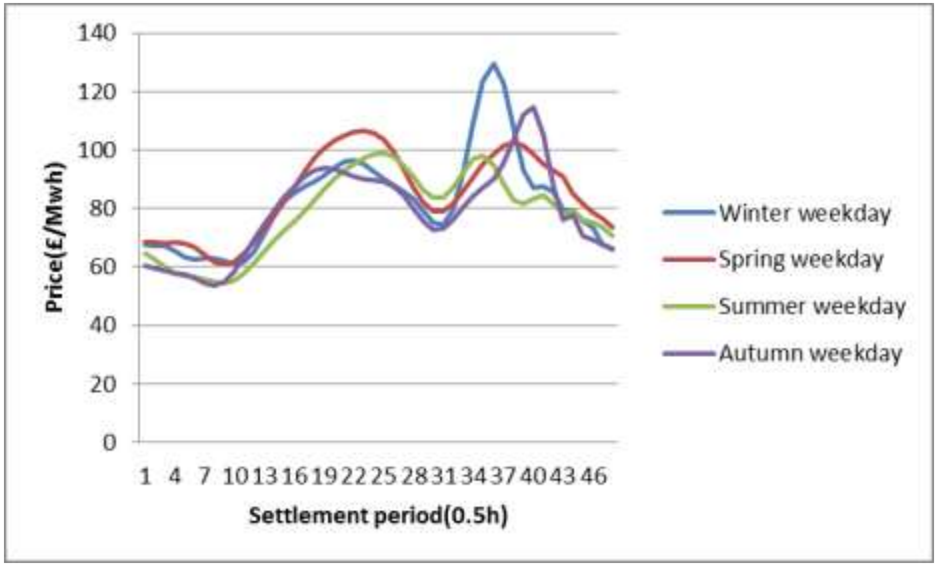
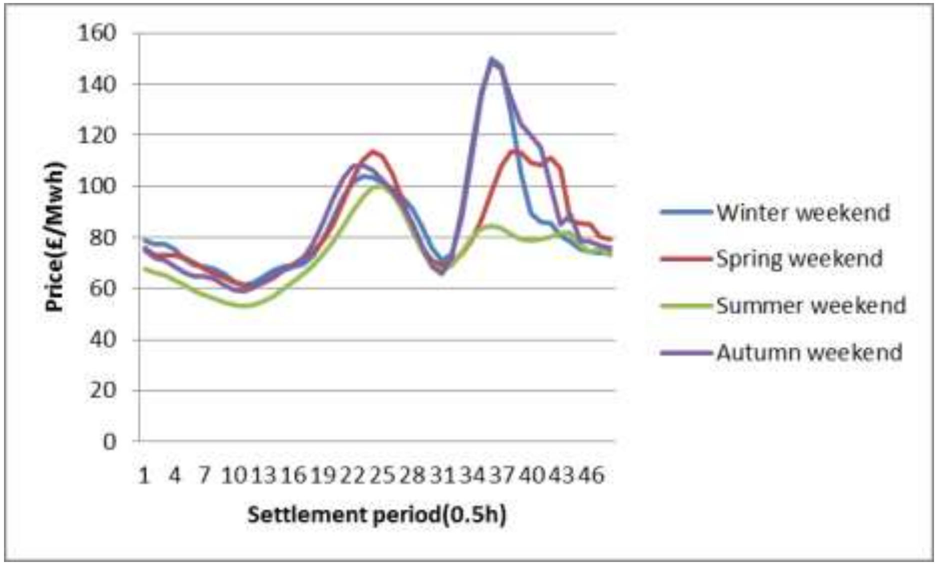
Real-time price profile plotting

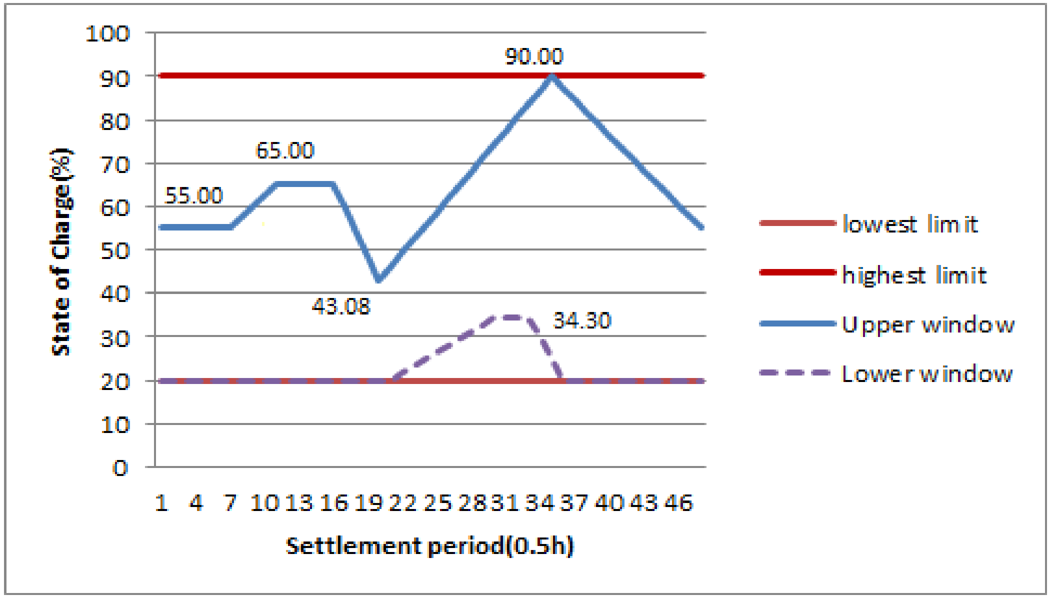
8 scenarios: winter, spring, summer & autumn,
--weekdays & weekends.





Optimising the use of battery storage for both customers and DNOs

The SoLa Bristol - LV Connection manager (in home intelligence) optimises the use of the batteries for both the customer and the DNO through the use of **battery charging envelopes.**



Battery charging envelopes comprise of both the minimum and maximum state of charge available to the LV Connection manager any time.

Key Characteristics

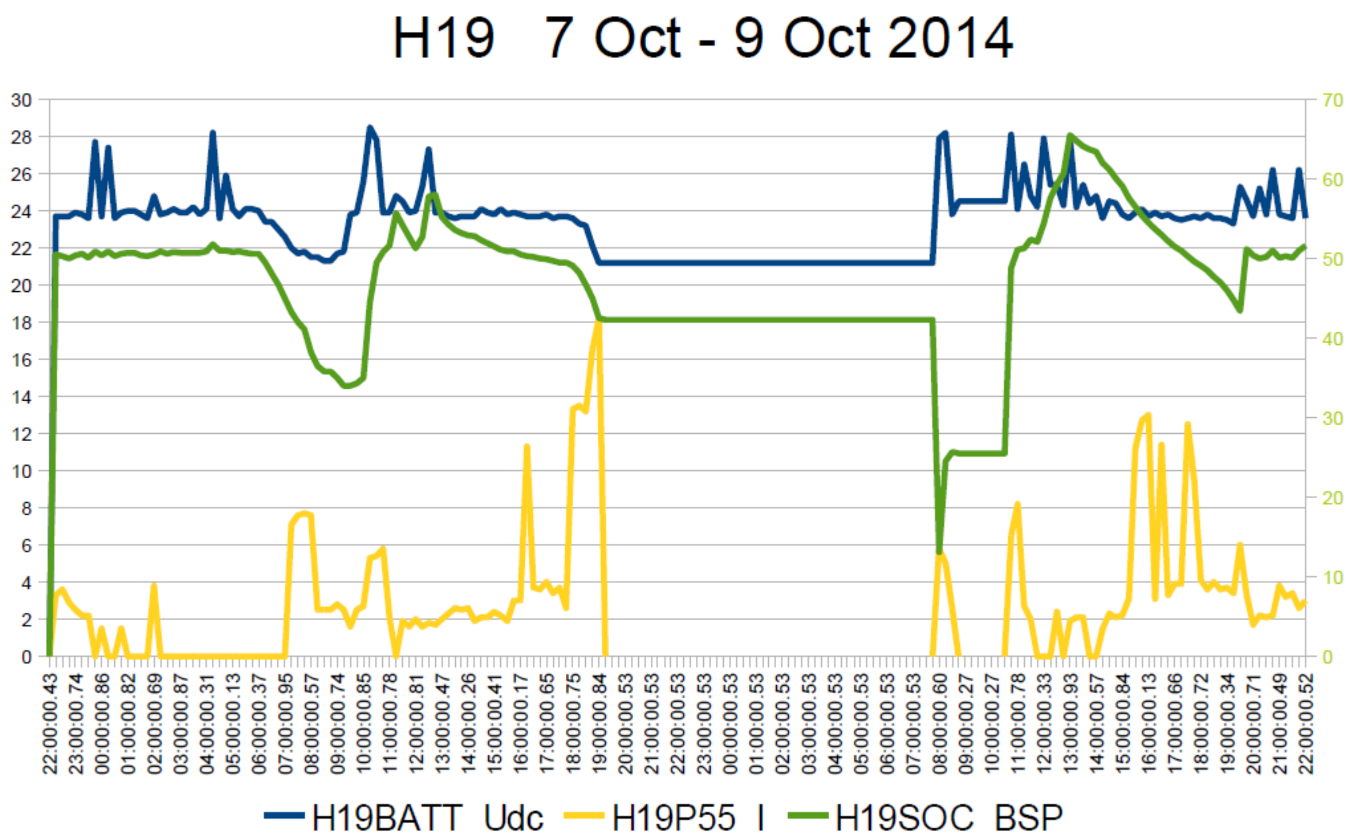
- initial state of charge,
- charging/discharging rates,
- charging/discharging start time,
- duration
- slopes

Battery Charging Envelopes – How they are used

- When the DNO has no network constraints
- When the DNO experiences Voltage or Thermal constraints
- How Charging envelopes change

Early Learning from domestic Data

In House 19 we have seen the domestic load remain abnormally high during the day. The target & minimum SOC 50% and 20% were not high enough to support the battery volts during the evening peak period.



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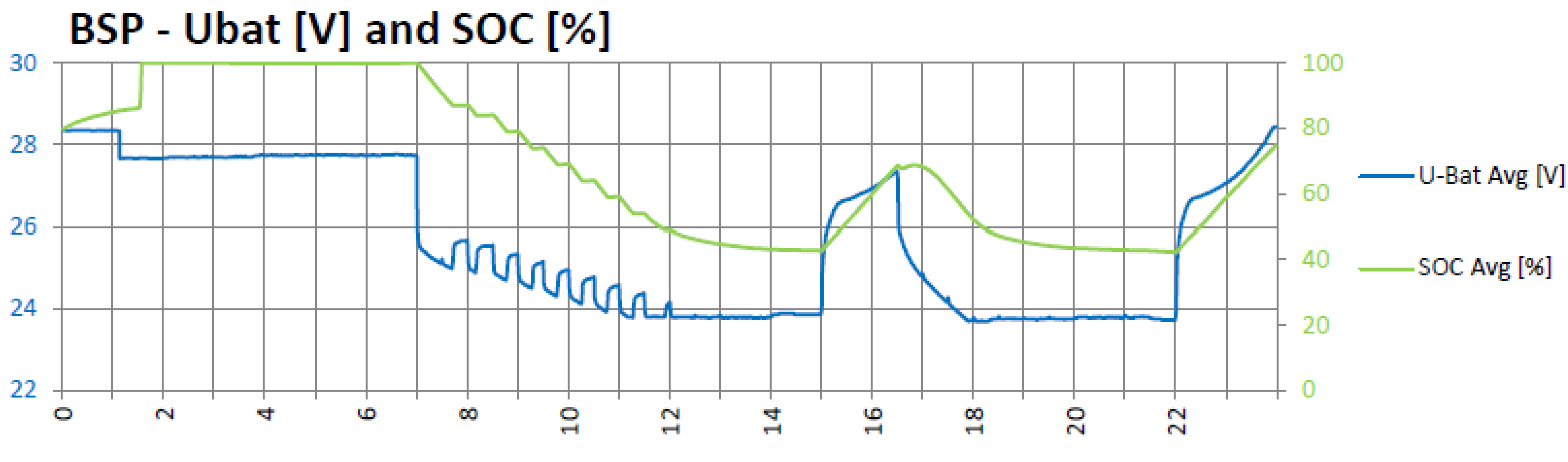
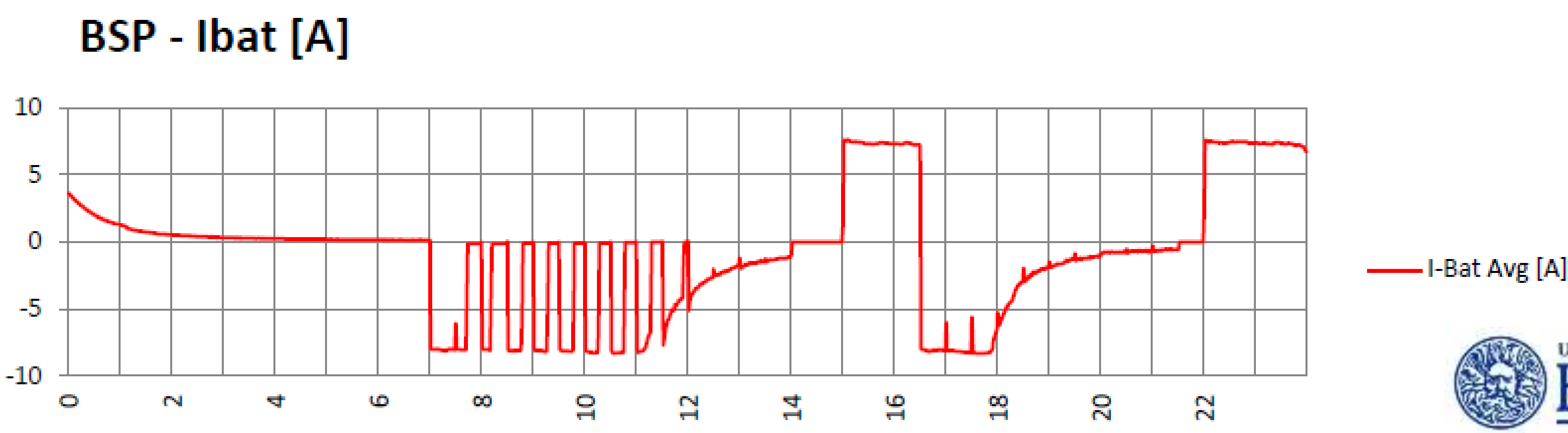
School Settings (Test Bed)

Set up to allow high DC load during the day to be supported by the battery





Customer Engagement Issues

- 30 customers required, but chosen primarily by the position of their roof
- Access difficulties, Installations typically take 2 -3 days plus commissioning
- High Poverty and unemployment area- certain amount of apathy and lack of interest in project goals – What's in it for me?

Participant Feedback

"I haven't used the tablet for months as it has never worked properly… but since May I've been saving at least £5 a week on electric. I used to put on £60 a month and now put on £40." House 18

"I look at the tablet almost every day now and it's quite useful," House 06

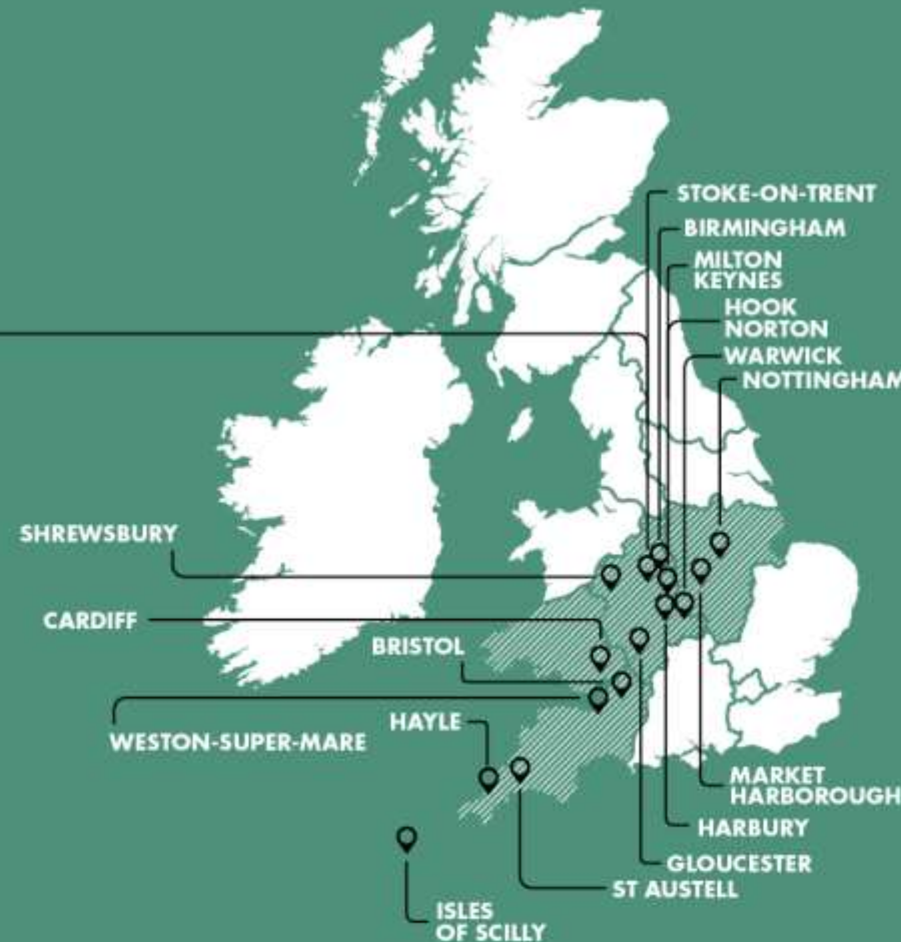
"When they disconnected the solar panels to put the box in I noticed our energy use went right up – so it's definitely saving us." House 10

"Our power went off as the meter had run down but we didn't realise as the lights were still on… It shows the panels are saving us." House 30

" I've never managed to see anything on the tablet. It only worked for a short time. I've always been a low user, so haven't seen much difference." House 21

WESTERN POWER DISTRIBUTION
INNOVATION

NEXT GENERATION NETWORKS



Distribution Networks: A Balancing Act

A DG Developer's Perspective

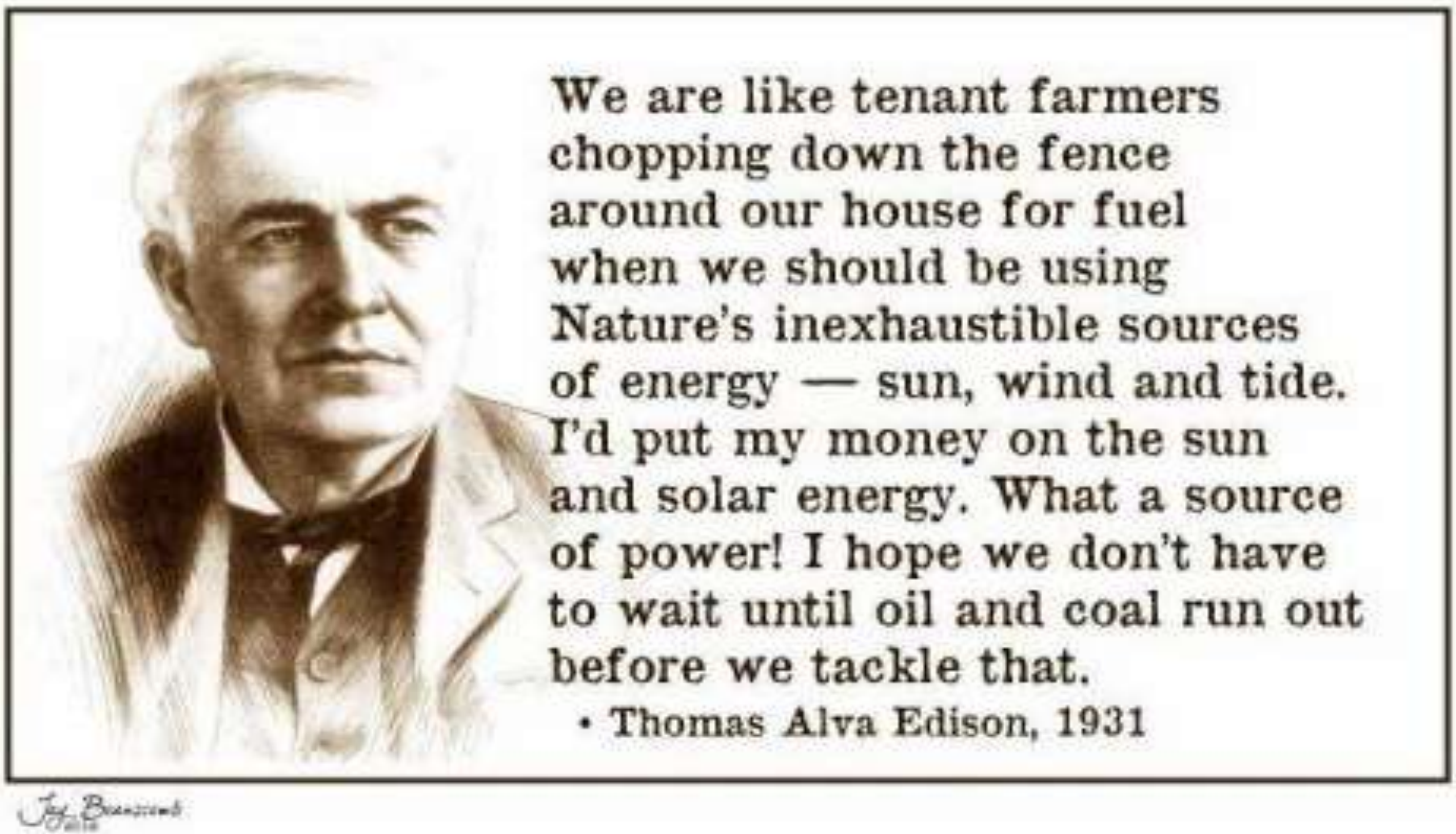
British Solar Renewables

Steve Edwards

Technical Director

British Solar Renewables

Thomas Alva Edison, 1931



British Solar Renewables

- BSR generates clean energy.
- We've delivered circa 200MWp since our launch in 2010.
- We finance, design, build & operate large scale solar parks, commercial and agricultural roof mounted arrays
- JV with Siem Industries Inc., a €7bN global diversified industrial group

The UK market for power is changing rapidly

Old World	New World
Predictable central generation, direct management of capacity	Controlled, predictable central generation Less predictable, uncontrolled distributed generation
Annual demand growth ~ GDP	Annual demand growth >> GDP
Predictable network load	Unpredictable swings in local network load
Low volatility	Rising volatility

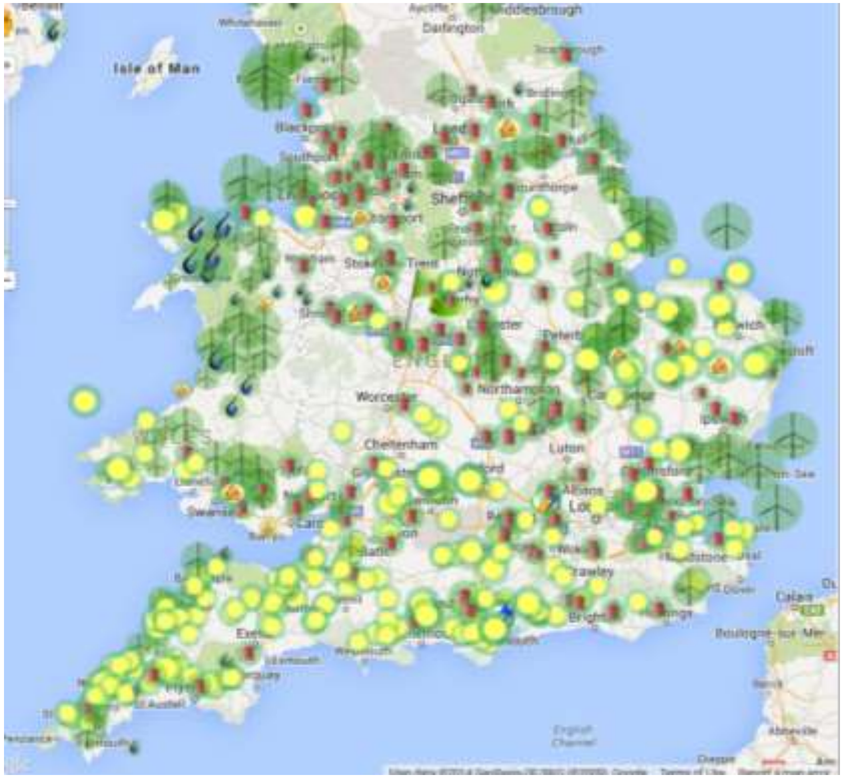
Combined with Distributed Generation, Storage has enormous potential

- PV is already deployed at scale, connected at or near demand
- Solar generation is predictable, but leaves almost 90% of connection capacity unused
- Combining PV with storage gives DNOs an alternative to wholesale reinforcement
- Network volatility needs a local rather than a centralised solution

The UK has 20GW of renewable generation installed

- 10GWp of Wind deployed
- - 70% on-shore

- 5GWp of Solar deployed
- - growing to 8GW by Q2 2015
- - 100% on-shore, near areas of demand

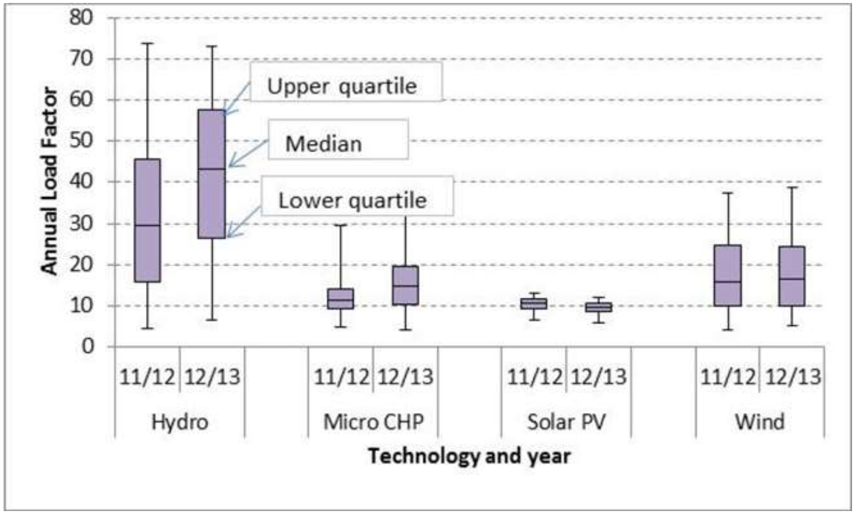


DECC's own figures demonstrate that PV power is very predictable

- PV generation is very predictable
  - Variation between installations is very low
  - Average Capacity Factor is similar to Wind, micro-CHP
  - Inter-year variation very low

- Predictability makes large scale integration far easier

Load factor and range for technologies installed under FIT

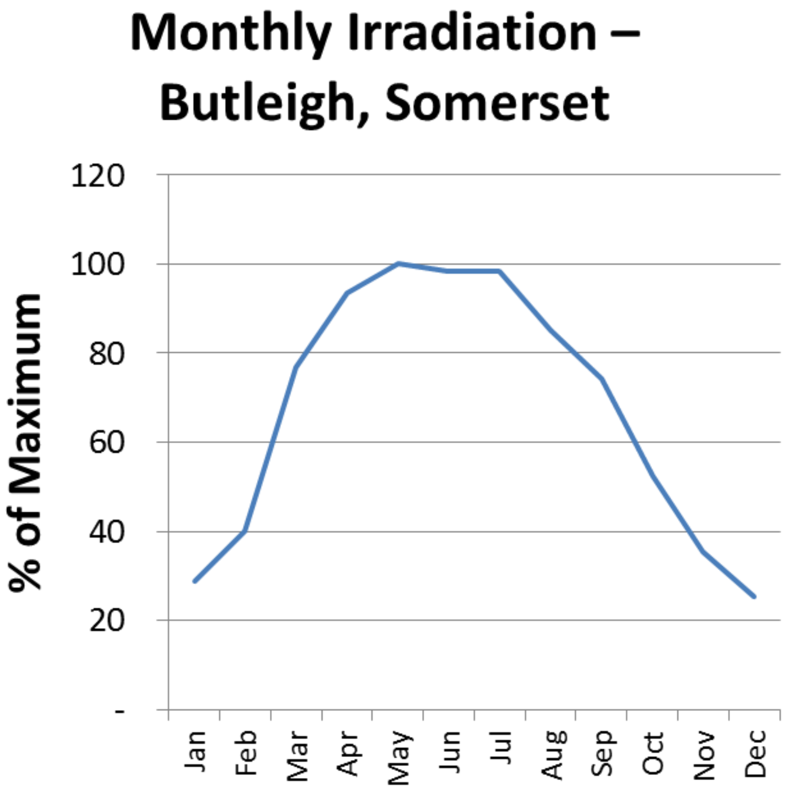


FIT data	Installations to 2011 / 12	Generation / MWhr 2011 / 12
Solar PV	39,715 / 295,378	12.4 / 109.1
All other	2,023 / 3,804	0.8 / 1.7

***Source**: DECC analysis*

PV is summer-biased, but always contributes a base load

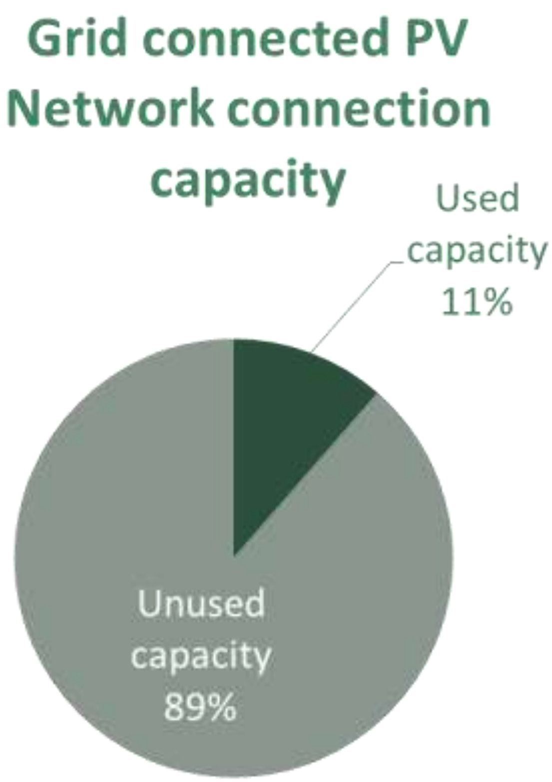
- Peak generation is mid-day and mid-summer
- However monthly generation never drops below 25% of maximum …
- … and is on average 67% of monthly maximum



WESTERN POWER DISTRIBUTION
INNOVATION

Grid linked PV only uses a fraction of its network capacity

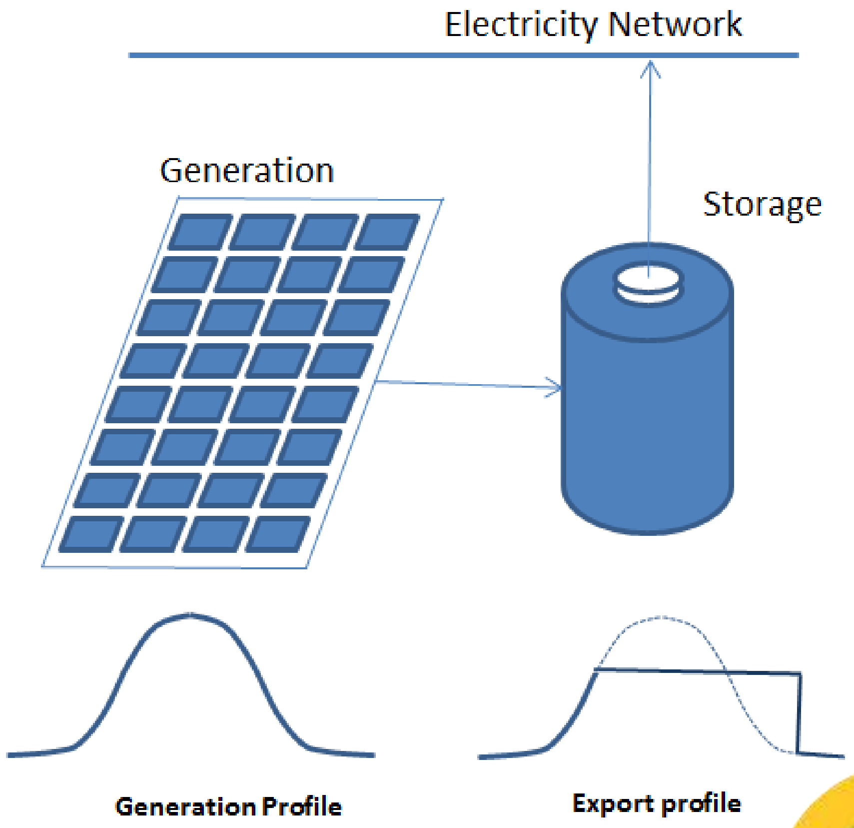
- Grid-connected PV almost never uses the full capacity of its connection
- Half of the time only half of that capacity is being used
- The opportunity for storage is to use more of that capacity to import and to export



Storage can benefit developers by expanding DC capacity

- Stores energy for export when most valuable

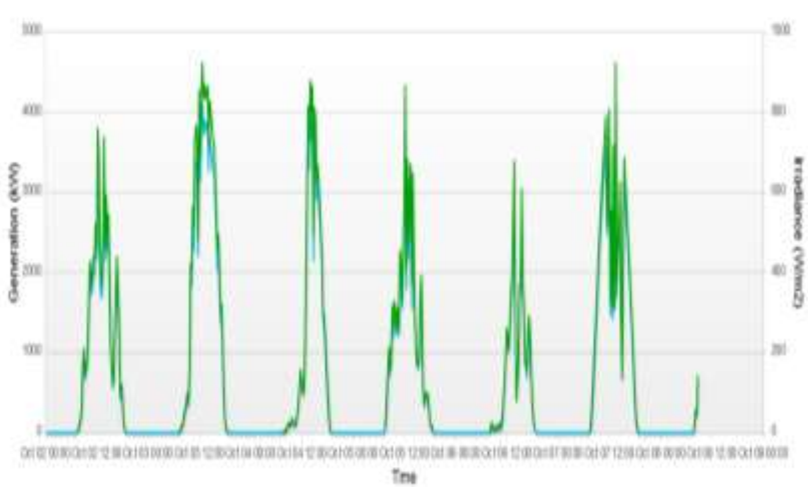
- Allows greater DC capacity to be connected per MW of grid capacity



Installing storage would fix short-term variability in export

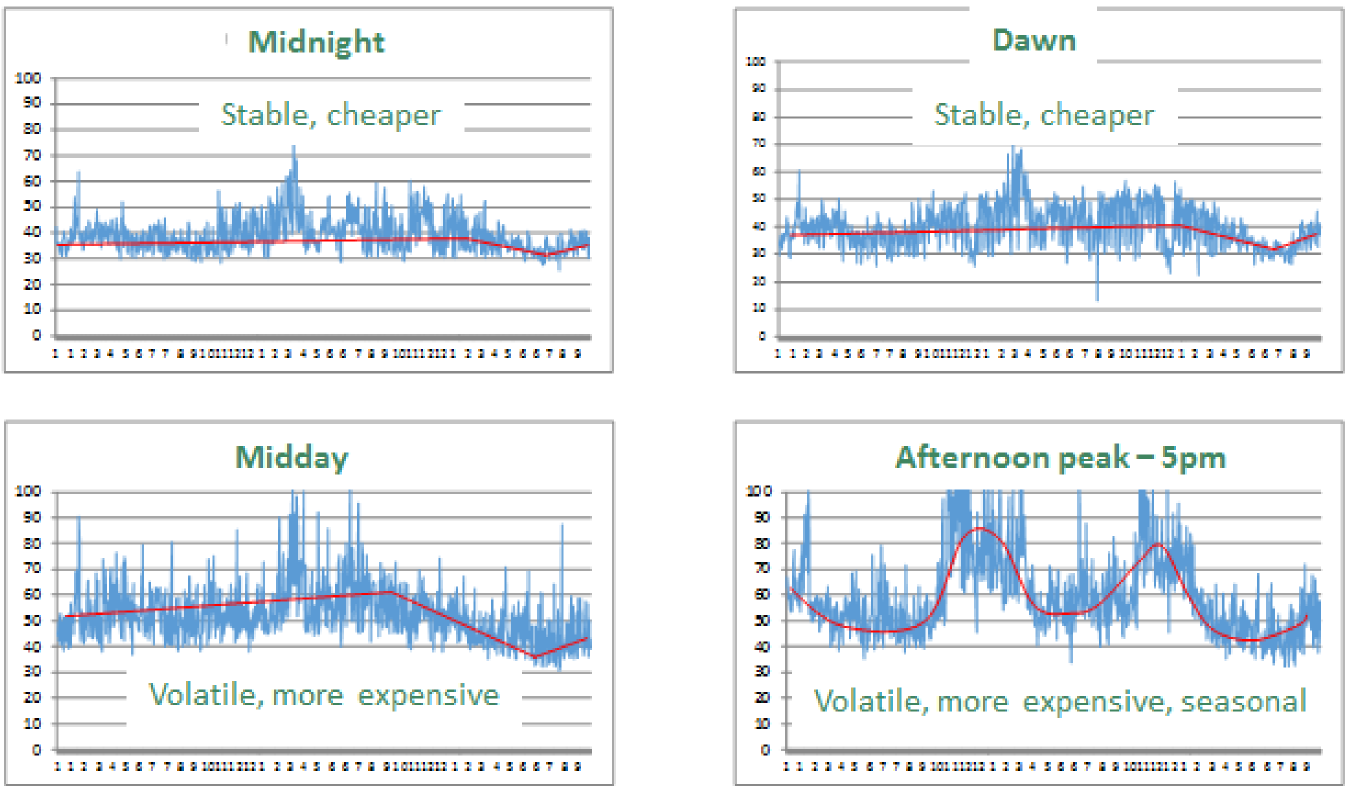
- Short-term variation in export is due to clouds
- Connection protocols protect the network but limit PV deployment
- Export smoothing would allow more PV onto sensitive networks

Chilton Cantelo 5MW
Generation 2 – 8 October '14



Storage can also help to address local or national volatility

Settled price per MWhr vs Time of Day
20011 – 2014 (by month)



We will install storage on 1.5MW PV array with storage at our head offices in Somerset

- Techno-economic trial of a real battery energy storage system on a large solar generator's side of the meter, in Somerset.
- Quantify benefits for both the DNO and Customer with real data.
- WPD South West & 3 other project partners:

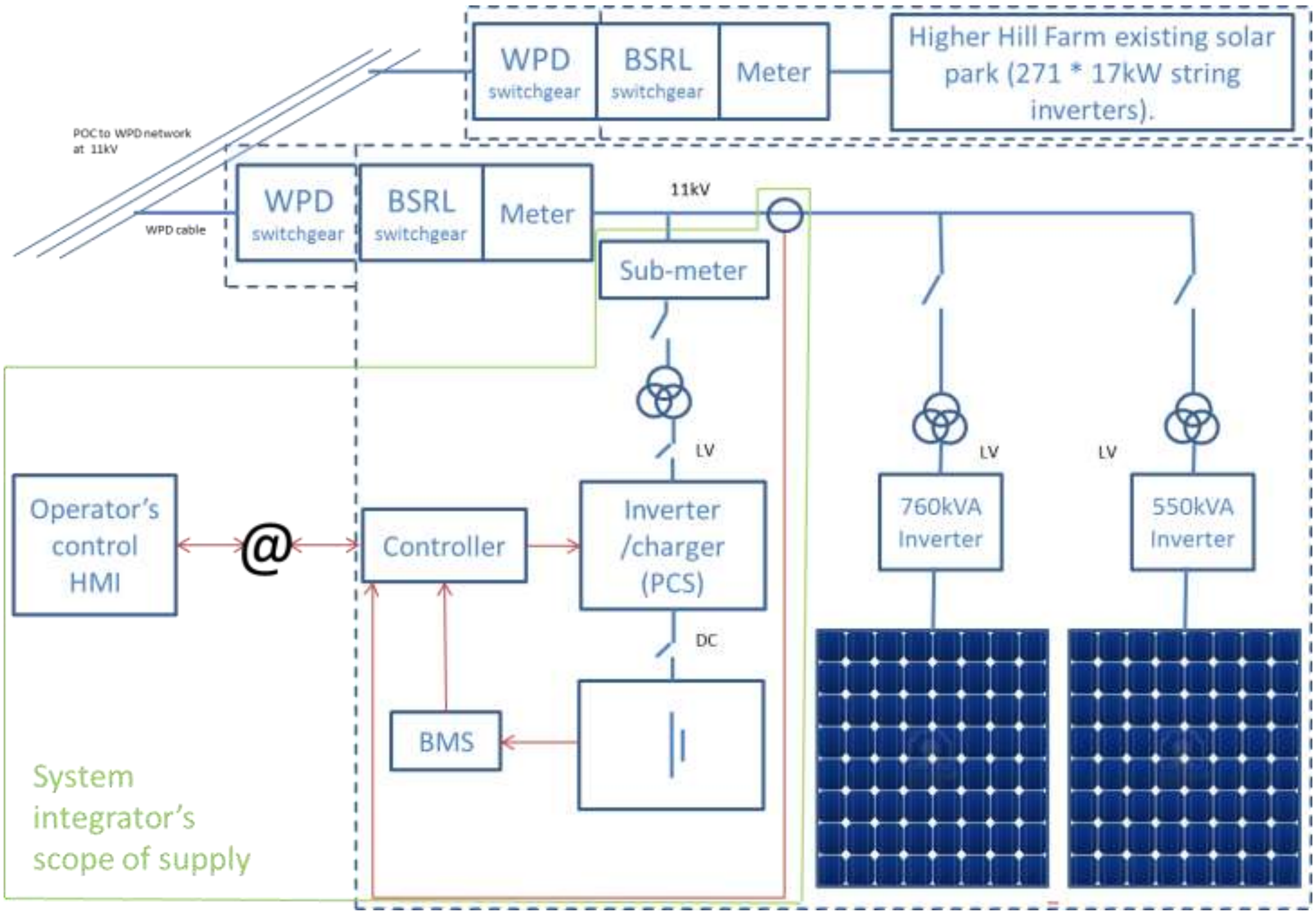
British Solar Renewables

ELEXON

BRE NATIONAL SOLAR CENTRE

- What will be the benefits of generator connected storage?
  - Generator earnings and project viability.
  - Network management services.
- Explore routes to market – challenges and rewards.
- Making the case for energy storage in new connection offers.

System schematic



Outputs of the project are designed to guide design, commercial arrangements and legislation

- The first commercial demonstration of Solar Integrated storage in the UK
- LCNF funded by Western Power Distribution, Elexon and NSC review
- Demonstrates at scale all of the modes in which storage and PV create value

Usage Case	Benefit
Sell electricity for a higher price per kWh	Owner
Shape generation profile to demand	DNO
Peak lop network demand (by exporting)	DNO
Raise minimum demand to limit voltage rise	DNO
Voltage control	DNO
Peak lop generation to build bigger solar parks	Owner
Smoothing / Power Quality	DNO
Change peak lopping level (glass ceiling)	DNO
Constructive system interactions	DNO

Steve Edwards

Technical Director

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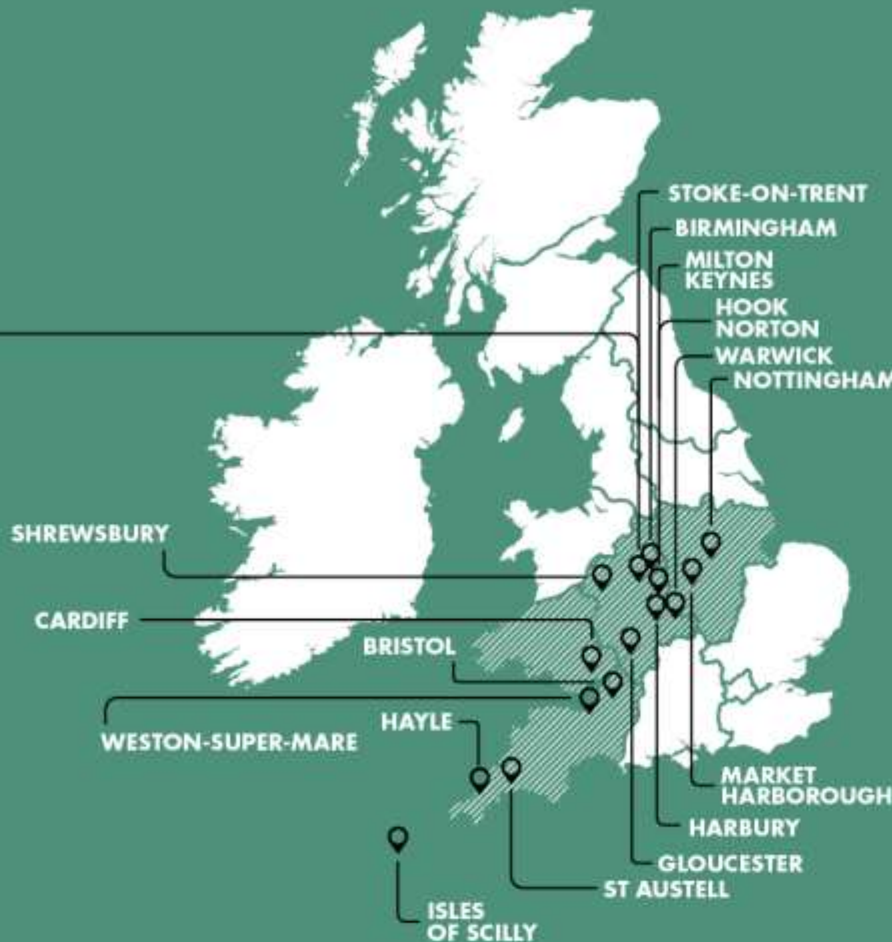
WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS



Distribution Networks: A Balancing Act

Identifying energy storage opportunities - a DNO's point of view

Philip Bale

Innovation & Low Carbon Networks Engineer

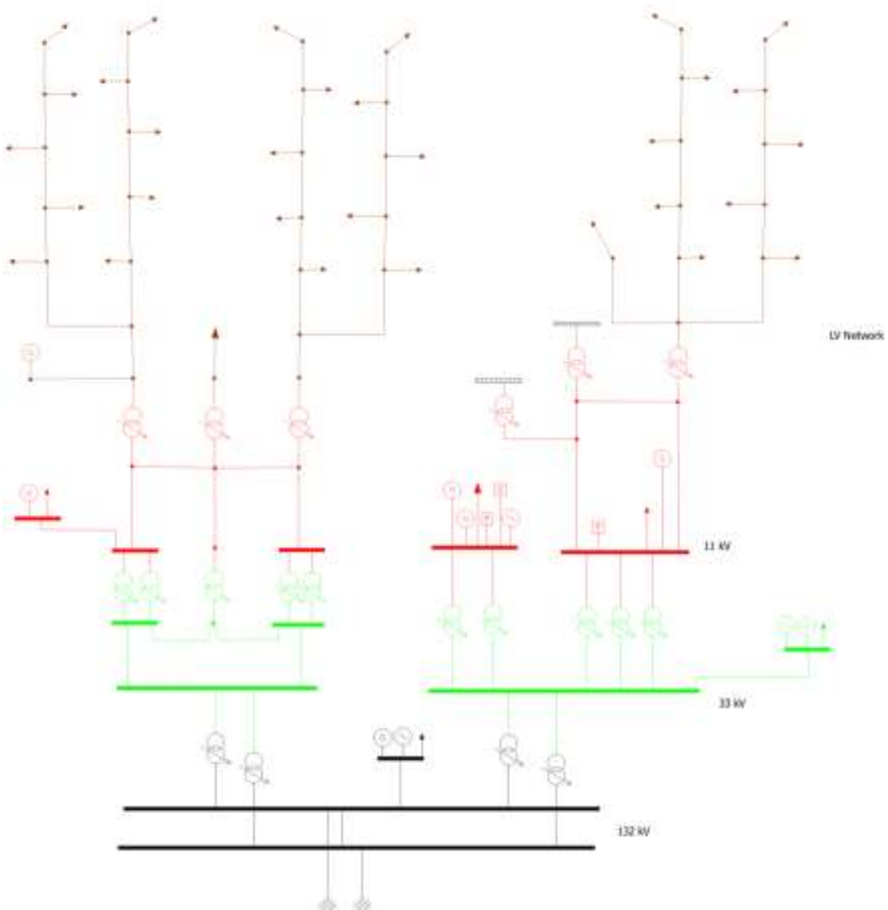
Energy storage - A DNO's considerations

1) Energy Storage - a "Black Box"
   - Where could energy storage be located? What size should it be? The pro's and con's.
   - How to model 3rd party energy storage?

2) The "Functional Specification" for Energy Storage as an alternative to conventional network reinforcement.
   - The study assumptions,
   - Analysis – Two demand scenarios,
   - Analysis – Two standard generation scenarios, and
   - The opportunities of using energy storage in Active Network Management areas to reduce constraints for generators.

3) Summary & Other considerations.
   - Ownership models and regulatory restrictions,
   - The benefits of whole network thinking and further analysis required.

Energy Storage - a “Black Box”



Energy Storage News – Across the world

http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=017db2b692&e=7f8c272bc0
- September 5th, 2014
http://cleanhorizon.us5.list-manage1.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=c65a3cbb4b&e=7f8c272bc0
- September 12th, 2014
http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=7da7a3b82a&e=7f8c272bc0
- September 19th, 2014
http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=8794fe809d&e=7f8c272bc0
- September 19th, 2014
http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=dfb6805973&e=7f8c272bc0
- September 25th, 2014
http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=33b7b49eaf&e=7f8c272bc0
- October 3rd, 2014
http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=d42c8e6ebd&e=7f8c272bc0
- October 3rd, 2014
http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=6a14064f62&e=7f8c272bc0
- October 10th, 2014
http://cleanhorizon.us5.list-manage1.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=13e77194b7&e=7f8c272bc0
- October 10th, 2014
http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=ea47619411&e=7f8c272bc0
- October 16th, 2014
http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=ed75ff558c&e=7f8c272bc0
- October 30th, 2014
http://cleanhorizon.us5.list-manage2.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=1ece2390c4&e=7f8c272bc0
- October 16th, 2014
http://cleanhorizon.us5.list-manage.com/track/click?u=c8fe16f28bd08d9c7858b5a33&id=b03e6bef1f&e=7f8c272bc0
- November 6th, 2014

Assumptions

- Steady state studies analysis using IPSA & Excel have modelled power flows using both ½ hourly SCADA data and LTDS weather normalised data.
- Demand studies have been conducted at sites reinforced during DR5.
- Case Studies have only assessed networks Classed as type B & C under Engineering Recommendation - P2/6 Planning minimum network security.
- Historic network demand has been scaled using three of National Grids "UK Future Energy Scenarios[1]" to assume changes in peak and off peak demands:
    - No Progression - 3.5% reduction in demand between the hours of 4pm and 8pm. A 2.2% decrease in demand for the remaining hours.
    - Low Carbon Life - 8.3% increase in demand between the hours of 4pm and 8pm and 8.1% increase in demand for the remaining hours.
    - Gone Green - 12.5% increase between the hours of 4pm and 8pm and 6.1% increase for the remaining hours.
- Demand studies assume no contribution from current or future embedded generation
- Studies assume longest credible outage during the most onerous period.
- There may be opportunities to reduce the installed Energy Storage MWh by a DNO combining Energy storage with mobile generators, DSM and/or agreeing to a greater level of risk for sustained outages.
- Generation studies have used anonymised real generation data for large scale wind and solar PV Generators.

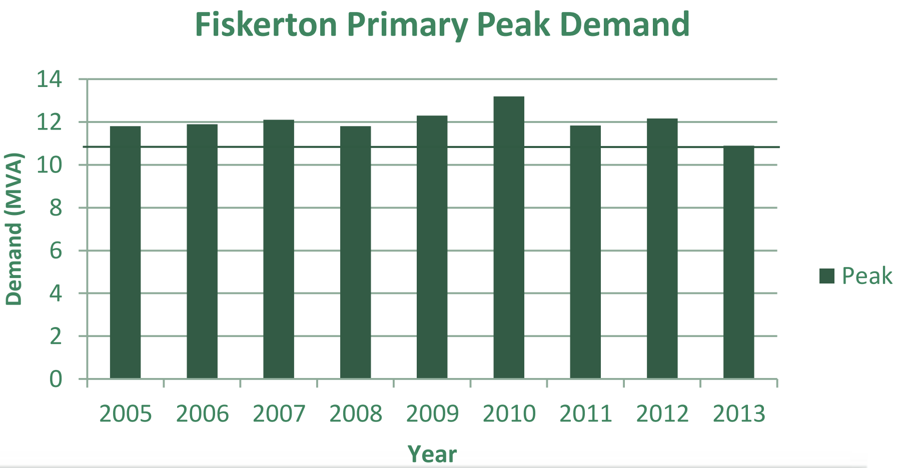
1 Available at: https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2013 [Accessed 28 August 2014].

Fiskerton Primary substation

- What is the issue?
- How could energy storage alleviate constraints between now and 2035?
- When might it be required, when would we not require energy storage, and
- What is the alternative and how much does it cost.

Scenario	Power (MW)	Capacity (MWh)
No Progression	2.6	6
Low Carbon Life	4.25	13
Gone Green	4.75	17

ITEM	COST
P + M	≈£700k
Civil	≈£30k
Cable jointing	≈£50k
Total	≈£800k

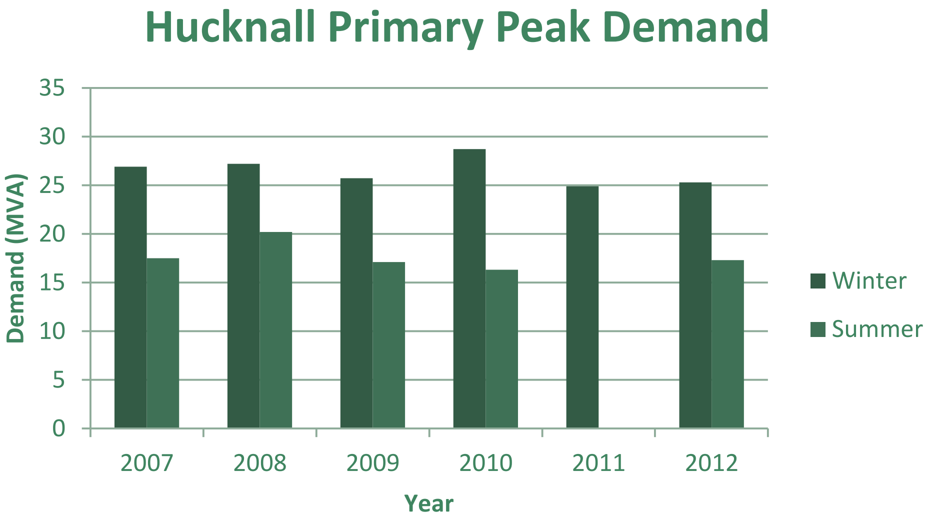


Hucknall Primary substation.

- What is the issue?
- How could energy storage alleviate constraints between now and 2035?
- When might it be required, when would we not require energy storage, and
- What is the alternative and how much does it cost.

Scenario	Power (MW)	Capacity (MWh)
No Progression	3.1	42
Low Carbon Life	5.5	79
Gone Green	6	67

ITEM	COST
Plant and Materials (P+M)	≈£100k
Cable works	≈£3m
Total	≈£4m



Wind Farm & PV Farm - conventional connections

- What is the issue?
- How could energy storage alleviate constraints
- When might it be required, when would we not require energy storage, and
- What is the alternative and how much does it cost.

12.5MW Wind Farm Connection
Northamptonshire

Period of minimum demand 7th Sept – 13th Sept 2013

Energy Storage requirements

- Maximum sustained power rating: 7.5 MW
- Useable capacity: 988.7 MWh+

Conventional Network Reinforcement

Item	Costs
Fees	≈£10k
P + M	≈£300k
Cable works	≈£7m
Overhead construction	≈£800k
Total	≈£8.3m

12MW Solar PV Farm Connection
Northamptonshire

Period of minimum demand 20th Jun 2013 – 26th Jun 2013.

Energy Storage requirements

- Maximum sustained power rating: 6 MW
- Useable capacity: 20 MWh

Conventional Network Reinforcement

Item	Costs
Fees	≈£10k
Cable works	≈£100k
Substation	≈£250k
Total	≈£350k

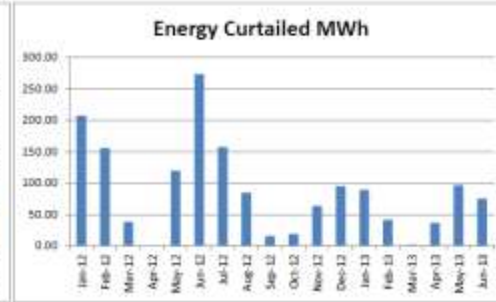
Case Study 4 - "Functional Specification"

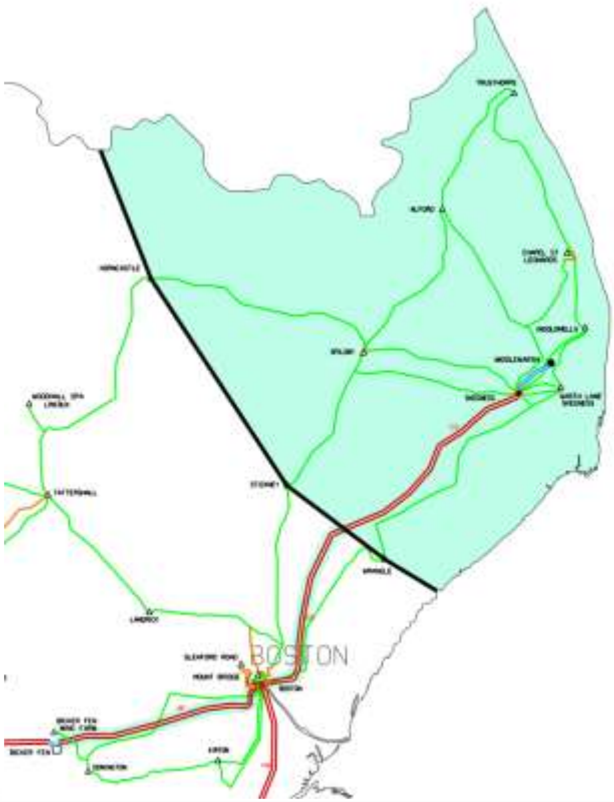
DG – ANM connections

- What is the issue?
- How could energy storage alleviate constraints , and
- When might it be required, when would we not require energy storage.

Analysis and Results Summary

Generator Type	Wind Generator 35%	Maximum Output	4.60MW
Generator Rating	4.60MW	Average Output	1.49MW
Connection Location	degN, degE	Minimum Output	0.00MW
Connection Distance	0.10km	Energy Generated	19560.5MWh p.a.
Connection Type	Tee	Curtailed Energy	1568.9MWh p.a.
Cable Type	150mm, 33kV	Network Constraint Level	4.26%
Global Load Scaling Factor	100.00%	Generator Constraint %	7.4% energy lost out of 21129.4MWh





GSP Group	Active BSP Group	Quoting form	Building during
Bicker fen	Skegness	Active	Active
Grendon	Corby Northampton	Active April 2016	April 2015 April 2017
Bridgwater	Bridgwater Street	November 2014 November 2014	November 2015 November 2015
West Burton	Horncastle	April 2015	April 2016
Indian Queens	Truro	November 2015	November 2016
Swansea North	Swansea Pembroke	November 2016 November 2016	November 2017 November 2017

Energy Storage :-

- Could be considered as a "black box",
- No one size fits all,
- Requirement for whole system thinking,
- CBA could be location specific, both for a DNO and other revenue streams (STOR, Fast Reserve, frequency response……),
- Additional revenue streams & opportunities may exist in some Active Network Management areas.

Why a DNO would want to use Energy Storage as an alternative to Conventional Network Reinforcement?

The current limitations that could prevent a DNO from using Energy Storage as an alternative to Conventional Network Reinforcement.

All DNOs are working together to share learning from all projects & trials in the form of a Good Practice Guide – December 2014.

ENERGY STORAGE esof OPERATORS' FORUM

State of Charge of GB

October 2014

Peter Lang	Stewart Reid	Ian Lloyd	Philip Bale	Alan Collinson	Geraldine Bryson	Esther Dudek
UK Power Networks	Scottish and Southern	Northern Powergrid	Western Power Distribution	SP Energy Networks	Electricity North West	EA Technology Ltd

***Abstract*—This paper is a summary of the electrical energy storage (EES) installations by GB Distribution Network Operators (DNOs). It shares some of the learning from these projects in relation to the business case for EES, network benefits and how EES can be integrated into Business as Usual (BaU).**

***Index Terms*—energy storage, power distribution, smart grids.**

I. INTRODUCTION

The Energy Storage Operators Forum (ESOF) was established in May 2012 as a forum to facilitate sharing of experiences between member DNOs.

Significant amounts of learning have been generated through the portfolio of energy storage activities undertaken by the ESOF membership. This learning spans the full project lifecycle – from specifying and procuring systems, through installation and commissioning, to realising value from operation of storage.

II. INSTALLATIONS

A number of DNOs have installed and continue to install electrical energy storage (EES) systems funded by the Low Carbon Network (LCN) Fund and Innovation Funding Incentive (IFI), established by Ofgem [1,2].

DNO projects have commissioned 12.45MW and 20.2 MWh of storage, with an additional 3 MW and 1.5 MWh either under construction or being planned. A number of DECC supported demonstration projects are also underway.

Installations range from domestic systems through community-scale devices to utility-scale. Demonstrations in Northern Powergrid's "Customer-Led Network Revolution"[3], WPD's "BRISTOL" and "Falcon" [4], UK Power Network's [5] and SSEPD's [6] various LCN Fund (Tier 1 and 2) projects are all delivering learning which is being disseminated throughout the industry.

The current status of these projects, their size and location is presented in Figure 1. A number of electrical storage technologies have been, or are being trialled and each has their own merits. These include sodium sulphur, sodium nickel chloride, gel-filled lead acid and various variants of Li-Ion batteries and a zinc bromine flow cell.

Figure 1: Locations of DNO Energy Storage Projects

III. INDUSTRY LEARNING

The range of deployments of EES systems supported by the LCN Fund and IFI has generated significant learning relating to the full project life-cycle. This paper focuses on learning in three key areas:

- Developing the Business Case;
- Integrating Storage into DNO BaU; and
- Network Benefits.

Further information is being shared by DNOs in formal project reports, and through ESOF and other dissemination events. This is being consolidated into a 'Good Practice Guide' on EES, to be published in December 2014.

A. Developing the Business Case

EES systems connected to the distribution network have multiple potential applications within the electricity system. These include providing thermal and voltage support to distribution networks (thus avoiding reinforcement), ancillary services to the transmission operator, constraint management to enable the connection of renewable generation and energy trading in the wholesale market. The business case for a given EES installation is formed by combining revenue/avoided reinforcement costs from each relevant application. It should be noted that some of these revenue streams are outside of the conventional DNO business, and this presents various regulatory barriers to the development of the business case.

Different ownership/business models can be used, and these are being investigated by the various LCN Fund

Distribution Networks: A Balancing Act

WPD believes opportunities already exist to better balance generation and demand.

- **Alternative Connections**
  - Business as Usual - Timed, Soft-Intertrip and ANM in selected areas,
  - A roadmap for 11 ANM zones across WPD by 2018,
  - Further opportunities will continue to be explored.
- **Demand Side Response**
  - Clear post trials road map outline for ED1.
- **Energy Storage**
  - Currently, WPD has no plans for WPD to fund Energy Storage in ED1,
  - However, there are currently a number of key variables which with further maturity could result in Energy Storage being used as an alternative to Conventional network reinforcement in certain circumstances.

Questions

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