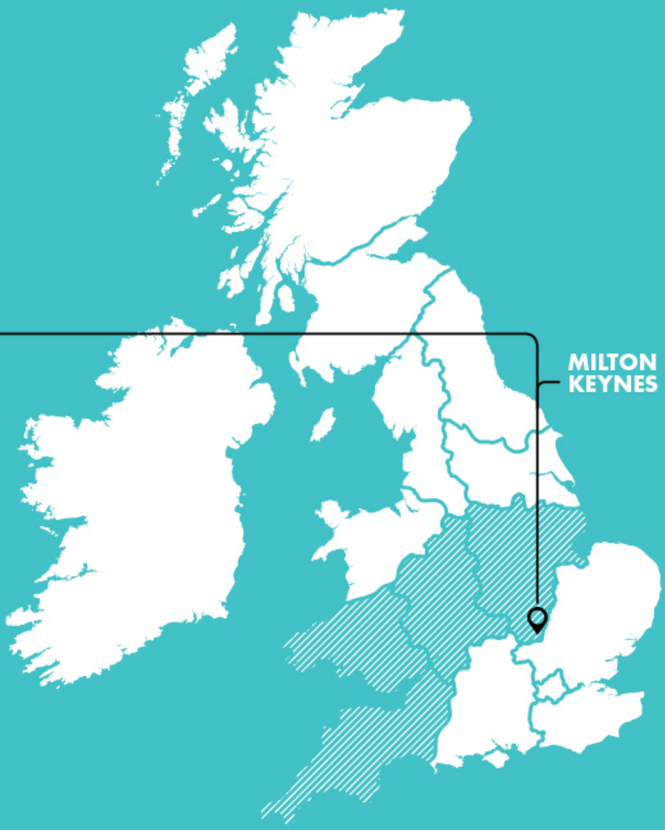
WESTERN POWER DISTRIBUTION

FALCON

DEVELOPING FUTURE POWER NETWORKS



Project FALCON

Final Dissemination Event

10th November 2015

LCN Fund Low Carbon Networks · ALSTOM · Aston University · CGI · CISCO · Cranfield UNIVERSITY

Agenda

Welcome, WPD overview, objectives and key messages of today - Phil	10.00
An overview of WPD innovation and an introduction to team - Roger	10.10
FALCON overview - Jenny	10.20
Engineering Trials - Chris	10.40
Q & A	11.10
Break for coffee	***11.30***
Commercial Trials- Gary	12.00
Q&A	12.30
LUNCH	***12.50***
Load Estimation and SIM - Jenny	13.50
Q&A	14.30
Telco's- Barrie	14.50
Q&A	15.10
Summary and close - Roger	15.30

Who are WPD ?

WPD is a Distribution Network Operator (DNO);

- operating in 4 of 14 distribution licence areas in the UK
- owning, operating, maintaining and replacing 31% of the UK's Distribution assets
- distributing electricity to 7.8 million customers
- connecting new customers (load/generation) via WPD or third party owned assets
- directly employing over 6,400 people

Innovation in WPD

- WPD has long been an innovative company and firmly believes that you have to continue to innovate as a company if you wish to survive long term
- Our innovation philosophy is simple – it's not about a collection of words or industry jargon – it is about exploring and developing new ideas and bringing successful outcomes to a practical application
- Many aspects of our innovative approach are already business as usual within the company
- Our past, current and on-going innovation projects combined with the learning from other organisations will help us to deliver affordable, reliable and sustainable energy

The key outputs from FALCON

FALCON was a key innovation project for us for a number of reasons;

- Particularly complex programme of work to test the network principles of a genuine Smarter Network
- Generated some powerful learning that has already formed the basis of subsequent projects;
  - Storage can do what it says on the tin and has a number of applications
  - DSR does provide good results for a DNO, but more changes are needed at industry and policy level to leverage effectively
  - Telco, further work necessary to make WiMAX achievable more widely
  - Cultural change in the industry? Support of innovation…?

Objectives for today

- Explain the FALCON project & it’s aims
- Give a high level overview of each workstream
- Disseminate the Key learning from each workstream
- Give key stakeholders the opportunity to ask questions of the team
- Invite further feedback and comment on the reports

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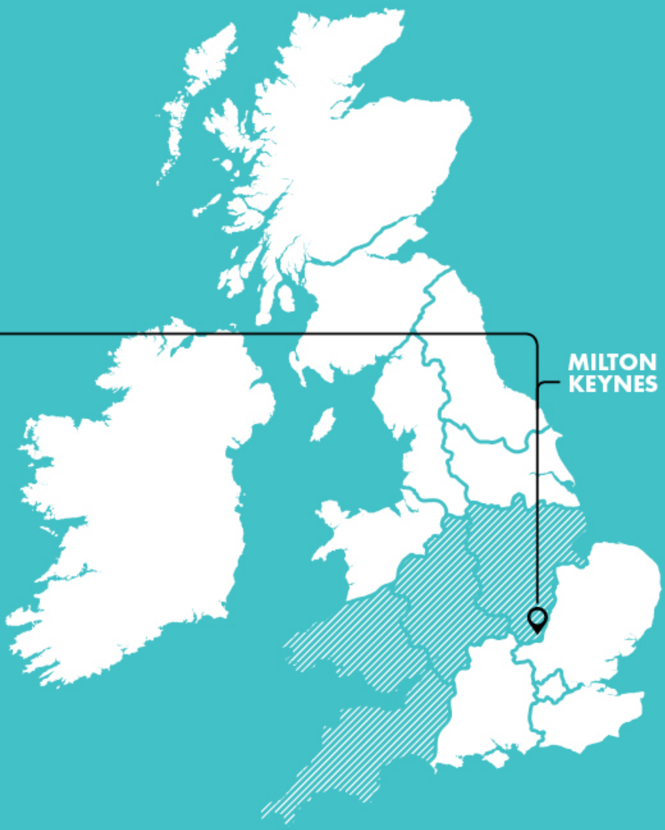

Innovation

Roger Hey

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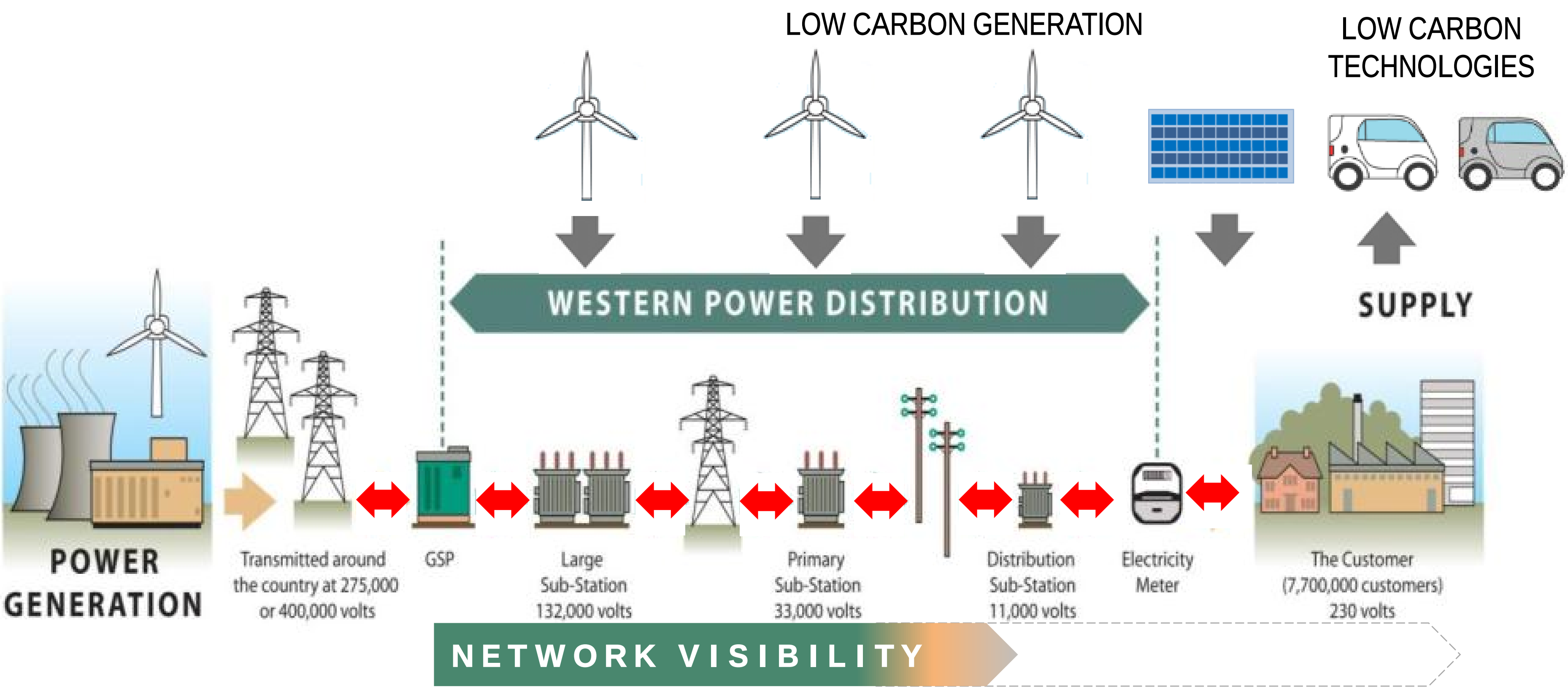

- Limited capacity
- Passive design / operation
- Centralised Generation
- Limited Visibility
- One-way power flow
- Load centric design

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

- WESTERN POWER DISTRIBUTION SOLA BRISTOL
- WESTERN POWER DISTRIBUTION FLEXDGRID
- WESTERN POWER DISTRIBUTION NETWORK EQUILIBRIUM
- WESTERN POWER DISTRIBUTION TELECOMS TEMPLATES
- WESTERN POWER DISTRIBUTION H2 BALANCE
- WESTERN POWER DISTRIBUTION LOCAL ENERGY MARKET

Innovation Strategy

Assets

- Telemetry
- Decision support
- Improved assets
- New assets
- Flexibility
- Automation
- Incident response

Customers

- New connections
- Upgrades
- Information
- Self Serve
- Products/Service
- Tariffs
- Communities

Operations

- Reliability
- Forecasting
- System Operation
- DSR
- GBSO Interface
- Efficiency
- SHE and Security

Network and Customer Data

- WESTERN POWER DISTRIBUTION LOW CARBON HUB
- WESTERN POWER DISTRIBUTION NETWORK TEMPLATES
- WESTERN POWER DISTRIBUTION FALCON
- CATAPULT WESTERN POWER DISTRIBUTION POWER & HEAT
- Innovate UK WESTERN POWER DISTRIBUTION LV PLUS
- Innovate UK WESTERN POWER DISTRIBUTION WIRELESS HIGHWAYS

- WESTERN POWER DISTRIBUTION ECHO
- WESTERN POWER DISTRIBUTION SOLAR STORAGE
- WESTERN POWER DISTRIBUTION LOSSES INVESTIGATION
- WESTERN POWER DISTRIBUTION STATISICAL RATINGS
- WESTERN POWER DISTRIBUTION PROJECT SYNC
- WESTERN POWER DISTRIBUTION REACT
- WESTERN POWER DISTRIBUTION D-SVC INTEGRATION
- WESTERN POWER DISTRIBUTION ELECTRIC BOULEVARDS
- WESTERN POWER DISTRIBUTION SUNSHINE TARIFF
- WESTERN POWER DISTRIBUTION AIRBORNE INSPECTIONS
- WESTERN POWER DISTRIBUTION VOLTAGE LEVEL ASSESSMENT
- WESTERN POWER DISTRIBUTION DS2030

Innovation into Business as Usual

- Innovation Team and Policy/Standards Team are combined
- Innovation is delivered by operational teams, who also feed in new ideas
- Projects develop policies and procedures as the projects grow
- Alternative Generator Connections – driven from an LCNF trial

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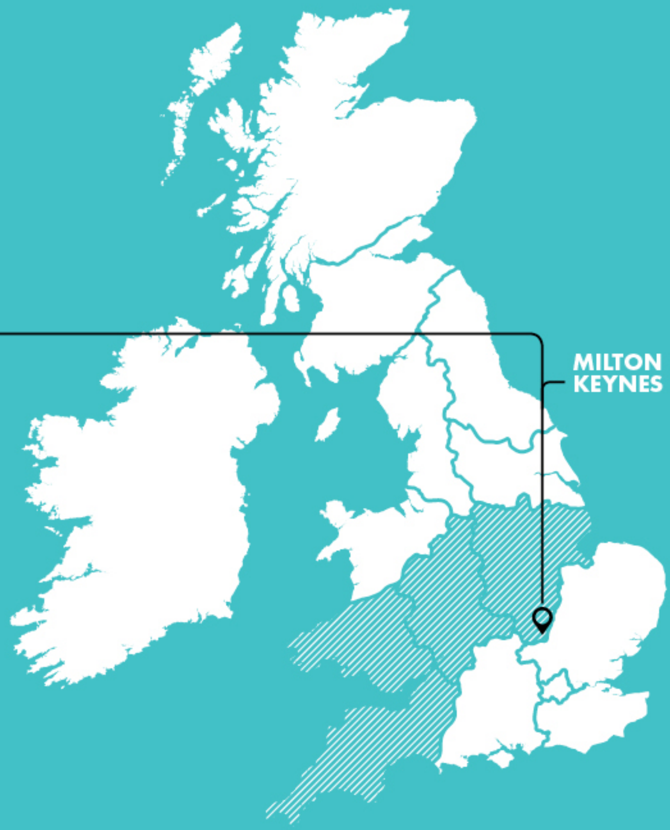

Project FALCON

Jenny Woodruff

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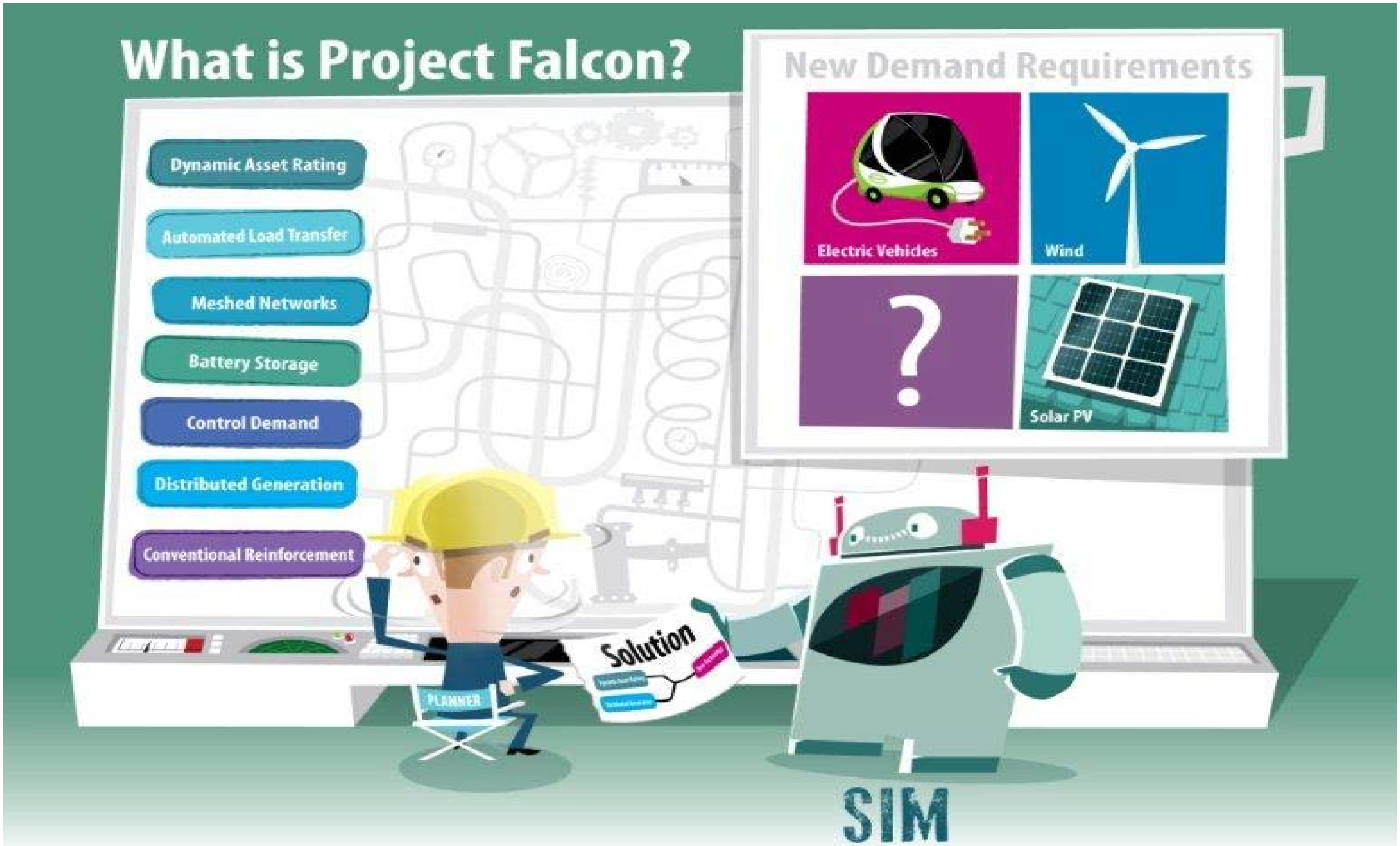
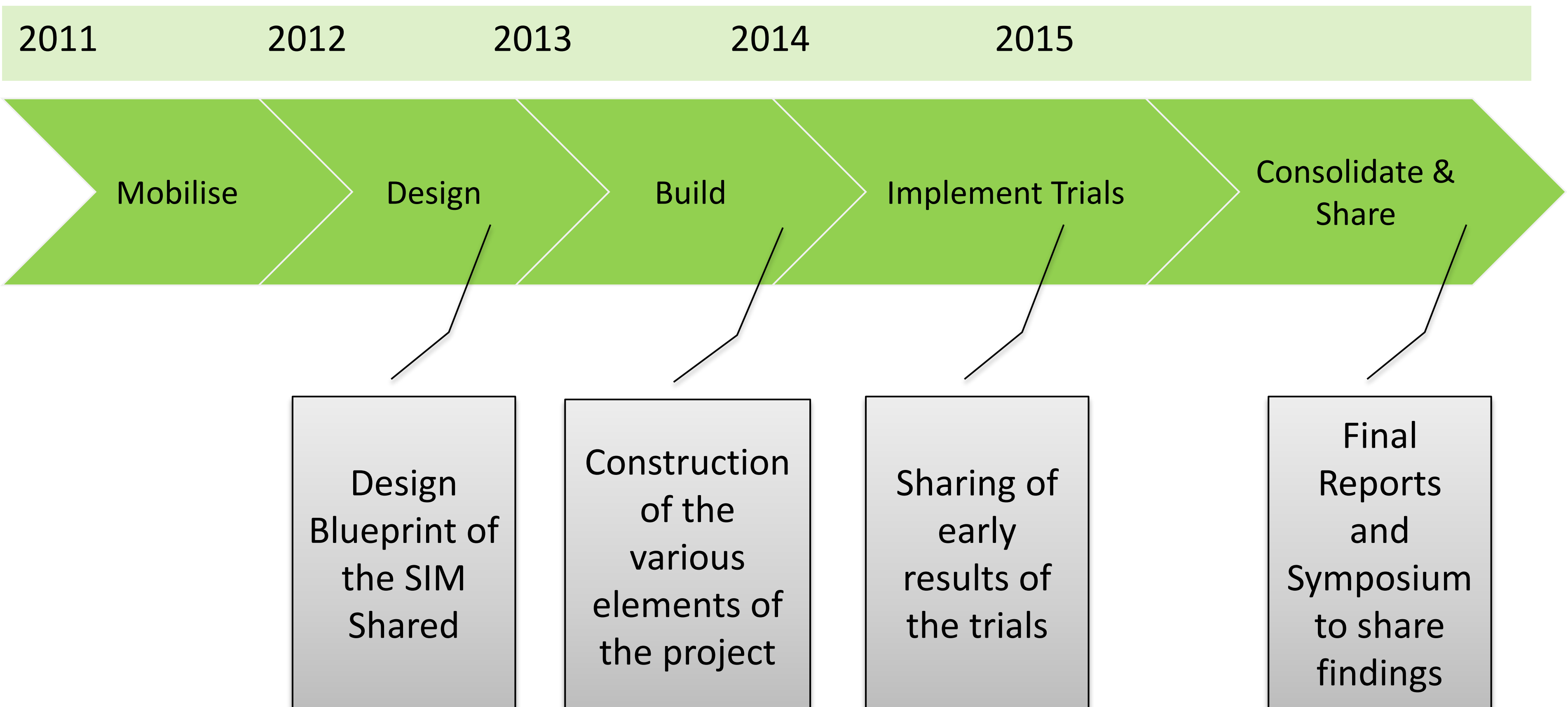

What is Project Falcon?
Dynamic Asset Rating
Automated Load Transfer
Meshed Networks
Battery Storage
Control Demand
Distributed Generation
Conventional Reinforcement
New Demand Requirements
Electric Vehicles
Wind
?
Solar PV
Solution
PLANNER
SIM

Timeline


2011
2012
2013
2014
2015
Mobilise
Design
Build
Implement Trials
Consolidate & Share
Design Blueprint of the SIM Shared
Construction of the various elements of the project
Sharing of early results of the trials
Final Reports and Symposium to share findings

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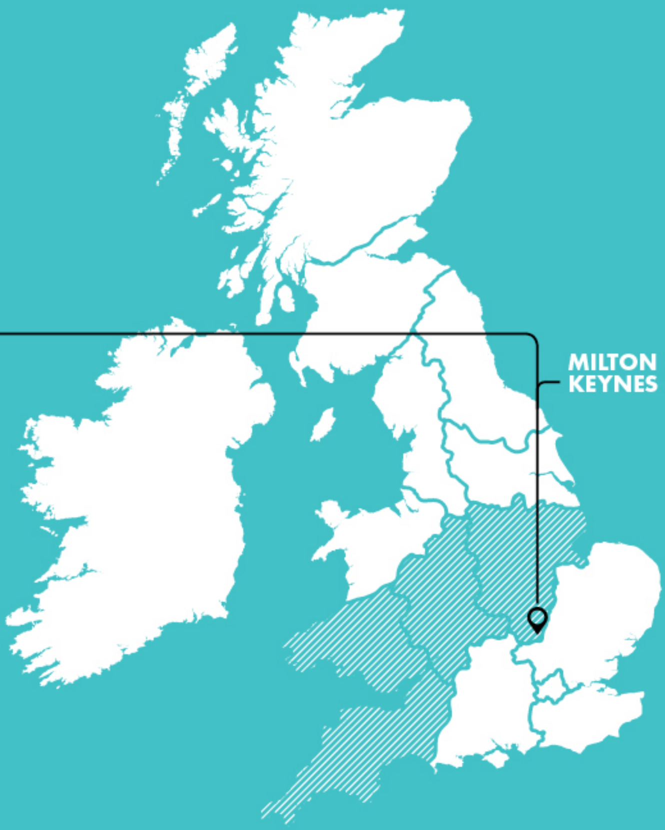
DEVELOPING FUTURE POWER NETWORKS

Engineering Trials

Chris Harrap



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Trial Techniques Presentation

- General trials introduction
- Discuss 4 trialled techniques:
  - What was done
  - Key findings
  - Key conclusions
- Q&A

Overview of Trials and Technique Implementation

- Broad trial objectives were:
  - to understand the implementation of the trial techniques;
  - to understand operational capability of the trial techniques; and
  - to inform changes to the modelling of the trial techniques within the SIM.

Note: Assets that were not actually under constraint

Overview of Trial Techniques

- Four engineering techniques:
  - Dynamic asset rating (DAR):
    - 11kV OHL
    - Primary (33/11kV) transformers & Distribution Transformers
    - 33kV & 11kV cable sections
  - Automatic Load Transfer (ALT)
    - Largely underground network section
    - Largely OH network section
  - Meshing networks (Mesh):
    - Interconnection of two feeders
  - Energy Storage (ES):
    - 5 LV packages, 5 sites, 1 11kV feeder

Overview of Trial Techniques

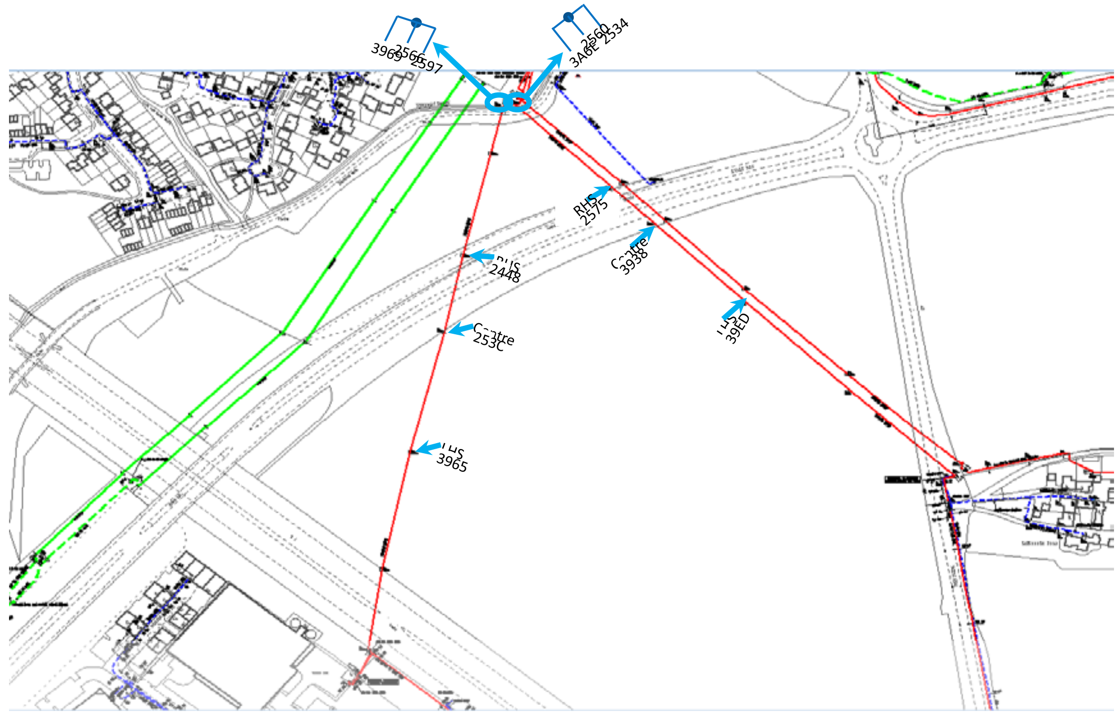
- Considered impact on:
  - Thermal/feeder capacity
  - Network voltage
  - Fault level
  - Losses
  - Power quality
  - Enablement of DG
  - Customer performance
  - Grid/network services

Dynamic Asset Rating

DAR OHL – installed #1

3 OHLs out of Newport Pagnell Primary:

- Way 9 type (150mm^2 ACSR)
- Way 8 (150mm^2 ACSR)
- Way 4 (0.15 SCA)



Scheme included:

- OHL load, wind speed/direction, air temp & solar monitoring
- Conductor temperature monitoring
- Online DAR relay
- Offline thermal modelling

DAR PTx – installed #2

2 Primary Transformers

- 12/19/24MVA
- sustained ONAN 98^{o}C
- summer cyclic OFAF 120^{o}C
- emergency continuous winter OFAF 140^{o}C

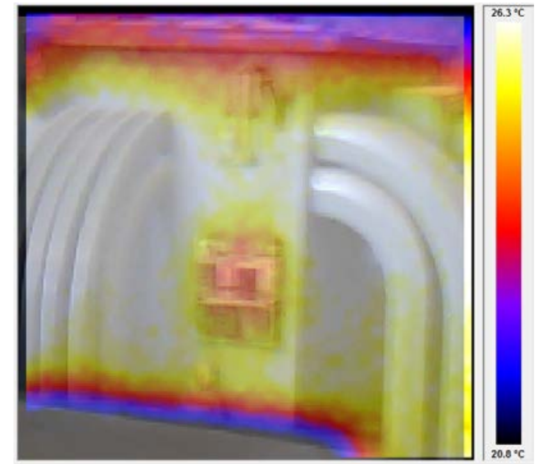
Scheme included:

- Tx load, and air temp monitoring
- Tx oil temperature measurement
- Online DAR relay
- Offline thermal modelling

DAR DTx – installed #3

16 Distribution transformers

- 200kVA – 800kVA
- Build Year - 1961 - 2005
- Mass: 1910kg – 3185kg (500kVA)



Scheme included:

- Tx load, and indoor & outdoor air temp monitoring
- Tx oil temperature measurement
- ~~Online DAR relay~~
- Offline thermal modelling

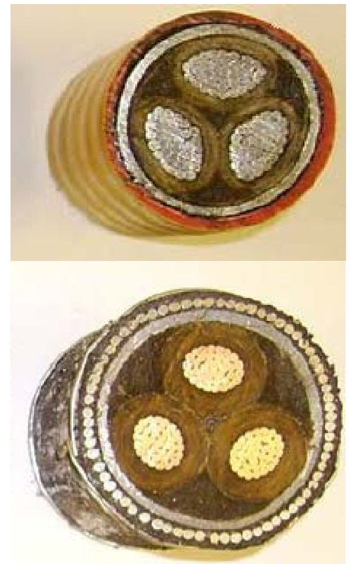
DAR Cable – installed #4

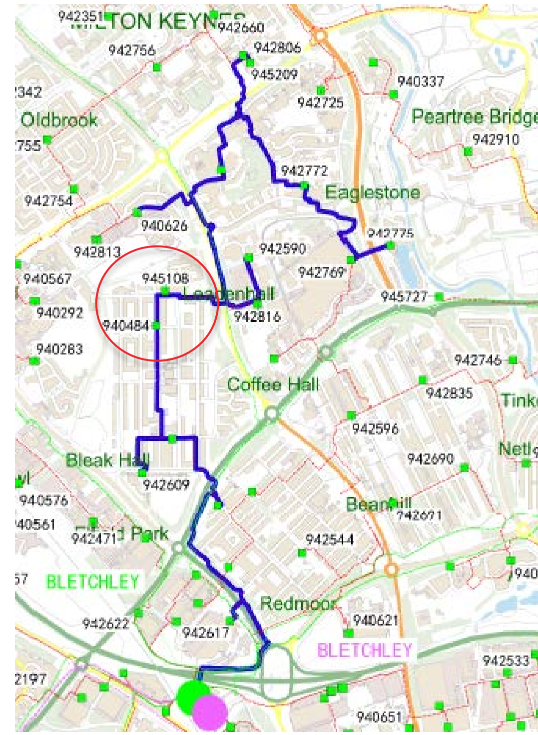
1 section of 11kV

- 185mm^2 Al PIAS

Sections of two 33kV circuits

- 185mm^2 3 core Cu



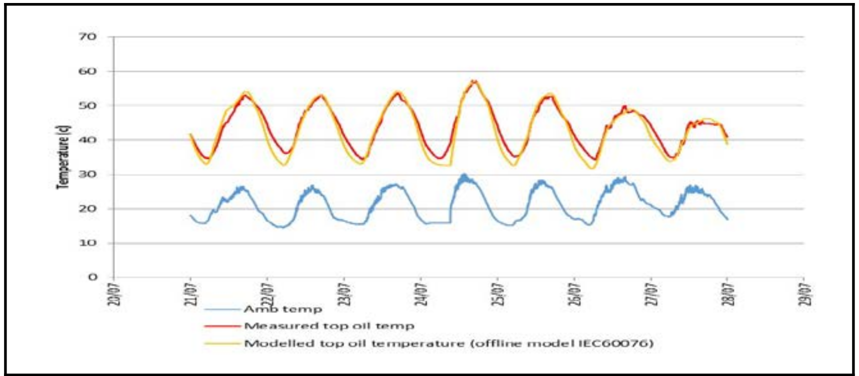


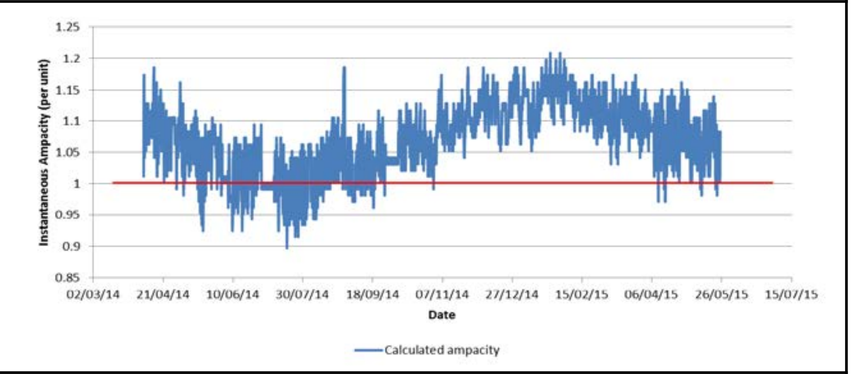
Scheme included:

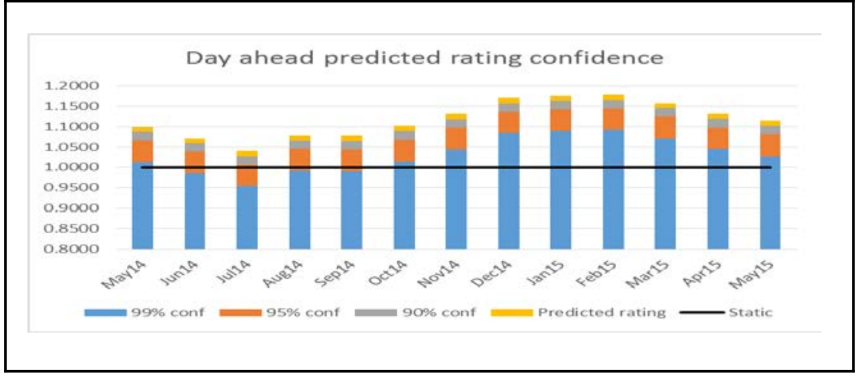
- Cable load, soil temp and moisture monitoring
- Cable sheath temperature measurement
- Online DAR relay
- Offline thermal modelling

DAR – Key Learning

- Thermal models agreed well with measured parameters
- Instantaneous dynamic ratings can be highly variable
- DAR was found to be both above and below static ratings
- Forecast dynamic ratings can be developed, that offer forward views of future ampacity





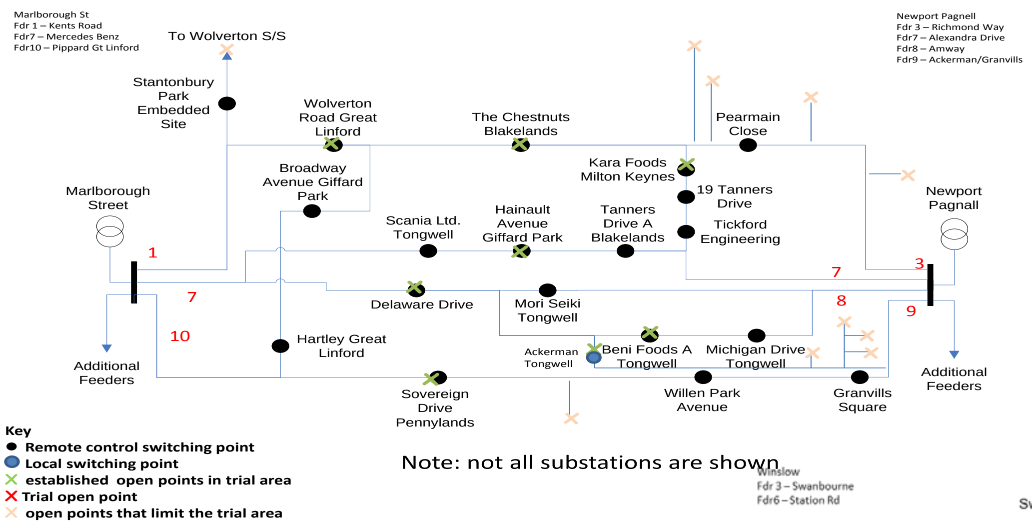


Conclusions: FALCON DAR

- 11kV OHL DAR highly variable, difficult to rely on in real-time, complex for widespread application
- PTx may offer up to 10% average increase in rating over winter, and should be developed further
- DTx offer DAR potential, but each transformer is likely to be bespoke, complex for widespread application
- Cables may offer up to 7% average increase in rating over winter – potential for selective application.

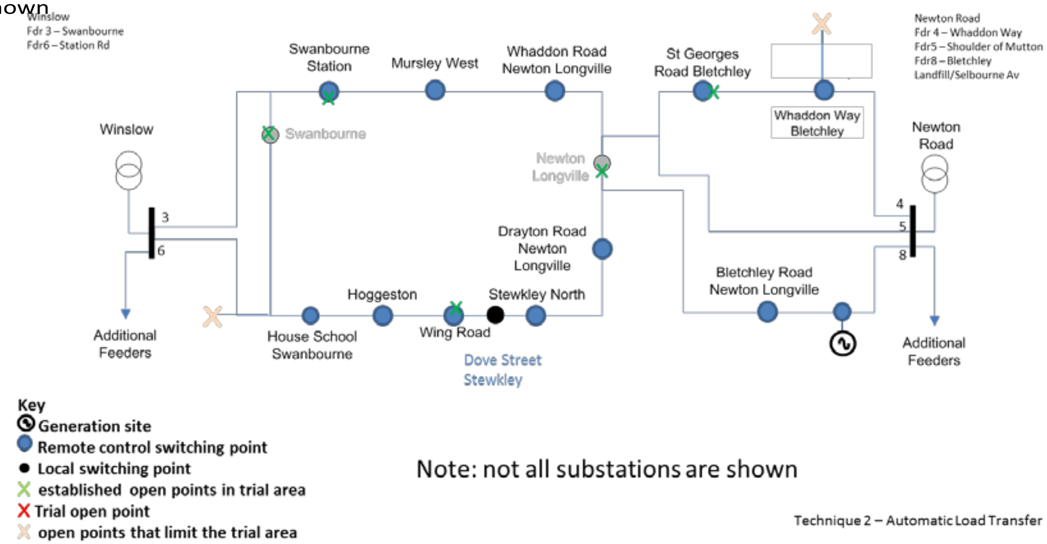
Automatic Load Transfer

ALT – installed #1



Scheme included:

- Two distinct sections of network



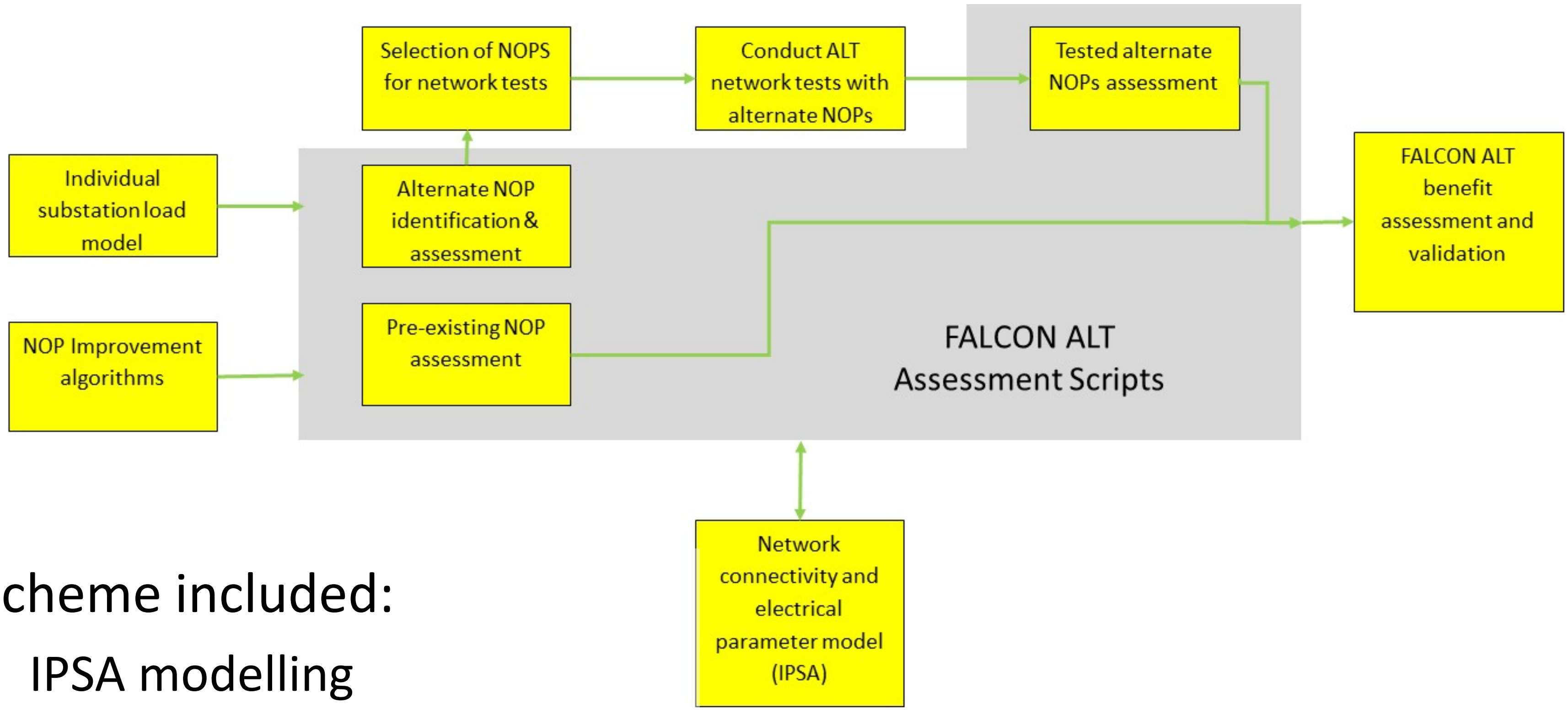
ALT – installed #2

Scheme included:

- Installation of remote control capability at:
    - 15 sites on UG network
    - 4 sites on OHL network

Selected automation sites based on early assessment work

ALT – installed #3



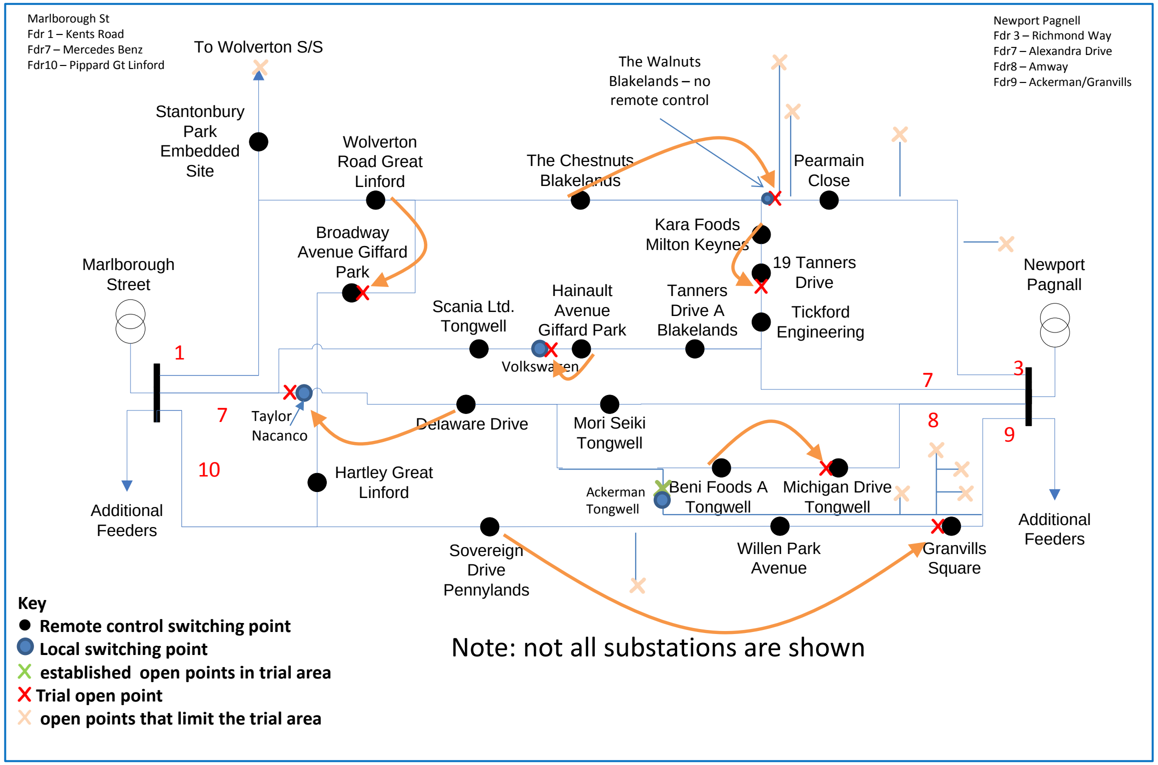
Scheme included:

- IPSA modelling
- Extensive Python programming controls

ALT – installed #4

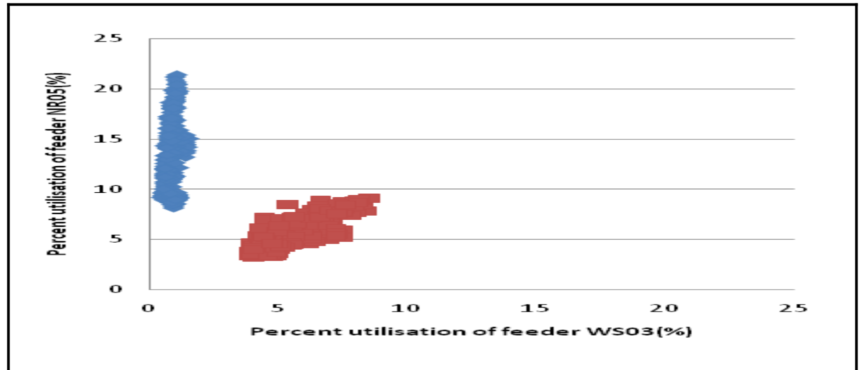
Trials included:

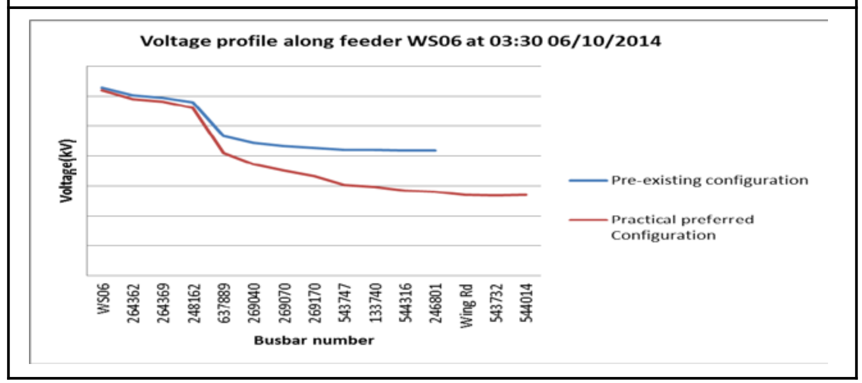
- Distribution substation load modelling
- Challenge that load changes
- Approach included
  - Pre-existing NOP period
  - Changed NOP period
  - Pre-existing NOP period
  - Plenty of modelling



ALT – Key Learning

- Different algorithms are required for different objectives (e.g. capacity vs losses)
- Capacity headroom increased
  - 4-12% points for OH
  - 8% points on most heavily loaded for UG
- Losses could also be reduced
- Network voltage only marginally affected on trial circuits
- Changes occurred to customer numbers per feeder – these would need to be mitigated





Conclusions – FALCON: ALT

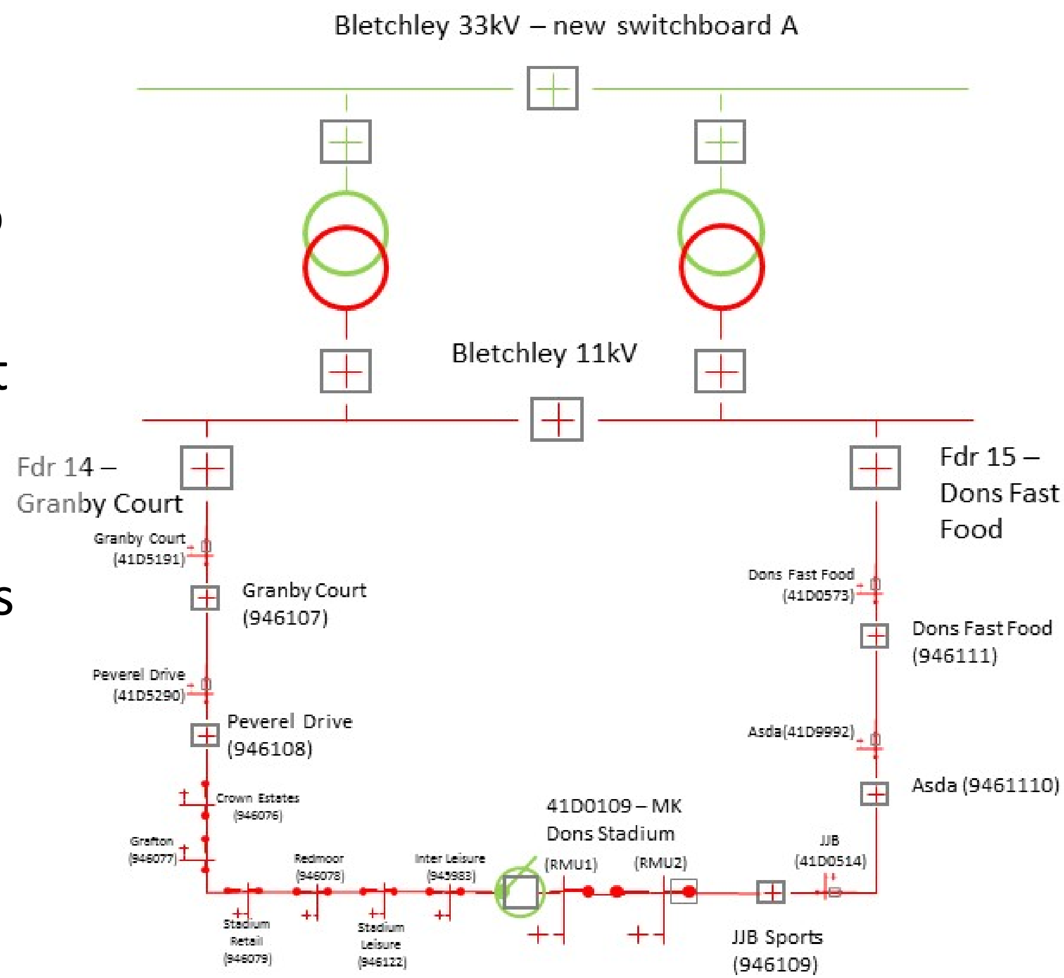
- Potential for some optimisation for capacity
  - It is recommended that a candidate portion of network should be assessed using this technique to trial actual solution provision, where network is currently approaching/is at limits.
- Potential to reduce losses through a one-off / occasional revision of NOPs
  - Currently consider how this could be utilised in wider loss reduction strategy

Mesh

Mesh – installed #1

Scheme:

- Reduced trial scope
- Focused on meshing of two feeders
- Key power measurement at feeders and the nominal open point
- Potential to revisit if comms issues can be addressed



Mesh – installed #2

Scheme:

- RMUs installed to provide CBs in circuit
- Protection relay commissioned at the nominal open point

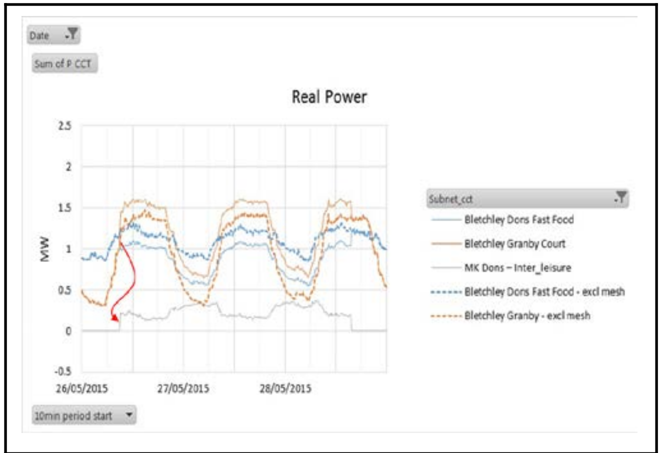
Overview of Key Trials Learning - Mesh

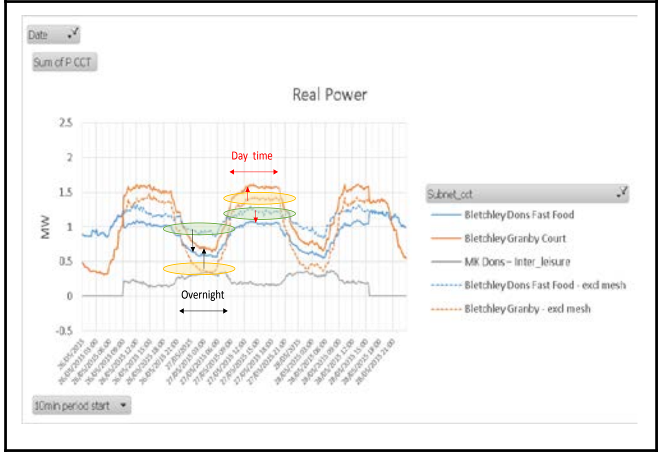
Meshing of a simple (two feeder) network changed loading on source breakers, however

- Did not reduce load on the more heavily loaded source

Other network parameters:

- Losses, Voltage & PQ – largely unaffected on this small compact urban network





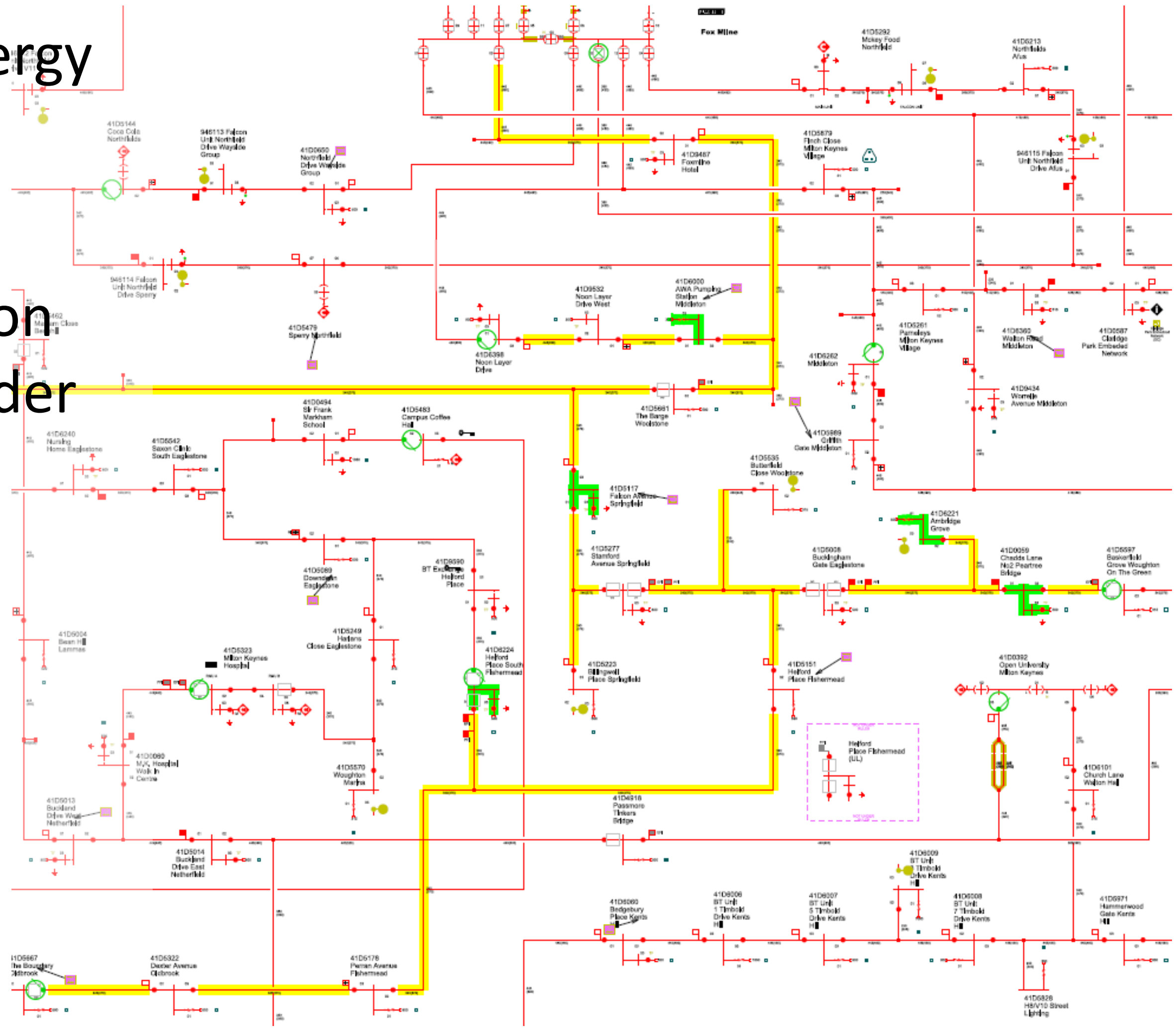
Conclusions – FALCON: Mesh

- Meshing does not necessarily equalise feeder loading:
  - It is recommended that work is undertaken to test feasibility of an algorithm that identifies possible feeders that could be meshed and would beneficially re-distribute load
- Retained existing simple mesh (in a mothballed condition) for future work on high-speed/high priority performance of communications networks

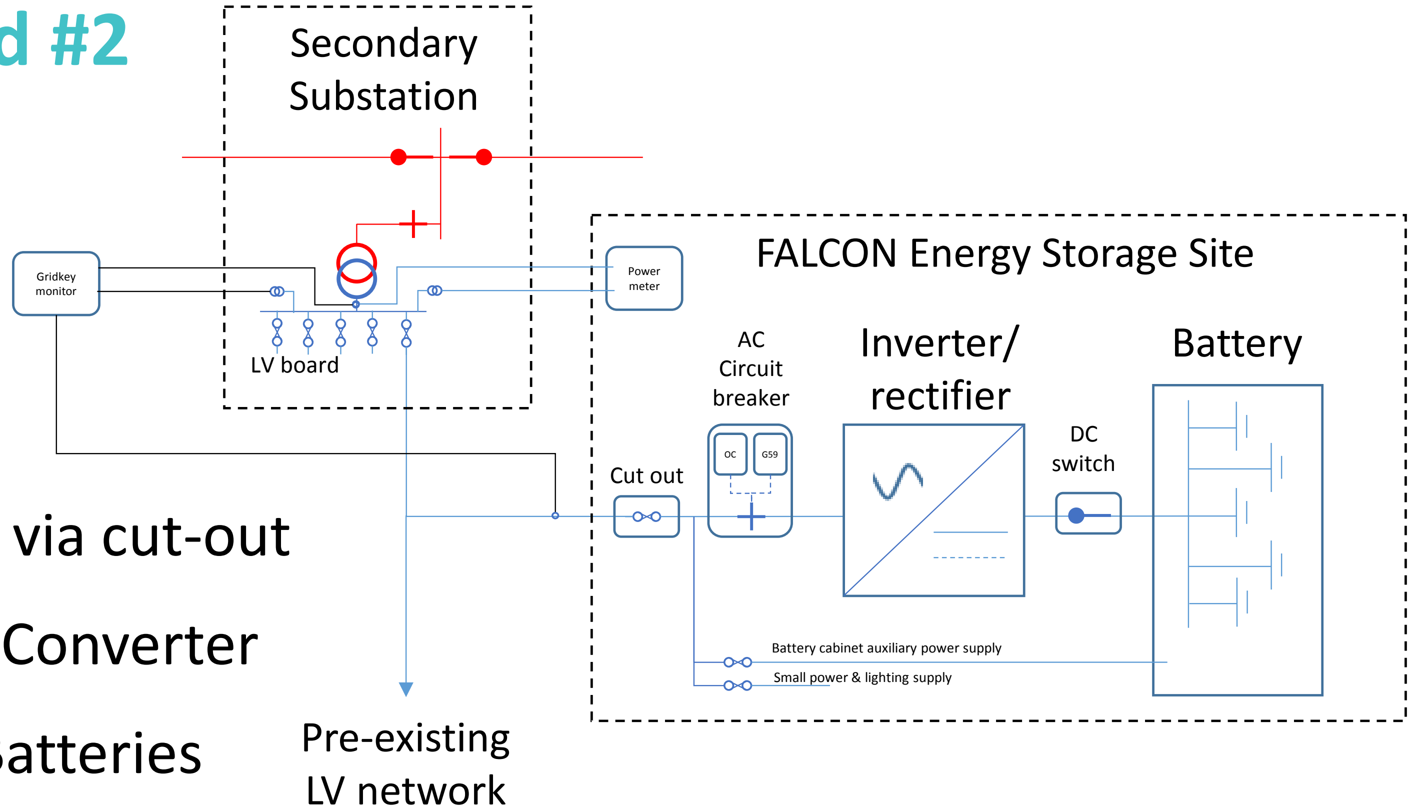
Energy Storage

ES – installed #1

- 50kW/100kWh energy storage packages (Sodium Nickel)
- Installed at 5 sites on the same 11kV feeder



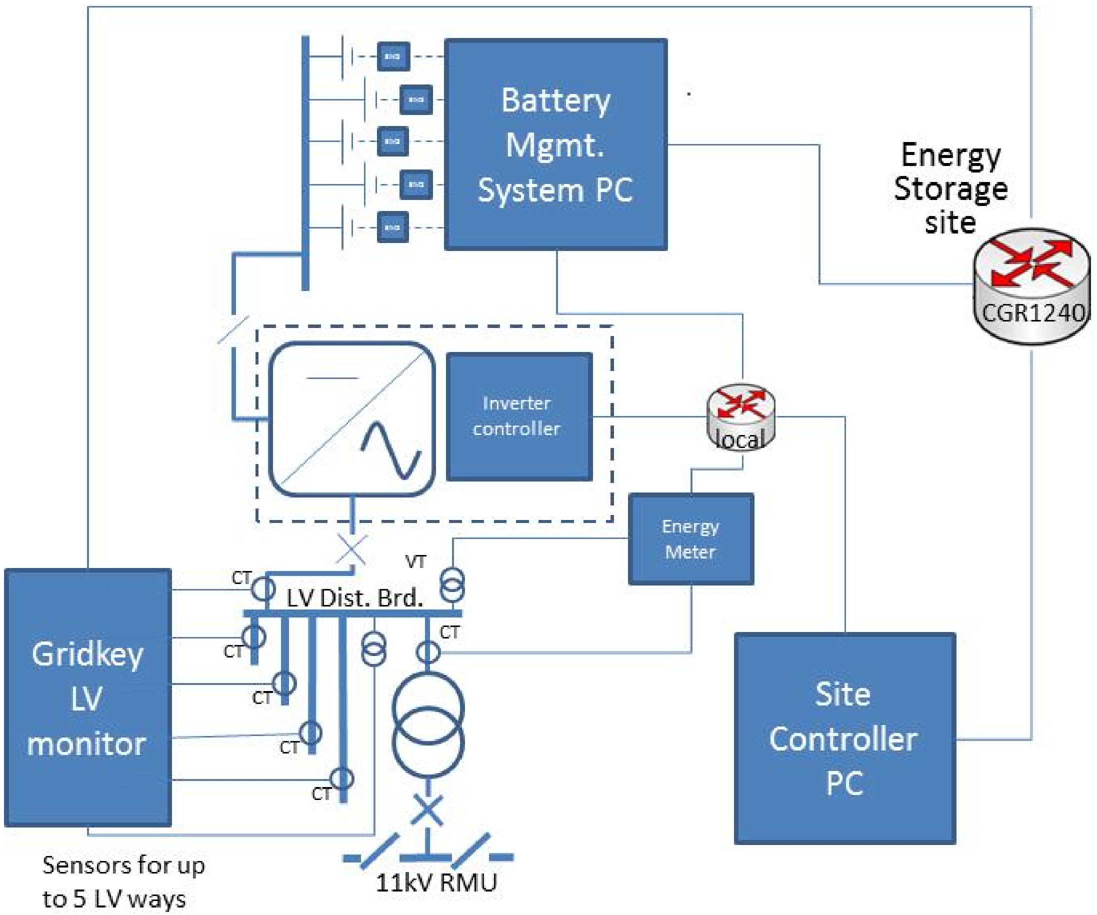
ES – installed #2



- LV Connected via cut-out
- AC breaker & Converter
- DC switch & Batteries
- Separate components

ES – installed #3

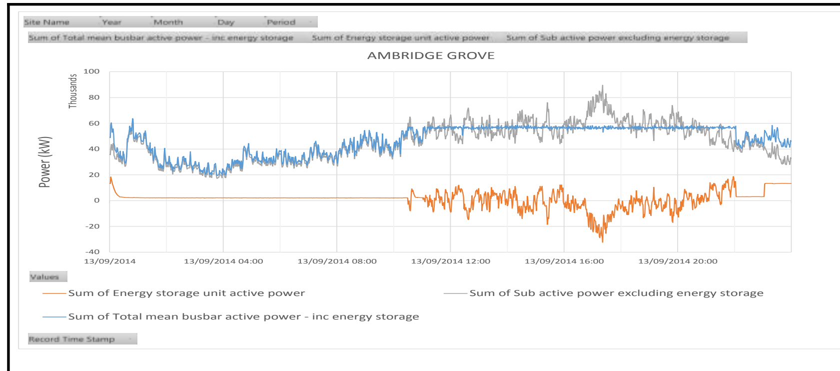
- Battery Management
  - Individual module
  - Management of 5 modules
- Inverter controller
- Site Controller
- Gridkey LV monitoring

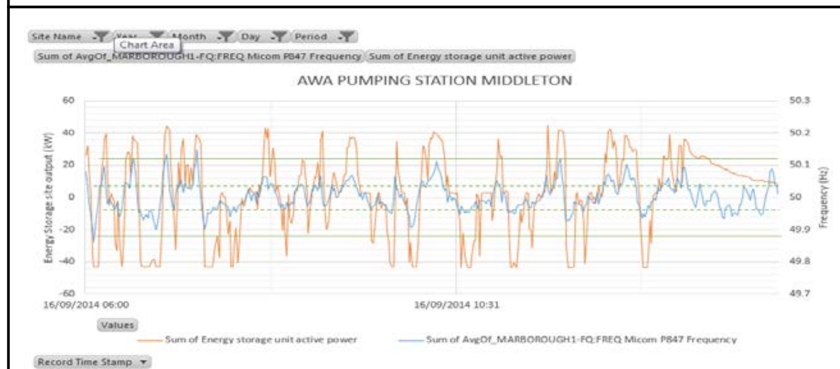


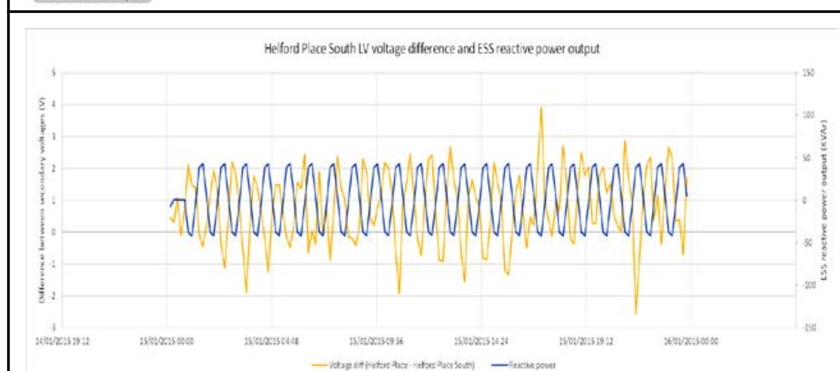
ES – installed #4

ES – Key Learning

- Reliable peak-shaving achieved
  - at individual sites
  - 11kV feeder load;
- Frequency response was achieved (for both above and below 50Hz);
- Operating limits of 50kVAr had limited impact on LV voltage;
- ES was found to increase losses in aggregate (considering both feeder I^2R losses, and ES system losses);
- PQ was improved at one site (highly circumstantial), though unchanged at the other more representative monitored site;







Conclusions – FALCON: ES

- Basic functionality proven
- Historic costs don’t justify DNO-only implementation for relief of distribution network thermal constraints
- Recommend technology tracking, particularly potential for connected customer applications

Summary

- Trials were successfully implemented for all four techniques
- Data was initially gathered in November 2013, and extended through until June 2015
- Valuable learning was identified and accrued from the design and installation phase through to final analysis and reporting
- Recommendations have been established associated with each of the techniques.

Q&A

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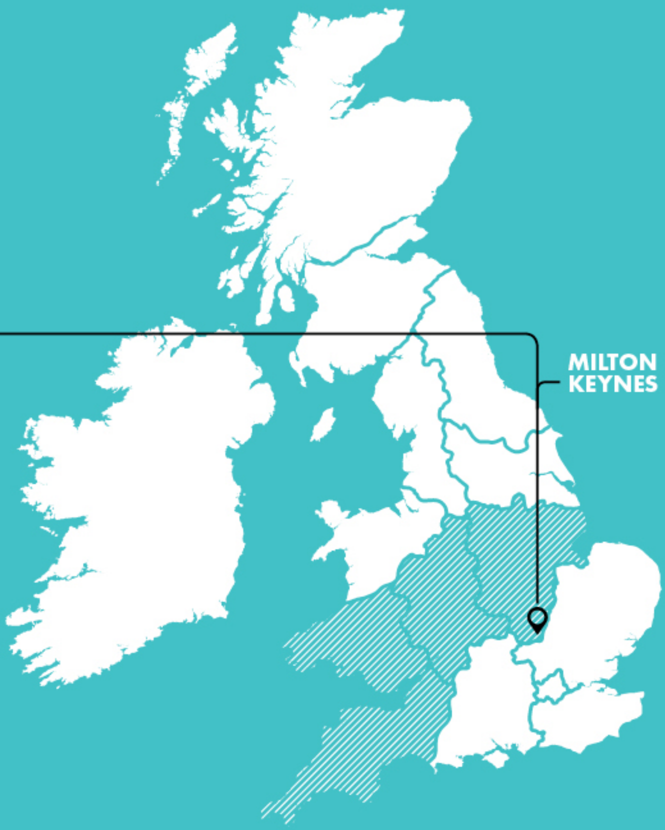
Commercial Trials

Gary Swandells

Smart Grid Consultancy



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Overview of the Commercial Trials

Commercial techniques 5 and 6 are commonly known as DSR

DSR is not ToU tariff seeking permanent and predictable reduction

T5 – Demand Reduction

T6 – Distributed Generation

Responding to an explicit instruction with the expectation of receiving a performance related incentive.

The Challenges

- DNOs are primarily engineering organisations.
- Conventional solutions are normally based on capital works
- Using official arrangements with customers
  - Customer Engagement
  - 3rd Party Aggregators

Preparation for the trials

- New resources and processes to engage with customers.
- Interact with customers directly and / or via aggregators
- Author and approve new ‘performance based’ contracts
- Financial approval of viable business proposition
- Control room dispatch arrangements
- Performance assessment software
- Back office systems for settlement processes
- Identify & detail market conflicts and propose any potential solutions

Preparation for the trials

- ✓ New resources and processes to engage with customers.
- ✓ Interact with customers directly and / or via aggregators
- ✓ Author and approve new ‘performance based’ contracts
- ✓ Financial approval of viable business proposition
- ✓ Control room dispatch arrangements
- ✓ Performance assessment software
- ✓ Back office systems for settlement processes
- ✓ Identify & detail market conflicts and propose any potential solutions

Headline Objectives for Energy Partnering

- Operate over two winters (November 1st to 28th February)
- Recruit up to 10MW via direct and 3rd party
- Load reduction and Generation
  - T6 - Various sizes and fuel types of generator
- Establish interaction with NG Balancing Services
- Establish Interaction with Triad / TNUoS
- Determine reliability
- Determine network impact

Season 1

Commercial trials Nov 2013 to Feb 2014

- Target Capacity 10MW achieved
- Majority of DSR offered from assorted generation types
- Direct and aggregated
- Week ahead declarations of availability
- Up to 20 events expected
  - 30 mins notice
  - Event duration 1 – 2 hours
- Data collection day + 1

Season 1

Commercial trials engagement

- Achieved Target Capacity 10MW
- Only distributed generation
- T5 prospects but no contracts
- Direct and aggregated participants

- Up to 20 events expected

Season 1

Commercial trials results

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

Season 1 Results

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	na	na	na	na	na	na	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

- 181 potential availability windows
- 61 declaration unavailable (66.3% reliability factor)
- Delivery failures reduced event reliability to 76.1%
- **Overall reliability 50.5%**

Season 1 Learning

- Contractual conflict with National Grid balancing services
- Data integrity issues with 3^{rd} party metering
- Delays in performance analysis and billing
- Reliability concerns
- Recruitment of T5 participants was challenging

Season 1 Learning

- Contractual conflict with National Grid balancing services
  - Shared Services Group
- Data integrity issues with 3rd party metering
  - Specific Smart Meter installation to suit new capped consumption measurement
- Delays in performance analysis and billing
  - Improved billing system
- Reliability concerns
  - Week ahead notifications
- Recruitment of T5 participants was challenging
  - Doubled the incentive £300 to £600 per MWh

Shared Services Group

- Including National Grid, DNOs and ENA
- Establish needs based use cases
- Contracts conflict but use cases don't
- Objective to eliminate arrangements that require SO and DNO to compete for exclusive access rather than asset sharing.
- Consultation with industry
- Proposals to trial

Season 2

Commercial trials Nov 2014 to Feb 2015

- Generating participants retained from Season 1
- Direct partnering acquired T5 participation
- Week ahead forecasting and notice of events
- Up to 20 events expected
  - 30 mins notice
  - Event duration 1 – 2 hours
- Data collection day + 1
- Network monitoring at 11kV and 33kV

Season 2

Site	03/11/2014	10/11/2014	17/11/2014	24/11/2014	01/12/2014	08/12/2014	15/12/2014	22/12/2014	29/12/2014	05/01/2015	12/01/2015	19/01/2015	26/01/2015	02/02/2015	09/02/2015	16/02/2015	23/02/2015
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	no events	no events	no events	no events	y	y	y	no events	no events	y	y	y	y	y	y	no events	no events
2	no events	no events	no events	no events	y	y	y	no events	no events	y	y	y	y	y	y	no events	no events
3	no events	no events	no events	no events	y	y	y	no events	no events	y	y	y	y	y	y	no events	no events
4	no events	no events	no events	no events	y	y	y	no events	no events	y	y	y	y	y	y	no events	no events
5	no events	no events	no events	no events	y	y	y	no events	no events	y	y	y	y	y	y	no events	no events
6	no events	no events	no events	no events	y	y	y	no events	no events	y	y	y	y	y	y	no events	no events
7	no events	no events	no events	no events	y	y	y	no events	no events	y	y	y	y	y	y	no events	no events

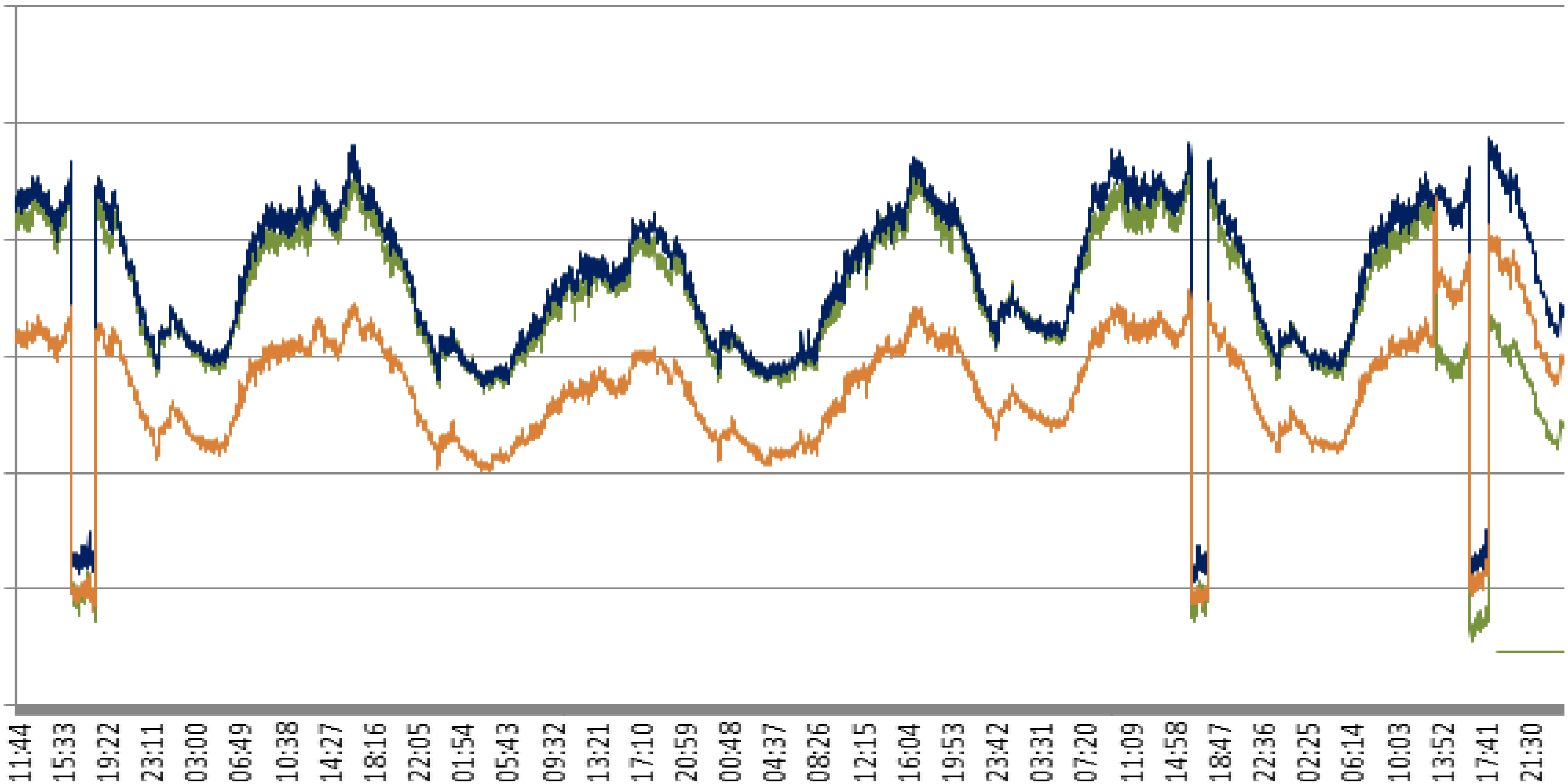
- Availability increased to 100%

Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1
4	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	27	5	4	0	60	0	0	0	0	60	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- 27 events achieved 96.3% reliability

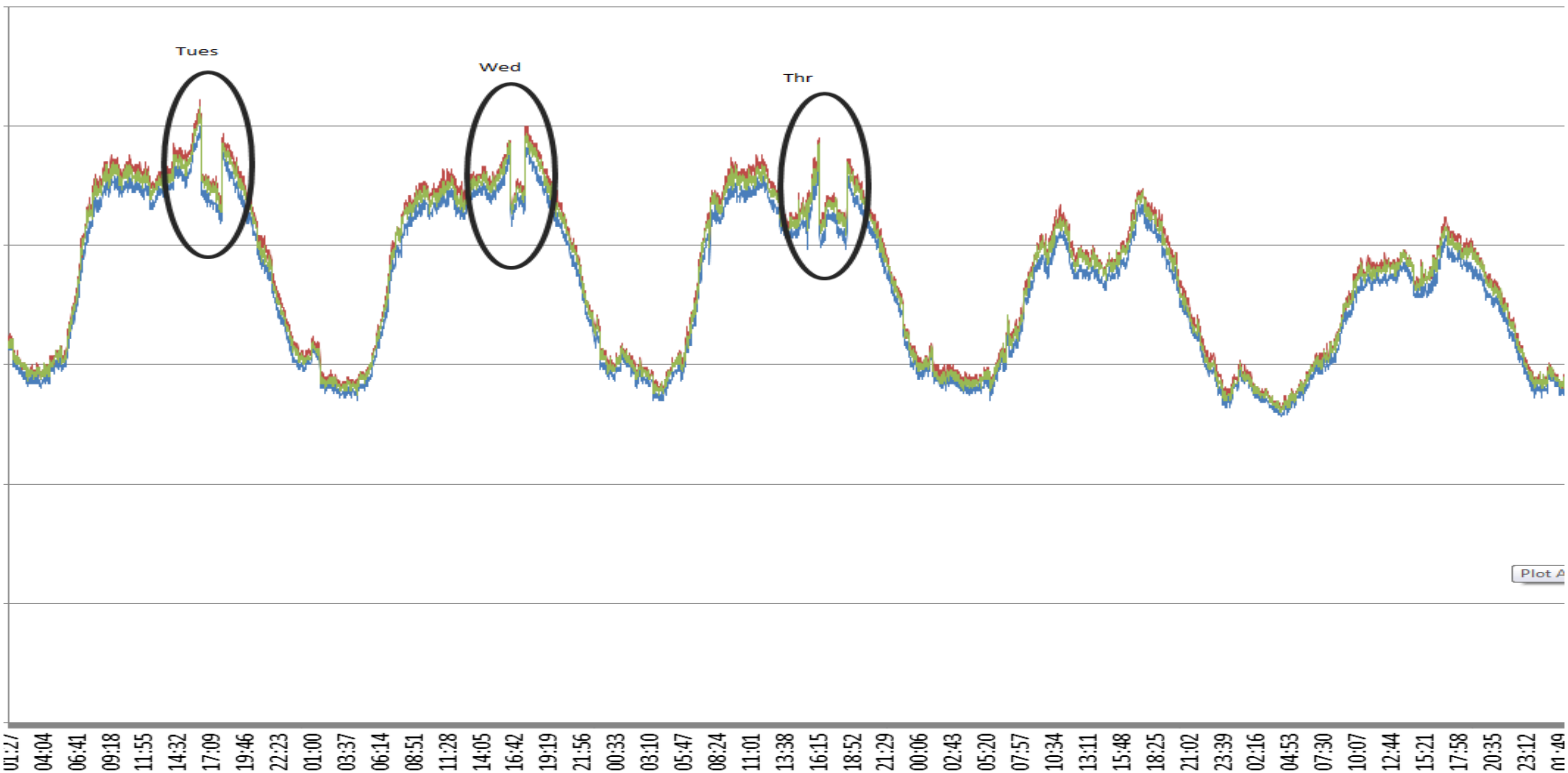
Season 2

11 kV Impact



Season 2

33 kV Impact



Summary of Learning

- Overall the trials were successful
- Further work necessary on development of industry frameworks
- Reliability and impact unsuitable at 11kV
- Further analysis required to develop 33kV and above
- Domestic DSR worthy of research for lower voltages.
- DSR currently presents greatest value for added resilience and transient issues.
- Long term or prolonged constraints better managed by capital upgrades
- DNOs can recruit and manage commercial arrangements directly.

Q&A

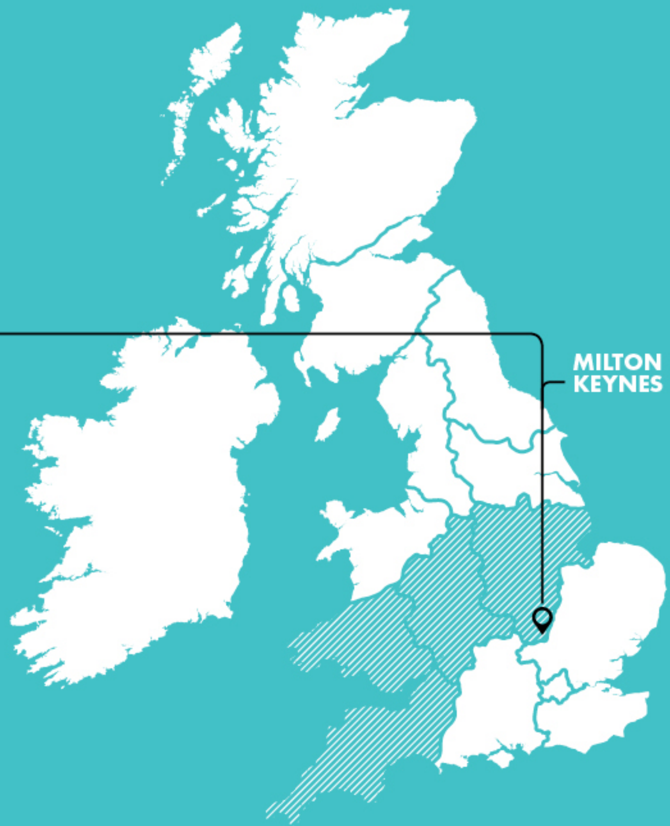
WESTERN POWER DISTRIBUTION

FALCON

DEVELOPING FUTURE POWER NETWORKS

Load Estimation and SIM

Jenny Woodruff



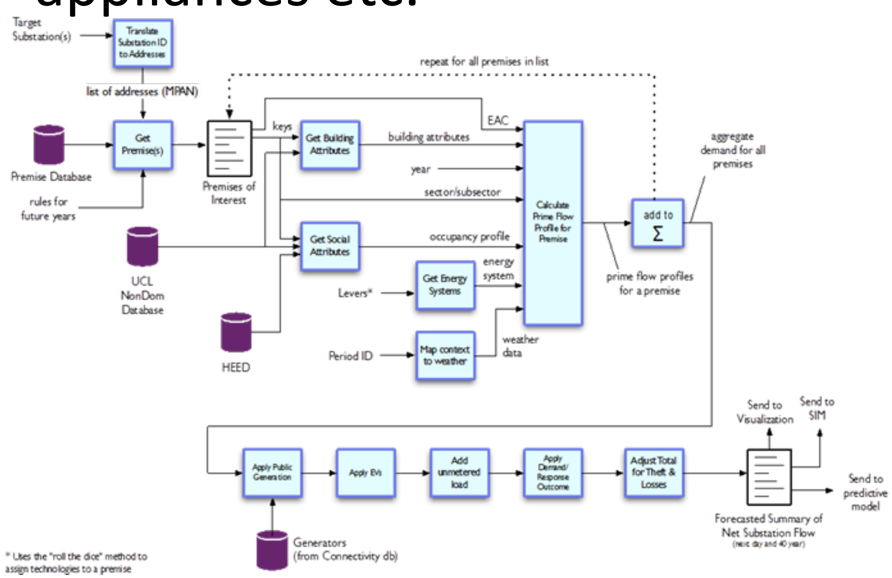
LCN Fund Low Carbon Networks | ALSTOM | Aston University | CGI | CISCO | Cranfield UNIVERSITY

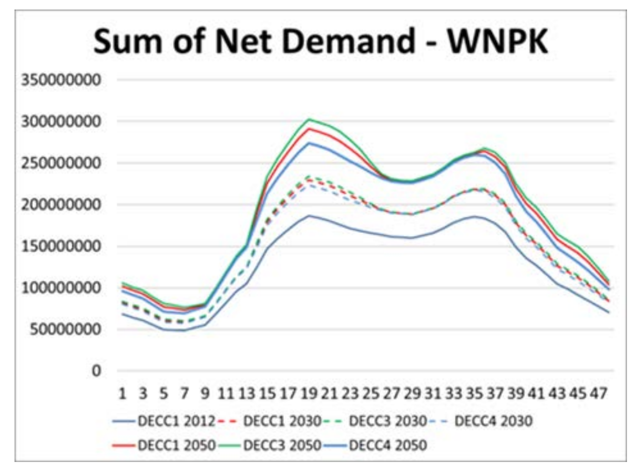
Load Estimation - Falcon Energy Model

Build up load profile by modelling building energy requirements for heating and water, profiling other end use types, lighting.

Scenarios models future adoption of heat pumps, EV, PV, efficient appliances etc.

Falcon Energy Model Overview





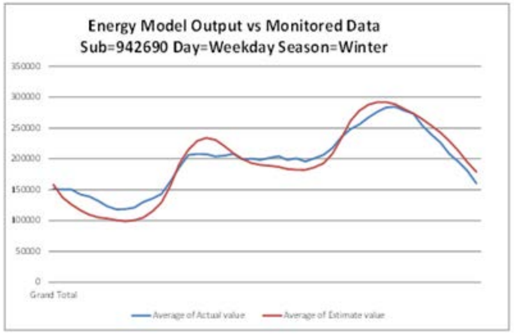
Challenges – Energy Model

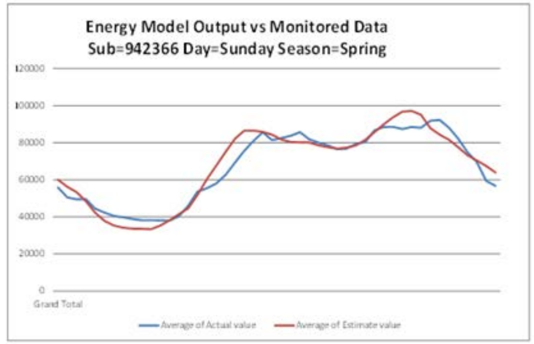
– Data intensive & time consuming to run.
  Off-line activity not providing data in real time.
  Errors in input data = errors in output.

– Matching with external data sets
  No building references, Address matching issues, Limited customer information, Data protection compliance

– Very large volumes of data coming back
  1700 substations x 48 hh x 18 daytypes x 35 years.
  X 4 scenarios with 4 sensitivity analysis versions too.

Falcon Energy Model





Can get very good results.

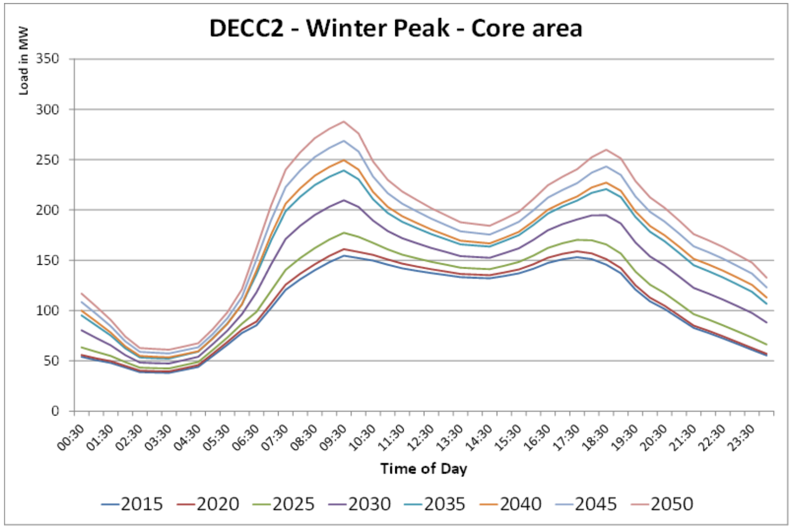
Poor results – generally where input data is wrong.

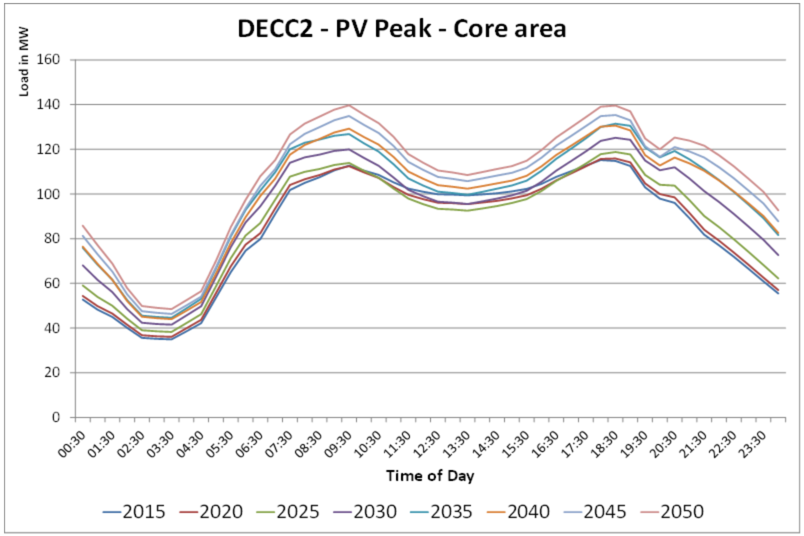
Quality metrics devised to compare estimation methods.

(LV Network Templates vs Profiles & EACs vs Energy Model)

Continual feedback / improvement required

Scenarios

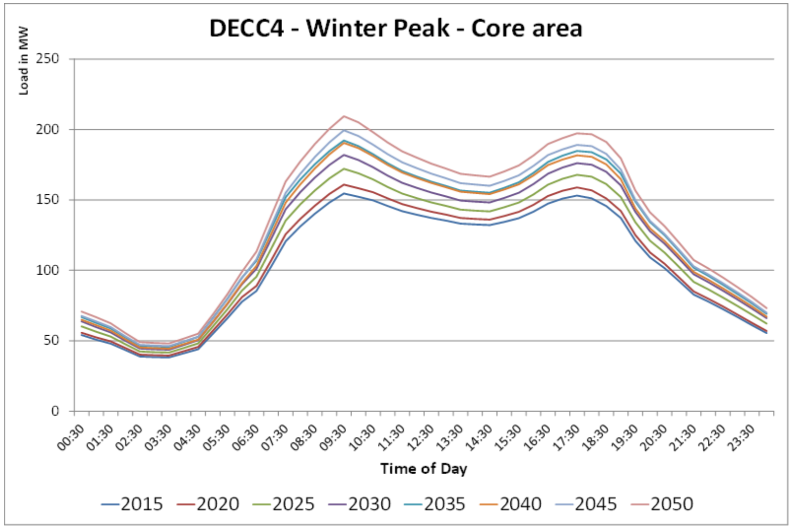




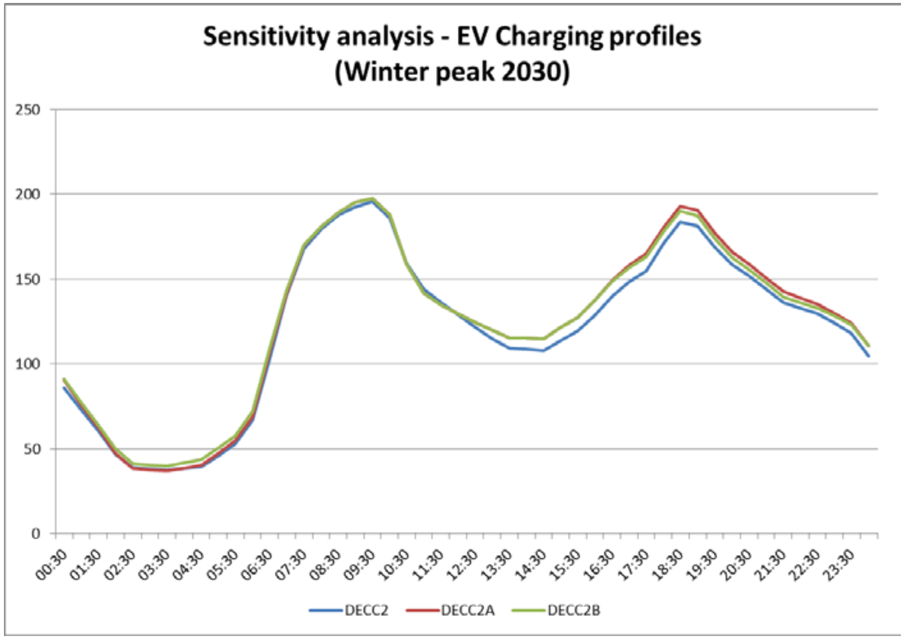
Load shape driven by EV charging assumptions.

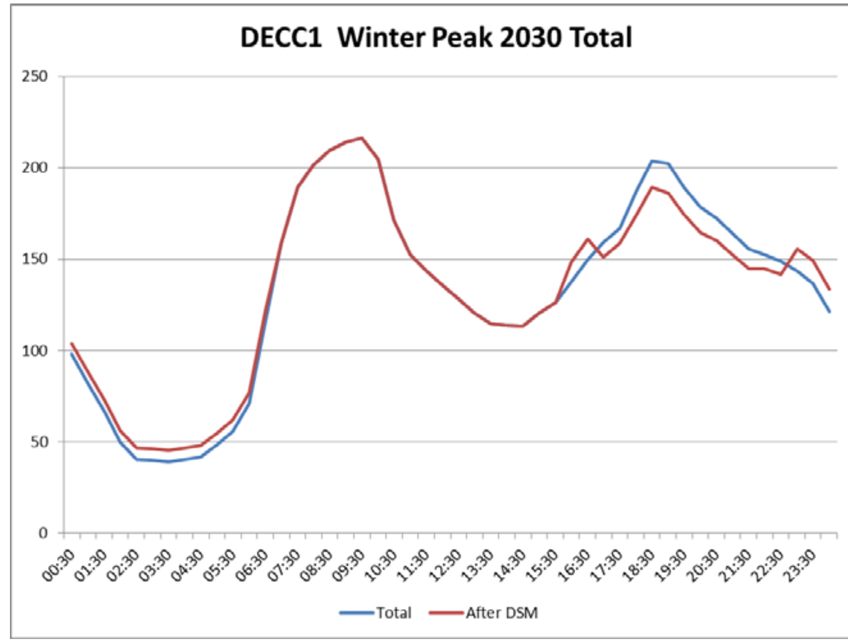
PV reducing loads at midday.

Increase in peak load up to 92% depending on scenario.



Sensitivity analysis





Versions of load profiles created to support sensitivity analysis.

- EV charging profiles
- Clustering of LCT
- Generalised demand side management

Load Estimation - Conclusions

It works

- Realistic load profiles for substations.
- Able to create different scenarios to support SIM.

Inaccuracies hard to iron out

- Smaller substations harder to model.
- Difficult to classify subs into accuracy categories.
- Input data sensitivity

Future Developments

- Formalise process for pre-processing data, system admin etc.
- Cheaper alternative for demographic data.
- Customer level output required for LV modelling
- Further Calibration of Energy Model output against SCADA data
- More balanced seasons (Winter too long)
- Potential of HH settlement for PC 5-8
- Opening hours to inform occupancy profiles
- Generalised demand side management profile smoothing

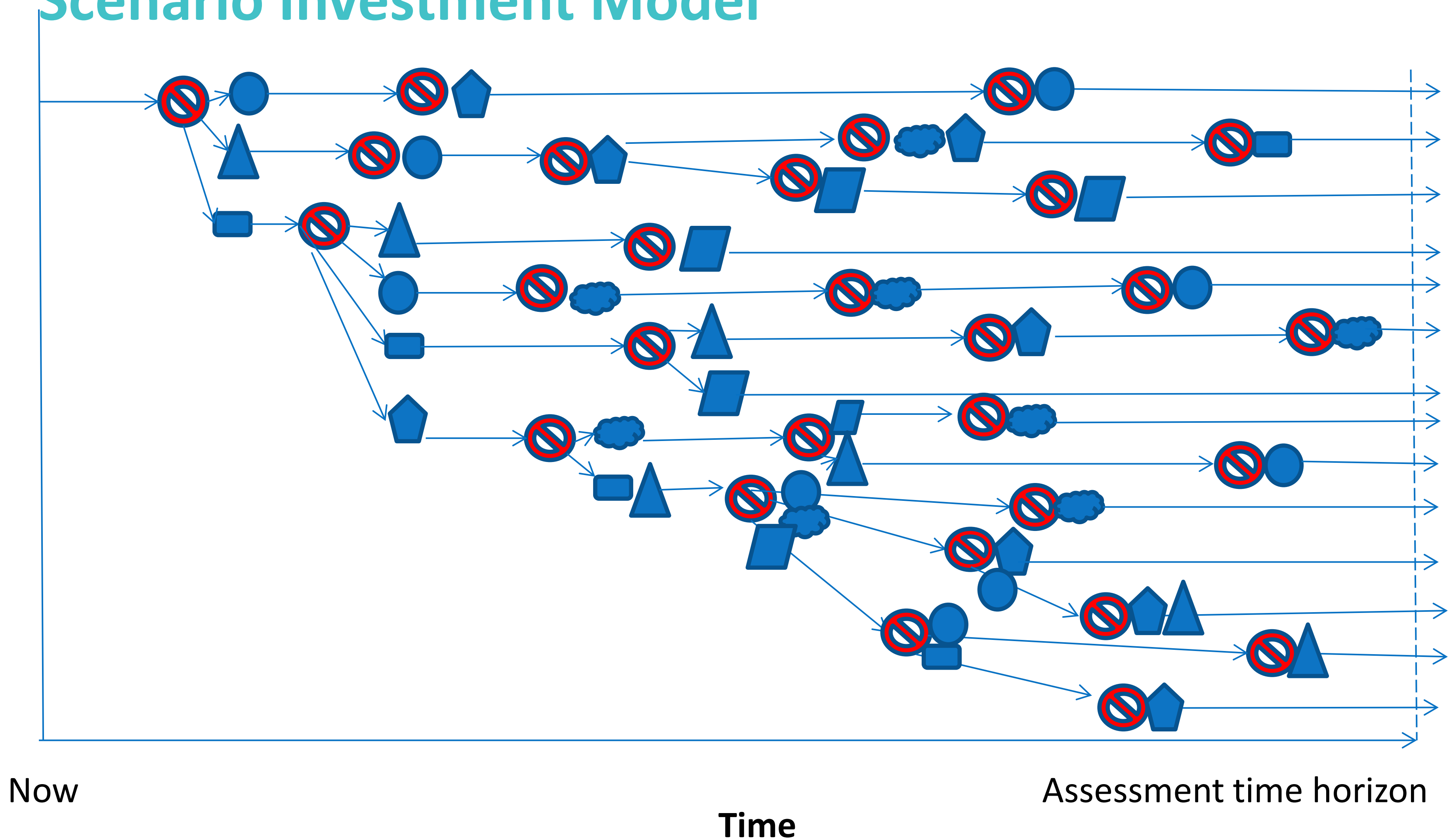
Scenario Investment Model - SIM

What is it?

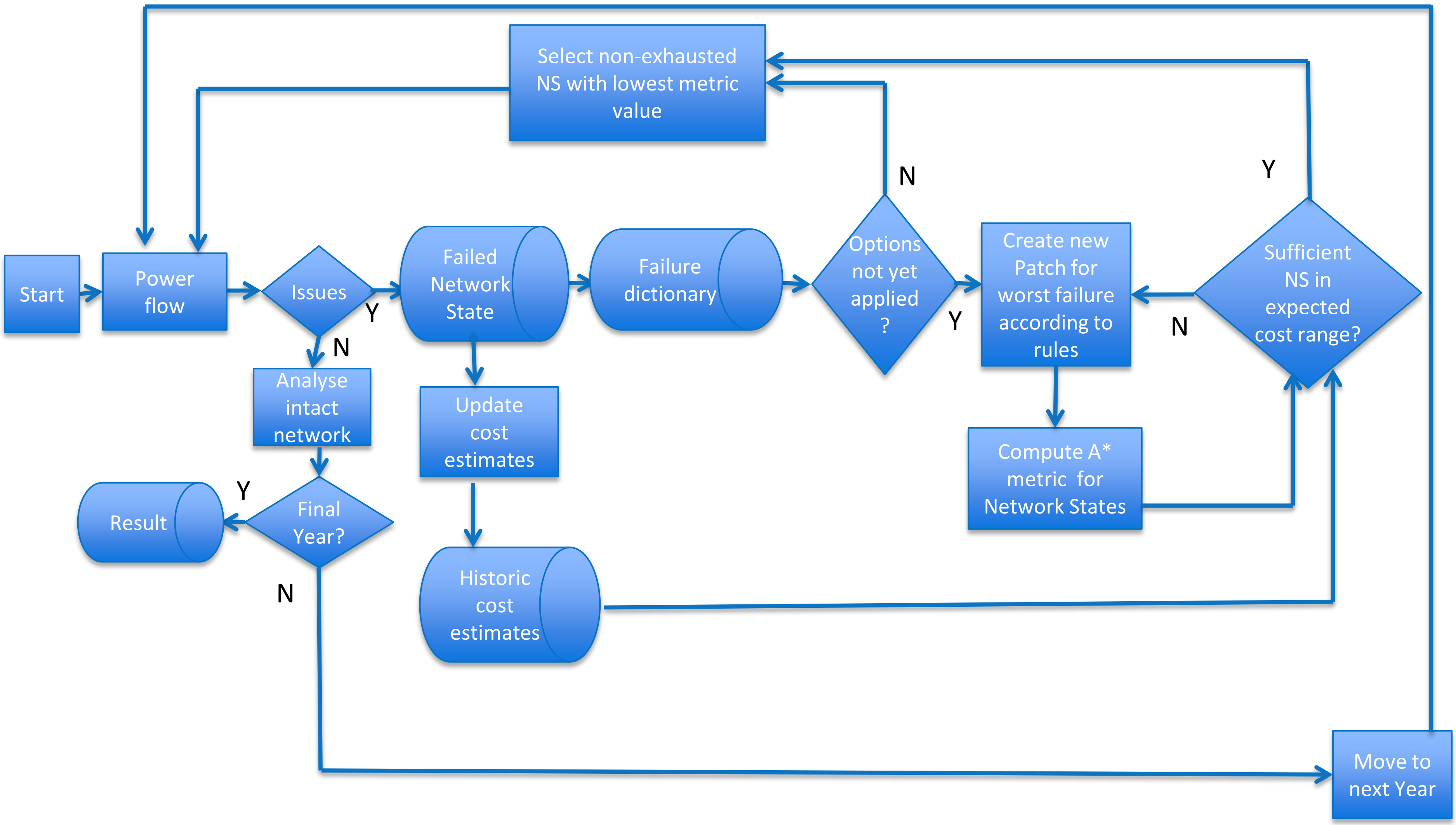
- Long term simulation / planning tool
- Uses power flow analysis of nodal network model
- Algorithmic generation of technique patches to resolve issues
- Guided search algorithm for optimisation – weighted for cost, CML, CI , losses, customer impact

Users – strategic, planner, policy

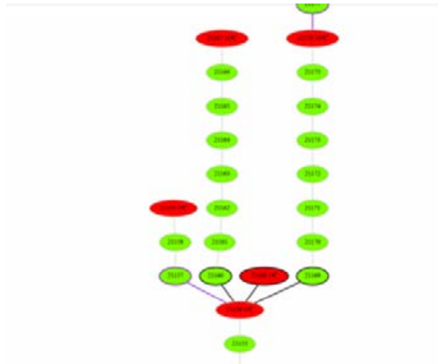
Scenario Investment Model

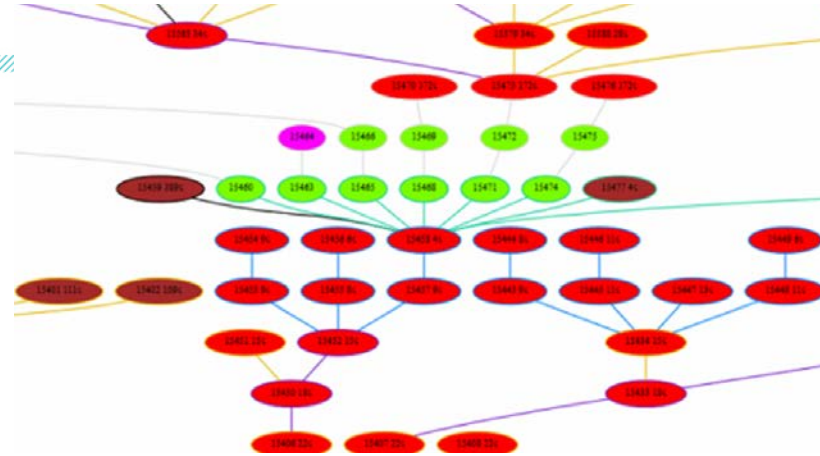


Scenario Investment Model

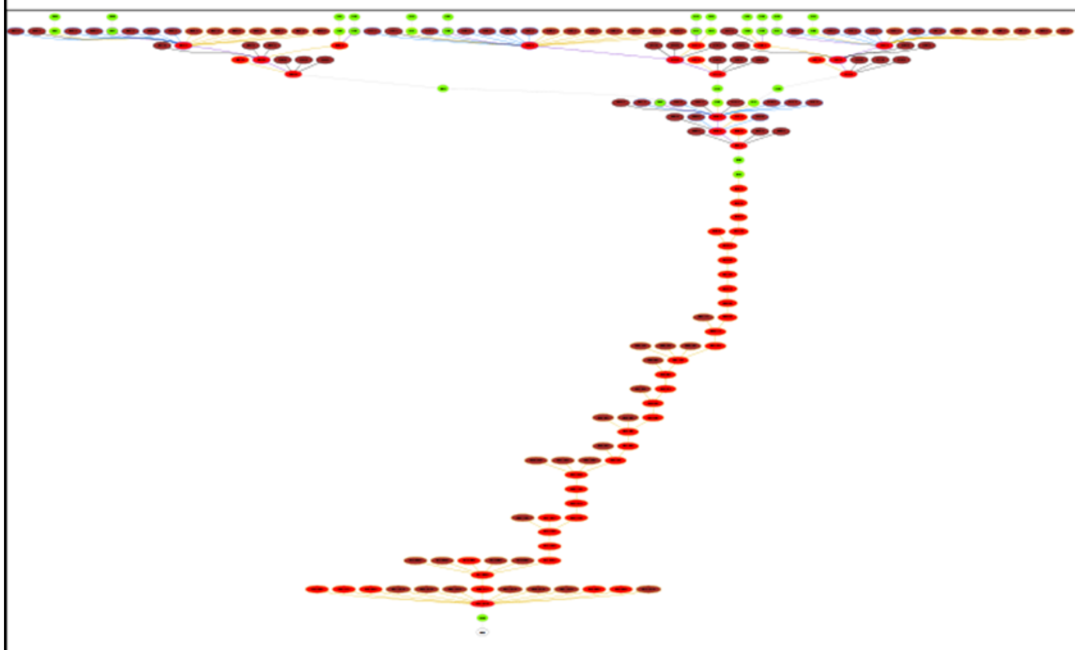


Visualisation

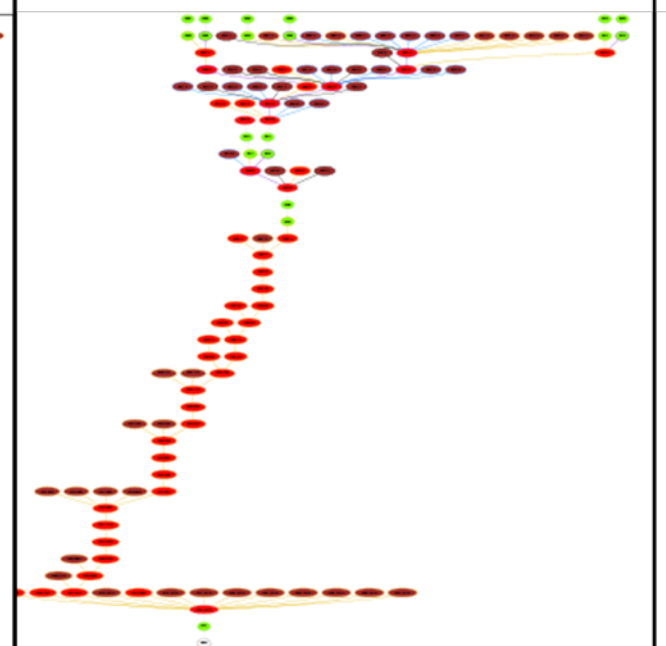




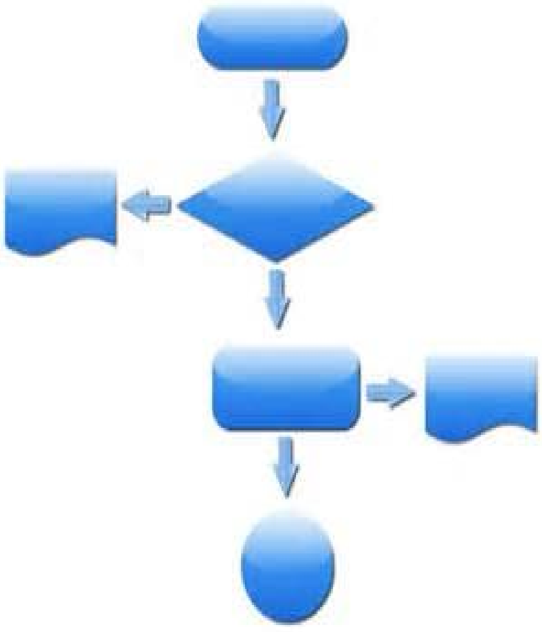
BletchleyDECC1 All Techniques



BletchleyDECC2 All Techniques



New Development



Authorised Network Model

IPSA extended

- CML/CI calculation
- multiple day types / half hourly data
- New technique plug-ins
- Increased limits -number of nodes, memory

Large volumes of data exchanged - file based.

Interface work is far harder than we thought

System upgrades – rework vs support

Cost model data sourcing is tricky.

Complex – but possible

SIM Run Findings

Remedial work required in 2015 for most substations.

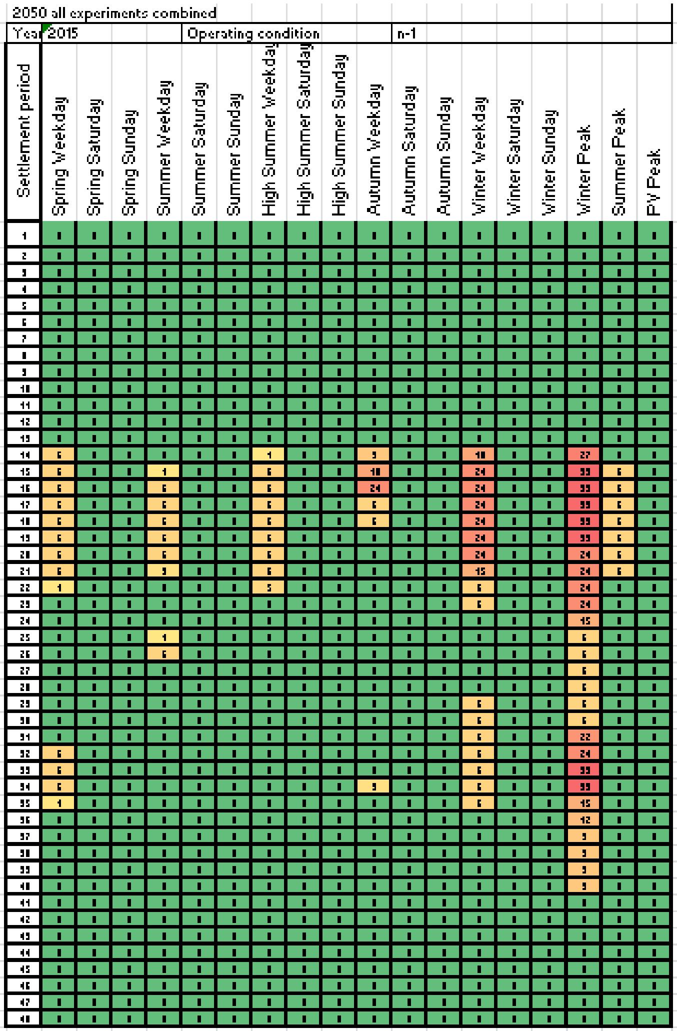
- Some over estimation of load
- Low thresholds for overloads

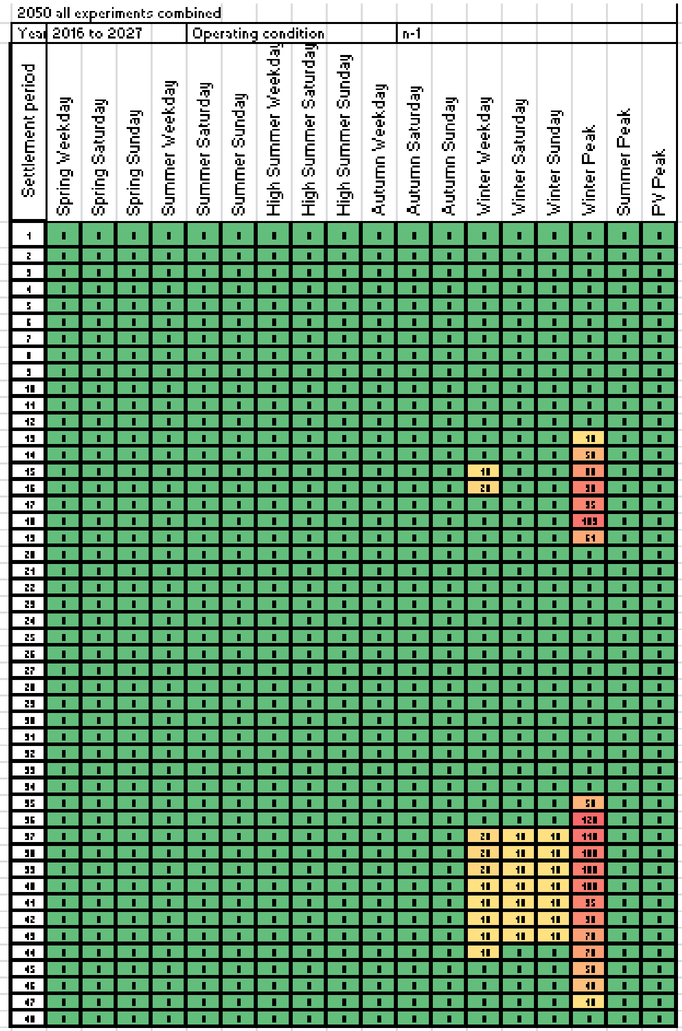
Large variance between substations

- Secklow Gate - little work required under any scenario
- Newport Pagnell – little spare capacity

Average Run took 1 ½ days
Typically 600-700 Network states before Results
Typically stop at 40 results for analysis.

When do issues occur?





Initially a wider spread of days when issues occur – Winter Peak and Winter Weekday are most likely time for issues, some summer peak and other weekdays.

Could reduce the number of days modelled. Weekends

When do issues occur?

Winter peak continues to be the most onerous day type, some issues on winter weekday

2050 all experiments combined

Year 2028 to 2039 | Operating condition | n-1

Settlement period	Spring Weekday	Spring Saturday	Spring Sunday	Summer Weekday	Summer Saturday	Summer Sunday	High Summer Weekday	High Summer Saturday	High Summer Sunday	Autumn Weekday	Autumn Saturday	Autumn Sunday	Winter Weekday	Winter Saturday	Winter Sunday	Winter Peak	Summer Peak	PV Peak
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	35	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
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48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2050 all experiments combined

Year 2040 to 2050 | Operating condition | n-1

Settlement period	Spring Weekday	Spring Saturday	Spring Sunday	Summer Weekday	Summer Saturday	Summer Sunday	High Summer Weekday	High Summer Saturday	High Summer Sunday	Autumn Weekday	Autumn Saturday	Autumn Sunday	Winter Weekday	Winter Saturday	Winter Sunday	Winter Peak	Summer Peak	PV Peak
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

What type of issues occur?

Thermal issues – the vast majority.

- Low threshold chosen to see DAR impact.
- Found overloaded busbars - amended cable replacement algorithm for switchgear upgrade

Some Low Voltage issues seen after 2040

No high Voltage issues seen

- No new large generation modelled
- Short term planning vs strategic planning

No fault level issues seen

Some issues in intact network but mostly n-1

What solutions are implemented?

Traditional reinforcement & DAR - vast majority

Some use of meshed networks

Battery use relatively infrequent – a handful of successful applications

DSM use very infrequent

DG use not seen at all

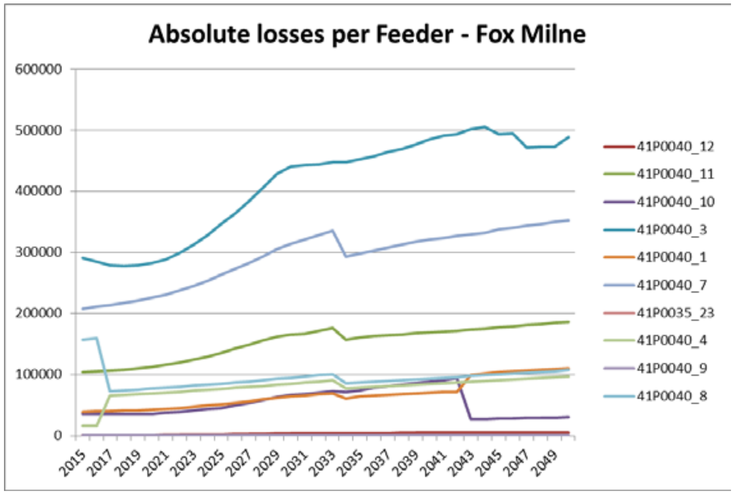
(low levels of availability)

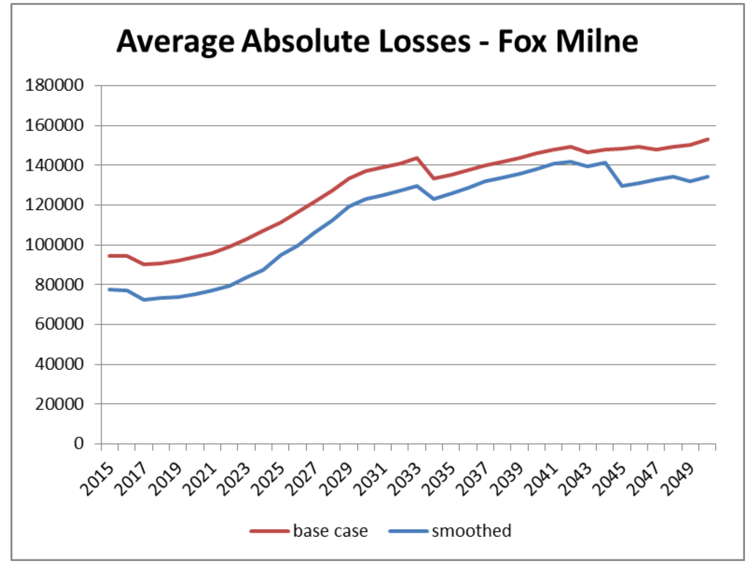
ALT not seen at all.

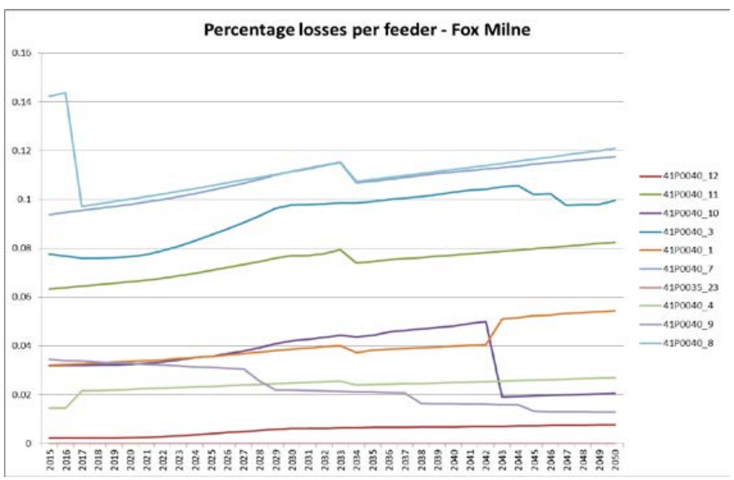
(greater flexibility still seen as useful)

2050 all experiments combined			
		Proportion of	
Technique Name	Number	Installation	Capex
DAR(Cable)	11	22%	5%
DAR (Transformer)	12	35%	11%
ALT	21	0%	0%
Mesh	31	4%	3%
Batteries	41	0%	0%
DSM	51	0%	0%
DG	61	0%	0%
Transformer replacement	71	16%	19%
Cable / line upgrade	72	21%	61%
Transfer load to adjacent feeder	73	1%	1%
New feeder	74	0%	1%

Losses







Losses increasing in absolute and percentage terms. Reflects increasing loads

Step changes as a result of network interventions.

Smoothing load profile reduces losses.

Sensitivity Analysis

Clustering

- Experiments unable to complete with given rule set – exhausted options.

Cost Reductions

- Batteries - Still rarely chosen at reduced cost
- Demand side management - no change

Charging profiles

- Modified assumptions to reflect LCL findings
- More evening charging
- Switch from DAR to traditional reinforcement

Conclusions

Traditional reinforcement will continue to form the vast majority of investment.

Smart techniques provide some flexibility but largely defer rather than avoiding traditional reinforcement.

Smart technique suitability depends on situation - nodal modelling required rather than rule of thumb approach.

Clustering implications suggest we need to track LCT installations

Model one primary at a time.

Future Development

- Explore performance improvement options
- Extend Integrated Network Model to other areas and voltages.
- Extend SIM to other voltages
- Compare other network modelling tools (Digsilent, Sincal)
- Explore potential for automatic planning algorithms for other work – new connections, quality of supply policies etc.
- Include asset health indices - include condition as a network issue.

Q&A

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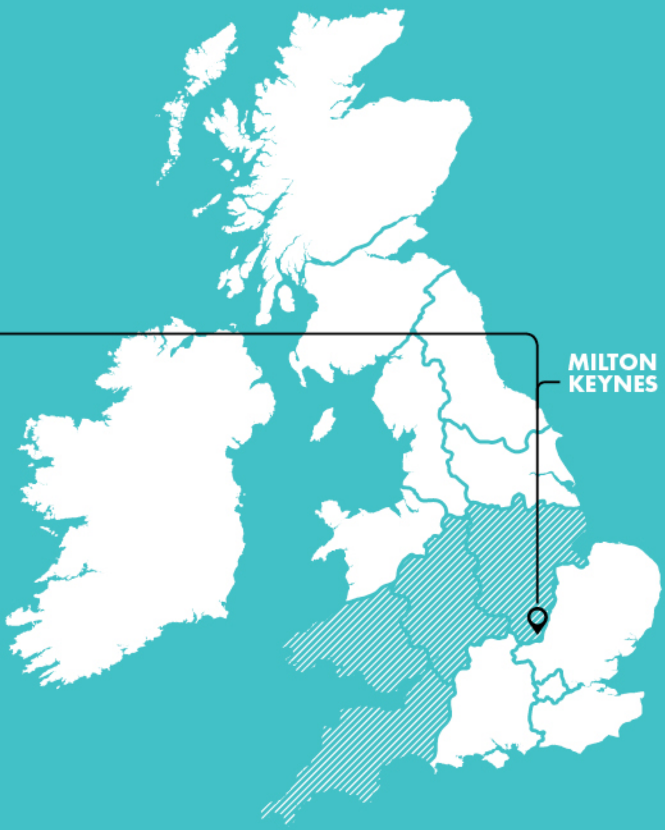


Telco's

Barrie Stephens

LCN Fund Low Carbon Networks | ALSTOM | Aston University | CGI | CISCO | Cranfield University

Telco's Workstream – Overview & Design Requirements

surftelecoms
Providing fibre, bandwidth and site facilities

- To Establish a Resilient High bandwidth Telecommunications network to fulfil the data requirements of the Project Falcon Techniques to a sample 200 Distribution Substations.
- This was to be a leading edge technology trial for the Electricity Distribution Industry, that would provide considerably more bandwidth compared to the traditional UHF spectrum usage for SCADA and Telemetry systems currently in national usage.
- The main designs for the IP network connectivity were conceived and driven by the main Falcon Project Telecoms partner Cisco, with the build undertaken by Surf Telecoms.

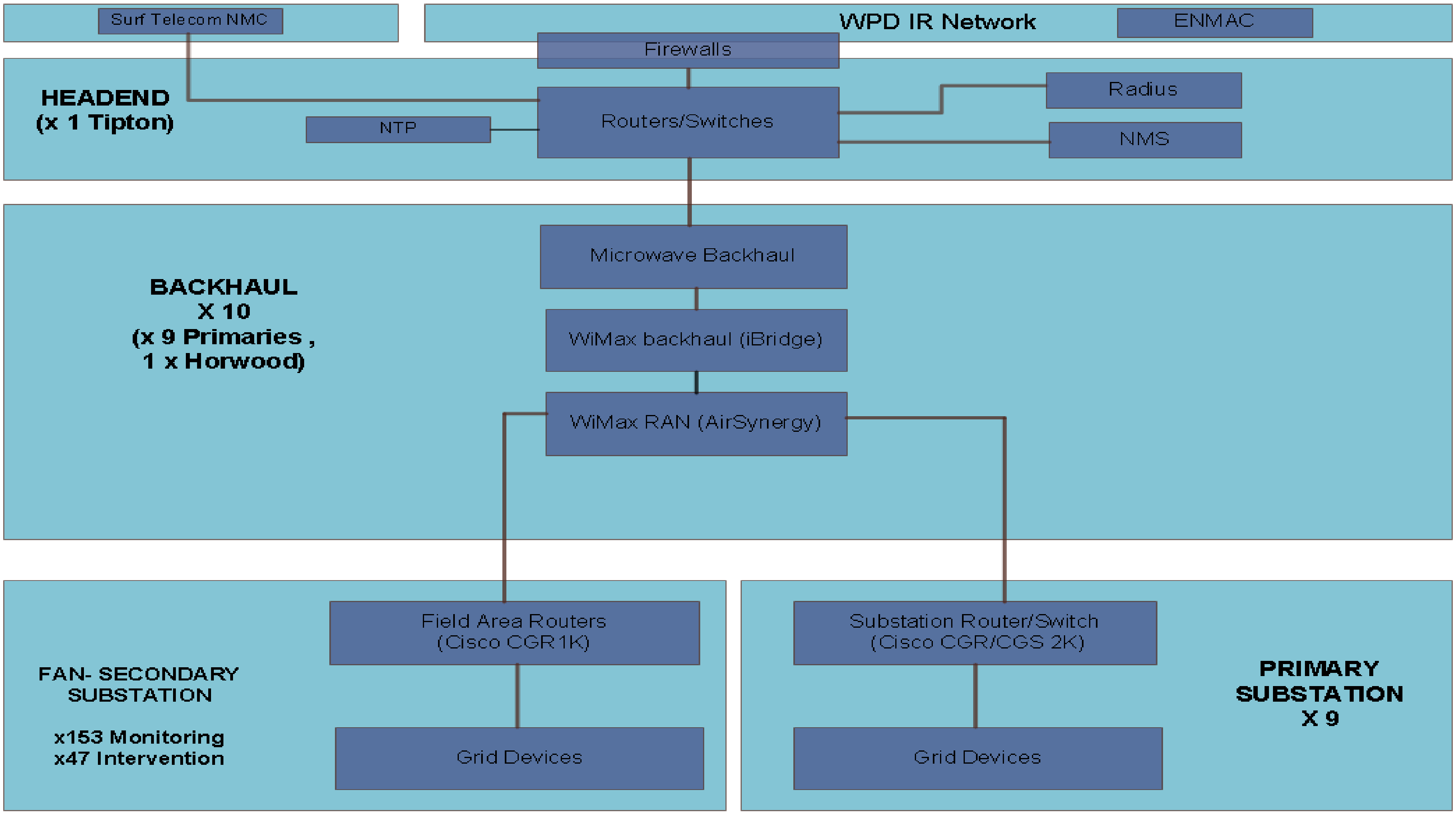
Telco's Workstream – Overview & Design Requirements

- The new network needed to be easy to roll out and designed to cover the required protocols of the trials equipment.
- Specific considerations included latency (especially for meshing requirements), bandwidth and security.
- Airspan were used as a vendor to trial WiMAX radio technology due to their previous working partnership with Cisco in the US.
- The project was designed around using only WPD's asset base and 8 Primary Substations were utilised to create radio access and backhaul cells within the FALCON trials area.
- Third party network services were only used where no other options were available.

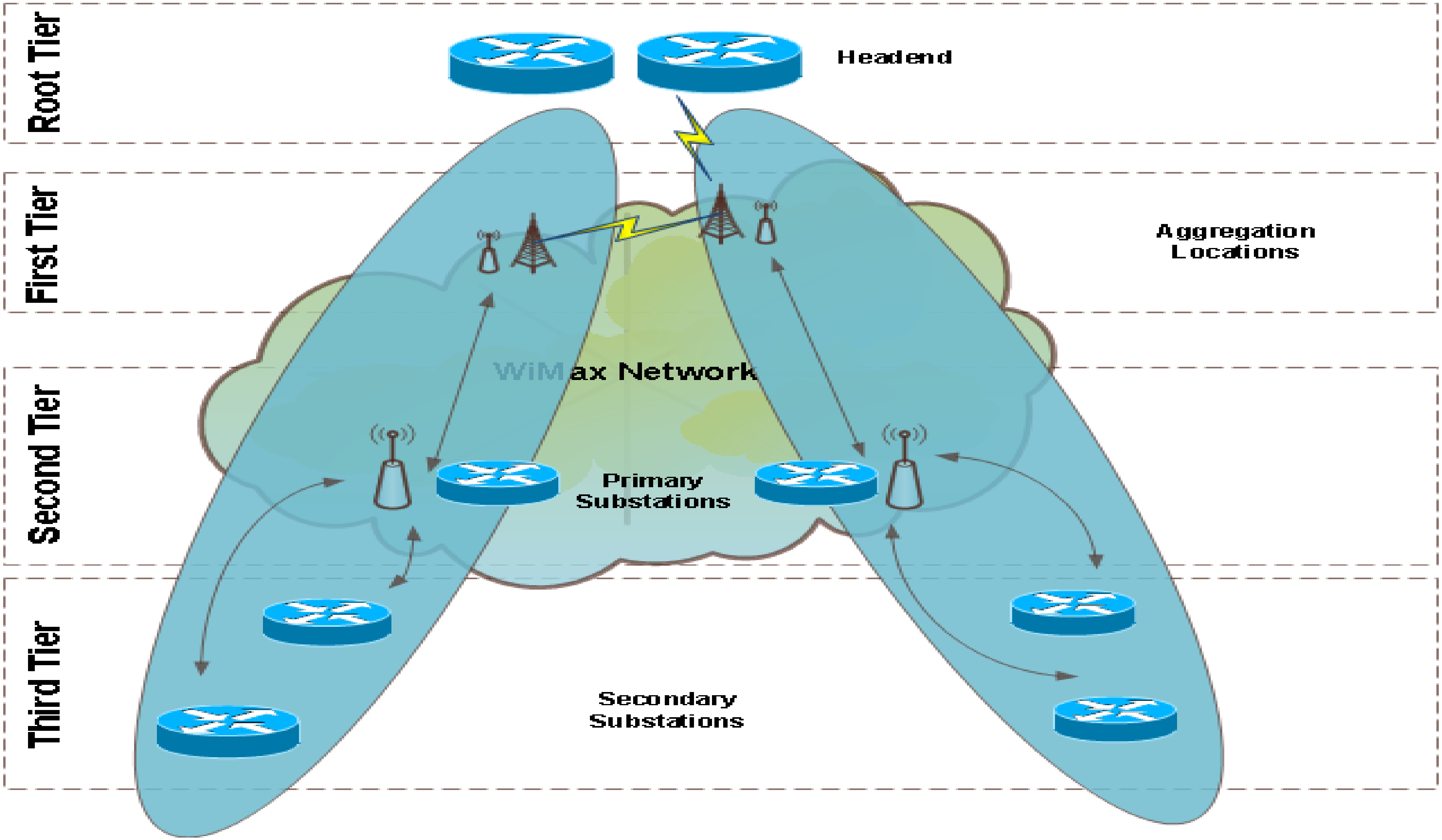
Initial Design Criteria

- Consideration was given to the network addressing requirements where a nationwide rollout would require IP version 6, however for the purposes of this project it was decided to use IP Version 4 due to the relatively small number of network devices.
- The required Frequencies are within the MOD owned spectrum. Negotiations were held in 2012 to seek permission to use the two frequency bands for the WiMAX implementation.
- Negotiations followed with Ofcom and the JRC.
- Test and development licences were then issued by Ofcom via the JRC for the three 10 Megabit Channels at both 1.4GHz Access and 3.5GHz Backhaul frequencies.

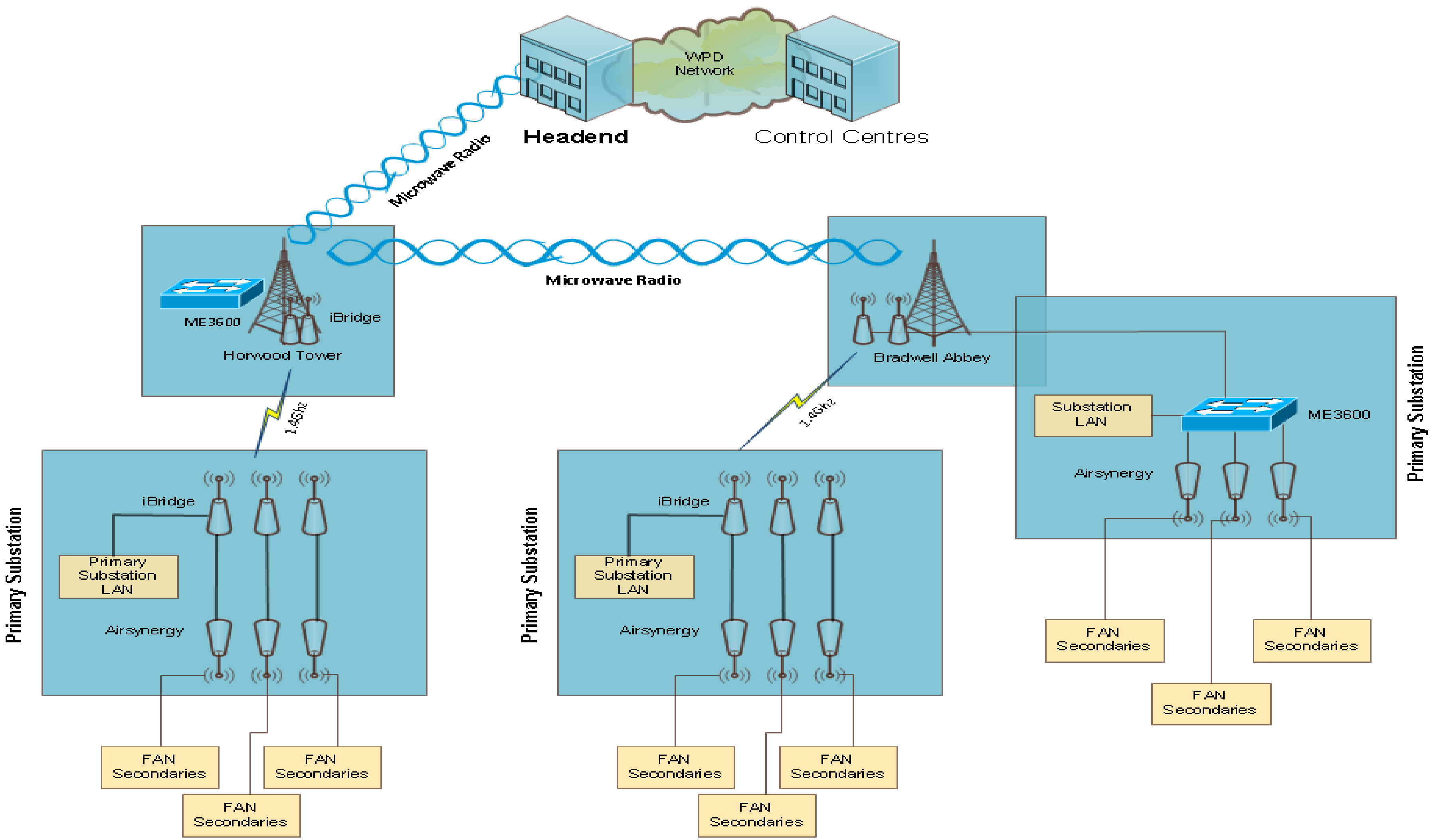
Functional Architecture



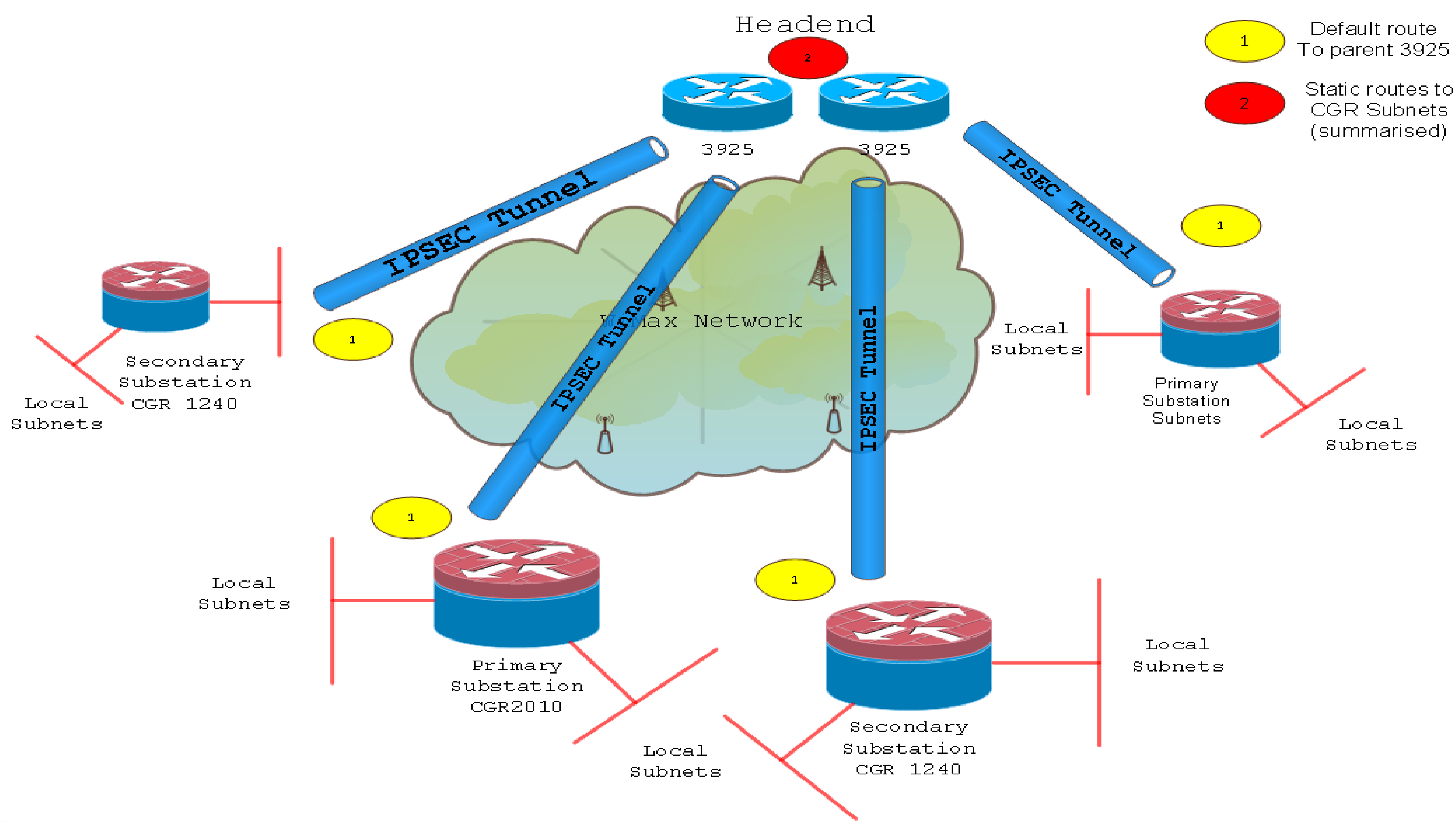
Tiered Architecture View



Solution Overview



Site to Site IPSec Tunnel Topology



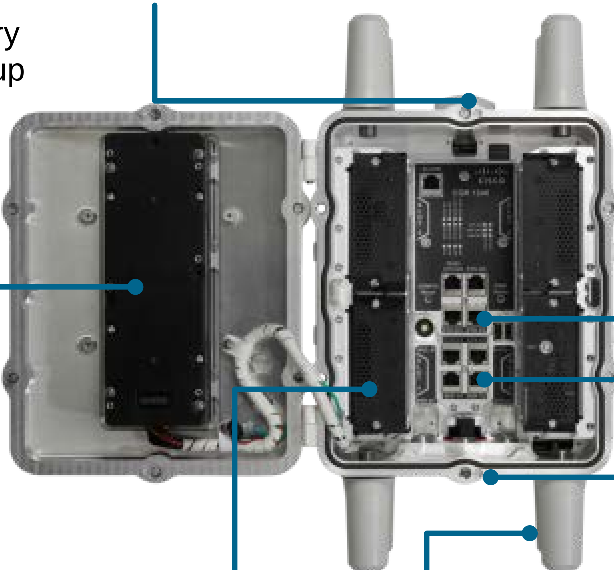
Technologies being Trialled

- Cisco CGR1240 Connected Grid Routers for Smart Grid Applications.
- Airspan WiMax Air Synergy 1.4GHz Access and iBridge 3.5KHz Backhaul.

Cisco CGR 1240 Hardware Overview

GPS Antenna

Battery Backup



Ethernet Switch 2GE WAN (Cu or SFP), 4FE LAN

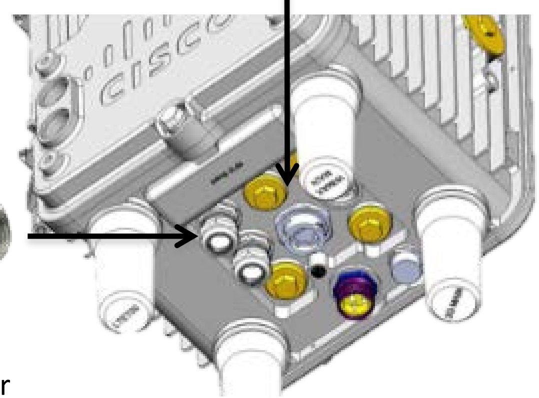
2 RS 232 / RS 485 Serial ports

AC Power Supply

4 Module Slots

Integrated Antennas for RF Mesh, WiMAX, 3G, Wifi

Ruggedized, IP67 Ethernet (RJ-45) connector



Liquid Tight (IP67) Adapter

- Dimensions: 30.48 cm (H) x 22.86 cm (W) x 21.59 cm (D) = 12” (H) x 9.0” (W) x 8.5” (D)
- Antennas shown above are optional; can be deployed with external antennas

AirSpan AirSynergy Pico Cell with iBridge Backhaul

Western Power AirSynergy Network Layout

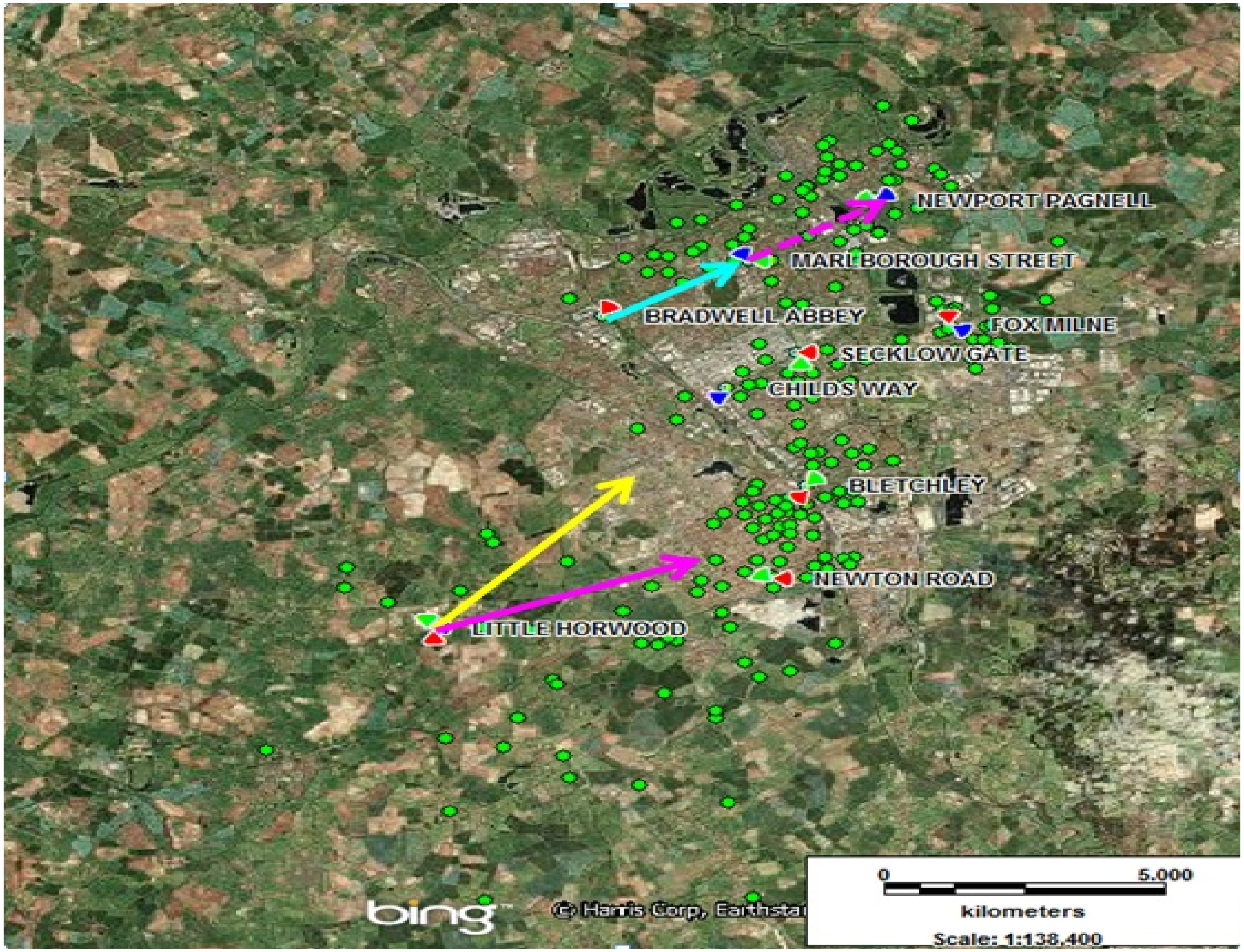
3.5GHz iBridge Channels

CHA	3525
CHB	3535
CHC	3545

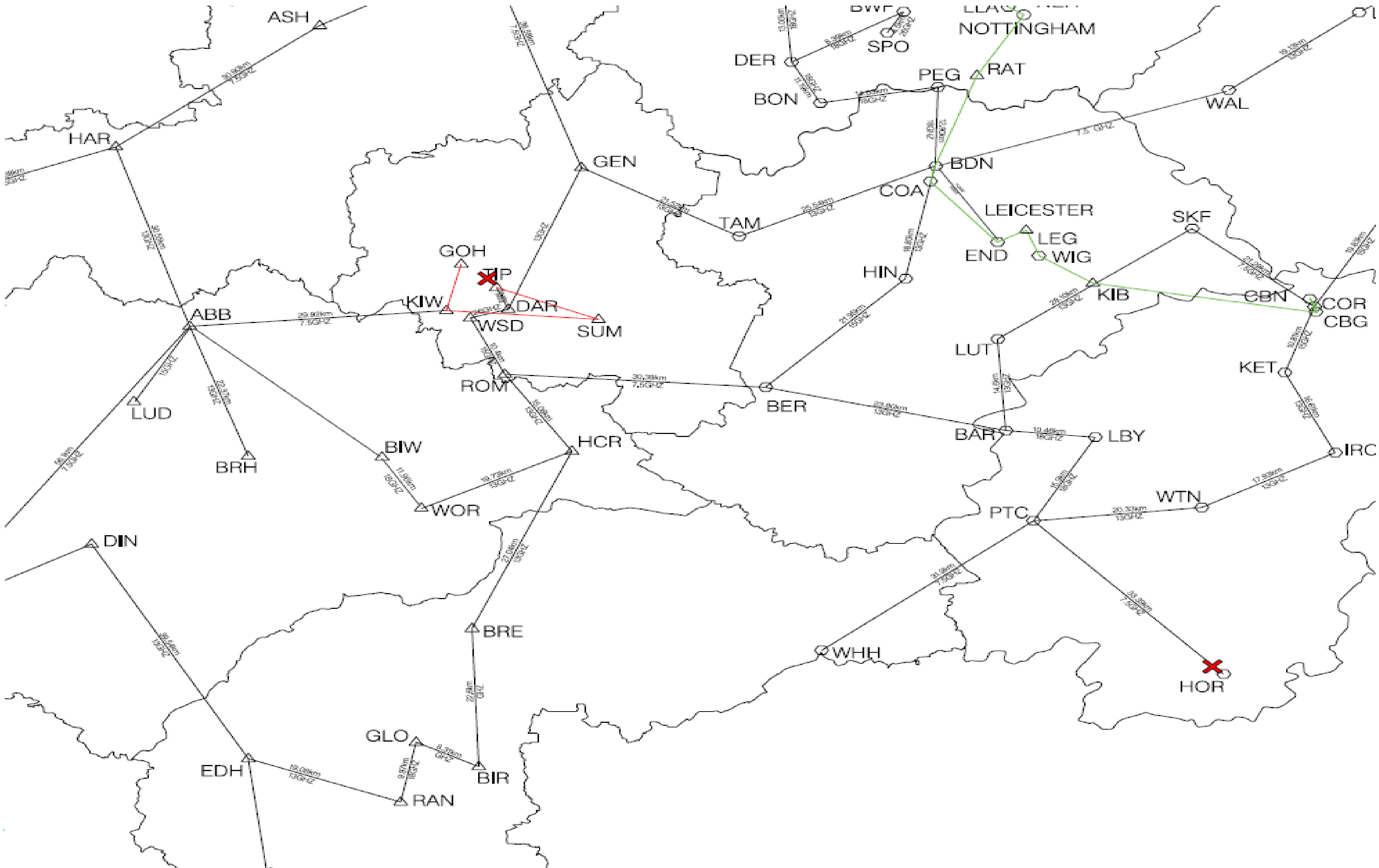
iBridge Relay

1.4GHz Access Channels

CH1	1432.5
CH2	1437.5
CH3	1442.5



Surf Telecoms Microwave Backhaul



Planning Requirements - How & Why Covered

Use of wood poles, why?

- Planning - the poles were installed under Permitted Development (15 Metres). However the local planning authority were informed of the project proposals.
- Costs - the poles were easily obtained and installed via WPD staff and supply chain. Steel towers were more costly due to procurement and foundation civils works requirements.
- Visual effect - wood poles, as opposed to a Steel lattice tower, at the primary substations were in keeping with a typical substation environment.

Planning Requirements - How & Why Covered

- Notifications to interested parties and neighbours.
- Two objections were received.
  - One prior to installation where the pole location was amended inline with the customer requirements.
  - Second, following the installation in the wrong location, where the pole was over towering a neighbouring customers property. A site visit and meeting with the customer was undertaken and an agreement was made to move the pole to a suitable location.
- Conclusion. Keeping interested parties and neighbours informed in the decision making process will save a lot of time and money later in the build phase.

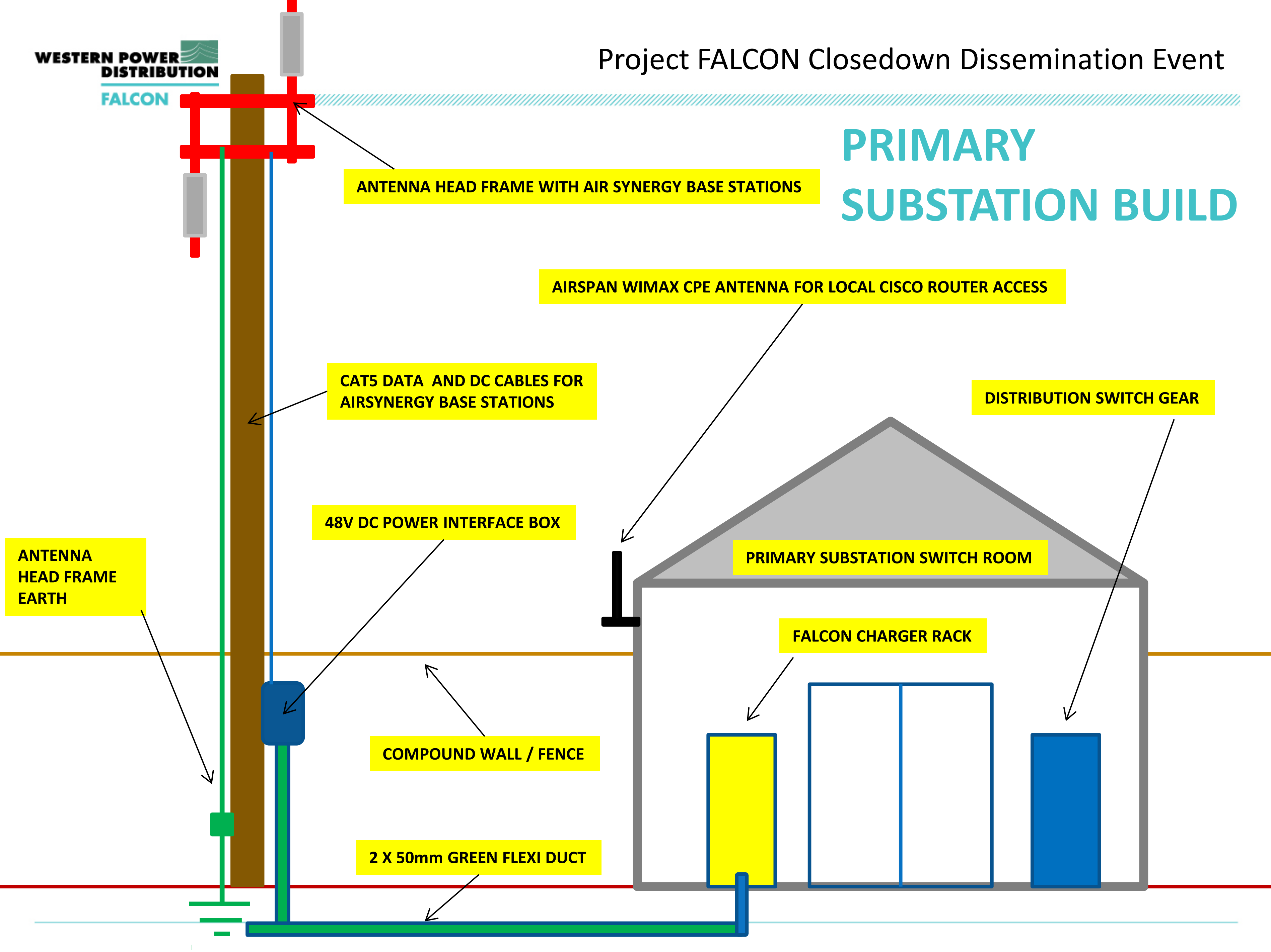
Build Phase - How it was Approached and Carried Out

- Following detailed designs from both Cisco and Airspan, the required network equipment was procured - followed by the installation in multiple phases.
- The Build started with the construction of the base stations at the primary substations to include Cisco routers, battery charging equipment together with the Airspan base station Airsynergy access and iBridge backhaul radios.
- The Build of the secondary substations should have followed with the installation of the CGR1240 routers and WiMAX antenna systems at the two hundred secondary substations and pole mounted locations.
- Backhaul from Milton Keynes to Tipton Headend was established. To include all routers and network monitoring kit.

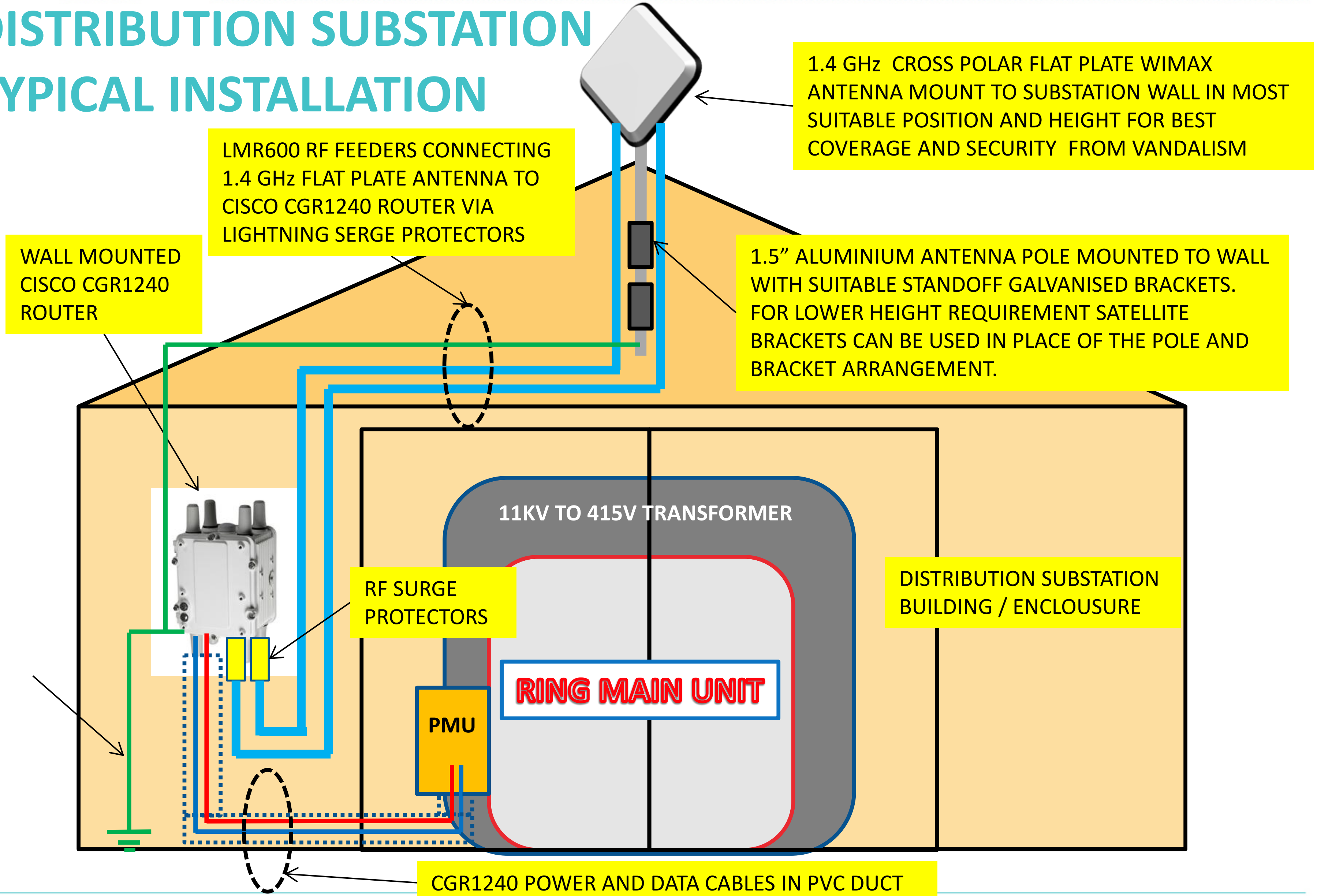
Build Phase - How it was Approached and Carried Out

- Due to Delays with the primary substation builds, it meant that the secondary substations were progressed without the ability to pan the antennas into the strongest signal paths in all cases.
- This resulted in a High number of sites requiring revisits to optimise the radio link paths. This process identified a high proportion of sites requiring taller 6 metre pole mounted installations to obtain suitable RF signal strengths.
- Installation progress using correctly skilled staff to ensure network optimisation at an early stage. Electrical engineering staff were used rather than radio installation teams which resulted in poor or non existent radio optimisation procedures.
- Cutting costs during the installation phase will in fact increase costs overall.

PRIMARY SUBSTATION BUILD



DISTRIBUTION SUBSTATION TYPICAL INSTALLATION



Trials Phase

- During the trials phase there was a process of ongoing actions to improve to the telecoms network reliability which was initially poor following the build phase with only 50 to 60% connectivity.
- Identification and implementation of ongoing network improvements were aided by the use of the monitoring systems such as Paessler PRTG, used to monitor the Cisco Network devices and NetSpan for the Airspan Network device management.

Issues Identified were:-

- Poor IP layer stability even with good RSSI levels (Poor CINR levels for a given RSSI implying interference).

Trials Phase - Continued

- Co-channel interference problems due to coverage from more than one site using the same frequency.
- Path restrictions due to parked high sided vehicles.
- All connectivity problems were improved to 100% by antenna panning, increased antenna height and general radio optimisation works.
- CGR1240 router occasional hangs, predominantly due to poor comms paths causing the WiMAX radio card to shutdown. Problem now fixed.
- These again were reduced by radio network optimisation works.

What Went Well and Lessons for the Future

- CGR1240 routers were an excellent piece of equipment originally designed and built for external pole installations.
- Early in the project it was identified that these were ideally suited to the distribution substation installation environment. It was decided to use these at all secondary locations.
- This saved on space compared to a traditional 19” rack installation. In addition to the labour savings this would need to be built with a suitable router, WiMAX radio and battery charging facilities.
- The CGR1240 routers are fully self contained units and include the IP68 weather proof enclosure, the router, WiMAX radio to include a battery charger together with 12 Hours battery autonomy.

What Went Well and Lessons for the Future

- The Airspan AirSynergy 1.4GHz WiMAX radios used for the access legs were ideal for the job and were found to be very reliable.
- The Airspan iBridge radios used for the backhaul at 3.5GHz were reliable but added to the overall latency by 20mS per HOP.
- The iBridge links also caused additional problems - as a condition of our test & development licence, we were required to disable this part of the network during the Silverstone Grand Prix week each year.
- Appropriate use direct of line of sight microwave radio links in the future will keep the latency to a minimum. This will require taller poles or masts which would be subject to the normal Local Planning restrictions together with associated additional costs.

Conclusions

- The Cisco CGR1240 routers proved excellent for the job required of them.
- Plus points were:-
  - Size and Ease of installation as one combined unit with rugged construction ideally suited to the distribution industry environment.
  - Security enabled as front door is alarmed and reports back to the network management system.
  - SNMP capable for extended monitoring capability.
- Negative points were:-
  - Cost of purchase for trial numbers and brand new technology. High end CGR1240 rolled out to all secondary sites (different levels of hardening are available however)

Conclusions - Continued

- AirSpan AirSynergy and iBridge WiMAX radio network equipment was well designed, reliable and had a very good network management system known as NetSpan.
- Plus Points were:-
  - Relatively low cost of purchase.
  - Reasonable cost of maintenance agreements.
  - Reliable equipment.
- Negative points were:-
  - Delivered with –ve Earth wrong polarity (This has been addressed with later builds).
  - iBridge increases latency by 20ms for every HOP.

Conclusions - Continued

- The mesh protection application initially proposed for the FALCON Project was not progressed due to concerns over service availability to our customers (this was mainly due to the telecoms network not being robust enough at that time of the initial project build).
- The telecoms network is now seen as being resilient following network optimisation and additional remedial works.
- As a result - if WPD are successful with the latest LCNF *Telecoms Templates Project* submission, it is planned to retain the FALCON network. This will be subject to extending the test & development frequency licences with Ofcom via the JRC. With these prerequisites being met, it is planned to prove the mesh Protection application working with both Cisco and Airspan.

Conclusions - Continued

- Government acceptance that affordable spectrum will be required to fulfil DNO's communications requirements for future Smart Grid Networks.

And Finally

- Food for thought! There is a need to weigh up the cost comparison of spectrum being sold off to the highest cell phone bidder compared to ability to fulfil the requirements for ongoing low carbon reductions for now and into the future.

Thank you

Q&A

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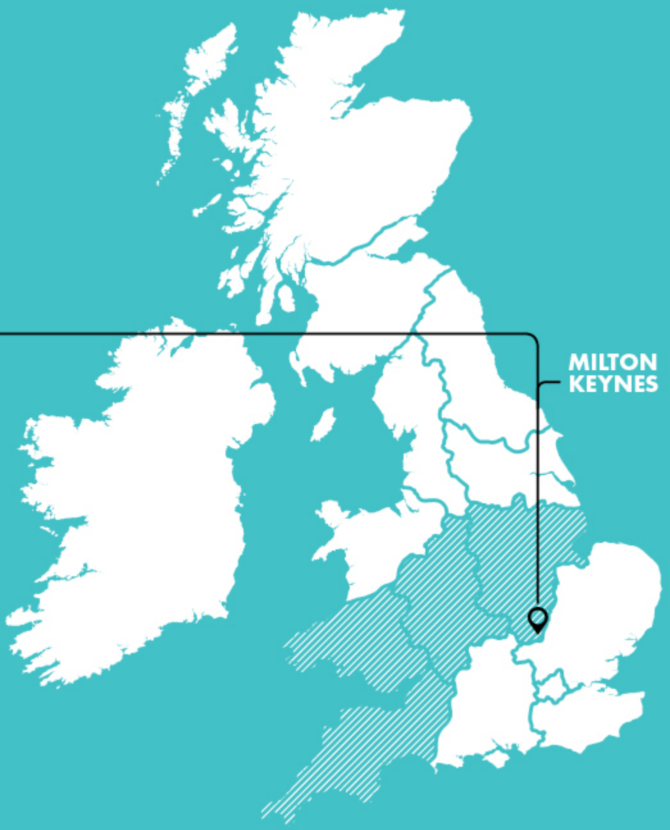
Project FALCON

Wrap Up

Roger Hey



Wrap Up

- Next steps
- Our thanks

WESTERN POWER DISTRIBUTION

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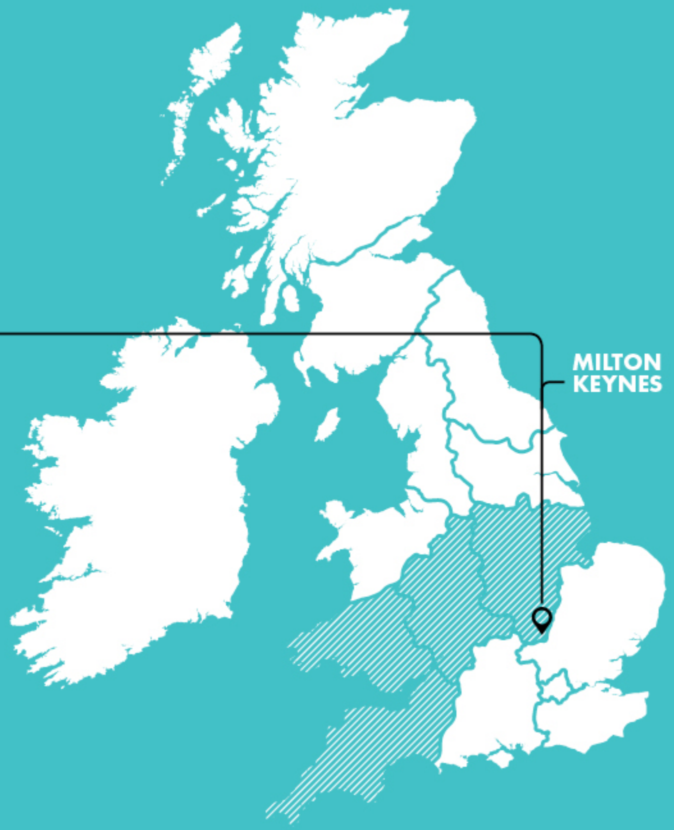
Thank you

DEVELOPING FUTURE POWER NETWORKS



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