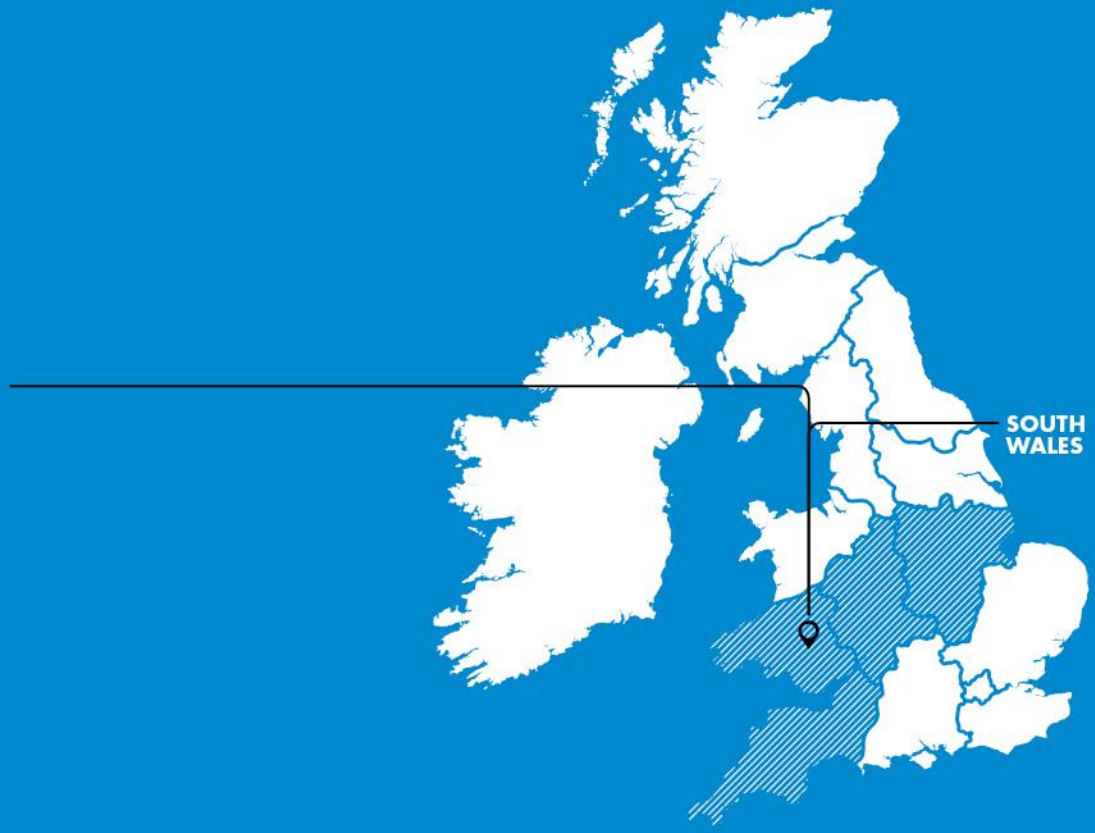
WESTERN POWER DISTRIBUTION

NETWORK TEMPLATES

LV NETWORK TEMPLATES FOR A LOW-CARBON FUTURE

Smart Energy Analytics

May 2015



LCN Fund Low Carbon Networks | Llywodraeth Cymru Welsh Government | npower | University of Bath | imagination at work | passivenergy

Agenda

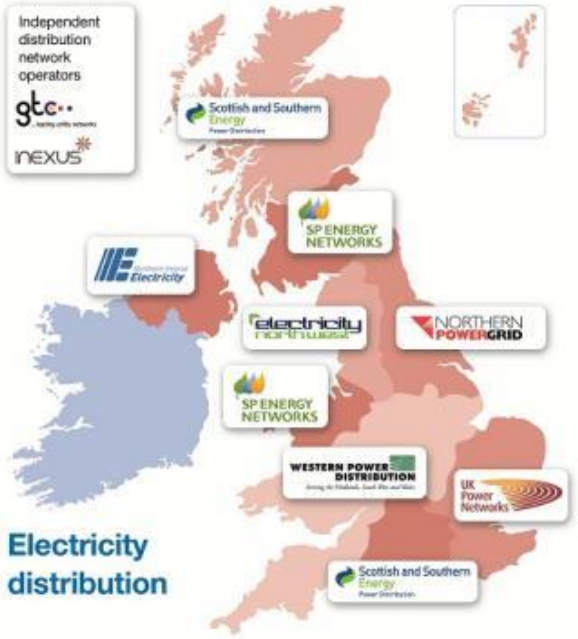
- Western Power Distribution – Who we are & what we do.
- Optimising Operations
- Recent analytics work
- Challenges
- Future plans

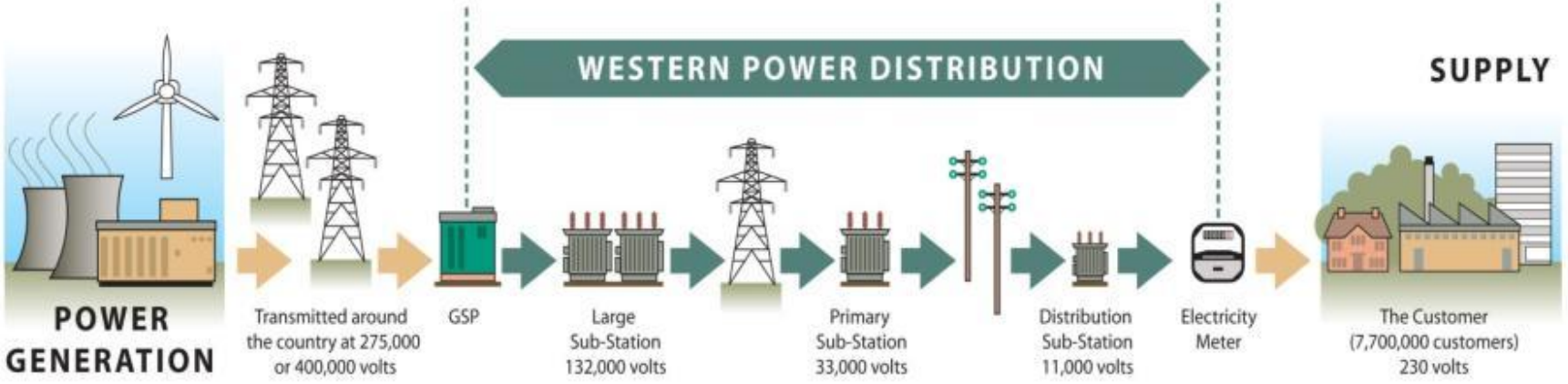
Who Are We

•We deliver electricity to over 7.8 million customers over a 55,500 sq km service area

•Our network consists of over 220,000 km of overhead lines and underground cables, and 185,000 substations maintained by over 6000 staff

•LV to 132kV Network ownership





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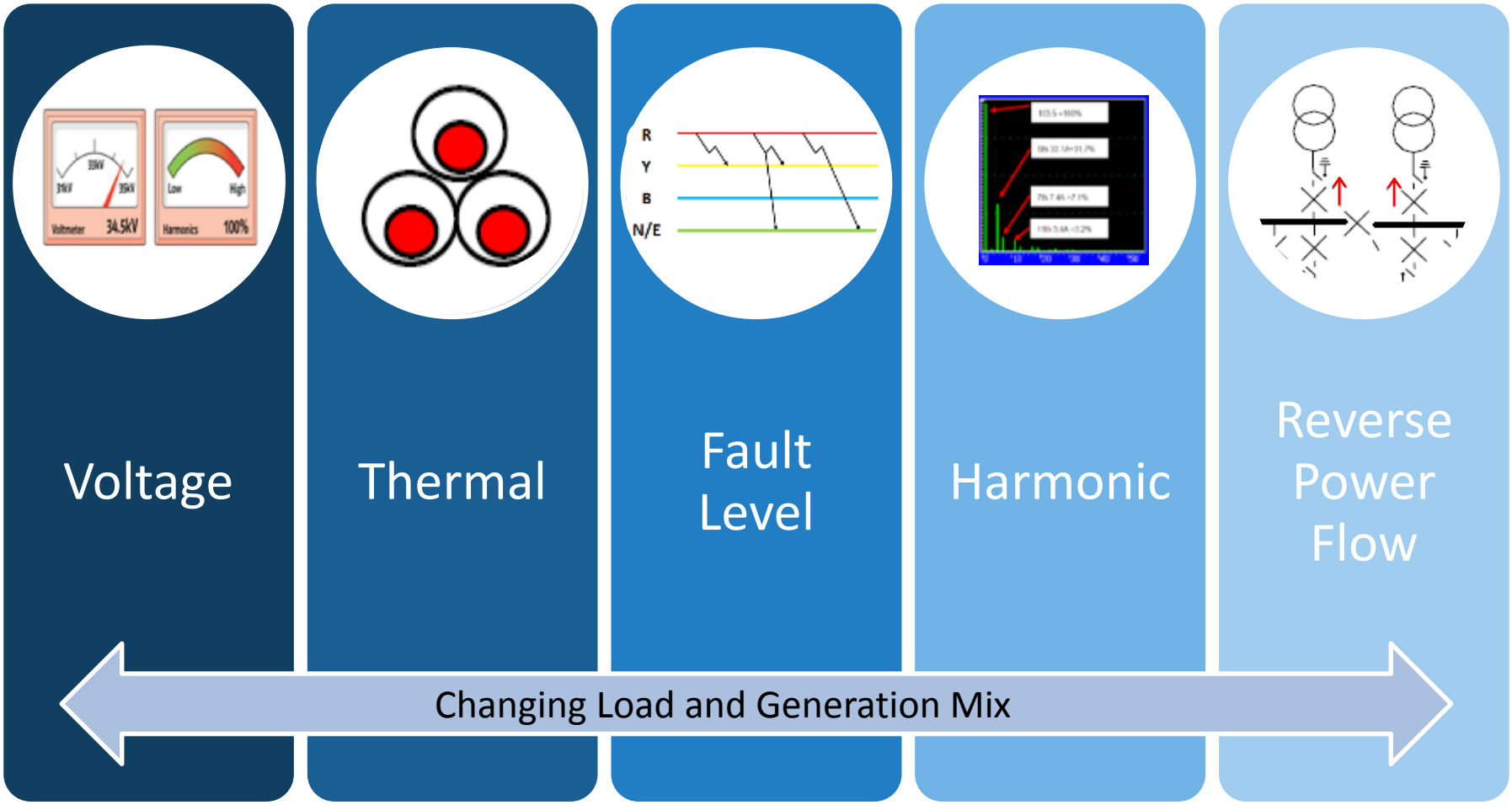
Distribution Network Challenges



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NETWORK TEMPLATES

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 NETWORK TEMPLATES

WESTERN POWER DISTRIBUTION LOW CARBON HUB

WESTERN POWER DISTRIBUTION SOLA BRISTOL

WESTERN POWER DISTRIBUTION FALCON

WESTERN POWER DISTRIBUTION FLEXDGRID

WESTERN POWER DISTRIBUTION NETWORK EQUILIBRIUM

WESTERN POWER DISTRIBUTION CLEAN ENERGY BALANCING

WESTERN POWER DISTRIBUTION TELECOMS TEMPLATES

WESTERN POWER DISTRIBUTION energy technologies institute POWER & HEAT

WESTERN POWER DISTRIBUTION energy technologies institute ISENTROPIC

WESTERN POWER DISTRIBUTION LV PLUS Innovate UK

WESTERN POWER DISTRIBUTION WIRELESS HIGHWAYS Innovate UK

WESTERN POWER DISTRIBUTION ECHO

WESTERN POWER DISTRIBUTION COMMUNITY ENERGY ACTION

WESTERN POWER DISTRIBUTION LOSS MITIGATION TEMPLATES

WESTERN POWER DISTRIBUTION SOLAR STORAGE

WESTERN POWER DISTRIBUTION STATISTICAL RATINGS

WESTERN POWER DISTRIBUTION D-SVC INTEGRATION

WESTERN POWER DISTRIBUTION ELECTRIC BOULEVARDS

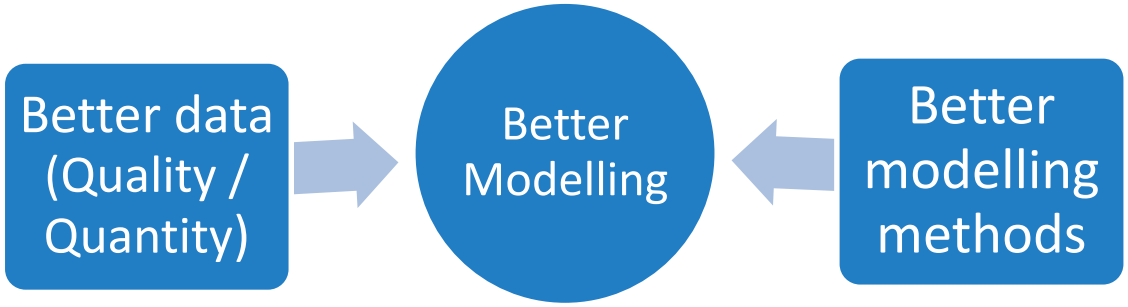
WESTERN POWER DISTRIBUTION CARBON TRACING

WESTERN POWER DISTRIBUTION SUNSHINE TARIFF

WESTERN POWER DISTRIBUTION AERIAL INSPECTION

Analytics & Optimising Operations

We have always used data to improve how we run our business.



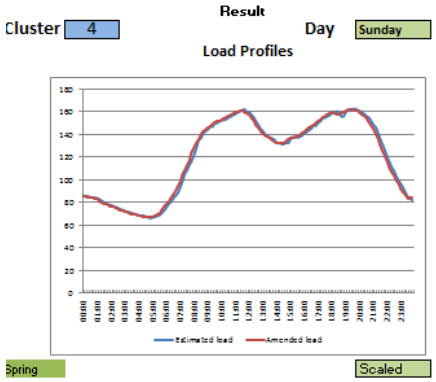
Planning	Real-Time Operations
Optimising long term investment Load prediction Network reconfiguration for losses	Automatic Load Transfer Voltage management scheme Dynamic Asset Rating Demand Side Response Battery Operation

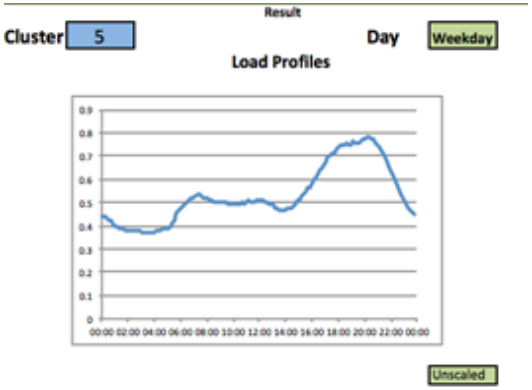
Recent Projects & Data

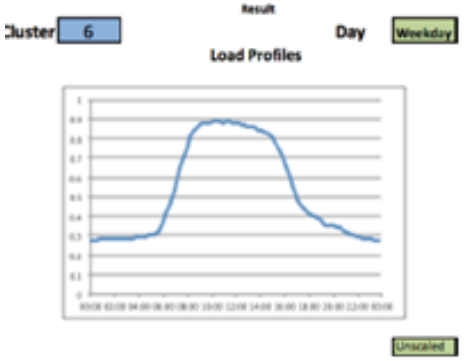
LV Network Templates	Substation monitoring - approx 800 LV Feeder end point voltage records – 3500 locations PV output data - over 500 installations (purchased)
FALCON	Substation load monitoring approx 150 sites. Monitoring data from trials of demand side management , battery operation, dynamic asset rating, automatic load transfer.
Alternative Connections	Under development - Automated network analysis to determine likely times and durations at which generation connection would be curtailed.

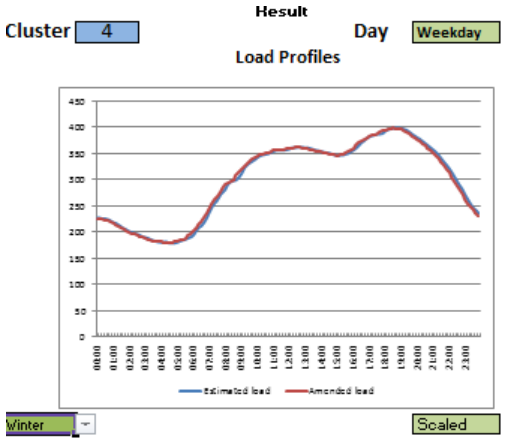
WESTERN POWER DISTRIBUTION
NETWORK TEMPLATES

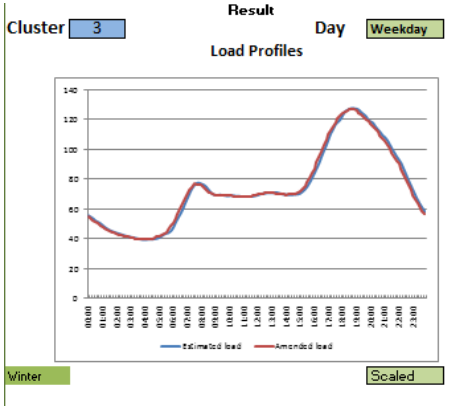
LV Network Templates - Substation Profiles

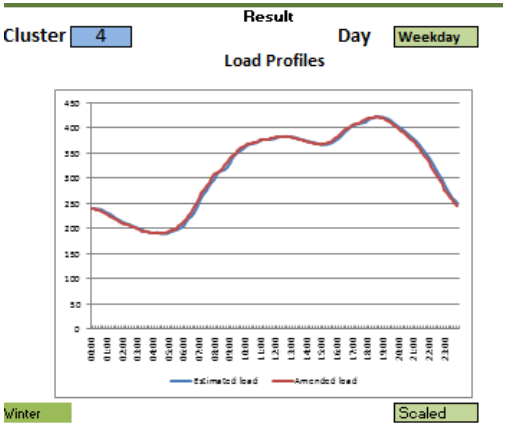








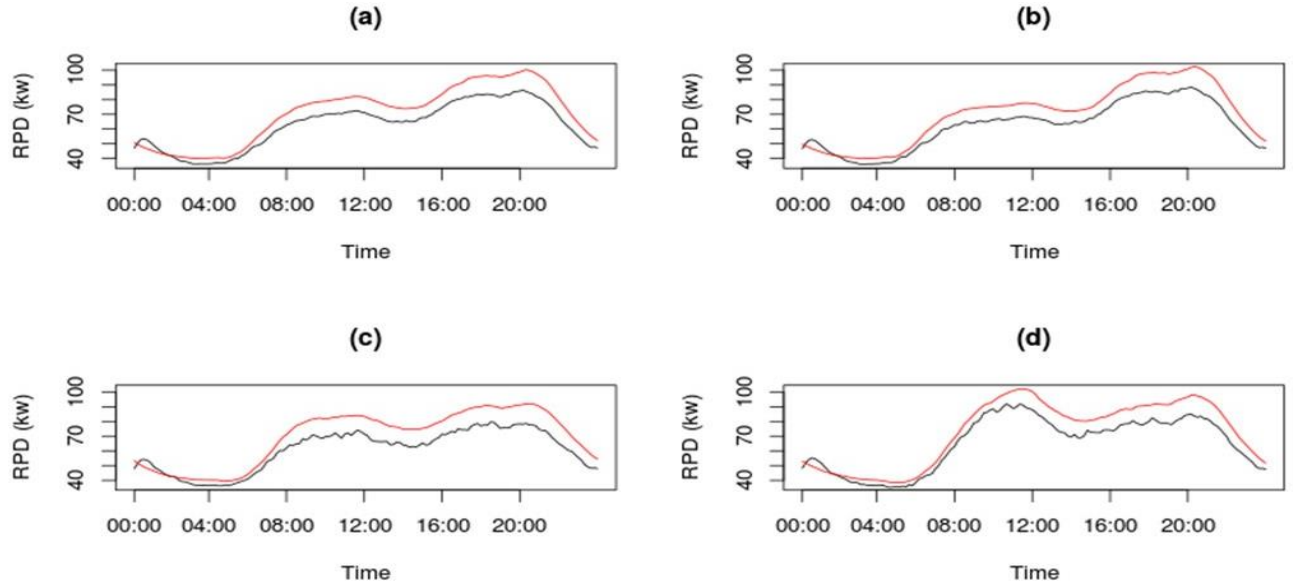




Agglomerative hierarchical clustering .
Values normalised by daily maximum so that clustering reflects profile shape.
Complex algorithm to allocate substation to cluster
Non-linear regression model used to create scaling factors.

Impact of PV on load

- Difference in load can be seen in daytime.

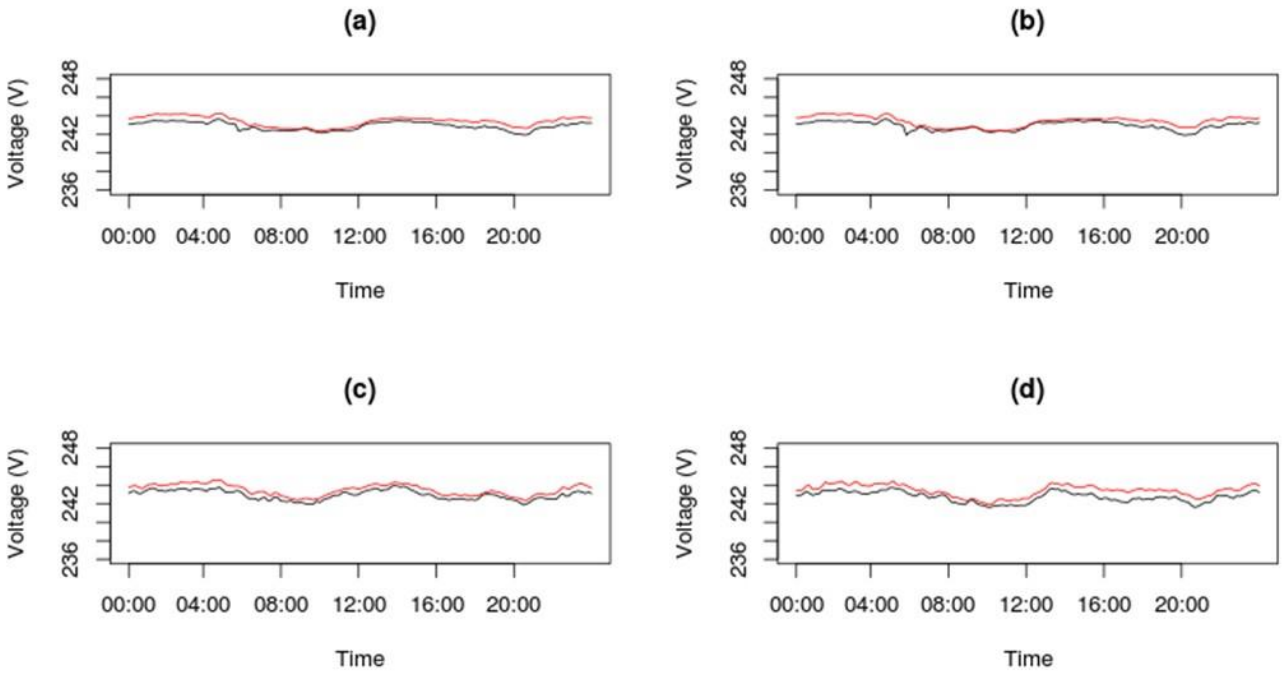


Black: Substations with PVs, Red: Substations without PVs

Panels show results for (a) all days; (b) Weekday; (c) Saturday; (d) Sunday.

Impact of PV on voltage profiles

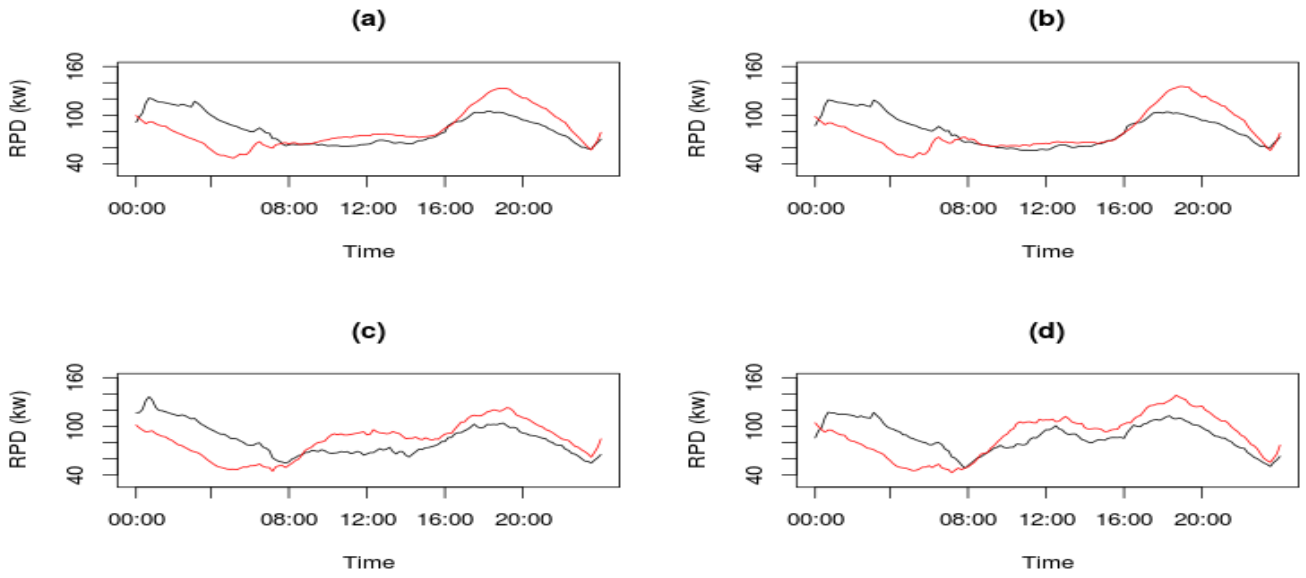
- Substations with PV have close voltage profiles compared to those without PV daytime



Medium-loaded substation voltage profiles (phase A)
Black: Substations with PVs, Red: Substations without PVs

Panels show results for (a) all days; (b) Weekday; (c) Saturday; (d) Sunday.

Impact of Heat Pumps



Heat pumps in this area seen to act like off-peak heating, increasing load in early morning and lower evening peak.

Substation load profiles (real power delivered) for substation 563672 with 23 Arbed registered air source heat pumps (black line) and substation 552240 (without any registered air source heat pumps) (red line). Panels show results for (a) all days; (b) Weekday; (c) Saturday; (d) Sunday. Results are for winter (28th Oct. 2012 – 30th Mar. 2013)

PV output

1) Output never exceeds 80% of installation rating.

2) At postcode district level (e.g. CF39) a reference unit can be used to estimate the output at other units.

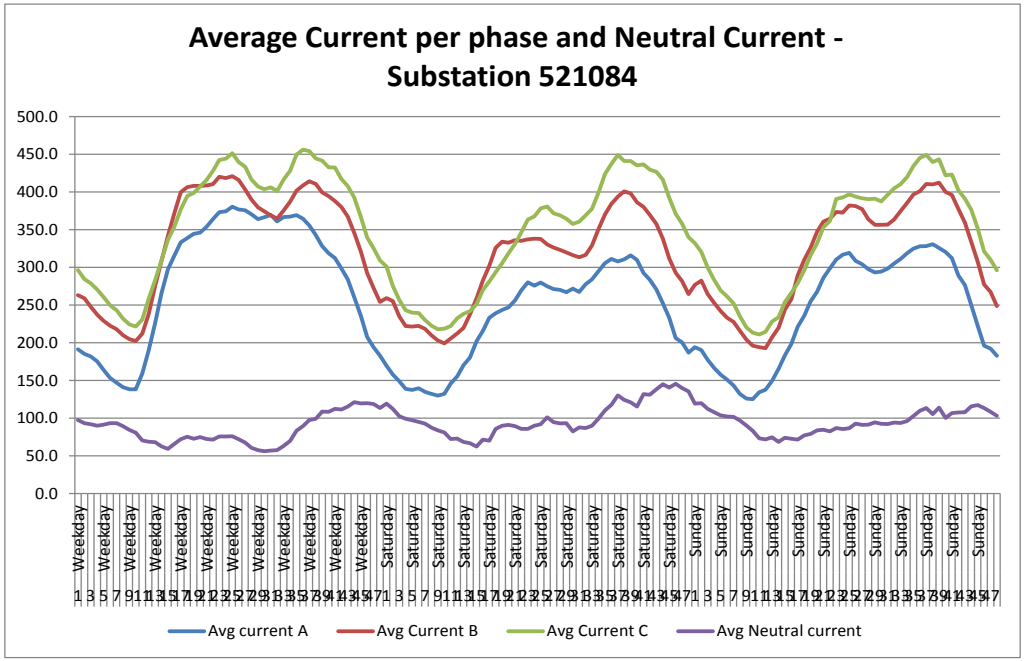
   Best estimates are given where the reference unit is average in terms of size, orientation, tilt.

   PV panel in each primary substation would allow for reasonable estimates of PV generation which would be useful for National Grid.

Distribution of voltage monitored at *substations*

Range: 230 V+/- given percentage	Substation Percentage	Feeder Ends
>10% (>253V)	0.69%	0.35%
8 to 10% (248.4V, 253V)	6.98%	5.22%
6 to 8% (243.8V, 248.4V)	*49.17%*	*32.30%*
-2% to +6% (225.4V, 243.8V)	*43.16%*	*61.94%*
-2 to -4 % (220.8V, 225.4V)	0.00076%	0.1234%
-4 to -6 % (220.8V, 216.2V)	0.00025%	0.0437%
-6 to -10% (216.2V, 207V)	0.00025%	0.0187%
<-10% (207V<)	0.00053%	0.0022%

Imbalance, Power Factor, Total Harmonic Distortion



Some high levels of imbalance observed.

Power factor assumptions generally correct, though some substations leading not lagging.

THD within limits - domestic dominated substations have higher values.

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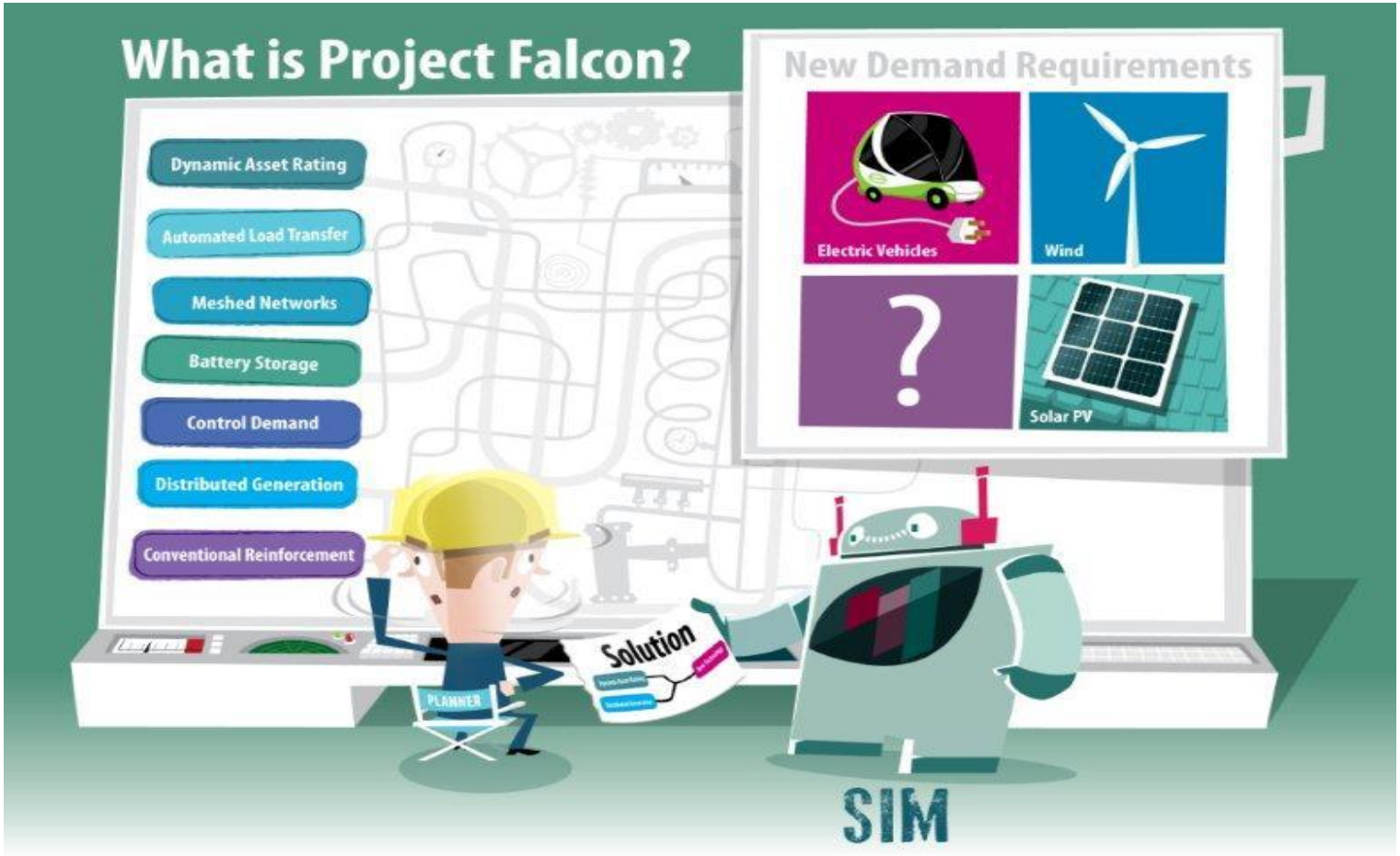
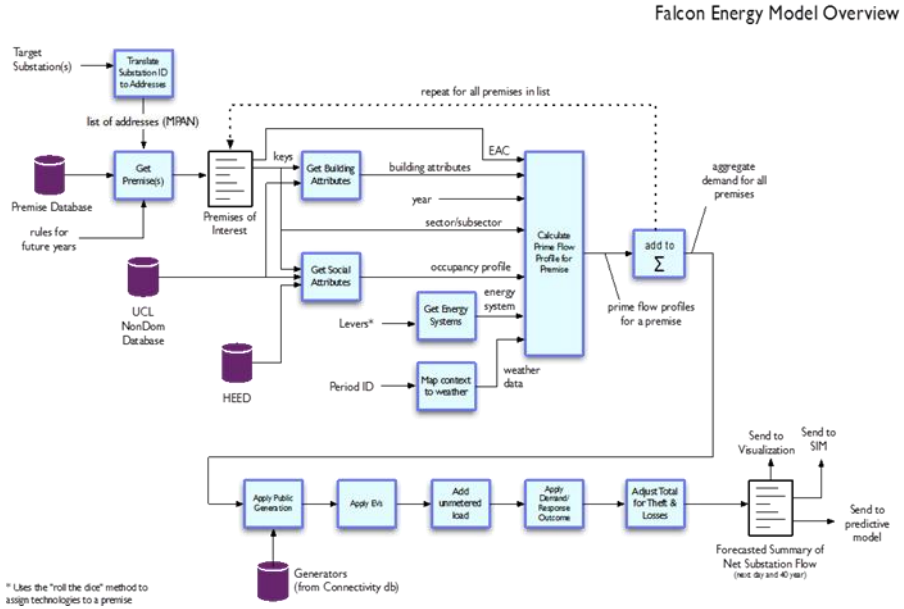
Flexible Approaches to Low Carbon Optimised Networks

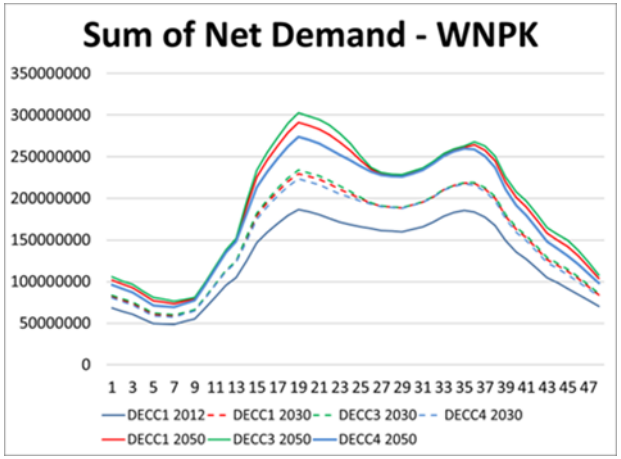


Falcon Energy Model

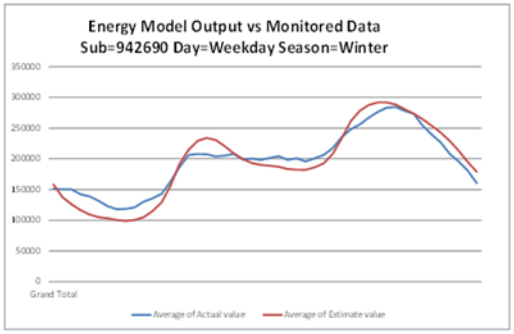
Build up load profile by modelling building energy requirements for heating and water, profiling other end use types, lighting.

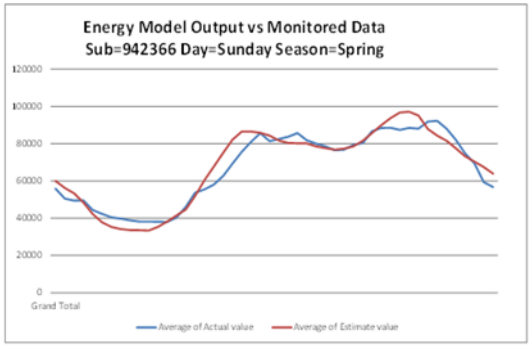
Scenarios models future adoption of heat pumps, EV, PV, efficient appliances etc.

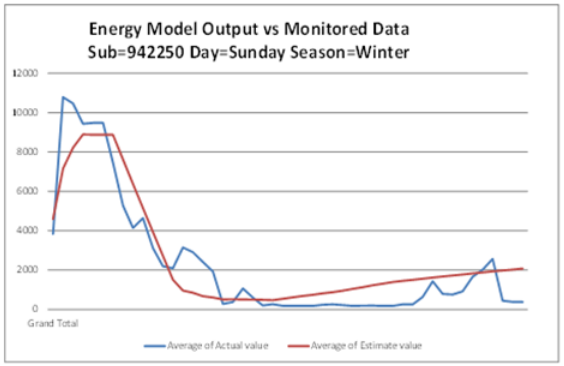




Falcon Energy Model





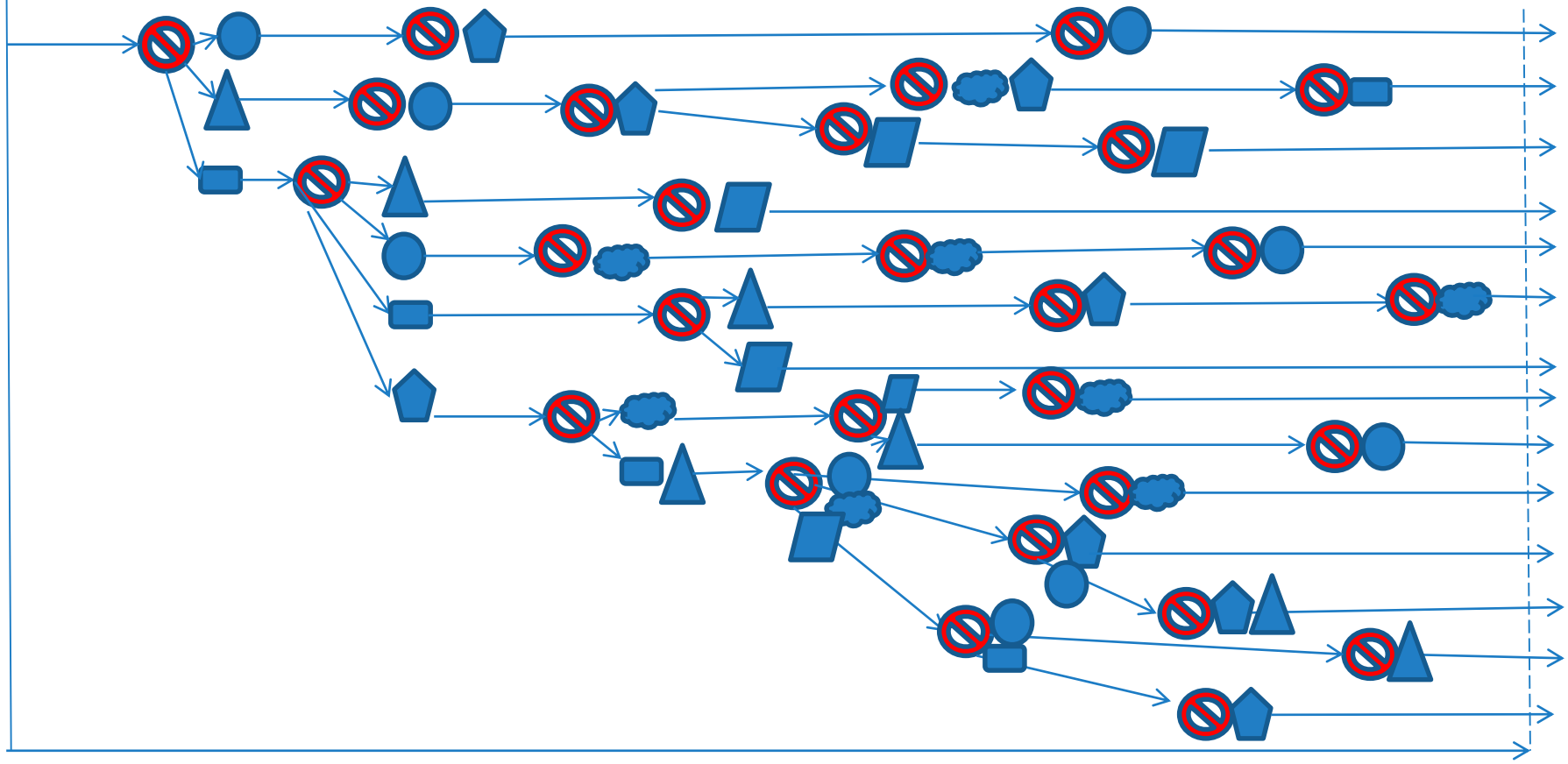


Can get very good results.

Analysis of outliers suggests odd results caused by data issues – likely to impact all estimation methods.

Potential barrier to implementation – Cost of Experian data.

Scenario Investment Model

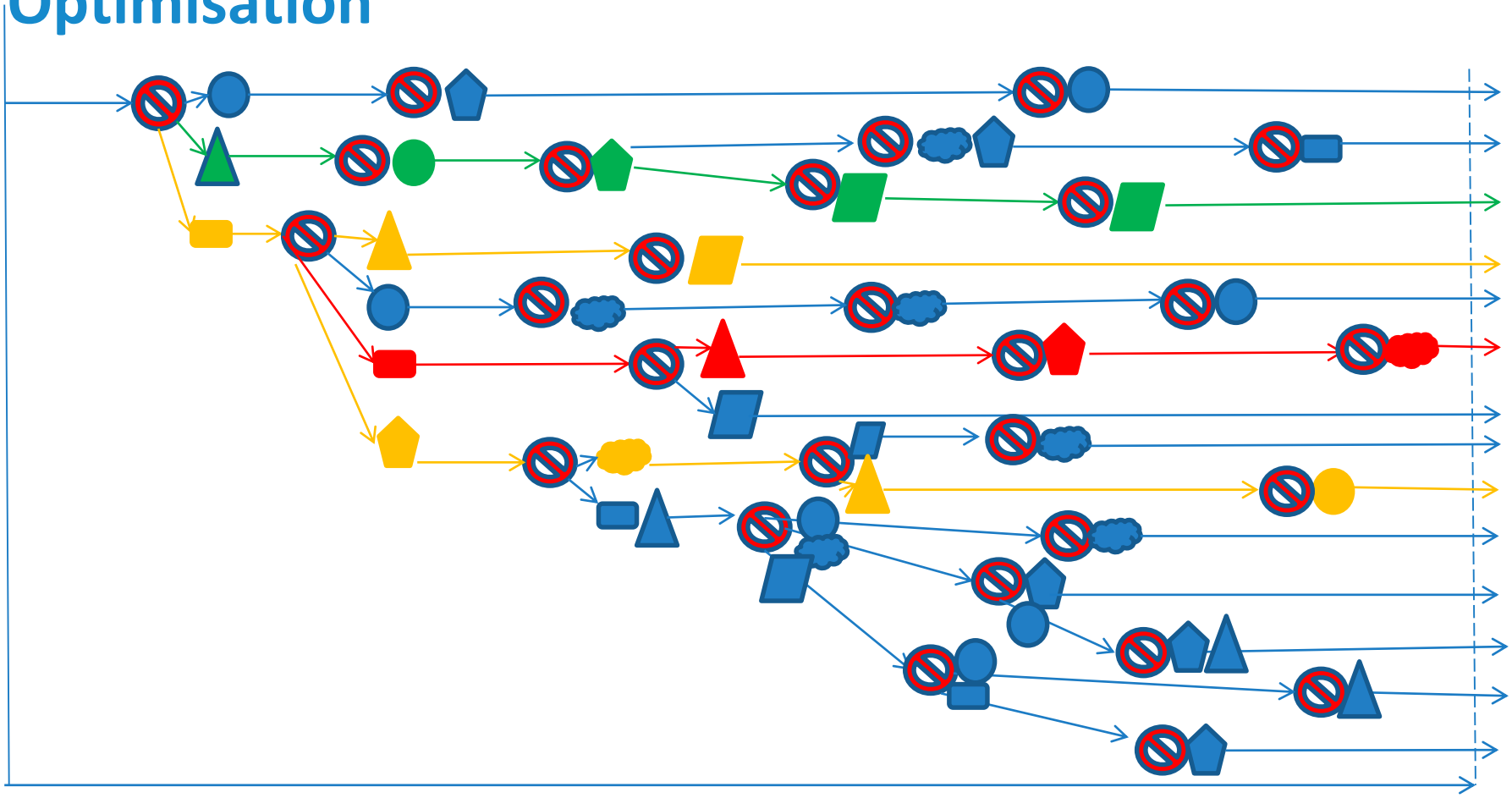


Now

Assessment time horizon

Time

Optimisation



Now

Assessment time horizon

Time

Alternative Network Connections

	Fit and Forget	Alternative
Approach	Reinforce network to perform under most onerous conditions. no monitoring or control	Curtail generation when most onerous conditions occur. Monitoring & control to direct curtailment when required.
Modelling	Model most onerous conditions only • Connected DG are all simultaneously operating at their full outputs • Whilst the distribution network is at minimum demand • Whilst the distribution network is operating the upper voltage bandwidth	Model representative days and seasons at half hourly resolution Use monitoring data rather than assumed values. This gives a more realistic estimate of diversity between generation.

Challenges to Analytics

- Disparate data sources

  Asset management, GIS, Control Room

  Need a combined network model – Common Information Model Format

- Matching with external data sets

  No building references, Address matching issues, Limited customer information

  Data protection compliance

- Developing new IT infrastructure / Services

  Requirements and Business case not always clear

Future Plans

Common Information Model

Losses
Improving our understanding with fully measured networks

Smart meter data
Phase identification & validating connectivity