WPD INNOVATION
Transforming the electricity network

Electricity Flexibility and Forecasting System (EFFS)

PD8 Trials Execution and Knowledge Capture Report

August 2021

WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

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Disclaimer

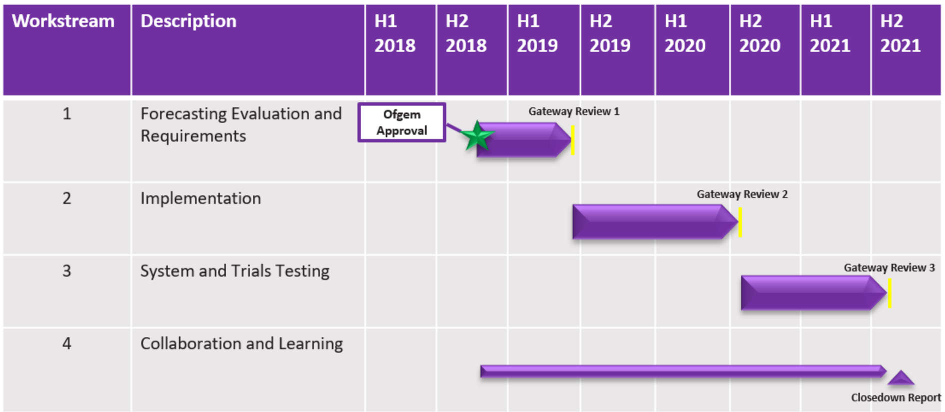
Contents

1 Executive Summary

The Electricity Flexibility and Forecasting System Project (EFFS or “the Project”) is funded through Ofgem’s Network Innovation Competition (NIC). EFFS was registered in October 2018 and will be complete by October 2021. The Project partners are AMT-SYBEX and National Grid ESO.

EFFS supports the Distribution System Operator (DSO) transition by developing and trialling a system to plan and dispatch flexibility services in operational timescales. EFFS is split into four workstreams:

1. Forecasting Evaluation and Requirements;
2. Implementation;
3. System and Trials Testing; and
4. Collaboration and Learning.



Workstream	Description	H1 2018	H2 2018	H1 2019	H2 2019	H1 2020	H2 2020	H1 2021	H2 2021
1	Forecasting Evaluation and Requirements								
2	Implementation								
3	System and Trials Testing								
4	Collaboration and Learning								

Figure 1 EFFS timeline overview

The project will specify and trial the additional system functionality required by a Distribution Network Operator (DNO) to help the transition to DSO as given in the following objectives:

1. Enhancing the output of the ENA Open Networks project, looking at the high-level functions a DSO must perform, provide a detailed specification of the new functions validated by stakeholders, and the inclusion of specifications for data exchange;
2. Determining the optimum technical implementation to support those new functions;
3. Creating and testing that technical implementation by implementing suitable software and integrating hardware as required; and
4. Using and testing the technical implementation, which will involve modelling the impact of flexibility services.

Objectives 1 and 2 have been achieved. This document serves to evidence that part of objective 3 has been completed in that suitable software has been developed, deployed on WPD infrastructure, and undergone preliminary tests to ensure that it has been delivered in a functional state.

This document presents a summary of the overall trials phase and learning for the project. As such it demonstrates the methodology in place to successfully carry out the trial, an evaluation of the results found in all key areas and a measure of its success when compared to its criteria.

The trial was successful in enabling us to fully test and evaluate the end to end EFFS process, including data processing, forecasting, constraint analysis, service selection and validation, and conflict avoidance.

2 Project Background

2.1 Purpose of this Document

This document serves to evidence the completion of Project Deliverable 8 (Trials Execution and Knowledge Capture) from the Ofgem issued Project Direction (ref: WPD EMID / EFFS / 28 September 2018). Project Deliverable 8 is described as:

- Completion report demonstrating outcomes of trial phases alongside test scripts, exit reports etc.

- Letter of support from external stakeholders and partners confirming completion of project trial phase and acceptance of the results.

2.2 Overall Project Progress

The project will specify and trial the additional system functionality required by a DNO to help the transition to DSO as given in the following objectives:

1. Enhancing the output of the Energy Networks Association (ENA) Open Networks Project, looking at the high-level functions a DSO must perform, provide a detailed specification of the new functions validated by stakeholders, and the inclusion of specifications for data exchange;
2. Determining the optimum technical implementation to support those new functions;
3. Creating and testing that technical implementation by implementing suitable software and integrating hardware as required; and
4. Using and testing the technical implementation, which will involve modelling the impact of flexibility services.

Objectives 1, 2 and 3 have been achieved. This document serves to evidence that objective 4 has been completed in that trialling of the technical implementation of the project solution has been completed by Western Power Distribution.

In additional to the objectives, the project has deliverables as agreed with Ofgem upon award and set out in the EFFS Project Direction. Of the nine deliverables, seven have been previously completed and this document represents the completion of the eighth. Please see Table 1 for more information:

Table 1 - Project Progress against Ofgem Deliverables

Ref.	Project Deliverable	Status
1	Mobilisation Exit Report	Completed
2	Output from the forecasting	Completed
3	Development of requirements specification for DSO functionality	Completed
4	Development of EFFS Design Specification document	Completed
5	Implementation and System Delivery	Completed
6	On-Site Testing	Completed
7	Trials Design and Preparation	Completed
8	Trials Execution and Knowledge Capture	Completed with the submission of this document
9	Gateway Reviews	On Track

3 Trials Methodology

This section outlines the process that took place to trial the systems developed as part of the EFFS project. This includes detail on individual areas of the system, including data cleansing, forecasting, constraint analysis and service selection and validation, before demonstrating how this process flows as an end to end system. This trials phase spanned from December 2020 through to July 2021.

The purpose of the trials phase of the project was to demonstrate that the software and interfaces developed to support the relevant DSO functionality work and that the forecasting and co-ordination elements function as intended. As such the process enabled regular and recurring use of the whole system, and the interface between the EFFS tools and multiple external platforms have been carried out.

The 24-week trial was split into four sequential phases:

1. **Pre-trials**: 2 weeks of preparatory work for completion of pre-requisite activities, including software deployments, pipe cleaning and data cleansing;
2. **Initiation**: 2 weeks of running the system without manual intervention;
3. **Operation**: 18 weeks of operational running of the EFFS solution, involving real-life scenarios and desktop exercises; and
4. **Closedown**: 2 weeks of closedown operation of the EFFS solution.

Prior to the commencement of the trials phase, the following entry criteria were satisfied:

Table 2 - Entry Criteria

No	Details	Status
1.	Completion of User Acceptance Testing;	Passed
2.	Production environment built, software installed and configured;	Passed
3.	Approval of the Trials Strategy and Trials Schedule documents; and	Passed
4.	Completion of a TEF co-operation plan to avoid duplication	Passed

3.1 Data Processing

A data processing system is in place within the EFFS tool to cleanse and prepare data to be used for forecasting, constraint analysis and flexibility service validation. This system has include the following interactions:

- Exchange of cleansed historic Time Series (TS) data and forecasted TS data;
- Exchange of network constraints and sensitivity factors of flexibility services;
- Exchange of selection and validation of flexibility services.

This process has been utilised during the weekly trial runs and has therefore been tested using a range of data sets with varying network conditions. The data exchange between the EFFS tool and DPS includes the following step by step interactions:

- Step 1: EFFS tool to provide DPS the weekly cleansed historic TS data file. This new instance of the weekly historic TS data is also added to the historic TS dataset which contains the two-year historic TS data and the added instances of weekly historic TS data and is stored internally in the tool.
- Step 2: DPS provides EFFS a week-ahead forecasted TS data of demand and generation for the EFFS tool to perform PSS®E system studies for identifying network constraints and calculation of sensitivity factors.
- Step 3: EFFS tool provides DPS the constraints and sensitivity factor data file for DPS's optimisation of service selection.
- Step 4: DPS provides EFFS tool the selected flexibility services for EFFS tool's validation.
- Step 5: EFFS tool provides DPS a summary status of whether the flexibility services have been accepted or not.

3.1.1 Time Series Data

The EFFS tool receives TS data at two stages during the process carried out. This includes historic TS data from WPD which is checked and prepared for use for forecasting, and then the forecast TS data which is used for network analysis and simulation.

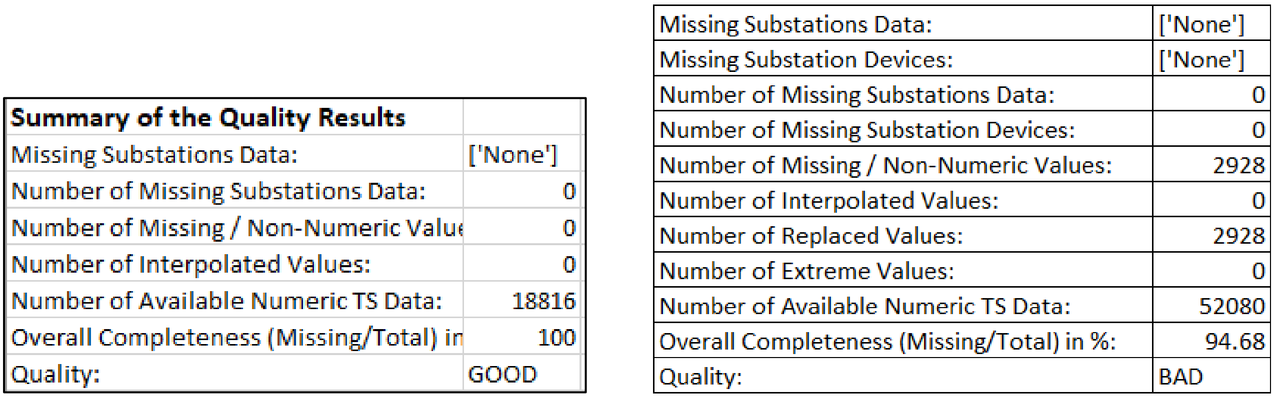
The EFFS tool receives the historic TS data in a pre-defined format and performs data cleansing in order to check for any issues and correct them based on some assumptions. Examples of those issues are either bad / missing data or illogical values that will need cleansing before it can be processed further. This ensures that the data will be of a good quality and format that is suitable to be passed to DPS for forecasting purposes. Checks carried out on this data include:

- File Naming Conventions
- Missing Substation Names or Substation Devices (e.g. circuit breakers)
- Non-numerical values in HH steps
- Load and Generation Units
- Sign Convention

When collating load and generation values, a hierarchy is in place to determine the best values provided to use as not all substation monitoring outputs have the same available data. This is as follows:

1. Use real power (MW) and reactive power (MVAr) values if available;
2. Use voltage (V) and current (I) values and typical power factors advised either by WPD or from the Long-Term Development Statement (LTDS) to calculate real power (MW) and reactive power (MVAr);
3. Use real power (MW) and apparent power (MVA) values to calculate real power (MW) and reactive power (MVAr);
4. Use real power (MW) values and typical power factors advised either by WPD or from the Long-Term Development Statement (LTDS) to calculate real power (MW) and reactive power (MVAr);
5. Use reactive power (MVAr) and apparent power (MVA) values to calculate real power (MW) and reactive power (MVAr);
6. Use current (I) values and typical power factors and nominal busbar voltages advised either by WPD or from the Long-Term Development Statement (LTDS) to calculate real power (MW) and reactive power (MVAr);
7. Use apparent power (MVA) values and typical power factors advised either by WPD or from the Long-Term Development Statement (LTDS) to calculate real power (MW) and reactive power (MVAr).

The output of this process includes the collated TS data, as well as files containing any data that was replaced and an overview of the quality of data assessed. Examples of this are shown in Figure 3.1-1.



Summary of the Quality Results	
Missing Substations Data:	['None']
Number of Missing Substations Data:	0
Number of Missing / Non-Numeric Valu	0
Number of Interpolated Values:	0
Number of Available Numeric TS Data:	18816
Overall Completeness (Missing/Total) in	100
Quality:	GOOD

Missing Substations Data:	['None']
Missing Substation Devices:	['None']
Number of Missing Substations Data:	0
Number of Missing Substation Devices:	0
Number of Missing / Non-Numeric Values:	2928
Number of Interpolated Values:	0
Number of Replaced Values:	2928
Number of Extreme Values:	0
Number of Available Numeric TS Data:	52080
Overall Completeness (Missing/Total) in %:	94.68
Quality:	BAD

Figure 3.1-1 - Examples of Time Series Data Quality Output

3.2 Forecasting Approach

In line with the key requirement of the EFFS project to accurately forecast flexibility requirements, the trials phase has included regularly carrying out forecasting for use within the EFFS tool for constraint analysis. This has been achieved using the previously developed forecasting algorithm, implemented within Networkflow, which can produce day ahead, week ahead, month ahead and six month ahead forecasts.

The trials process made use of week ahead and two week ahead forecasting created at the start of each weekly trial run. The effectiveness and accuracy of these has been monitored throughout the trial phase, both using comparison with EFFS alternative forecast types, real network data, and by comparing with other existing forecasting tools. More detail on this is provided within section 4.2.

Following on from earlier deliverables within the project, the approach to forecasting uses Extreme Gradient Boosting (XGBoost). This is a machine-learning technique based on decision trees that has performed well in recent machine learning and forecasting competitions. Previous work compared this method with Auto-Regressive Integrated Moving Average (ARIMA) and Long Short Term Memory (LSTM) Artificial Neural Networks. For the majority of test cases, Extreme Gradient Boosting outperformed the other methods tested, therefore this method was selected for the project.

The project produced forecasts at 21 primary substations and 7 generation sites (4 Short Term Operating Reserve (STOR), 2 Solar and 1 Multi-Fuel Generator). This represented the full trial area and was used within the later constraint analysis process.

3.2.1 Forecast updates to enable tool utilisation

To maximise the testing of the EFFS process carried out within the trial period, a forecast alteration method was developed to ensure constrains were found on the network each week allowing for demonstration of the procurement and selection of flexibility services.

To ensure that the trials provided value, the forecast demand and generation profiles for each week were adjusted to increase the demand or generation to a level where it would produce a constraint. This was done by identifying assets which could become overloaded during certain contingencies but would also result in at least 1 of the available flexible services being able to contribute to resolving the constraints. Assets to target were selected in a way that in some instances a single service would be able to contribute and in others multiple services would be able to contribute to ensure that optimisation algorithms were also tested.

Figure 3.2-1 below shows an example of the half hourly demand profile across a single 33/11 kV transformer within the trial region. The blue line showing the original demand profile and the orange line showing the altered demand profile which now crosses the transformer rating during certain outages on the system. This large alteration is representative of a change made by the python tool, but will only be applied to nodes which would not produce a constraint, therefore the overall change to the forecast is smaller than this change shown.

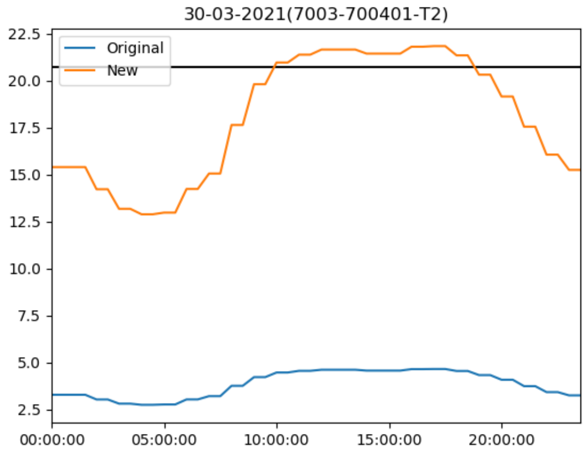
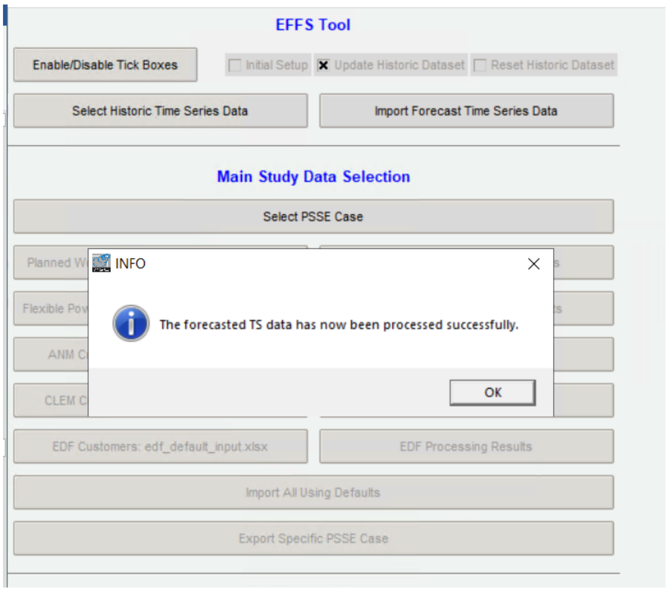


Figure 3.2-1: Adjustment to load forecasting to establish load constraints

Constraint analysis was then carried out using both the raw forecast data and the updated forecast data.

3.3 Constraint Analysis Methods

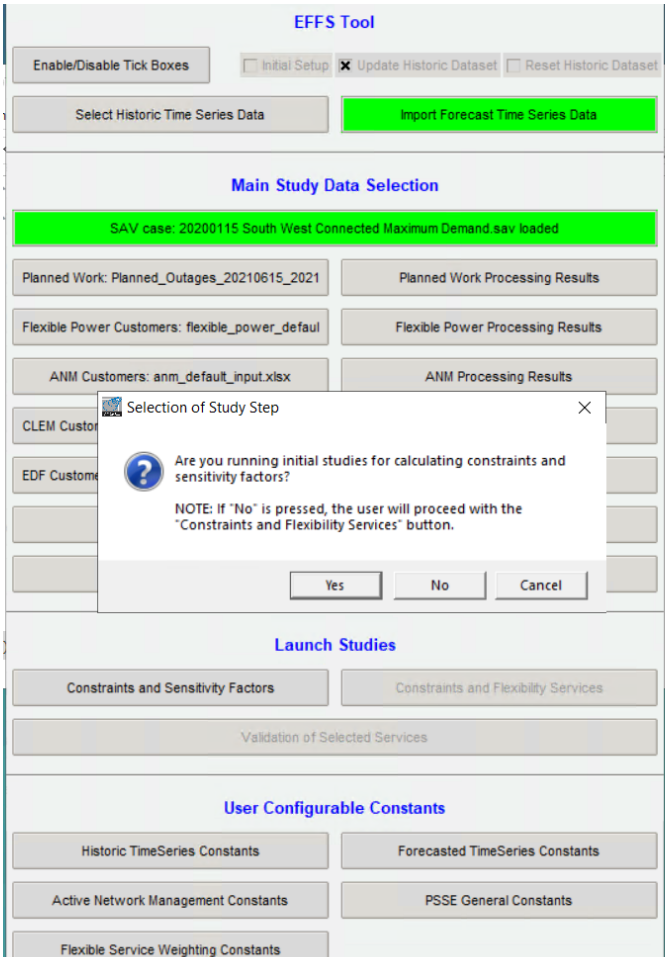
Within the trial, Constraint Analysis has been carried out for each run. This is carried out by the EFFS tool and its interface with PSS®E, using a network model which is updated with load and generation forecast data, planned outage information and active network management (ANM) information. Constraints are identified by the tool checking the analysis results against defined threshold values, to demonstrate where assets are above acceptable load flow conditions in any HH period.



The forecasted TS data has now been processed successfully.

EDF Customers: edf_default_input.xlsx

Figure 3.3-1 - Imported Forecast Data Processing Completion



SAV case: 20200115 South West Connected Maximum Demand.sav loaded

Planned Work: Planned_Outages_20210615_2021

Flexible Power Customers: flexible_power_defaul

ANM Customers: anm_default_input.xlsx

Are you running initial studies for calculating constraints and sensitivity factors?

NOTE: If "No" is pressed, the user will proceed with the "Constraints and Flexibility Services" button.

Figure 3.3-2 - Constraints and Sensitivity Factor Calculation using EFFS Tool

3.3.1 Regions of Interest

The network models used within this process are our network models within the project trial area under maximum demand conditions. An initial convergence check was conducted, which confirmed that a convergent power flow simulation could be achieved, and the data appeared realistic. This PSS®E model was utilised for power system analysis with the demand / generation adjusted based on the forecast TS data.

As the trial area is focussed around Exeter City and Plymouth 33kV BSPs, the network models shown in Figure 3.3-3 and Figure 3.3-4 have been used. Further information on the trial area can be found within section 3.6.

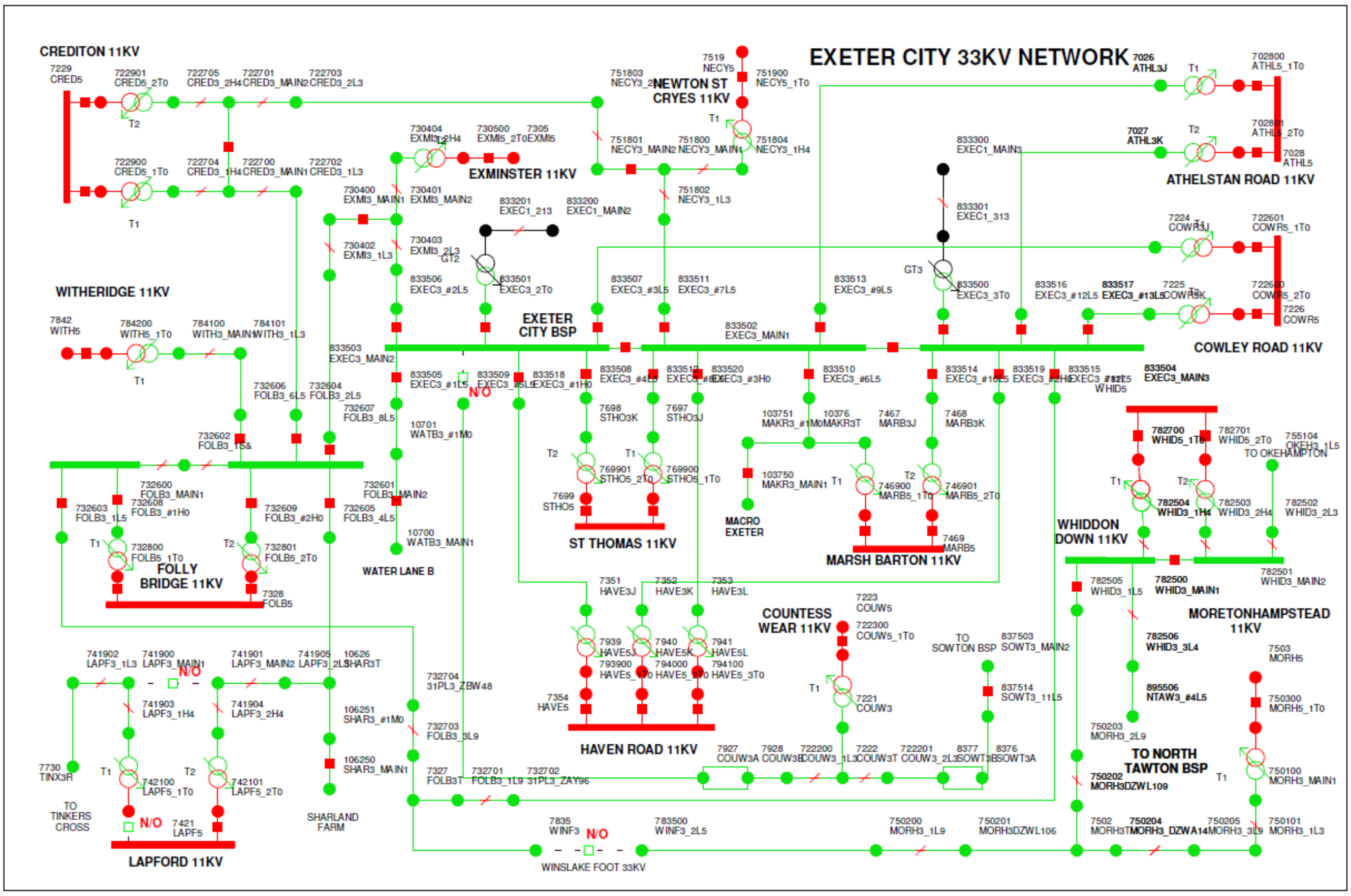


Figure 3.3-3 - Exeter City Network Model

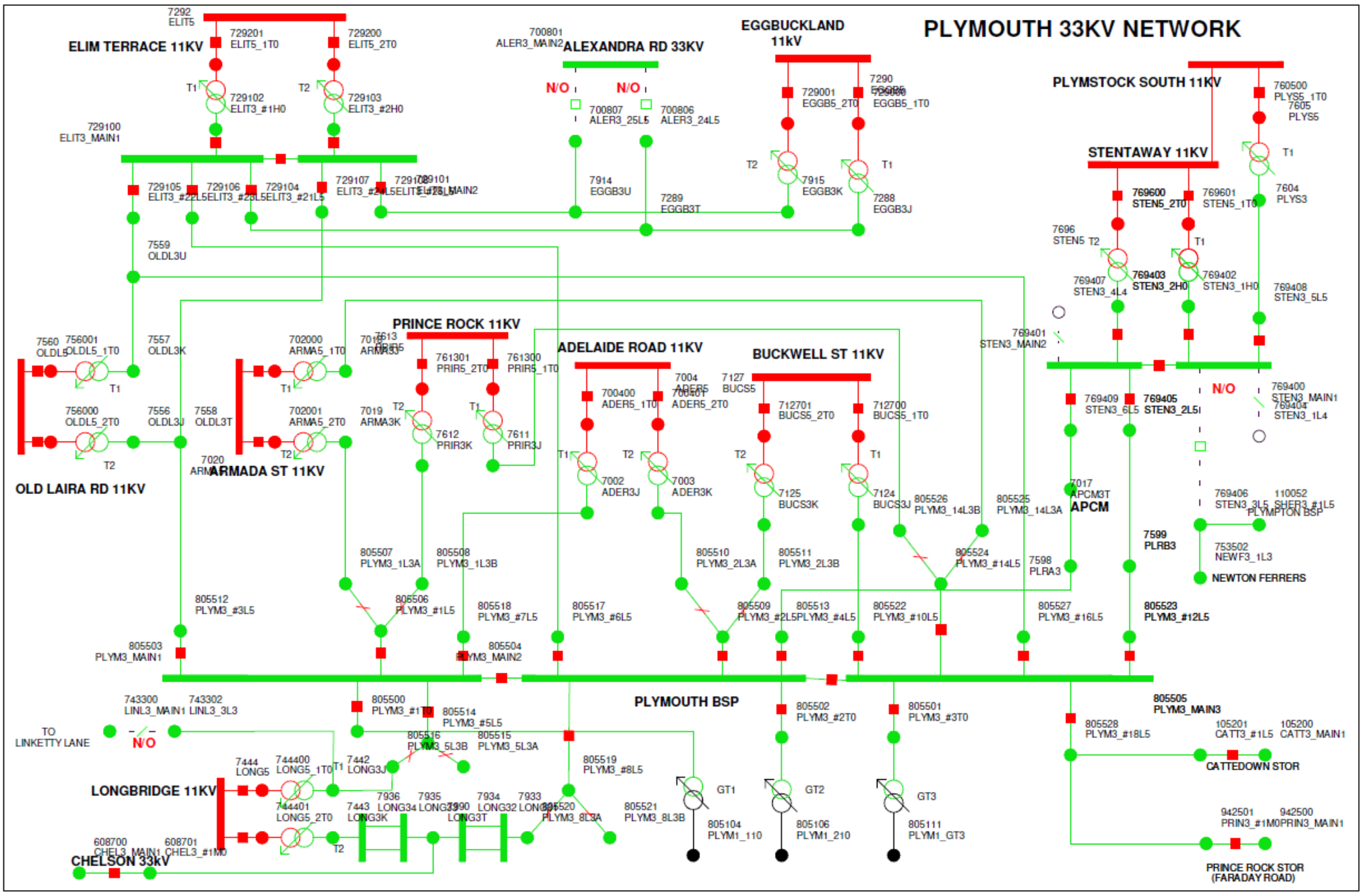


Figure 3.3-4 - Plymouth Network Model

3.3.2 Power Flow Analysis

The EFFS tool runs PSS®E load flow studies utilising forecasted load and generation data for the week ahead in order to identify network constraints and calculate sensitivity factors. In doing this, the tool runs iterative studies for each HH step of the forecasted TS data.

Prior to running the iterative load flow studies, the tool performs an initial preparation of the PSS®E case by doing the following:

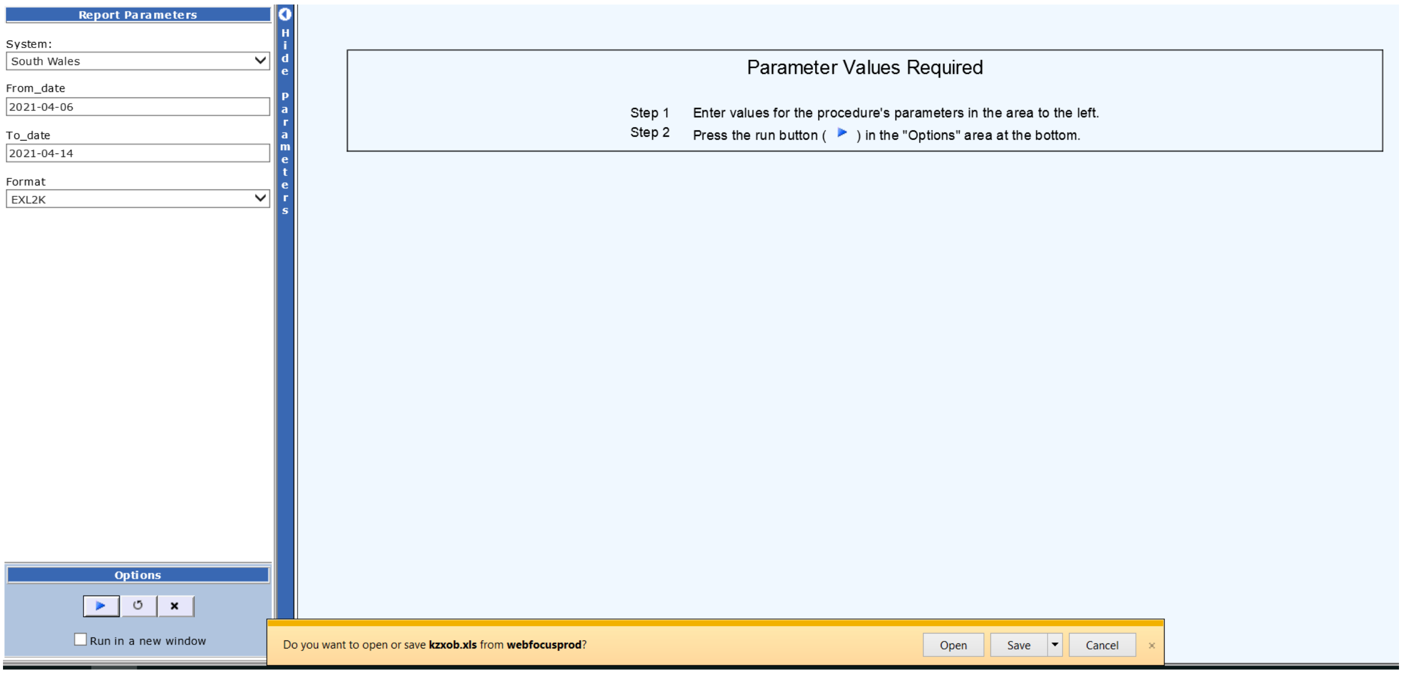
- Removal of existing loads and generators in the regions of interest;
- Mapping of the ANM customers;
- Mapping of the flexible platform customers.

Following this the tool runs a power flow iteration for each HH step and imports the power values from the forecasts for each substation in the area. In order to ensure that the results from the load flow studies are consistent, the tool is designed to run studies utilising the ‘Full Newton-Raphson’ power flow calculation method. The results of this power flow analysis are checked against a user defined threshold value in order to identify assets with a loading above the user defined threshold limit for each HH period and the thermal violation is calculated.

In addition to considering the normal running arrangements on our network, the impact of possible outages of network assets were also considered as these may lead to constraint situations that could be resolved with flexibility services. For the purpose of this project, network outages were considered under two distinct categories:

1. Planned Network Outages
2. Post-fault Outages (Contingencies)

Planned network outages refer to outages which are scheduled to take place by WPD for particular time periods. During each simulation these are considered as the starting system configuration rather than the intact system. For the EFFS trial process these have been collated using our Webfocus Planned Outage Reporter, a screenshot of which can be seen within Figure 3.3-5. Post-fault outages refer to network configurations that occur after a fault has occurred and the necessary fault clearing actions have been completed. These fault clearing actions include isolating the faulted network asset as well as automated inter-tripping schemes to reconfigure the network.



System: South Wales

From_date: 2021-04-06

To_date: 2021-04-14

Format: EXL2K

Parameter Values Required

Step 1 Enter values for the procedure's parameters in the area to the left.

Step 2 Press the run button (▶) in the "Options" area at the bottom.

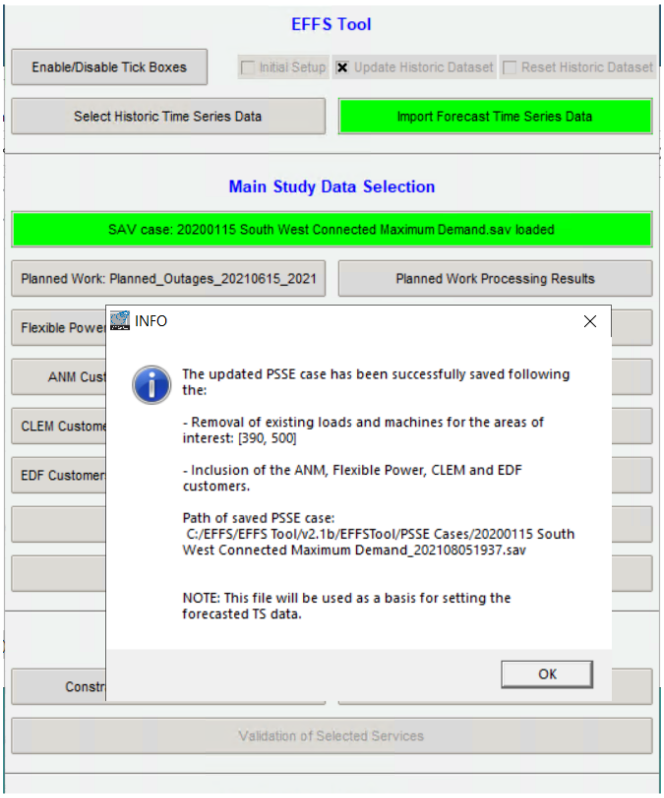
Do you want to open or save **kzxob.xls** from **webfocusprod**?

Figure 3.3-5 - Planned Outage Reporter

3.3.3 Calculation of Identified Constraints and Sensitivity Factors

Since the impact of a flexibility service on the constraint is expected to be different for flexibility services located at different locations, sensitivity analysis was performed in order to quantify the impact that a change in the flexible services will have on the constraints. Sensitivity factors have been utilised which effectively are ratios that show how much the flexibility service will impact the constraint.

Once the constraints and sensitivity factors have been calculated for each HH step and contingency, the worst values are calculated in order to be utilised in the next step of the process where the flexibility requirements are calculated, and the selection of flexibility services takes place.



SAV case: 20200115 South West Connected Maximum Demand.sav loaded

Planned Work: Planned_Outages_20210615_2021

The updated PSSE case has been successfully saved following the:

- Removal of existing loads and machines for the areas of interest: [390, 500]

- Inclusion of the ANM, Flexible Power, CLEM and EDF customers.

Path of saved PSSE case:
C:/EFFS/EFFS Tool/v2.1b/EFFSTool/PSSE Cases/20200115 South West Connected Maximum Demand_202108051937.sav

NOTE: This file will be used as a basis for setting the forecasted TS data.

Figure 3.3-6 - EFFS Tool during Constraint Analysis Process

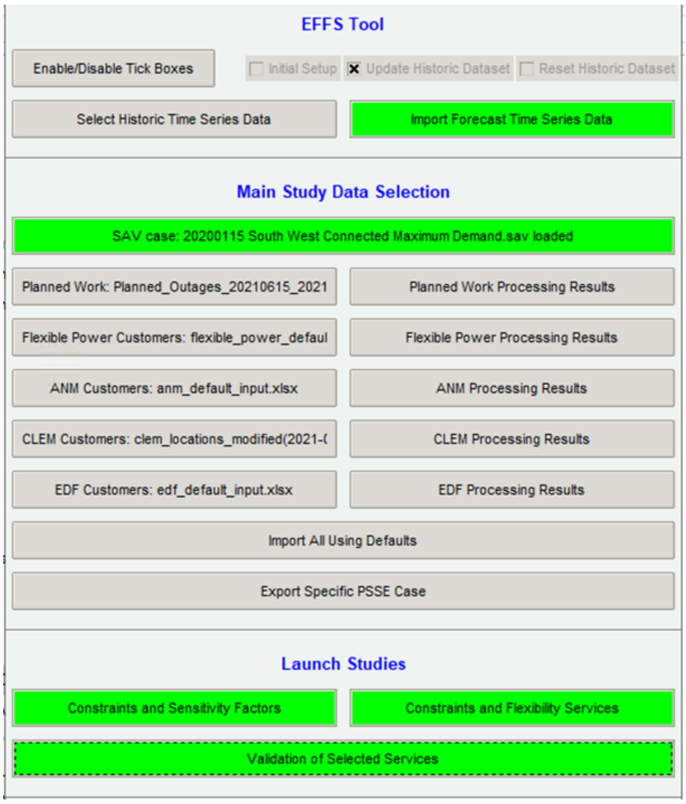
3.4 Procurement and Selection of Services

3.4.1 Selection and Optimisation of Services

Optimisation was used throughout the trial each week services were generated and available. However, due to lack of market liquidity, it was very difficult to fully test largely because not every substation that had a constraint has a service. Given the lack of services available the project chose to optimise based on the lowest price in each weekly run. The optimisation performed very well in terms of timings and also functionally, the lowest cost service was always selected within a few seconds.

3.4.2 Validation of Flexibility Service Selection

Following the selection process of the optimum services, the EFFS tool proceeds with the validation of the selected services where the PSS®E load flow studies are re-run for the forecasted TS generation / load data including the selected services. The studies are performed for the same contingencies of interest and future network conditions in terms of planned outages. The system calculates the new network constraints which are then compared with the ones prior to the inclusion of the services and validates whether they are accepted or not. The EFFS tool provides an Excel output of the results, an example of which can be seen in Figure 3.4-2.



SAV case: 20200115 South West Connected Maximum Demand.sav loaded

Planned Work: Planned_Outages_20210615_2021

Flexible Power Customers: flexible_power_defaul

ANM Customers: anm_default_input.xlsx

CLEM Customers: clem_locations_modified(2021-(

EDF Customers: edf_default_input.xlsx

Figure 3.4-1 - EFFS Tool Validation Interface

Transaction Type	PublishAvailableFlexibilityServicesToProcValidate
Transaction ID	PublishAvailableFlexibilityServicesToProcValidate_20210518_110928.json
Service ID	310020_18052021114700923
Service Type	Scheduled
Start Date	2021-05-21T12:00:00Z
End Date	2021-05-21T13:00:00Z
Market Platform	CLEM
Asset ID	CLEM
Status	Accepted
Service ID	310020_18052021114701129
Service Type	Scheduled
Start Date	2021-05-21T21:00:00Z
End Date	2021-05-21T22:00:00Z
Market Platform	CLEM
Asset ID	CLEM
Status	Accepted
Service ID	310049_18052021114701460
Service Type	Scheduled
Start Date	2021-05-22T18:00:00Z
End Date	2021-05-22T19:00:00Z
Market Platform	CLEM
Asset ID	CLEM
Status	Accepted
Service ID	310020_18052021114701699
Service Type	Scheduled
Start Date	2021-05-23T12:00:00Z
End Date	2021-05-23T14:00:00Z
Market Platform	CLEM
Asset ID	CLEM
Status	Accepted
Service ID	330014_18052021114700433
Service Type	Scheduled
Start Date	2021-05-19T09:00:00Z
End Date	2021-05-19T20:00:00Z
Market Platform	CLEM
Asset ID	CLEM
Status	Accepted

Figure 3.4-2 - Service Validation Output

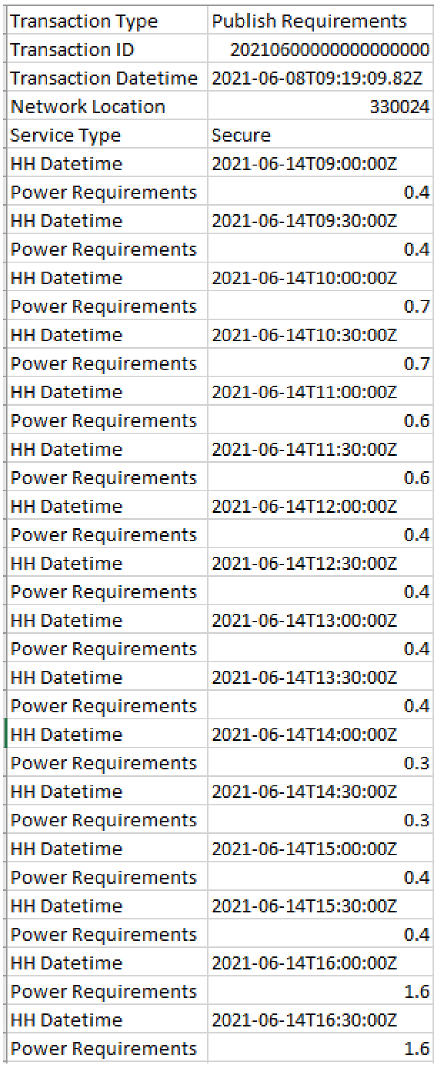
Optimisation of this validation process was able to be carried out using bids from the multiple flexibility service providers that took part in the trial. This included making use of the range of prices present from each. During the trial, we have used the anonymised historic production pricing data from the market platforms to analysis the operating costs of flexibility.

3.5 Platform Integration

As part of the EFFS project trial third party flexibility service providers have been engaged to facilitate demonstration of the tools working with each of their platforms, and to provide a range of data for use in the testing of service selection, optimisation and validation. As such, we have worked with Cornwall Local Energy Market (CLEM) and EDF PowerShift, and a comparison then been made with our own FlexiblePower platform. This demonstrated the EFFS process capability to output required services to each platform, receive their availability and reserve contracts, and select and validate the optimal services to avoid constraints.

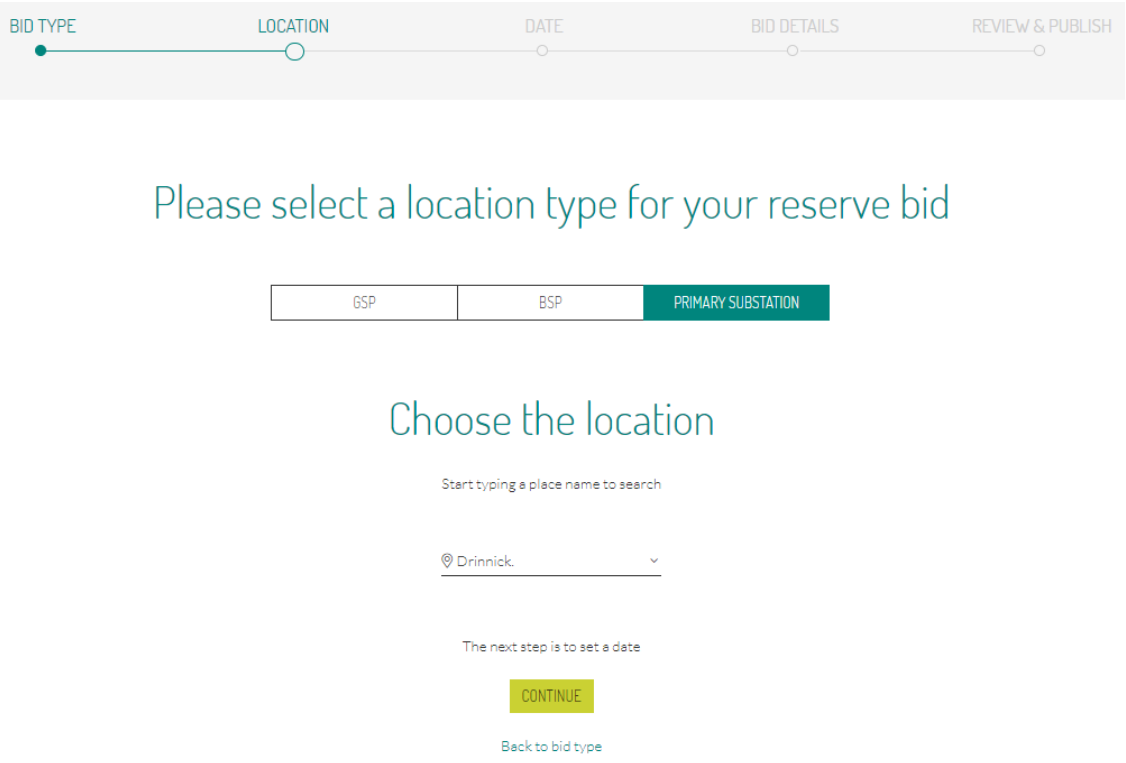
3.5.1 Submitting bids for services

Two methods of requesting the reserve of services were carried out during the trial. These were by means of sharing the data for required locations, power outputs and timings produced in Excel sheets by the EFFS tool, and by a trial operative using the platforms user interface to create bids for each required service. Figure 3.5-1 demonstrates an example of a weekly output from the EFFS tool for the EDF PowerShift platform, and Figure 3.5 2 demonstrates the process used with Cornwall Local Energy Market to request services on their user interface. Figure 3.5-3 then demonstrates the list of bids inputted using this interface.



Transaction Type	Publish Requirements
Transaction ID	20210600000000000000
Transaction Datetime	2021-06-08T09:19:09.82Z
Network Location	330024
Service Type	Secure
HH Datetime	2021-06-14T09:00:00Z
Power Requirements	0.4
HH Datetime	2021-06-14T09:30:00Z
Power Requirements	0.4
HH Datetime	2021-06-14T10:00:00Z
Power Requirements	0.7
HH Datetime	2021-06-14T10:30:00Z
Power Requirements	0.7
HH Datetime	2021-06-14T11:00:00Z
Power Requirements	0.6
HH Datetime	2021-06-14T11:30:00Z
Power Requirements	0.6
HH Datetime	2021-06-14T12:00:00Z
Power Requirements	0.4
HH Datetime	2021-06-14T12:30:00Z
Power Requirements	0.4
HH Datetime	2021-06-14T13:00:00Z
Power Requirements	0.4
HH Datetime	2021-06-14T13:30:00Z
Power Requirements	0.4
HH Datetime	2021-06-14T14:00:00Z
Power Requirements	0.3
HH Datetime	2021-06-14T14:30:00Z
Power Requirements	0.3
HH Datetime	2021-06-14T15:00:00Z
Power Requirements	0.4
HH Datetime	2021-06-14T15:30:00Z
Power Requirements	0.4
HH Datetime	2021-06-14T16:00:00Z
Power Requirements	1.6
HH Datetime	2021-06-14T16:30:00Z
Power Requirements	1.6

Figure 3.5-1 - Flexibility Requirements Excel File



Please select a location type for your reserve bid

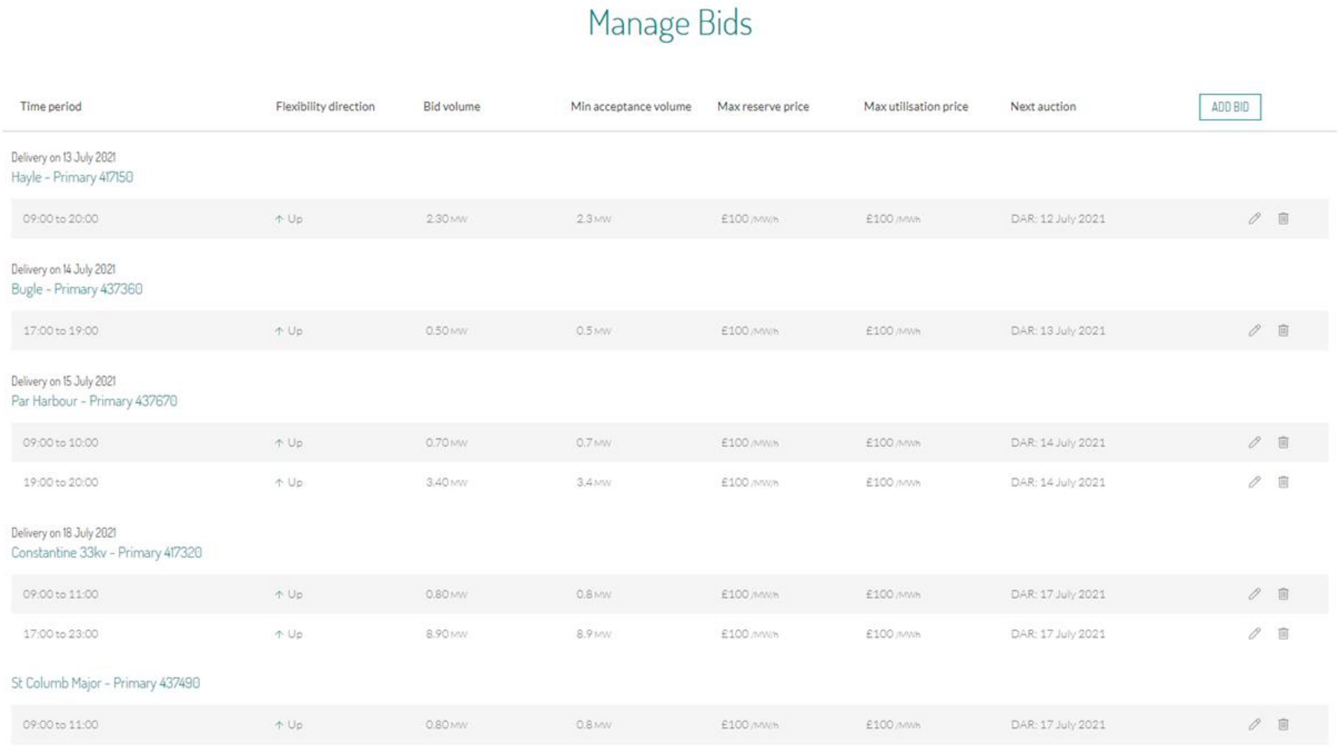
Choose the location

Start typing a place name to search

Drinnick.

The next step is to set a date

Figure 3.5-2 - CLEM Service Requirement Input Interface


Manage Bids

Time period	Flexibility direction	Bid volume	Min acceptance volume	Max reserve price	Max utilisation price	Next auction
Delivery on 13 July 2021 Hayle - Primary 417150						
09:00 to 20:00	↑ Up	2.30 MW	2.3 MW	£100 /MW/h	£100 /MWh	DAR: 12 July 2021
Delivery on 14 July 2021 Bugle - Primary 437360						
17:00 to 19:00	↑ Up	0.50 MW	0.5 MW	£100 /MW/h	£100 /MWh	DAR: 13 July 2021
Delivery on 15 July 2021 Par Harbour - Primary 437670						
09:00 to 10:00	↑ Up	0.70 MW	0.7 MW	£100 /MW/h	£100 /MWh	DAR: 14 July 2021
19:00 to 20:00	↑ Up	3.40 MW	3.4 MW	£100 /MW/h	£100 /MWh	DAR: 14 July 2021
Delivery on 18 July 2021 Constantine 33kv - Primary 417320						
09:00 to 11:00	↑ Up	0.80 MW	0.8 MW	£100 /MW/h	£100 /MWh	DAR: 17 July 2021
17:00 to 23:00	↑ Up	8.90 MW	8.9 MW	£100 /MW/h	£100 /MWh	DAR: 17 July 2021
St Columb Major - Primary 437490						
09:00 to 11:00	↑ Up	0.80 MW	0.8 MW	£100 /MW/h	£100 /MWh	DAR: 17 July 2021

Figure 3.5-3 - CLEM Submitted Weekly Bids

3.5.2 Flexibility Service Types

In order to ensure the trial represented the areas selected and to ensure learning from all service types were captured, the project made no effort to select generation technologies or control options. It therefore used all those available in the trial areas selected. The direct interface with individual flexibility services was previously de-scoped so individual generator type selection could not be carried out. Direct asset control was assessed, and the Project concluded that this form dispatch was not relevant, as the market platforms manage this stage of the process for the secure service. As captured in WPD EFFS_Ofgem Annual PPR_2_v1.0 - 07-10-19 (page 22) this is due to the evolution of the market platforms and not something within the control of the Project. This area will be further explored by the other TEF group partners (FUSION).

3.6 Trial Area

The EFFS trial area was focussed around Plymouth and Exeter in our South West Licence area. As such the network assessed has surrounded the Exeter City and Plymouth BSPs. This area is depicted within Figure 3.6-1.

The selection of this network was based around the number of flexibility schemes active in the area, allowing for adequate trial engagement, the range of sites locations and asset types present, and the suitability of our existing PSS®E models for use within the EFFS tool. This network encompassed a range of voltage levels, network types (overhead and underground). The areas selected also provided a range of geographic location types, where the cities of Plymouth and Exeter represent urban areas, but the surrounding towns and villages are on a smaller rural scale.

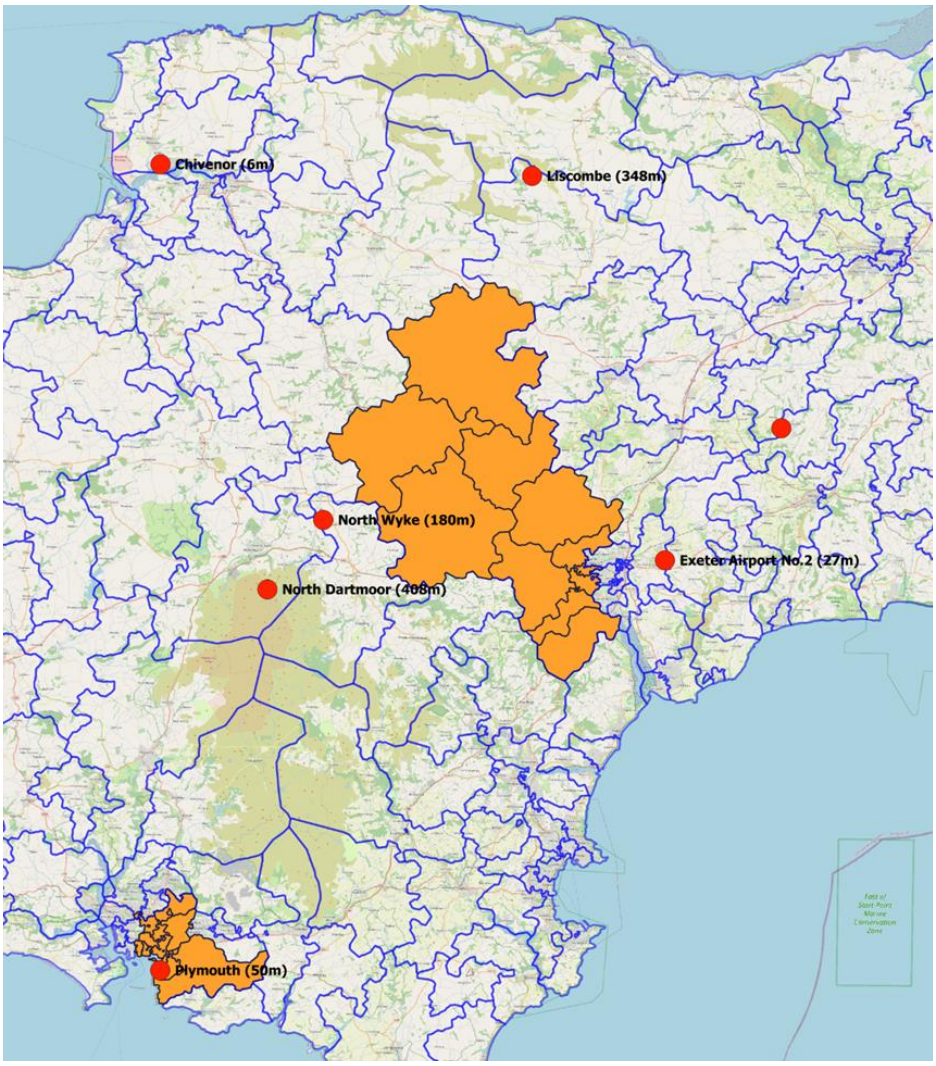


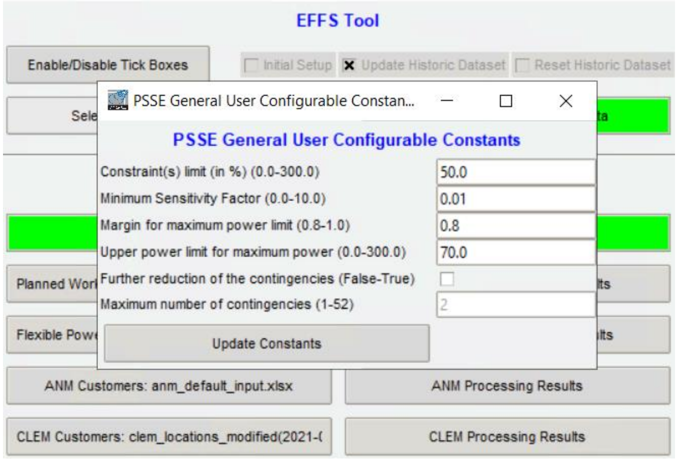
Figure 3.6-1 - Trial Area

3.7 Stress Testing

During the latter stages of the trial period, we carried out stress testing on the system to ensure its suitability for use in the future. The project undertook a review of the Distribution Future Energy Scenarios (DFES) to plan the stress testing. Through the analysis, it was ascertained that running all the scenarios would not provide much learning. Largely because a stress test is about volume and running different permutations would not show any more than the worst case. Initially the steady progression scenario was run, demonstrating an increase of around 10% from our currently loading conditions.

This was followed by further testing to represent 2035 conditions, where much higher penetration of LCTs are expected. In order to achieve this, our DFES data was once again used to create profiles with which the forecasts could be updated. This source of data was used to represent our future network generation and demand as it was the best fit for the trial area and represented a wider WPD view on what the tool would need to be able to function under. Once the forecasts for 2035 had been created, the EFFS process was run for a period of one month.

Following this an additional method of stress testing was carried out to demonstrate the ability of the EFFS tool to optimise a large number of services. As such, constraint analysis was carried out with a low set constraint limit as shown in Figure 3.7-1. This demonstrated a condition where a large number of constraints were identified and this enabled a stress test of the optimisation process to be carried out. Information on the outputs from this stress testing can be found within Section 4.5.



☐ Initial Setup ☒ Update Historic Dataset ☐ Reset Historic Dataset

Constraint(s) limit (in %) (0.0-300.0)	50.0
Minimum Sensitivity Factor (0.0-10.0)	0.01
Margin for maximum power limit (0.8-1.0)	0.8
Upper power limit for maximum power (0.0-300.0)	70.0
Further reduction of the contingencies (False-True)	☐
Maximum number of contingencies (1-52)	2

Figure 3.7-1 - EFFS Tool Constraint Configuration for Stress Testing

3.8 Conflict Avoidance

The initial Conflict Avoidance output for the project was the proposed high-level design of how the ESO and DSO would interface to facilitate conflict avoidance and the process to support this. The outputs from these sessions included:

- A proposed process to facilitate conflict avoidance;
- Creation of a list of conflict scenarios;
- Proposed principles on how to resolve conflict.

This work was used as a basis to inform the Primacy work of the Open Networks Project[1], specifically definition of the below user cases:

- More than one user of flexibility services trying to use the same asset at the same time. (regardless of whether they want the same action).
- More than one flex service user trying to use the same asset – only if working in opposite directions.
- Different flex service users procuring/dispatching services on different assets that are electrically arranged so that one service negates or partially negates the other.
- DNOs ANM scheme reducing generation constriction (or load restriction on Load ANM scheme in the future) which negates the impact of a flexibility service procured/dispatched by a third party.

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[1] Open Networks - Project 2021 Project Initiation Document - January 2021 │Version 1

- A flex service user (other than DNO) procuring/dispatching a service that results in a capacity threshold being breached on the DNO network, and then causes the DNO to take action (may or may not be flex service) to avoid that threshold.
- A DNO procuring/dispatching a service that results in a capacity threshold being breached at the Grid Supply Point and then causes the ESO a problem.
- The session discussed principles of how to resolve the constraints and an initial view of the data exchange data items.

During the project's build and test phase, it became apparent that implementing an operational conflict avoidance process would be too difficult for the following factors:

1. ESO services are dispatched near real-time and not necessarily scheduled, therefore making it difficult to share data or for a DSO to run operational conflict avoidance analyses; and
2. ESO assets were not located in the trial area and thus it was not appropriate to model the network to identify constraints.

Due to this complication and the infancy of ESO-DNO conflict avoidance in the industry, it was deemed impractical to implement an operational conflict avoidance process in the EFFS Trial. Moreover, due to the parallel work being undertaken by the Open Networks Project, anything established would have been superseded and very little learning derived.

However, it was deemed valuable to generate learning via creation of a data exchange interface mechanism that could be used to inform the Open Networks Project. The project designed a data exchange template that helped inform the Open Networks' Primacy work. The project facilitated workshops to design the initial data interface layer that would be used between the DSO and ESO to exchange service data to support conflict avoidance.

The final form of an operational data exchange for the DSO and ESO interface remains unclear. However, it was agreed that Comma Separated Values (CSVs) transferred via email or file transfers via an industry gateway could be used initially to start the process before a more thorough mechanism is established. One suggested future mechanism could be the use of the pre-existing mechanism Inter-Control Centre Communications Protocol (ICCP).

Table 3 is an example interface that the Project agreed on in the workshop that shows what items could be required to facilitate data exchange between parties.

Table 3 Conflict Avoidance Example Interface

Message Record	Cardinality	Data Item	Cardinality	Data Item Description	Data Item Data Type
Unit Data	1-*	Unique Identifier (To Be Considered)	1-1	A unique identifier that allows for the ESO and DSO to uniquely identify an asset proving a service	String
		General Unit ECR Data (To Be Considered)	1-1	Data items from the Embedded Capacity Register such as an address, location coordinates, resource type to be considered)	String
Service Definition Data (Procured/Scheduled/Dispatched)	1-*	Service Direction	1-1	The direction in which the service is being delivered	String
		Service Type	1-1	The type of service such as Real/Reactive/Up/Down	String
		Service Total Volume	1-1	The total amount of MW the service is delivering	Float
		Ramp Rate	1-1	The ramp rate of the asset in minutes	Integer
Service Window Procured/Scheduled/Dispatched	1-*	Service Start Date & Time	1-1	The service start date and time	Datetime

		Service End Date & Time	1-1	The service end date and time	Datetime
		HH Service Profile	1-*	The half-hourly MW profile the service is delivering	Float
ANM Static Data	0-*	Number of Monitoring Constraints	1-1	The total number of monitoring constraints the ANM monitors that the asset is connected.	String
		Type of Constraints	1-1	The type of constraints the ANM will manage	String
		Seasonal Constraints	1-1	Description of the seasonal constraints implemented	String

The information above is key and would enable the ESO and DSO staff to compare data and spot potential conflicts and resolve them. Below describes what each section of the message is and what it is used for.

3.8.1 Unit Data

Unit data is the fundamental part of the message and would contain a unique identifier to identify the asset. The industry is still working through this but it would likely be a newly created identifier or a Meter Point Administration Number (MPAN). Then the next piece of this record is the General unit data, WPD already publishes an extensive list of generation assets using its Embedded Capacity Register. Contained within this document is an abundance of 37 general data items collected about an asset. These data items range from asset address, its location coordinates and which primary substation it is connected to. General data can be grouped into the following categories:

- Uniquely Identifier i.e., MPAN;
- Asset Address Information;
- Network Location Data e.g., license Area, primary substation;
- Technology information e.g., resource type;
- Connection information e.g., flexible contract and connection status.

This information is quite key to determine that the ESO and DSO assets as either the same or different.

3.8.2 Service Definition Data

Focuses on the service information related to how the service is defined such as what type of service the asset is providing, what volume of power the asset will provide and how long the asset will take to ramp up to full power output.

3.8.3 Service Window Data

The service window data is the information concern with the actual timings and duration of the service. This would inform operators if a conflict existed by looking at the service start and end times in addition to the half-hourly profile of the power being outputted.

3.8.4 ANM Data

This is an optional record and would only be used when the asset was connected to an ANM part of the network. The ANM record helps understand if a constraint can be caused due to the automated nature of the system for example curtailing generation used by the ESO on the DSO system.

All in all the above data exchanged between the ESO and DSO would be sufficient to create a conflict avoidance process and would help both parties facilitate and resolve constraints. Although the industry has not established a process for resolution so would be hard to describe what this would look like and the benefit would lie, either way, conflict avoidance would still benefit the industry but to what extend is to be determined given this is not actively undertaken by industry at the moment.

4 Trials Evaluation

This section provides information on the overall performance, and success of the trials carried out, before providing significant detail on a number of key aspects of the process trialled.

4.1 Trials Performance

The trials carried out as part of the project have been successful in meeting the aims and timescales set out. As outlined below, 22 weeks of trial operation have been carried out with forecasting, constraint identification and service optimisation carried out in each. This was successfully carried out in line with the GANTT chart shown in Figure 4.1-1 which formed part of the PD7 Trials Strategy document submission.

Table 4 Trials Process Summary

Field	Count
No. Weeks Trialled (Operational)	22
No. Forecast Runs	4,028
No. Network Constraints Identified	366
No. Network Constraints Resolved	98
No. Flexibility Bids Received	390
No. Flexibility Bids Selected	102
No. MWs Selected	4,084
No. Services Where Asset Dispatched on Time	102

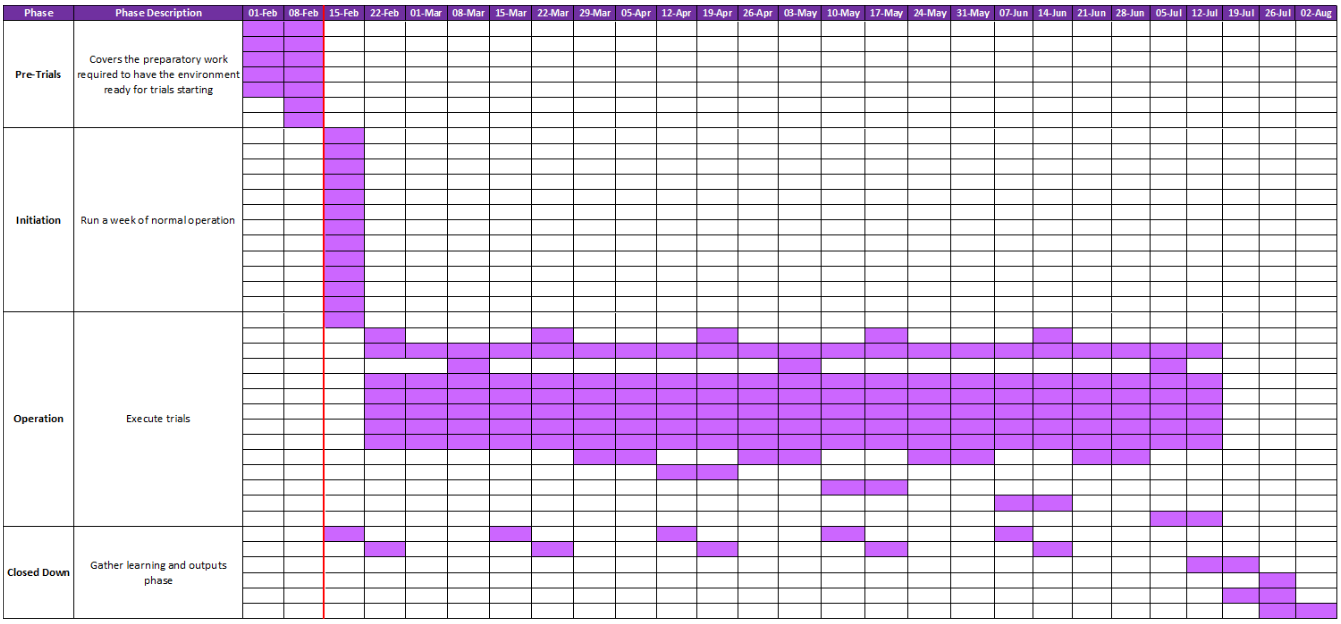

Figure 4.1-1 - Trial Period GANTT Chart

The following Exit Criteria were satisfied, which demonstrated that the aims of the trial had been met and enabled the closedown process to be carried out.

Table 5 - Exit Criteria

No	Details	Status
1.	The trial schedule is fully executed.	Passed
2.	Sufficient evidence and learning from each of the requirements are documented.	Passed

4.2 Forecasting Accuracy

Forecasting is a key part of the EFFS process, so it has therefore been important to assess this area during the trial and maximise learning by carrying out a comparison with real network data, and an alternative forecasting mechanism.

4.2.1 Networkflow Forecasting Accuracy

As outlined in the methodology above, regular forecasts have been produced by Networkflow as part of the EFFS trial process. These have been analysed to understand the accuracy seen when compared with real network load and generation data. The project produced forecasts at 21 primary substations and 7 generation sites (4 Short Term Operating Reserve (STOR), 2 Solar and 1 Multi-Fuel Generator). These sites were forecasted for throughout the trial at the following time-horizons:

- Six Months Ahead
- Month Ahead
- Two Weeks Ahead
- Week Ahead
- Day Ahead

Throughout the project, MAPE (Mean Absolute Percentage Error) has been used as the measure of forecasting accuracy. This follows on from work carried out in the assessment and design stages within forecasting for the EFFS project. When the forecast algorithm was developed by Smarter Grid Solutions, MAPE was chosen to be the standard accuracy metric.

MAPE is a measure of how accurate a forecasting system is. This figure is presented as a percentage and can be calculated using the following equation:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|$$

Where:

- n is the number of points
- A_t is the actual value
- F_t is the forecast value

As such, higher accuracy is demonstrated by a lower MAPE value, and a value of 0% would indicate that the forecast data and real data are equal.

Table 6 and Table 7 below show a summary of the accuracy, shown in MAPE, found during the trial period, both as a general view and by equipment type forecasted:

Table 6 - Forecasting Performance Summary

Forecast type	MAPE	Median MAPE
Overall MAPE Across All Channels and Forecast Types	52.18%	18.49%
Overall MAPE MW Across All Forecast Types	41.93%	18.19%
Overall MAPE MVAR Across All Forecast Types	62.40%	19.05%

Table 7 - Forecasting Performance by Equipment Type

Equipment type	No. Of Equipment Types	Unit of measurement	MAPE	Median MAPE
Primary Substation	21	MW	21.15%	14.76%
		MVAR	50.43%	14.62%
STOR	4	MW	132.41%	142.73%
		MVAR	122.91%	126.5%
Solar Farm	2	MW	92.88%	71.89%
		MVAR	93.20%	86.25%
Multiple Fuel Type Generation[2]	1	MW	0%	0%
		MVAR	0%	0%

These figures demonstrate that overall the Networkflow forecasting method performed best when forecasting demand, but its outputs were limited when STOR and Solar Farm forecasting was carried out. The Multiple Fuel Type Generation has been included within these results as it was present within the trial area, but forecasting on this was not possible due to a lack of historic generation data. It was found that this asset had not been active since 2018, so no data was available as an input for the algorithm.

Use of Historic Weather Data

The project undertook two scenarios of forecasting, with and without the use of historic weather data. The core production environment ran forecasts without weather data for each node. The test environment used historic weather data to evaluate the impact on accuracy. The conclusion was that historic weather data did not improve forecast accuracy in all instances, about a third of the sites benefited from historic weather data. Although only 40% of the sites where historical weather was better would it improved the accuracy by greater than half an MW per Half Hour. The project concluded that historic load data was the key driver for accurate forecasts with the XGBoost Method. For confirmation of the impact of this historic weather data further testing would need to be carried out, as this represents the impact in the cases studied using only the XGBoost forecasting method.

Below, Table 8 and Table 9 summarise the findings and provides counts of the number of equipment where the forecast scored best based whether historical weather data was used using the projects accuracy scores:

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[2] Note: this asset has produced zero output since 2018. It was included in the forecast as it was part of the trial area.

Table 8- Comparison of forecasts scenarios using historical weather data (MW)

		MAPE			
Equipment Type	**No. Sites Historical Weather Was More Accurate**	**Difference Range (%)**	**No. Sites No Weather Was More Accurate**	**Difference Range (%)**	**No Data**
Primary Substation	6	0.5 - 14.13	15	0.17 - 4.9	0
STOR	0	0	4	0 -3407	0
Solar Farm	0	0	2	100 - 149.28	0
Multiple Fuel Type Generation	0	0	0	0	1
Total	6	31%	21	69%	1

Table 9 - Comparison of forecasts scenarios using historical weather data (MVAr)

	MAPE				
Equipment Type	**No. Sites Historical Weather Was More Accurate**	**Difference Range (%)**	**No. Sites No Weather Was More Accurate**	**Difference Range (%)**	**No Data**
Primary Substation	6	1.25 - 31.91	10	0.06 - 16.29	5
STOR	0	0	4	0 - 435	0
Solar Farm	0	0	2	8.33 - 23.85	0
Multiple Fuel Type Generation	0	0	0	0	0
Total	6	31%	16	59%	6

The project identified poor forecast accuracy caused by the 2020 lockdowns. As the forecast algorithm was trained on 2020 data to predict 2021, the algorithm predicted a downward trend yet demand in May 2021 was higher than usual due to poor weather causing the actual and predicted values to diverge.

The forecasting inaccuracy up to the end of March 2021 was circa 7% error rating. In April and May it averaged circa 22.31% for substation loading (i.e. MW consumption). Two studies were done to evaluate how best to solve this issue. The first was to train the model with two years' worth of MW load data (2019 and 2020); this resulted in a MAPE of 18.15%. The second was overlaying the 2019 dataset with 2020's. This resulted in a MAPE of 16.19%. Forecasting performance improved once load profiles returned to normal in June and July.

Forecasting Horizon Comparison

Forecasting accuracy has been compared over multiple time horizons during the course of the trial period. The aim of this was to provide learning on what is the best fit horizon to use for forecasting, demonstrate where value lies in carrying out forecasting further ahead of time, and to validate all time horizons against each other's outputs.

Table 10 below shows the MAPE findings for this process. As in previous accuracy data, limitations due to available data have reduced the accuracy of some generation types.

Table 10 - Equipment Type against Time-Horizon Performance

	MAPE				
Equipment Type	**Channel Type**	**One Week Ahead**	**Two Weeks Ahead**	**One Month Ahead**	**Six Months Ahead**
Primary Substation	MW	21.49%	21.85%	19.76%	21.07%
	MVAr	47.70%	47.58%	54.51%	52.21%
STOR	MW	107.89%	78.86%	93.34%	98.34%
	MVAr	92.78%	85.95%	100.91%	96.03%
Solar Farm	MW	144.70%	141.53%	126.65%	121.48%
	MVAr	124.00%	122.48%	133.19%	117.68%
Multiple Fuel Type Generation	MW	0.00%	0.00%	0.00%	0.00%
	MVAr	0.00%	0.00%	0.00%	0.00%

Day Ahead Forecasting Comparison

The day ahead forecast analysis is separate from the Forecast Detail in Table 10 as this forecast type was run occasionally over the course of the trial. It would therefore be inappropriate to compare accuracies with longer, more consistent time periods. However, for the period the day ahead forecast was run the analysis below shows the accuracy of other forecasts during that time to give a more representative view of forecast accuracy.

Table 11 - Equipment Type against Time-Horizon Performance Including Day Ahead

		MAPE				
Equipment Type	**Channel Type**	**Day Ahead**	**One Week Ahead**	**Two Weeks Ahead**	**One Month Ahead**	**Six Months Ahead**
Primary Substation	MW	16.47%	15.59%	15.94%	16.53%	16.73%
	MVAr	89.29%	59.18%	60.73%	60.88%	61.73%
Solar Farm	MW	0.00%	119.10%	84.42%	110.56%	103.73%
	MVAr	0.00%	98.72%	98.72%	106.73%	108.80%
STOR	MW	243.86%	149.88%	149.26%	137.98%	134.17%
	MVAr	144.21%	127.14%	122.85%	137.53%	131.41%
Multiple Fuel Type Generation	MW	0.00%	0.00%	0.00%	0.00%	0.00%
	MVAr	0.00%	0.00%	0.00%	0.00%	0.00%

As outlined within section 3.2, week ahead and two week ahead forecasting has been utilised for the trial runs, as it had been deemed most suitable for this use case. The MAPE values calculated suggest that the Networkflow method of forecasting provides limited benefit for altering the forecast horizon under primary substation demand, and once again the outputs were limited in terms of accuracy for the Solar Farm and STOR forecasting.

Primary Substation Forecast Breakdown

This section contains a profile comparison of the forecasting carried out at primary substation level. This has been carried out over a range of dates during the trial period, and primary substations within each of the two trial BSP areas.

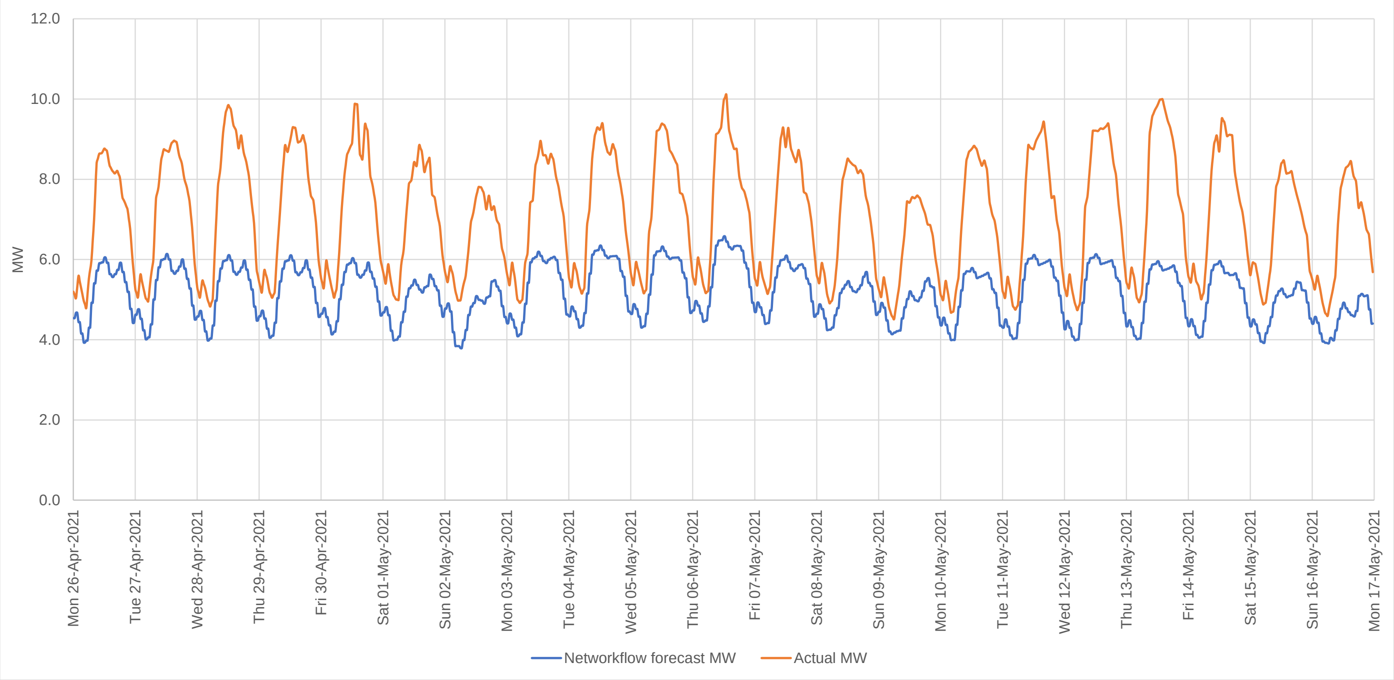


Figure 4.2-1 Athelstan Road MW forecast comparison (Networkflow forecast and actual)

Figure 4.2 1 shows that the Networkflow forecast MW for Athelstan Road during the period 26-Apr-2021 to 16-May-2021 falls in the range 3.8-6.6 MW with an average daily range of approximately 2.0 MW. This is compared with actual demand in the range 4.5-10.1 MW and an average daily range of approximately 4.0 MW. The profile of the Networkflow demand forecast appears to approximately mirror that of the actual demand profile, but based on visual inspection the minimum forecast values appear to be on average approximately 0.8 MW lower than the actual values and the maximum forecast values appear to be on average approximately 3.0 MW lower than the actual values. There is no clear reason to indicate why the Networkflow forecast is well below the actual demand at Athelstan Road as the demand at this site has not varied substantially over the last 5 years.

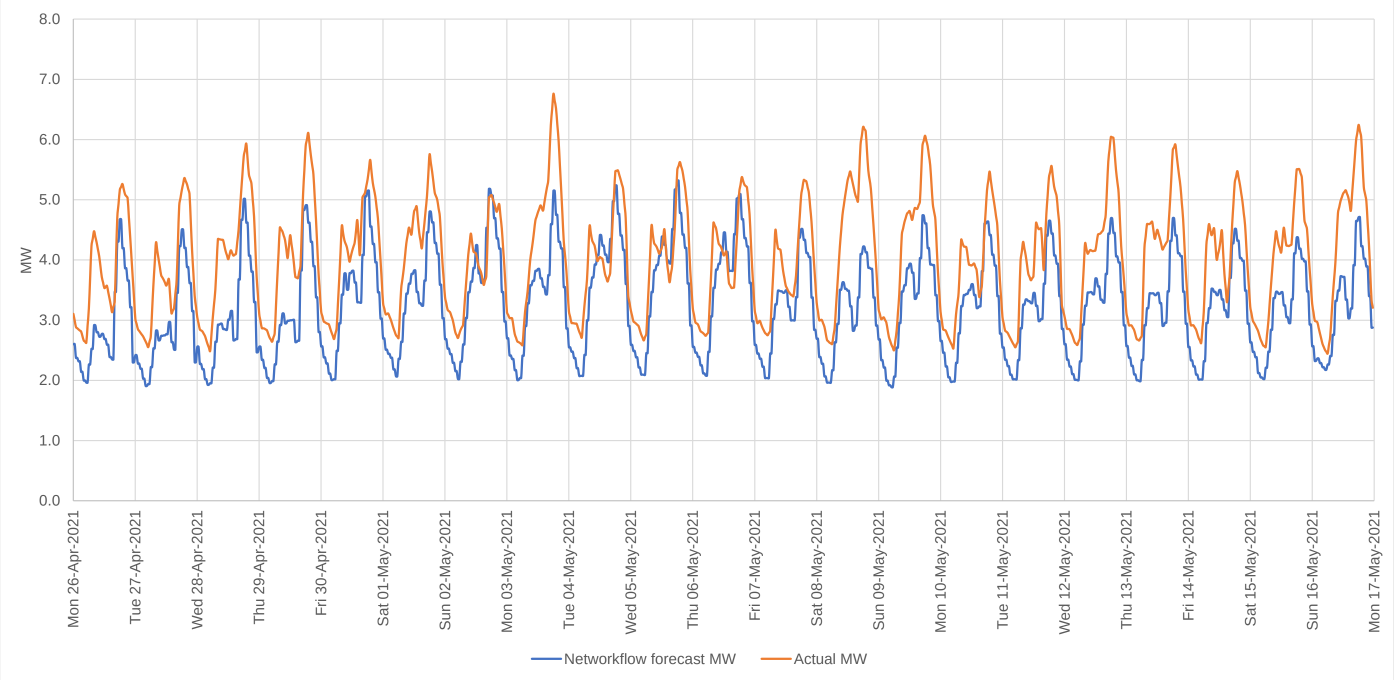


Figure 4.2-2 **Elim Terrace MW forecast comparison (Networkflow forecast and actual)**

Figure 4.2 2 shows that the Networkflow forecast MW for Elim Terrace during the period 26-Apr-2021 to 16-May-2021 falls in the range 1.9-5.3 MW with an average daily range of approximately 3.0 MW. This is compared with actual demand in the range 2.4-6.8 MW and an average daily range of approximately 3.0 MW. The profile of the Networkflow demand forecast appears to approximately mirror that of the actual demand profile, but based on visual inspection the minimum forecast values appear to be on average approximately 0.7 MW lower than the actual values and the maximum forecast values appear to be on average approximately 1.0 MW lower than the actual values. The forecast for Elim Terrace was the most accurate out of all the substations selected for comparison. It was noted that Elim Terrace had the lowest recorded maximum demand compared with the other sites and has the highest proportion of domestic customers. These factors could have contributed to a more accurate Networkflow forecast for this particular substation when compared with others.

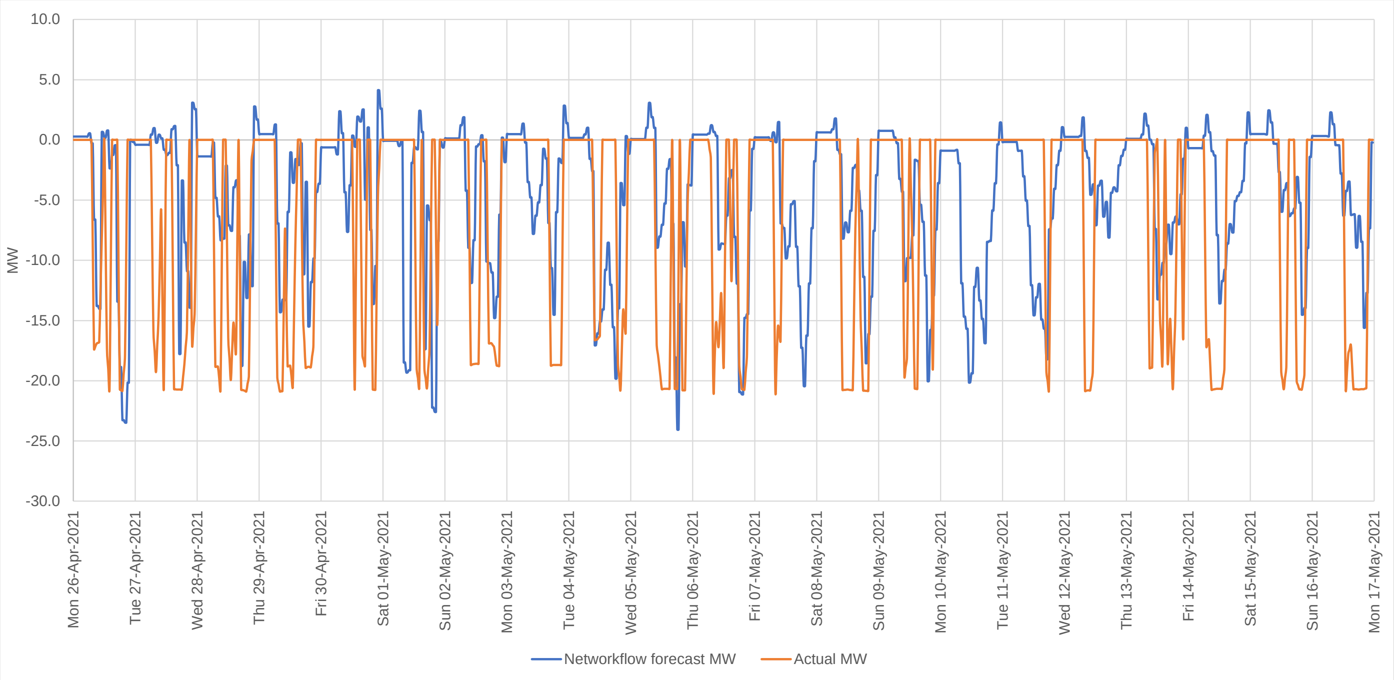


Figure 4.2-3 **Cattedown 33kV STOR Site MW forecast comparison (Networkflow forecast and actual)**

Figure 4.2 3 shows that the Networkflow forecast MW for Cattedown 33kV STOR site during the period 26-Apr-2021 to 16-May-2021 falls in the range -24.0-4.1 MW (where negative means that the generator is exporting power). This is compared with actual generation in the range -20.9-0 MW. There is no discernible daily profile for the generation from a STOR generator, which is dispatched by National Grid ESO. However, from visual inspection the Networkflow forecast values appear to include periods of import (positive) as well as export above 21 MW.

4.2.2 Primary Substation comparison against alternative Forecasting Metrics

In order to fully assess the competency of the forecasting system developed within the EFFS project, and to maximise the project learning on load and generation forecasting, a comparison with an alternative forecasting tool has been carried out.

The alternative tool used for this comparison uses historic demand, generation and weather data combined with forecast weather data to produce a minimum of one week ahead real and reactive power forecasts. The methodology adopted correlates historic measured electricity demand and generation with the key drivers influencing them (weather effects: historic temperature and solar radiation scaled by the installed solar PV generation capacity). The tool uses an Excel spreadsheet, which gathers data from supporting spreadsheets for each primary substation within the trial areas. The spreadsheet provides transparent calculation of the forecast demand using historic demand profiles and relationships with historic weather data. The methodology using such historic patterns is appropriate for relatively short-term forecasting, in which time the nature of the users and producers of electricity and relationships between the key variables remains broadly static.

The following comparisons have been made using the same sets of input data to ensure a valid comparison could be carried out. Presented within this section is a selection of representative figures from multiple substations with each of the trial BSP areas.

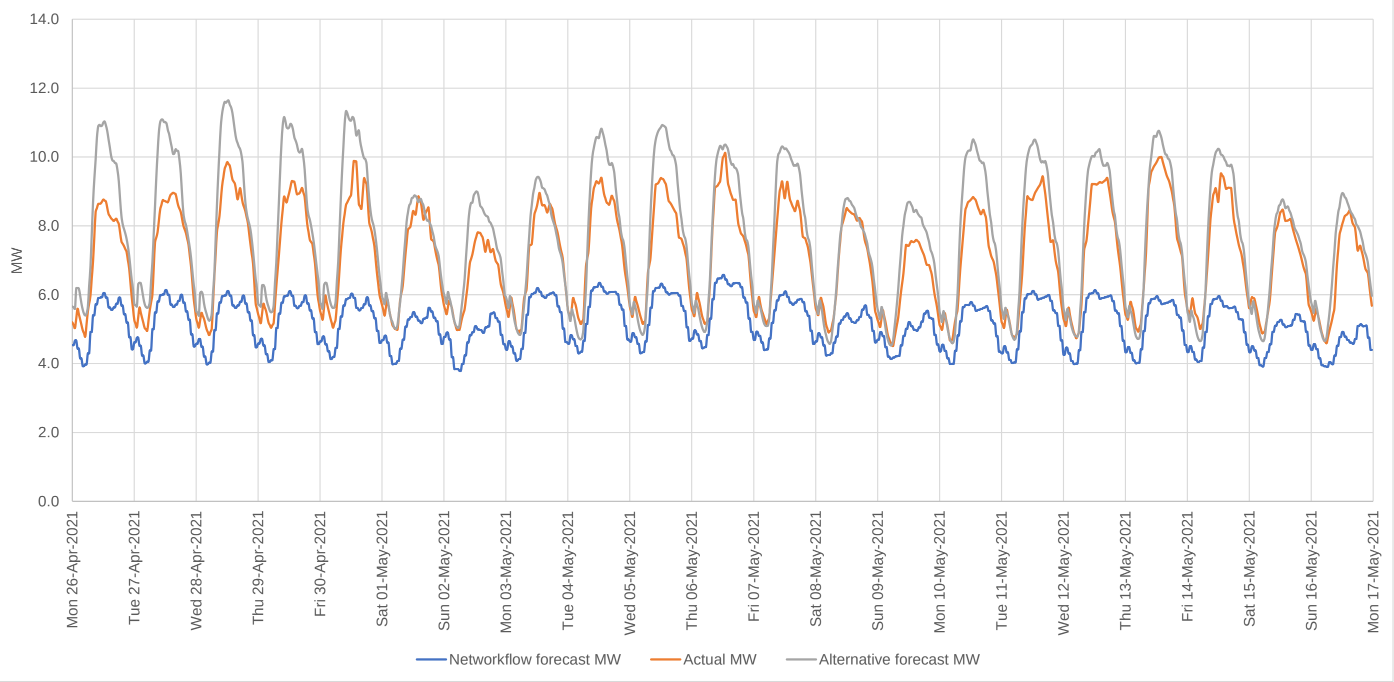


Figure 4.2-4 Athelstan Road MW forecast comparison (Networkflow forecast, alternative forecast and actual)

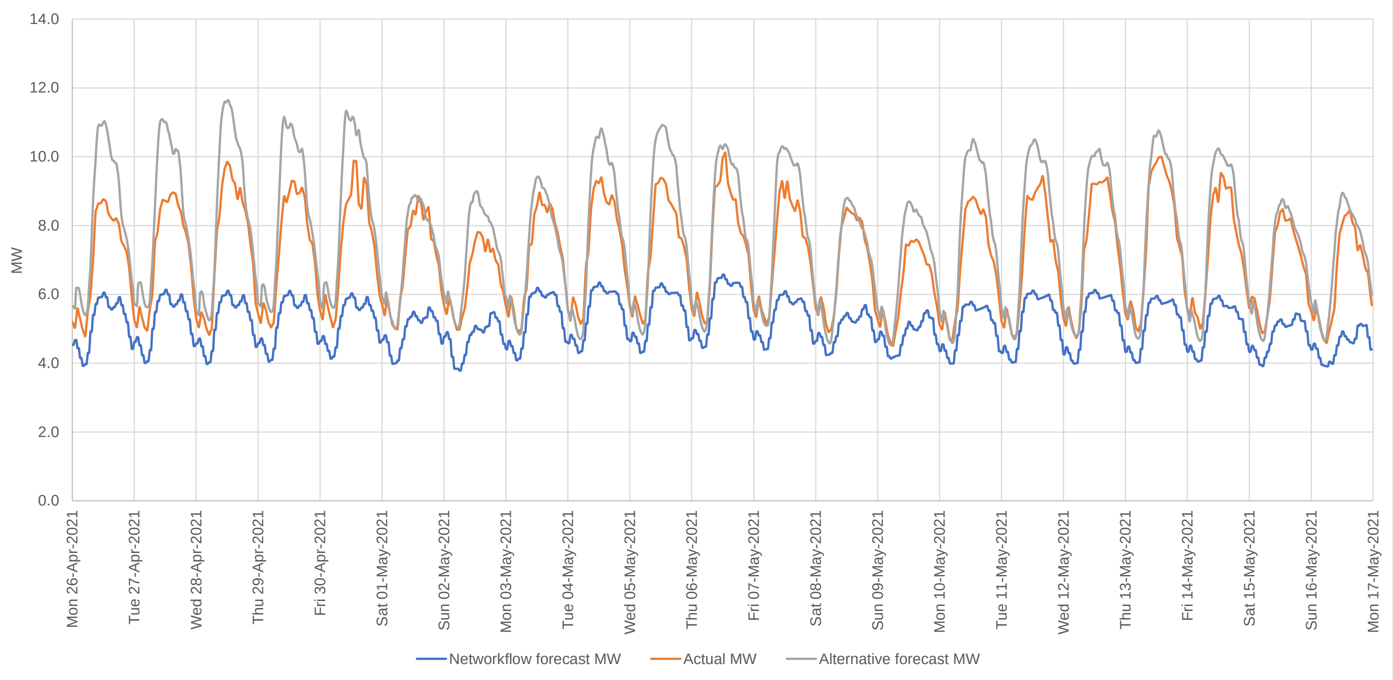


Figure 4.2-4Figure 4.2 4 shows a comparison of Networkflow forecasting to the alternative approach at Athelstan Road. The maximum demand for Athelstan Road primary in the 2020 LTDS is recorded as 14.0 MVA. The alternative forecast for Athelstan Road appears to match the actual minimum demand values well and the maximum demand values are on average approximately 1.0 MW higher than the actual values. The variations in the alternative forecast values look to be caused by varying solar PV output, and this may be an area for further refinement within the tool.

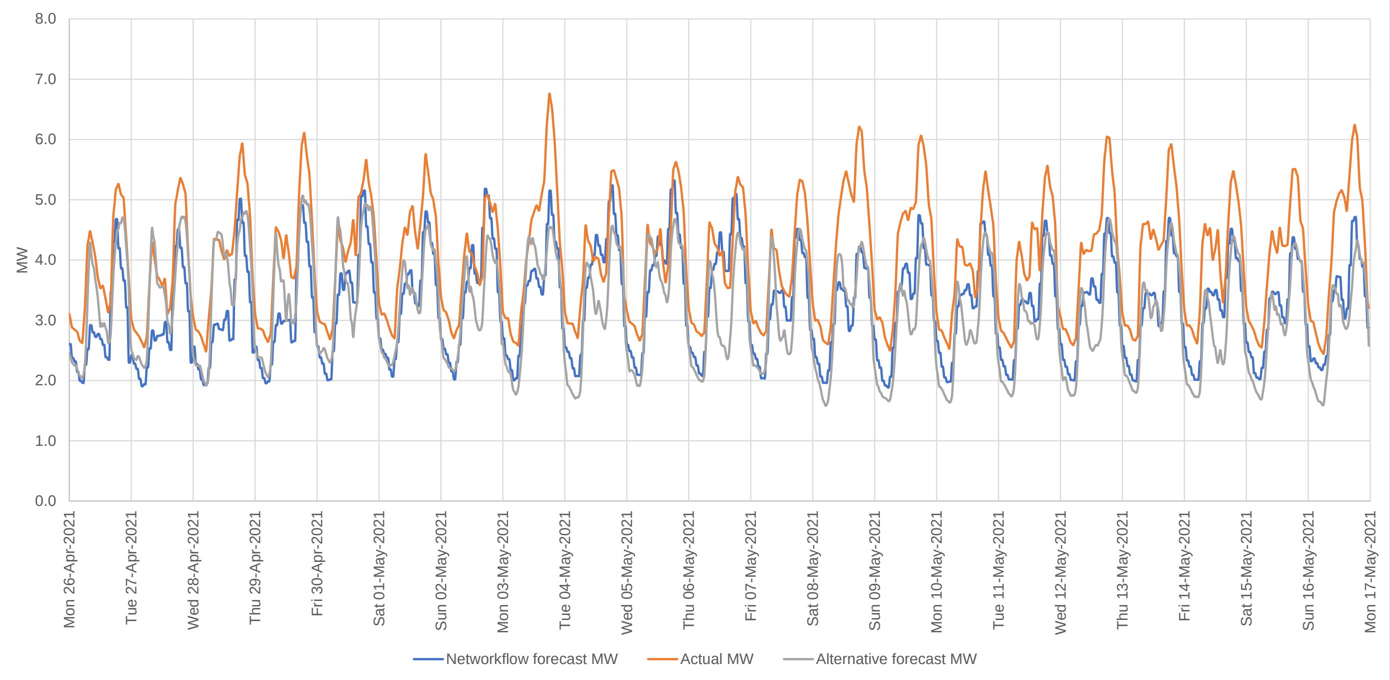


Figure 4.2-5 Elim Terrace MW forecast comparison (Networkflow forecast, alternative forecast and actual)

Figure 4.2 5 shows a comparison of Networkflow forecasting to the alternative approach at Elim Terrace. The maximum demand for Elim Terrace primary in the 2020 LTDS is recorded as 7.4 MVA. This alternative forecast for Elim Terrace appears to align closely with the Networkflow forecast values.

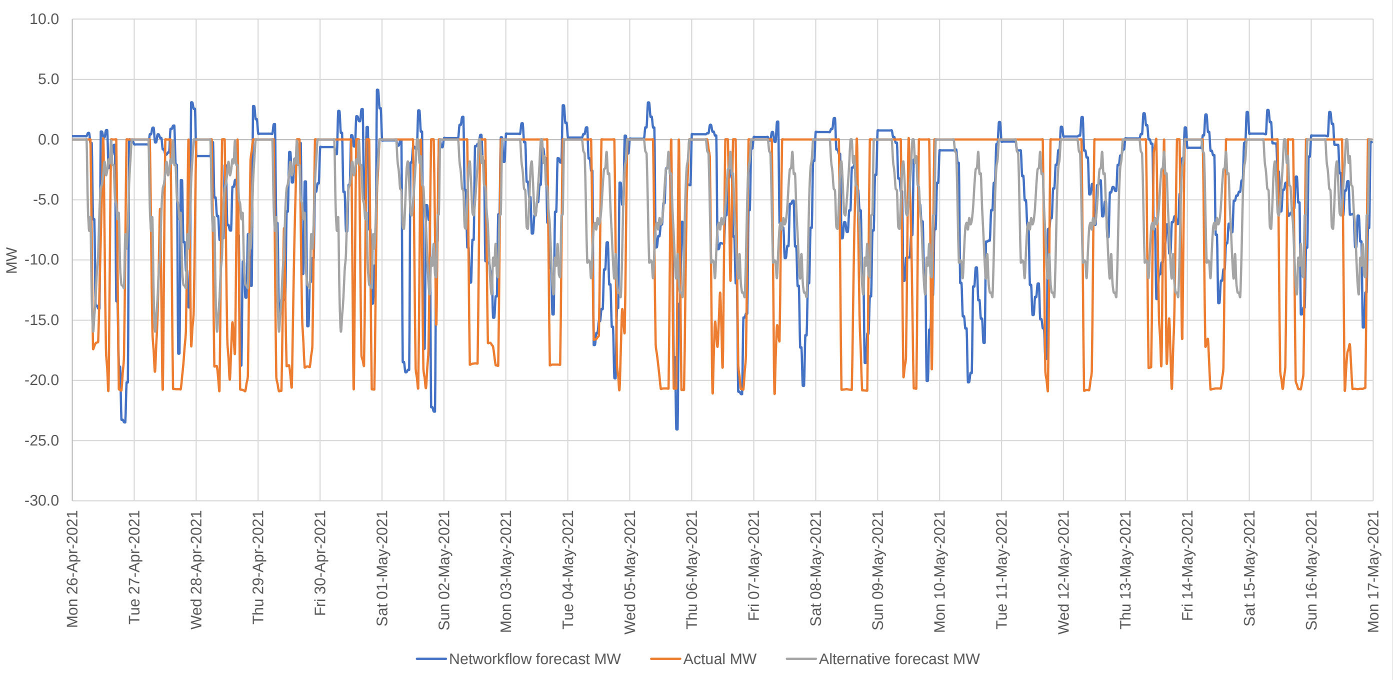


Figure 4.2-6 Cattedown 33kV STOR Site MW forecast comparison (Networkflow forecast, alternative forecast and actual)

Figure 4.2 6 shows a comparison of Networkflow forecasting to the alternative approach at Cattedown STOR Site. The alternative forecast for Cattedown 33kV STOR site appears to match the actual minimum generation marginally better than the Networkflow forecast, but forecasting of output from STOR generators requires caution. Rather than using the historical forecasting approach, for STOR generators it is proposed that it might be more appropriate to obtain an understanding about the algorithm and parameters used for the ESO dispatch instructions.

4.3 Constraint Analysis

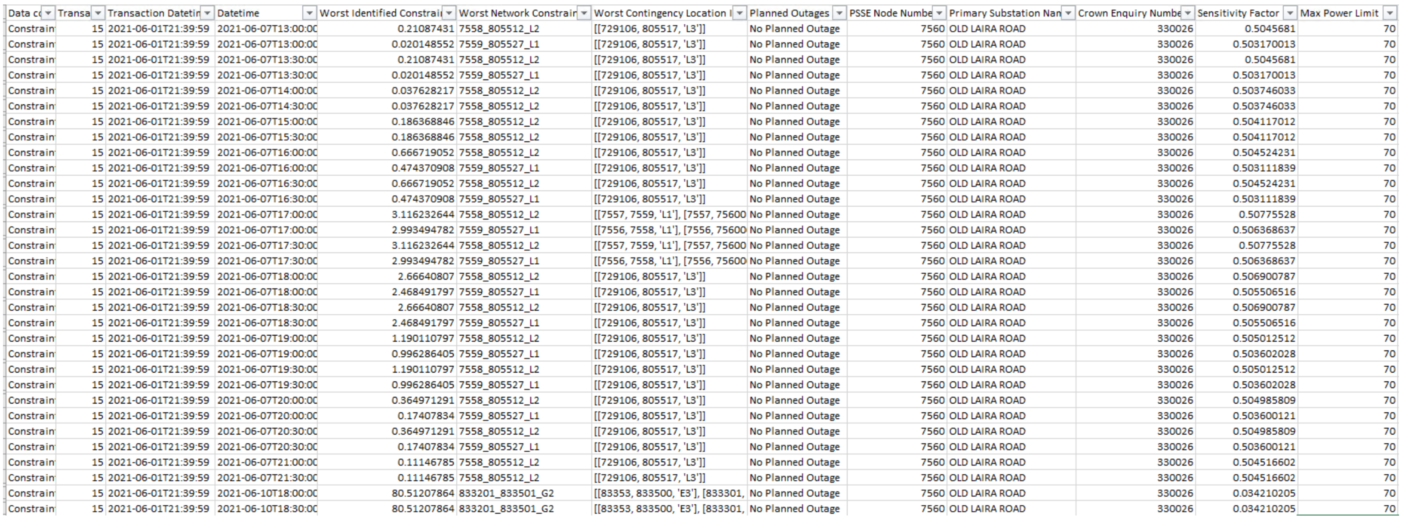
Constraints are identified in every run of the EFFS system, and as part of the trial constraint analysis has been run for four different scenarios. These are:

- Networkflow Forecast Data
- Updated Networkflow Forecast Data
- Actual TS data taken following the trial week
- Stress Testing Data reflecting DFES Scenarios

The aim of this was to fully demonstrate the capabilities of the constraint analysis function and demonstrate its ability to calculate constraints under different conditions.

4.3.1 Constraints under Networkflow Forecast Data

For each weekly run, as part of the end to end system testing a constraints and sensitivities factor file was produced by the EFFS tool. Please see Figure 4.3-1 below for an example. This demonstrated the output of the constraint analysis for each given forecast and network condition, and was used as an input into the later service selection process.



Data c	Transa	Transaction Datetin	Datetime	Worst Identified Constrai	Worst Network Constrai	Worst Contingency Location I	Planned Outages	PSSE Node Numbe	Primary Substation Na	Crown Enquiry Numbe	Sensitivity Factor	Max Power Limit
Constrain	15	2021-06-01T21:39:59	2021-06-07T13:00:0	0.21087431	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.5045681	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T13:00:0	0.020148552	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503170013	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T13:30:0	0.21087431	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.5045681	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T13:30:0	0.020148552	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503170013	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T14:00:0	0.037628217	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503746033	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T14:30:0	0.037628217	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503746033	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T15:00:0	0.186368846	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.504117012	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T15:30:0	0.186368846	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.504117012	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T16:00:0	0.666719052	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.504524231	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T16:00:0	0.474370908	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503111839	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T16:30:0	0.666719052	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.504524231	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T16:30:0	0.474370908	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503111839	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T17:00:0	3.116232644	7558_805512_L2	[[7557, 7559, 'L1'], [7557, 75600	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.50775528	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T17:00:0	2.993494782	7559_805527_L1	[[7556, 7558, 'L1'], [7556, 75600	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.506368637	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T17:30:0	3.116232644	7558_805512_L2	[[7557, 7559, 'L1'], [7557, 75600	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.50775528	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T17:30:0	2.993494782	7559_805527_L1	[[7556, 7558, 'L1'], [7556, 75600	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.506368637	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T18:00:0	2.66640807	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.506900787	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T18:00:0	2.468491797	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.505506516	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T18:30:0	2.66640807	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.506900787	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T18:30:0	2.468491797	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.505506516	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T19:00:0	1.190110797	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.505012512	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T19:00:0	0.996286405	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503602028	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T19:30:0	1.190110797	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.505012512	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T19:30:0	0.996286405	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503602028	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T20:00:0	0.364971291	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.504985809	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T20:00:0	0.17407834	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503600121	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T20:30:0	0.364971291	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.504985809	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T20:30:0	0.17407834	7559_805527_L1	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.503600121	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T21:00:0	0.11146785	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.504516602	70
Constrain	15	2021-06-01T21:39:59	2021-06-07T21:30:0	0.11146785	7558_805512_L2	[[729106, 805517, 'L3']]	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.504516602	70
Constrain	15	2021-06-01T21:39:59	2021-06-10T18:00:0	80.51207864	833201_833501_G2	[[83353, 833500, 'E3'], [833301,	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.034210205	70
Constrain	15	2021-06-01T21:39:59	2021-06-10T18:30:0	80.51207864	833201_833501_G2	[[83353, 833500, 'E3'], [833301,	No Planned Outage	7560	OLD LAIRA ROAD	330026	0.034210205	70

Figure 4.3-1 - Constraint Analysis Output

4.3.2 Comparison of EFFS Tool Constraints with Flexible Power Constraint Management Zone (CMZ) Data

To demonstrate how constraint analysis occurred during the trials, we performed several power-flow analysis runs to identify constraints and compared them to Flexible Power's "best view" flexibility requirements datasets for the two CMZs that the trial area covered. To align with the Flexible Power datasets the powerflow analysis runs were done for a month at a time by aggregating day files (WPD time series data) and week files (Networkflow default forecasts), and then CMZs were disaggregated after the analysis run using constraint location IDs contained within the output.

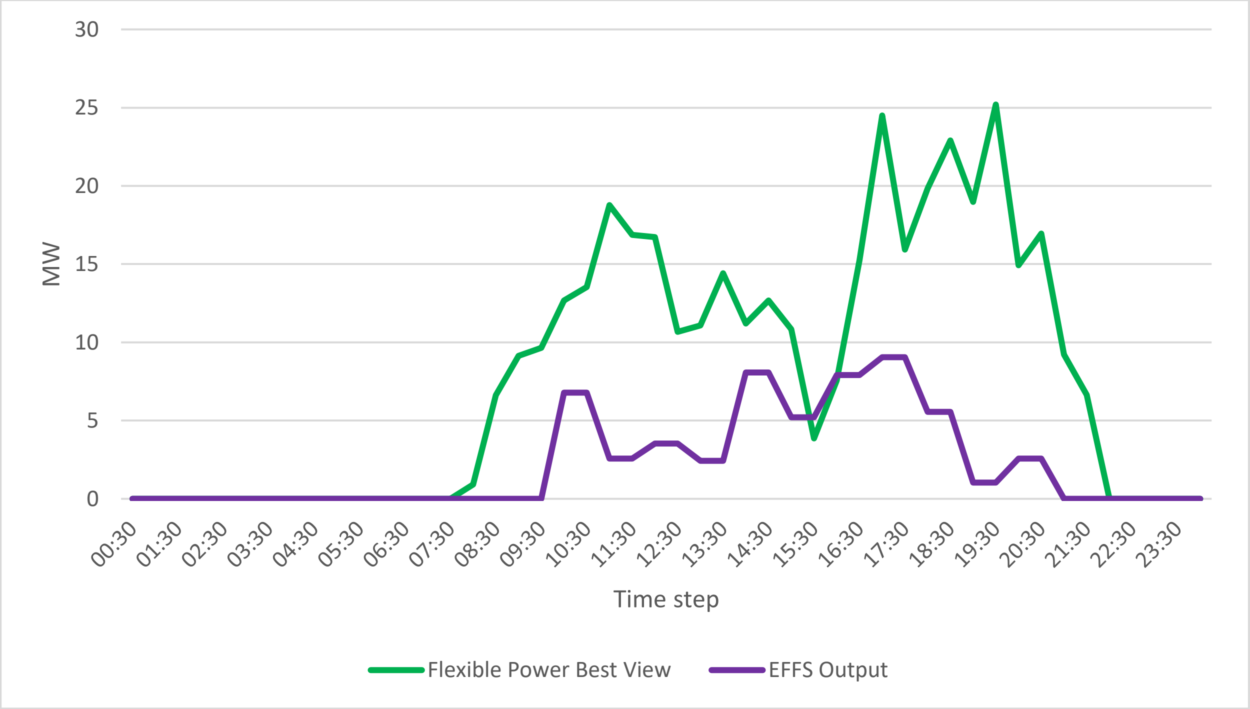


Figure 4.3-2 - Calculated constraints within Plymouth CMZ during June 2021 using Networkflow Forecasts

Figure 4.3-2 was generated by aggregating Networkflow weekly forecasts for the whole of June and passing them through the EFFS Tool at 95% constraint threshold. The MW required at each half-hour time step for each day were then aggregated to give a profile of what is required for each time step over the month. The Flexible Power best view for the same area of network and month was then overlaid to give an indication of how they differ.

However Networkflow forecasts have a degree of inaccuracy as explained above in this report, it was decided that the same exercise would be run using WPD recorded time series data, running constraint analysis on this data post-event.

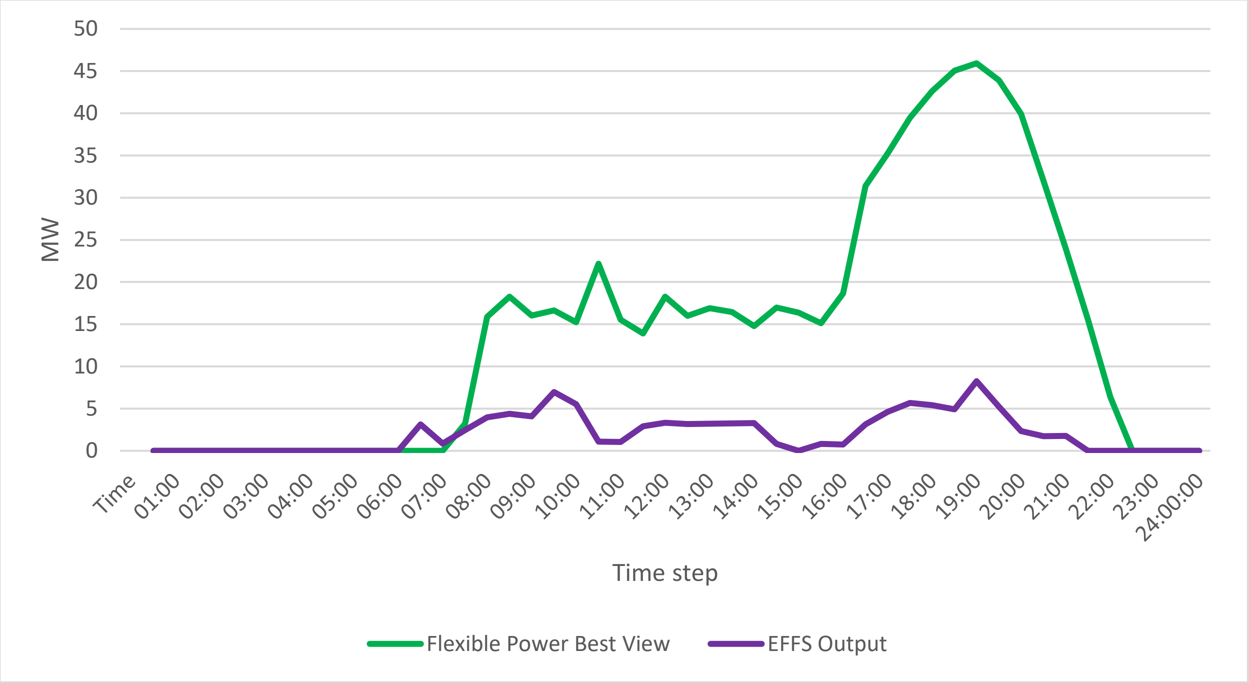


Figure 4.3-3 - Calculated constraints within Plymouth CMZ during March 2021 using recorded time-series data

Figure 4.3-3 was generated by aggregating WPD's recorded time series data, cleansing it and running it through the EFFS Tool Power-flow analysis function as if it were a forecast. This outputted the constraints that would have been required for the month (March 2021) at a 95% constraint threshold under the worst-case contingencies considered by the tool. The Flexible Power best view for the same area of network and month was then overlaid to give an indication of how they differed.

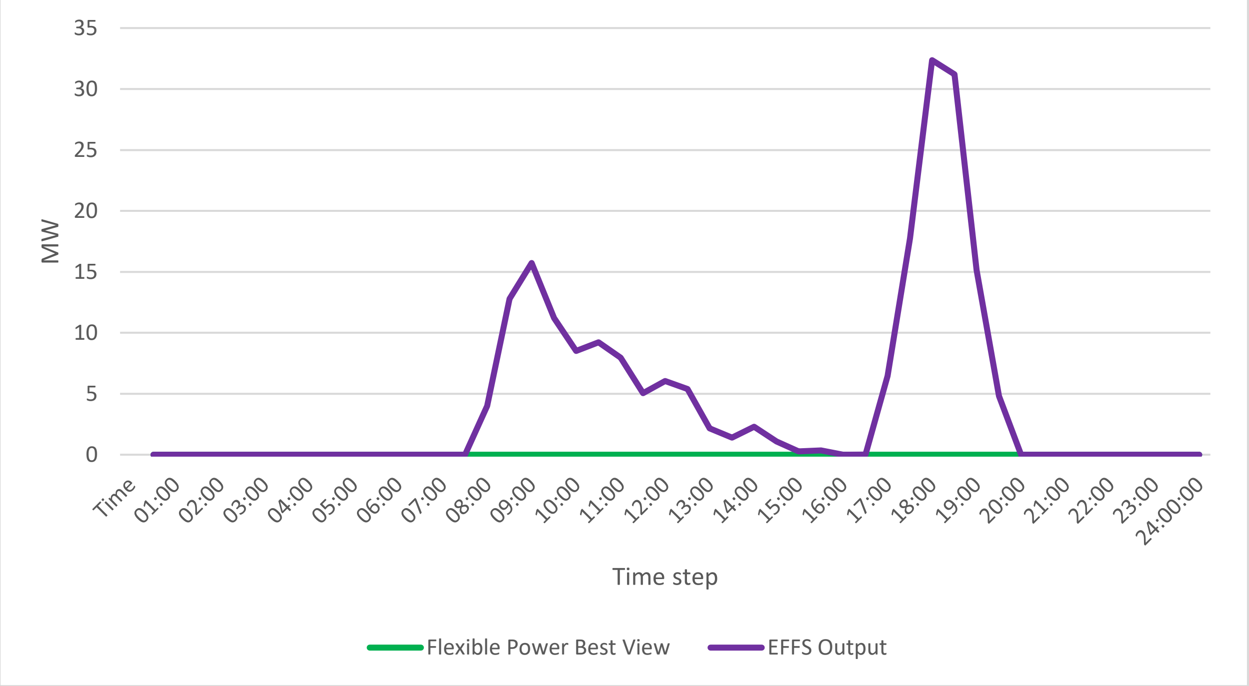


Figure 4.3-4 - Calculated constraints within Exeter City CMZ during March 2021 using recorded time-series data

Figure 4.3-4 was generated by aggregating WPD's recorded time series data, cleansing it and running it through the EFFS Tool Power-flow analysis function as if it were a forecast. This outputted the constraints that would have been required for the month (March 2021) at a 95% constraint threshold under the worst-case contingencies considered by the tool. Note that within this period within Exeter City CMZ, Flexible Power had no flexibility requirements forecasted, however the EFFS Tool calculated a requirement of 101MWh.

The comparison of EFFS output and Flexible Power's 'best view' data should only be considered indicative as each dataset is generated using different parameters.

4.3.3 Contingencies from Non-Convergent Load Flows

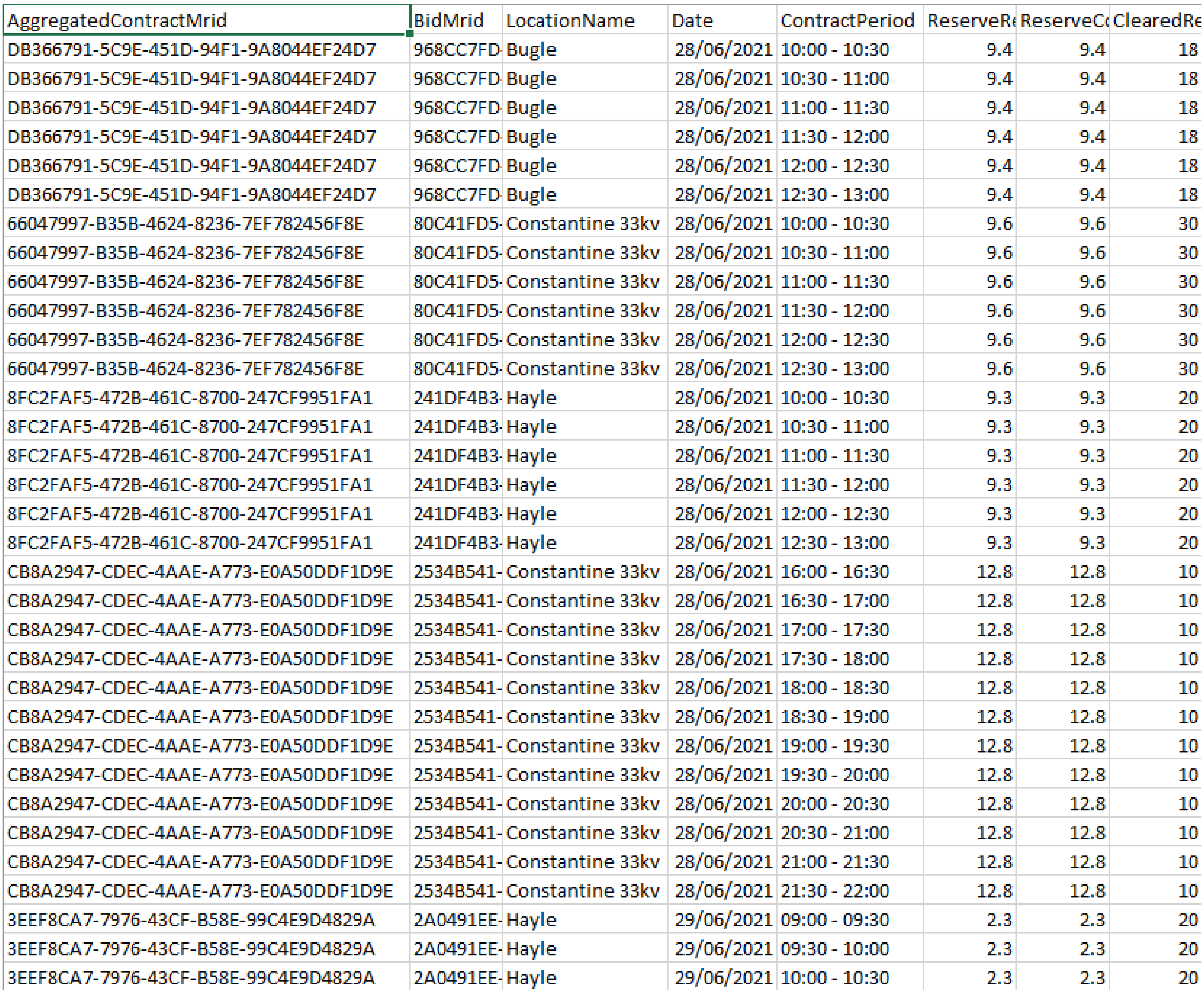
During power system analysis it is possible for a load flow case to be non-convergent and unable to produce reliable results. To overcome this the EFFS Tool originally stopped the analysis if this occurred and required the user to update the forecast demand and generation profile. As a result of altering the forecasts as detailed above it occasionally became apparent that it was possible to unintentionally produce contingencies which were unstable in the PSS®E analysis software. This meant that some time steps would become non-convergent and therefore unable to generate reliable results. Constantly adjusting the forecasts to create convergent load flows for these extreme contingencies is time consuming and does not offer significant value for the limited situations that it occurs.

During the trial, initially these non-convergences were ignored but this resulted in the identification of unrealistic services that had to be manually checked and cleansed before optimising the available flexible services. To resolve the non-convergent cases as a longer term solution the EFFS Tool was updated to identify cases which were non-convergent and then exclude them from analysis.

4.4 Procurement and Selection of Services

4.4.1 Processing available flexibility services

Following the process carried out to request services, outputs from each platform were received weekly to be input in the service optimisation process. These outputs were provided by the platforms as an Excel sheet, or by updates to their online system where an Excel file of the reserve contracts could be exported. An example of this for the CLEM platform can be seen in Figure 4.4-1. These Excel sheets were directly accepted by the Networkflow optimisation process, therefore not requiring alteration by the user.

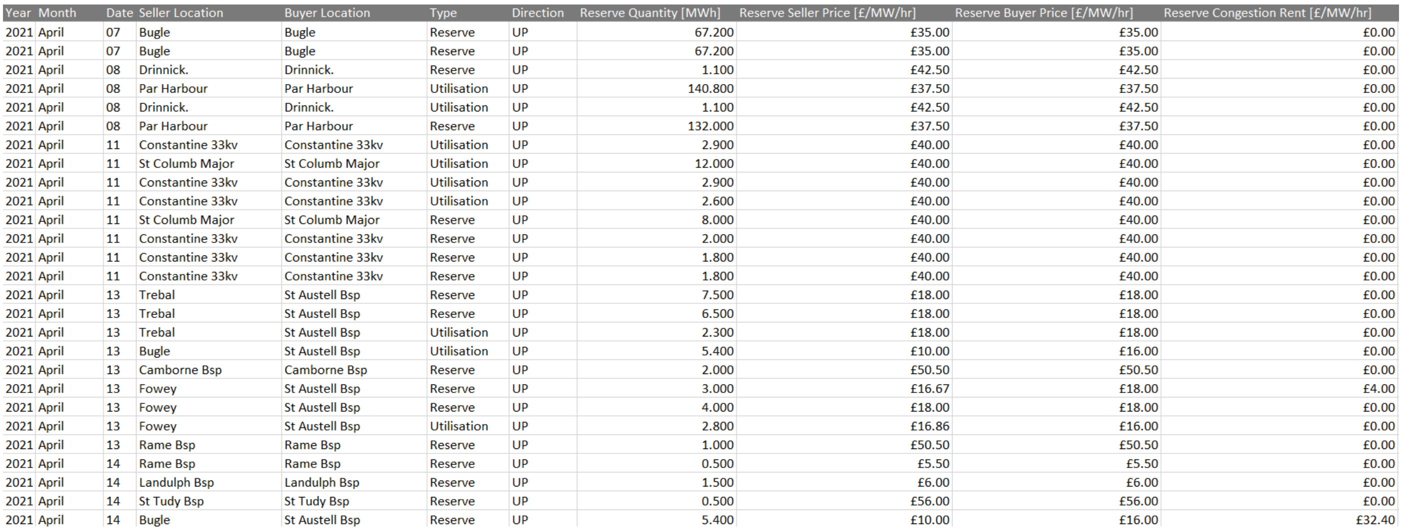


AggregatedContractMrid	BidMrid	LocationName	Date	ContractPeriod	ReserveR	ReserveC	ClearedRe
DB366791-5C9E-451D-94F1-9A8044EF24D7	968CC7FD	Bugle	28/06/2021	10:00 - 10:30	9.4	9.4	18
DB366791-5C9E-451D-94F1-9A8044EF24D7	968CC7FD	Bugle	28/06/2021	10:30 - 11:00	9.4	9.4	18
DB366791-5C9E-451D-94F1-9A8044EF24D7	968CC7FD	Bugle	28/06/2021	11:00 - 11:30	9.4	9.4	18
DB366791-5C9E-451D-94F1-9A8044EF24D7	968CC7FD	Bugle	28/06/2021	11:30 - 12:00	9.4	9.4	18
DB366791-5C9E-451D-94F1-9A8044EF24D7	968CC7FD	Bugle	28/06/2021	12:00 - 12:30	9.4	9.4	18
DB366791-5C9E-451D-94F1-9A8044EF24D7	968CC7FD	Bugle	28/06/2021	12:30 - 13:00	9.4	9.4	18
66047997-B35B-4624-8236-7EF782456F8E	80C41FD5-	Constantine 33kv	28/06/2021	10:00 - 10:30	9.6	9.6	30
66047997-B35B-4624-8236-7EF782456F8E	80C41FD5-	Constantine 33kv	28/06/2021	10:30 - 11:00	9.6	9.6	30
66047997-B35B-4624-8236-7EF782456F8E	80C41FD5-	Constantine 33kv	28/06/2021	11:00 - 11:30	9.6	9.6	30
66047997-B35B-4624-8236-7EF782456F8E	80C41FD5-	Constantine 33kv	28/06/2021	11:30 - 12:00	9.6	9.6	30
66047997-B35B-4624-8236-7EF782456F8E	80C41FD5-	Constantine 33kv	28/06/2021	12:00 - 12:30	9.6	9.6	30
66047997-B35B-4624-8236-7EF782456F8E	80C41FD5-	Constantine 33kv	28/06/2021	12:30 - 13:00	9.6	9.6	30
8FC2FAF5-472B-461C-8700-247CF9951FA1	241DF4B3-	Hayle	28/06/2021	10:00 - 10:30	9.3	9.3	20
8FC2FAF5-472B-461C-8700-247CF9951FA1	241DF4B3-	Hayle	28/06/2021	10:30 - 11:00	9.3	9.3	20
8FC2FAF5-472B-461C-8700-247CF9951FA1	241DF4B3-	Hayle	28/06/2021	11:00 - 11:30	9.3	9.3	20
8FC2FAF5-472B-461C-8700-247CF9951FA1	241DF4B3-	Hayle	28/06/2021	11:30 - 12:00	9.3	9.3	20
8FC2FAF5-472B-461C-8700-247CF9951FA1	241DF4B3-	Hayle	28/06/2021	12:00 - 12:30	9.3	9.3	20
8FC2FAF5-472B-461C-8700-247CF9951FA1	241DF4B3-	Hayle	28/06/2021	12:30 - 13:00	9.3	9.3	20
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	16:00 - 16:30	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	16:30 - 17:00	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	17:00 - 17:30	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	17:30 - 18:00	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	18:00 - 18:30	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	18:30 - 19:00	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	19:00 - 19:30	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	19:30 - 20:00	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	20:00 - 20:30	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	20:30 - 21:00	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	21:00 - 21:30	12.8	12.8	10
CB8A2947-CDEC-4AAE-A773-E0A50DDF1D9E	2534B541-	Constantine 33kv	28/06/2021	21:30 - 22:00	12.8	12.8	10
3EEF8CA7-7976-43CF-B58E-99C4E9D4829A	2A0491EE-	Hayle	29/06/2021	09:00 - 09:30	2.3	2.3	20
3EEF8CA7-7976-43CF-B58E-99C4E9D4829A	2A0491EE-	Hayle	29/06/2021	09:30 - 10:00	2.3	2.3	20
3EEF8CA7-7976-43CF-B58E-99C4E9D4829A	2A0491EE-	Hayle	29/06/2021	10:00 - 10:30	2.3	2.3	20

Figure 4.4-1 – Response from CLEM providing unique ID’s, location, time, and magnitude for services

4.4.2 Procurement of services

The service optimisation part of the EFFS process outputs a list of the services to be procured for each weekly run of the trial period. This output could be used to procure the correct service from each of the providers engaged. An example of this output can be seen within figure Figure 3.4-2 and this was then used to feed into the procurement methods for platforms, an example of which can be seen for CLEM in Figure 4.4 2.



Year	Month	Date	Seller Location	Buyer Location	Type	Direction	Reserve Quantity [MWh]	Reserve Seller Price [£/MW/hr]	Reserve Buyer Price [£/MW/hr]	Reserve Congestion Rent [£/MW/hr]
2021	April	07	Bugle	Bugle	Reserve	UP	67.200	£35.00	£35.00	£0.00
2021	April	07	Bugle	Bugle	Reserve	UP	67.200	£35.00	£35.00	£0.00
2021	April	08	Drinnick.	Drinnick.	Reserve	UP	1.100	£42.50	£42.50	£0.00
2021	April	08	Par Harbour	Par Harbour	Utilisation	UP	140.800	£37.50	£37.50	£0.00
2021	April	08	Drinnick.	Drinnick.	Utilisation	UP	1.100	£42.50	£42.50	£0.00
2021	April	08	Par Harbour	Par Harbour	Reserve	UP	132.000	£37.50	£37.50	£0.00
2021	April	11	Constantine 33kv	Constantine 33kv	Utilisation	UP	2.900	£40.00	£40.00	£0.00
2021	April	11	St Columb Major	St Columb Major	Utilisation	UP	12.000	£40.00	£40.00	£0.00
2021	April	11	Constantine 33kv	Constantine 33kv	Utilisation	UP	2.900	£40.00	£40.00	£0.00
2021	April	11	Constantine 33kv	Constantine 33kv	Utilisation	UP	2.600	£40.00	£40.00	£0.00
2021	April	11	St Columb Major	St Columb Major	Reserve	UP	8.000	£40.00	£40.00	£0.00
2021	April	11	Constantine 33kv	Constantine 33kv	Reserve	UP	2.000	£40.00	£40.00	£0.00
2021	April	11	Constantine 33kv	Constantine 33kv	Reserve	UP	1.800	£40.00	£40.00	£0.00
2021	April	11	Constantine 33kv	Constantine 33kv	Reserve	UP	1.800	£40.00	£40.00	£0.00
2021	April	13	Trebal	St Austell Bsp	Reserve	UP	7.500	£18.00	£18.00	£0.00
2021	April	13	Trebal	St Austell Bsp	Reserve	UP	6.500	£18.00	£18.00	£0.00
2021	April	13	Trebal	St Austell Bsp	Utilisation	UP	2.300	£18.00	£18.00	£0.00
2021	April	13	Bugle	St Austell Bsp	Utilisation	UP	5.400	£10.00	£16.00	£0.00
2021	April	13	Camborne Bsp	Camborne Bsp	Reserve	UP	2.000	£50.50	£50.50	£0.00
2021	April	13	Fowey	St Austell Bsp	Reserve	UP	3.000	£16.67	£18.00	£4.00
2021	April	13	Fowey	St Austell Bsp	Reserve	UP	4.000	£18.00	£18.00	£0.00
2021	April	13	Fowey	St Austell Bsp	Utilisation	UP	2.800	£16.86	£16.00	£0.00
2021	April	13	Rame Bsp	Rame Bsp	Reserve	UP	1.000	£50.50	£50.50	£0.00
2021	April	14	Rame Bsp	Rame Bsp	Reserve	UP	0.500	£5.50	£5.50	£0.00
2021	April	14	Landulph Bsp	Landulph Bsp	Reserve	UP	1.500	£6.00	£6.00	£0.00
2021	April	14	St Tudy Bsp	St Tudy Bsp	Reserve	UP	0.500	£56.00	£56.00	£0.00
2021	April	14	Bugle	St Austell Bsp	Reserve	UP	5.400	£10.00	£16.00	£32.40

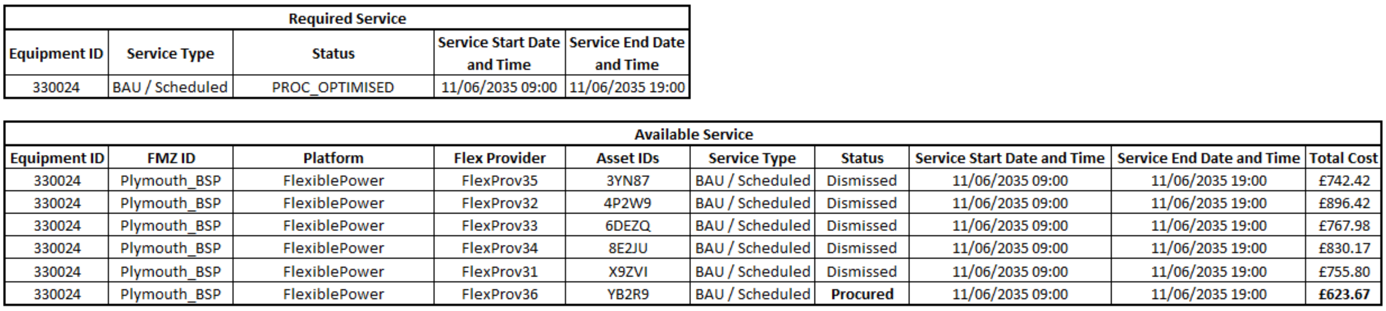
Figure 4.4-2 CLEM Utilisation Response File providing time and date, location, contract type, magnitude and pricing

4.5 Stress Testing

The decision was taken to start by running the Steady progression DFES scenario that was circa 10% increase in load to test the process. We decided to ensure the process got a real stress test we upped the number of sites from one BSP to the whole trial area this resulted in:

- A single forecast being run for the week.
- Powerflow analysis was generated for that week.
- This generated 25 constraints.
- Simulation and creation of six bids for every service, a total of 150.

The result was the optimisation was performed in less than one second at choosing the cheapest services due to the enterprise-grade level of the solution. A sample of the services optimised within this process can be seen within Figure 4.5-1.

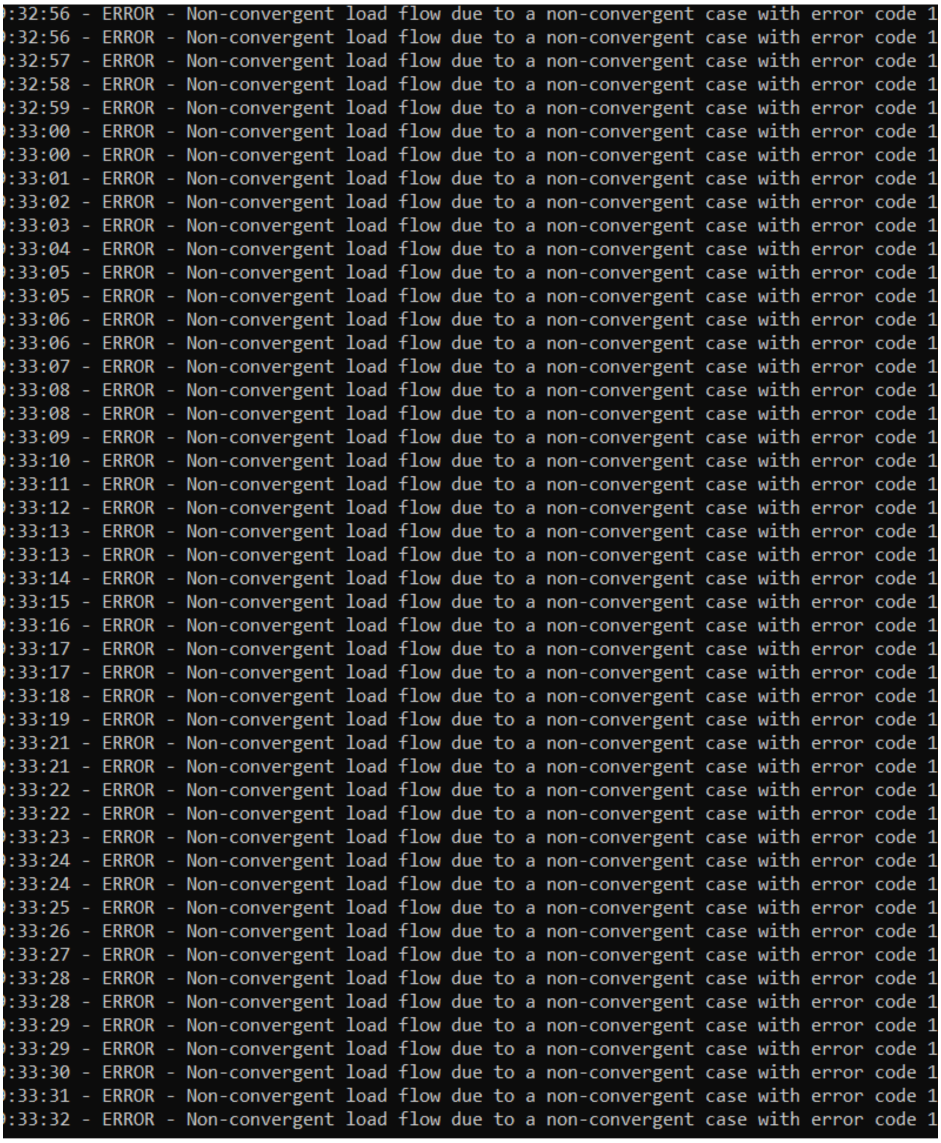


Required Service				
Equipment ID	**Service Type**	**Status**	**Service Start Date and Time**	**Service End Date and Time**
330024	BAU / Scheduled	PROC_OPTIMISED	11/06/2035 09:00	11/06/2035 19:00

Available Service									
Equipment ID	**FMZ ID**	**Platform**	**Flex Provider**	**Asset IDs**	**Service Type**	**Status**	**Service Start Date and Time**	**Service End Date and Time**	**Total Cost**
330024	Plymouth_BSP	FlexiblePower	FlexProv35	3YN87	BAU / Scheduled	Dismissed	11/06/2035 09:00	11/06/2035 19:00	£742.42
330024	Plymouth_BSP	FlexiblePower	FlexProv32	4P2W9	BAU / Scheduled	Dismissed	11/06/2035 09:00	11/06/2035 19:00	£896.42
330024	Plymouth_BSP	FlexiblePower	FlexProv33	6DEZQ	BAU / Scheduled	Dismissed	11/06/2035 09:00	11/06/2035 19:00	£767.98
330024	Plymouth_BSP	FlexiblePower	FlexProv34	8E2JU	BAU / Scheduled	Dismissed	11/06/2035 09:00	11/06/2035 19:00	£830.17
330024	Plymouth_BSP	FlexiblePower	FlexProv31	X9ZVI	BAU / Scheduled	Dismissed	11/06/2035 09:00	11/06/2035 19:00	£755.80
330024	Plymouth_BSP	FlexiblePower	FlexProv36	YB2R9	BAU / Scheduled	**Procured**	11/06/2035 09:00	11/06/2035 19:00	**£623.67**

Figure 4.5-1 - Service Example from Stress Testing

This was followed by the further increased demand and generation scenario It was found during this testing that the level of loading represented led to a fully non-convergent load flow, demonstrating that although the tooling had the capability to simulate this condition on the PSS®E network model, without any reinforcement the network in the trial area was unable to be assessed.



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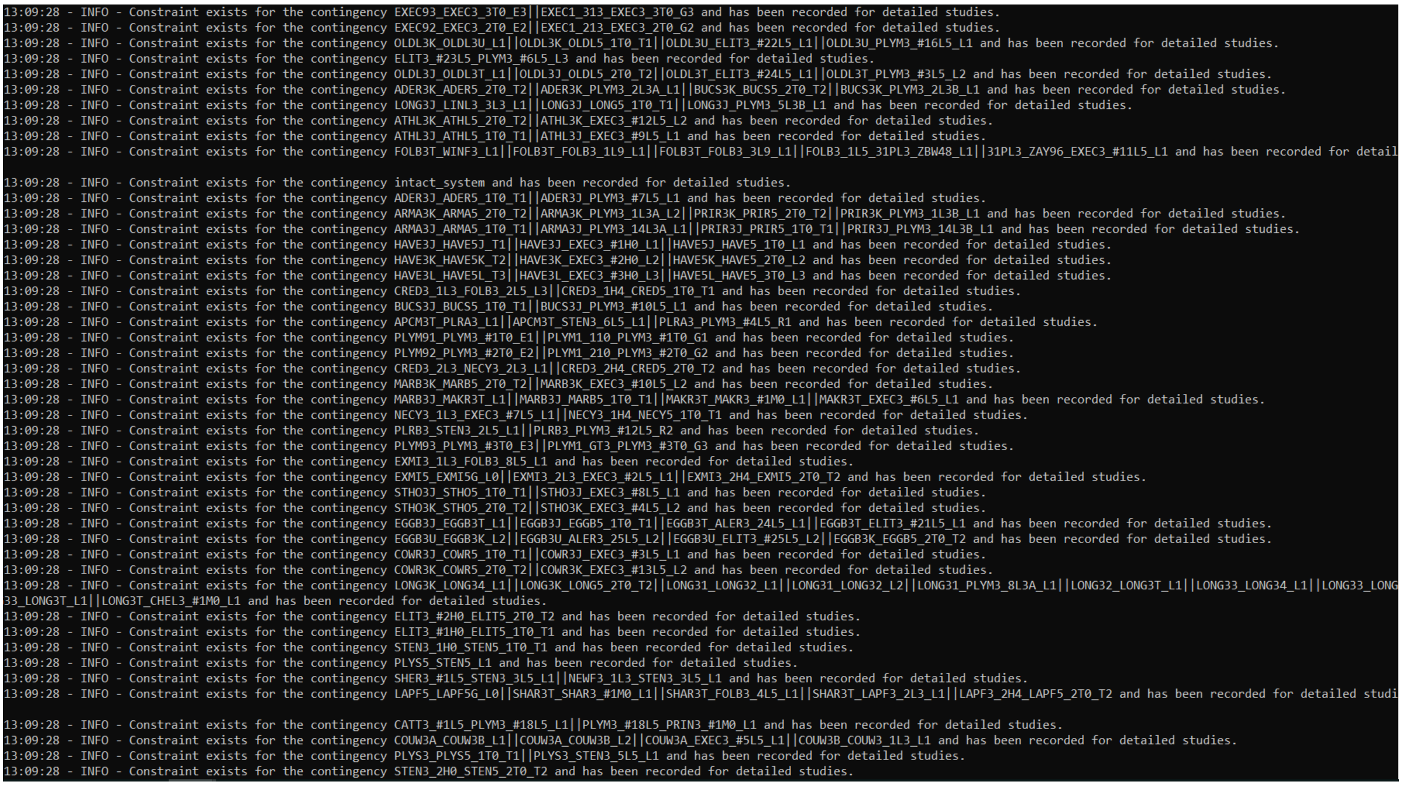
:32:56 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:32:56 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:32:57 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:32:58 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:32:59 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:00 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:00 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:01 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:02 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:03 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:04 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:05 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:05 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:06 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:06 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:07 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:08 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:08 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:09 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:10 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:11 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:12 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:13 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:13 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:14 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:15 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:16 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:17 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:17 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:18 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:19 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:21 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:21 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:22 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:22 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:23 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:24 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:24 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:25 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:26 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:27 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:28 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:28 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:29 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:29 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:30 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:31 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
:33:32 - ERROR - Non-convergent load flow due to a non-convergent case with error code 1
```

Figure 4.5-2 – EFFS Tool highlighting non-convergence errors under 2035 representative power flow analysis in PSS®E

The final method of stress testing, where the process constraint factor was reduced from 95% to 50%, demonstrated that the tool was able to handle a large number of constraints and therefore service selections. The limitation of this process was the time taken under this level of output. Although it was successful in defining the constraints, for future use it would be preferred that the run time could be reduced by the use of more suitable IT equipment. An output from this stress testing level, which demonstrates the constraints identified, can be seen within Figure 4.5-3.



```
13:09:28 - INFO - Constraint exists for the contingency EXEC93_EXEC3_3T0_E3||EXEC1_313_EXEC3_3T0_G3 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency EXEC92_EXEC3_2T0_E2||EXEC1_213_EXEC3_2T0_G2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency OLDL3K_OLDL3U_L1||OLDL3K_OLDL5_1T0_T1||OLDL3U_ELIT3_#22L5_L1||OLDL3U_PLYM3_#16L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency ELIT3_#23L5_PLYM3_#6L5_L3 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency OLDL3J_OLDL3T_L1||OLDL3J_OLDL5_2T0_T2||OLDL3T_ELIT3_#24L5_L1||OLDL3T_PLYM3_#3L5_L2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency ADER3K_ADER5_2T0_T2||ADER3K_PLYM3_2L3A_L1||BUCS3K_BUCS5_2T0_T2||BUCS3K_PLYM3_2L3B_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency LONG3J_LINL3_3L3_L1||LONG3J_LONG5_1T0_T1||LONG3J_PLYM3_5L3B_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency ATHL3K_ATHL5_2T0_T2||ATHL3K_EXEC3_#12L5_L2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency ATHL3J_ATHL5_1T0_T1||ATHL3J_EXEC3_#9L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency FOLB3T_WINF3_L1||FOLB3T_FOLB3_1L9_L1||FOLB3T_FOLB3_3L9_L1||FOLB3_1L5_31PL3_ZBW48_L1||31PL3_ZAY96_EXEC3_#11L5_L1 and has been recorded for detail

13:09:28 - INFO - Constraint exists for the contingency intact_system and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency ADER3J_ADER5_1T0_T1||ADER3J_PLYM3_#7L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency ARMA3K_ARMA5_2T0_T2||ARMA3K_PLYM3_1L3A_L2||PRIR3K_PRIR5_2T0_T2||PRIR3K_PLYM3_1L3B_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency ARMA3J_ARMA5_1T0_T1||ARMA3J_PLYM3_14L3A_L1||PRIR3J_PRIR5_1T0_T1||PRIR3J_PLYM3_14L3B_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency HAVE3J_HAVE5J_T1||HAVE3J_EXEC3_#1H0_L1||HAVE5J_HAVE5_1T0_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency HAVE3K_HAVE5K_T2||HAVE3K_EXEC3_#2H0_L2||HAVE5K_HAVE5_2T0_L2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency HAVE3L_HAVE5L_T3||HAVE3L_EXEC3_#3H0_L3||HAVE5L_HAVE5_3T0_L3 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency CRED3_1L3_FOLB3_2L5_L3||CRED3_1H4_CRED5_1T0_T1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency BUCS3J_BUCS5_1T0_T1||BUCS3J_PLYM3_#10L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency APCM3T_PLRA3_L1||APCM3T_STEN3_6L5_L1||PLRA3_PLYM3_#4L5_R1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency PLYM91_PLYM3_#1T0_E1||PLYM1_110_PLYM3_#1T0_G1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency PLYM92_PLYM3_#2T0_E2||PLYM1_210_PLYM3_#2T0_G2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency CRED3_2L3_NECY3_2L3_L1||CRED3_2H4_CRED5_2T0_T2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency MARB3K_MARB5_2T0_T2||MARB3K_EXEC3_#10L5_L2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency MARB3J_MAKR3T_L1||MARB3J_MARB5_1T0_T1||MAKR3T_MAKR3_#1M0_L1||MAKR3T_EXEC3_#6L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency NECY3_1L3_EXEC3_#7L5_L1||NECY3_1H4_NECY5_1T0_T1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency PLRB3_STEN3_2L5_L1||PLRB3_PLYM3_#12L5_R2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency PLYM93_PLYM3_#3T0_E3||PLYM1_GT3_PLYM3_#3T0_G3 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency EXMI3_1L3_FOLB3_8L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency EXMI5_EXMI5G_L0||EXMI3_2L3_EXEC3_#2L5_L1||EXMI3_2H4_EXMI5_2T0_T2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency STHO3J_STHO5_1T0_T1||STHO3J_EXEC3_#8L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency STHO3K_STHO5_2T0_T2||STHO3K_EXEC3_#4L5_L2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency EGGB3J_EGGB3T_L1||EGGB3J_EGGB5_1T0_T1||EGGB3T_ALER3_24L5_L1||EGGB3T_ELIT3_#21L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency EGGB3U_EGGB3K_L2||EGGB3U_ALER3_25L5_L2||EGGB3U_ELIT3_#25L5_L2||EGGB3K_EGGB5_2T0_T2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency COWR3J_COWR5_1T0_T1||COWR3J_EXEC3_#3L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency COWR3K_COWR5_2T0_T2||COWR3K_EXEC3_#13L5_L2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency LONG3K_LONG34_L1||LONG3K_LONG5_2T0_T2||LONG31_LONG32_L1||LONG31_LONG32_L2||LONG31_PLYM3_8L3A_L1||LONG32_LONG3T_L1||LONG33_LONG34_L1||LONG33_LONG
33_LONG3T_L1||LONG3T_CHEL3_#1M0_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency ELIT3_#2H0_ELIT5_2T0_T2 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency ELIT3_#1H0_ELIT5_1T0_T1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency STEN3_1H0_STEN5_1T0_T1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency PLYS5_STEN5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency SHER3_#1L5_STEN3_3L5_L1||NEWF3_1L3_STEN3_3L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency LAPF5_LAPF5G_L0||SHAR3T_SHAR3_#1M0_L1||SHAR3T_FOLB3_4L5_L1||SHAR3T_LAPF3_2L3_L1||LAPF3_2H4_LAPF5_2T0_T2 and has been recorded for detailed studi

13:09:28 - INFO - Constraint exists for the contingency CATT3_#1L5_PLYM3_#18L5_L1||PLYM3_#18L5_PRIN3_#1M0_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency COUW3A_COUW3B_L1||COUW3A_COUW3B_L2||COUW3A_EXEC3_#5L5_L1||COUW3B_COUW3_1L3_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency PLYS3_PLYS5_1T0_T1||PLYS3_STEN3_5L5_L1 and has been recorded for detailed studies.
13:09:28 - INFO - Constraint exists for the contingency STEN3_2H0_STEN5_2T0_T2 and has been recorded for detailed studies.
```

Figure 4.5-3 - Contingencies under 50% constraint analysis threshold

4.6 End to End System Process

The purpose of the EFFS End-to-End system is to process a collection of input data and carry out power system analysis for various contingencies and planned outages in the network in order to identify network constraints for the week ahead. If a network constraint is identified, the EFFS system will select the optimal flexible services for the week ahead based on the availability of the flexibility services in the flexible market.

In principle, the EFFS system therefore consists of the following parts:

- Defined Input Data: Consists of all the input data required for the analysis.
- Flexible Market Interface: Consists of the flexible platforms participating in the EFFS project
- EFFS Tool: Consists of the processes executed by EFFS tool
- Data Processing System (DPS): Consists of the processes executed by an external system

The trial period has allowed the project to confirm and validate the End-to-End process flow, and ensure that the interfaces can run smoothly. This has been deemed successful during this period, as a result of the design phases utilising feedback on how flexibility service procurement is carried out, and ensuring that data flows can be carried out efficiently.

The EFFS process was able to work with the flexibility service providers by ensuring that its timeframes accommodated their standard processes. An example of this was the midweek auction carried out by CLEM, which set a deadline of Tuesday afternoon each week for the forecasting and service requirements to be complete.

5 Evidence Documentation

The below summarises the evidence documentation that has been produced during this trials phase:

5.1 Letters of Support

Letters of Support can be found in Appendix 1 of this Evidence Report to demonstrate the engagement with third parties within the trial process. These have been provided from each external party that took part in the trial and therefore includes:

- Flexibility Service Providers
    - Centrica Business Solutions
    - EDF Energy Customers Ltd
- EFFS Trial Partners which submitted Letters of Support
    - AMT-SYBEX
    - Power Systems Consultants UK Ltd

5.1.1 Role of the documents

The role of these letters is to evidence and document the engagement had by the project with third party organisations, in order to successfully trial the end to end process and platform integration.

5.2 Test Script

The test script for the EFFS Trials process can be found within Appendix 2. This documents sets out the aims and objectives of the running of the system, and defines the scenarios runs took place within. This also contains the entry and exit requirements for the trial execution, and demonstration of where all elements have been met.

5.3 Ongoing Trial Reports

Throughout the trials phase, PSC have provided WPD with monthly progress reports, demonstrating the work carried out in each month and the lessons learned. This ensured that learning was captured during the trial phase, and was used to supplement records kept for the overall trial and project. These reports can be found within Appendix 3.

6 Learning

Throughout the trials process, learning has been documented and assessed to provide as much value as possible to the remainder of the project, future roll out and use of any of the tools developed within the EFFS project and to feed into any further work carried out by WPD or the wider industry. The following sections summarise the key learning found in a number of areas.

6.1.1 Data Cleansing

During the trial, historic TS data used within certain runs was found to include values slightly above 0MVA.In these cases the data cleansing methods employed assumed the values to be correct, and often these values were present in our data sets for a significant chunk of the day, but not for the entire day. The chunk of the day made interpolation between nearby points impossible, but it was not a sufficiently big enough period to require replacement with a previous value. Initially these were not flagged as an issue and replaced. Updates to the tool were need to avoid this data being used in forecasting, as it leads to unrealistically low forecasts. When cleansing historic data ensuring that the 0MVA value had a tolerance, and that a robust replacement method is in place for when any number of untrue 0 values are present.

6.1.2 Time Series Data

In earlier stages of the project it was decided to consider aggregated load and generation connected to primary substation busbars at 11 kV for the TS data entry. In cases where a high amount of flexibility services had been procured, this would create reduced historic aggregated load / generation power values that may impact on the estimation of the forecasted TS data. As the use of flexibility services becomes more widely adopted it will be important to take these into consideration as part of the load / generation cleansing and forecasting processes.

It should also be noted that using SCADA systems as a source of TS data led to limitations. SCADA measurements can occasionally become stuck at specific values and this is believed to be due to communication errors. It is difficult to always distinguish these from real values and as part of any EFFS Tool roll out a more advanced cleansing algorithm may be necessary to distinguish these.

6.1.3 Forecasting

By its nature demand forecasting is complex and subject to uncertainty, any approach to forecasting will be shown to have limitations of some kind and, in the case of forecasting for the purpose of informing decisions about procurement of flexibility services, particular attention should be paid to the time granularity of the data inputs and timescales for production of forecasts and subsequent processes that make use of them.

With all methods of forecasting assed during this trial process, demand forecasting was found to be most successful, with generation outputs always showing higher MAPE figures and therefore lower forecasting accuracy. The output from STOR generators is extremely difficult to forecast without understanding of the basis for the dispatch decisions and instructions issued by the ESO. Both Networkflow and the alternative forecast methods were not able to predict the unpredictable. Whilst improving demand forecasts can be achieved, the challenge in being able to predict 20-25MW of STOR on the 33kV network will impact the identification of constraints in future.

Weather data was assessed in two ways during the trial, Networkflow forecasting trialled historic weather data input, which was found to not increase the outputs from the XGBoost approach. The alternative forecasting method however made use of forecast weather data. Due to its more likely impact on network conditions than previous and not necessarily repeated weather conditions, it was found the utilising weather forecast data resulted in a high forecasting accuracy.

The overall learning from the comparison of forecasting methodologies demonstrated that a simplistic approach, as demonstrated by the alternative tool's Excel format, could provide higher forecasting accuracy than the Networkflow method.

Whilst not pertinent with the currently levels of flexibility dispatched by DNOs, it was considered during the trial that forecasting will become less accurate without redacting flexibility dispatch from historic time series data that is used to train the forecasting model. This is because without redaction a feedback loop would be created where data containing post-dispatch network loading would suggest a lesser need for flexibility because constraints have already been actively mitigated.

6.1.4 Constraint Analysis

For two runs during the trial period there were a significant number of services that were rejected even though they fell within the requested MW requirement. Further investigation into this highlighted that this was a result of non-convergence in the load flow. This was found to be as a result of adjusting the forecast demand to force system overloads to occur. To enable the trials to continue the error checking for non-convergence was disabled and at the time limited consideration as to the impact this might have was considered. During this trial period it has been identified to have the following impact:

- Non-convergent load flows are reported to the user through the error reporting, but the results of those cases are still considered
- Calculation of circuit overloads during non-convergent cases cannot be determine reliably but yet was still being included when identifying flexibility requirements
- Sensitivity factors cannot be calculated for non-convergent cases reliably

Typically, the non-convergences were for one specific contingency and so the analysis for the rest of the time step would still be reliable. However, once the flexible services have been identified the same cases were run and so the non-convergent contingencies end up rejecting the services since the overload data is unreliable.

When looking to resolve or improve constraints, the EFFS Tool aims to utilise flexibility services without any constraints becoming worse. A more practical view would be to take into consideration some more factors when ascertain whether a constraint or contingency is critical. For example, some assets may be able to handle an overload more reliably than others and therefore preferential treatment would aim to resolve specific constraints as a priority.

The planned outage functionality in the EFFS Tools power flow analysis during the trial did not work as well as expected. This was because planned outage are recorded as free text data which assets and network locations difficult to match within the EFFS Tool’s reference data. Changes to planned outage recording should be considered to resolve this,

6.1.5 Platform Integration

When integrating with multiple flexibility platforms, delays in their internal processes occasionally limited the optimisation that took place. This was due to the optimisation needing to take place prior to dispatch of any services for the week, but flexibility auction delays would mean reserve contracts were not produced before the Monday of the week ahead forecast. Agreement of set timescales with the providers limited the impact, and would need to be maintained in order for the EFFS process to successfully work.

6.1.6 Trial Area Selection

As part of the trial development it was decided to consider the Exeter City and Plymouth BSPs as the trial areas and three flexible platforms with assets within the South West region. Two of the market platforms had all their flexible assets outside those areas of interest which resulted in challenges in terms of having a meaningful impact on potential constraints. It may be appropriate to consider a wider area of interest in the future or more flexible assets located within the trial area in order to maximise the learning outcomes.

Availability of data for assets to be forecast within the trial area need to be considered for any future area selection. The trial area selected in the case contained generator sites, including the Multiple Fuel Type Generation site, which had no data to be used for input into the forecasting systems. This limited the output of forecasting in a way that meant the accuracy could not be assessed for this generation type.

6.1.7 Suitability for Future Energy System

The initial stress testing run, representing an increase of around 10% in demand and generation, demonstrated that a future scenario could be run and optimised using the EFFS system. In this case constraints could be identified, services selected and then optimisation could take place. When carrying this out at a higher level of loading, representing 2035 conditions, the tool was once again able to take and use the forecast demand and generation data, but non-convergence caused by the network model being unfit for this use case meant that constraints could not be identified. It would be expected that the EFFS system can be used for assessing this level of forecast if the network model was able to converge during load flow studies, therefore representing the network reinforcement required.

Running of the EFFS tool under a 50% constraint threshold demonstrated the need for improved IT resource when generating large numbers of constraints and services. The tool was able to run successfully, but at this level the time take for simulations to take place was longer than would be acceptable for regular usage.

6.1.8 Tool Implementation within WPD

In order for the machine learning algorithms for the forecasting systems to work effectively there is a need to have a significant historic time series demand dataset to learn from. However, the measurement datasets produced by WPD SCADA systems inevitably have some poor or inconsistent data that require cleansing prior to use. During the trials phase a 2 year historic dataset was cleansed for providing to the forecasting system to support the initial learning algorithms. Due to the number of datapoints in a 2 year half-hourly dataset along with the additional capacity needed to manipulate and cleanse the restrictions in the RAM of the WPD Virtual Machine were identified. To resolve this a new virtual machine was created with a RAM capacity of at least 4 GB.

The EFFS Tool utilises Python (v2.7) and a number of associate data processing Python packages to run. During the trials phase it became apparent that WPD did not have the access permissions required to enable these additional Python packages and therefore another solution was necessary. The EFFS Tool was updated to include all of the necessary packages, which could then be installed without the need for internet connectivity.

7 Conclusion

As is critical for any innovative new solution, a thorough trial is important to demonstrate value and also maximise learning potential from the solution and its individual component parts. The EFFS trials has demonstrated some valuable learning for consideration during any future rollout or future developments within the forecasting and flexibility areas. The trial phase of the EFFS project has been successful in carrying out a robust test of the tooling developed during the course of the project. Weekly runs of the process have allowed us to demonstrate each of the components, including data cleansing, forecasting, constraint analysis, service selection, and validation, as well as demonstrating the system's ability to operate as an end to end process. Working with multiple flexibility service providers has showed us that we can support their platforms, and ensures that the tools developed are fit for purpose.

The trial was able to be carried out in line with its schedule, and was successful in meeting the elements defined within our criteria for success and the objectives set out within the test script. This meant that we were able to carry out a full 24 weeks of trial, and run in multiple scenarios of operation.

Key learning has been developed across multiple aspects. This has included forecasting, where our weekly use of the Networkflow tool have provided us the data to analysis forecasting horizons and make comparison with an alternative tool. This has outlined the importance of good input data and data cleansing, highlighted the impact that weather data can have, and showed that primary substation demand forecasting is more achievable than generation and STOR sites. Our constraint analysis work has demonstrated that it could operate throughout the trial, and led to the successful selection and validation of flexibility services. Our work with flexible service providers has demonstrated the need for a robust schedule if an automated system for service selection and procurement is to be carried out. This avoids any one provider limiting another's output, and ensures that the process is carried out ahead of time.

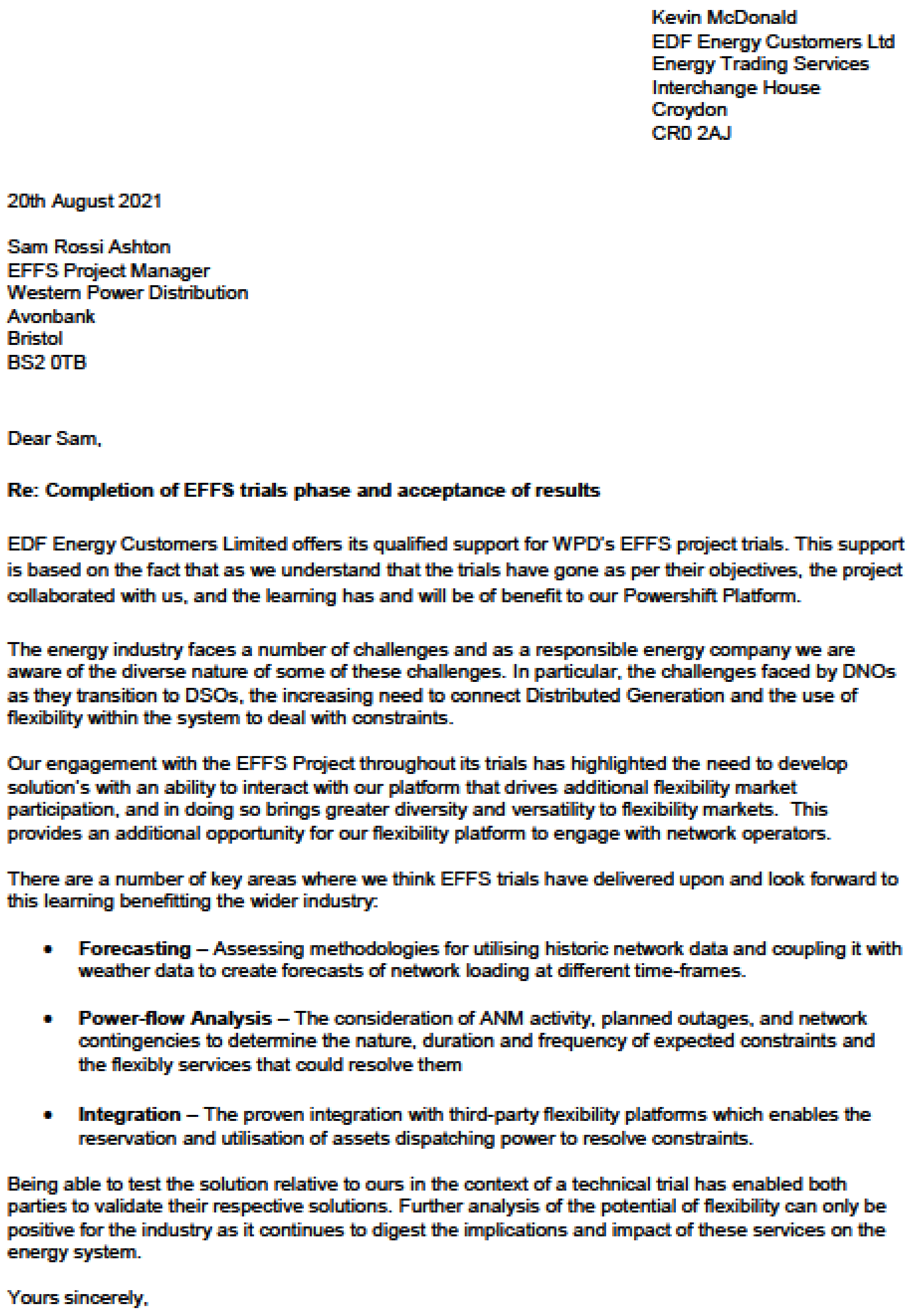
By carrying out stress testing in a number of ways, we have been able to assess and confirm the EFFS system's suitability for a future energy system. When the scenarios run were possible on the existing network the system was able to operate in line with the remainder of the trial. When scenarios led to load flows being non-convergent, the system was still able to set up and execute the load flows, and given an updated network model to reflect future reinforcement it is expected that the system would once again operate fully.

This trial period has also provided us with significant learning to be taken forward for future Innovation and Business as Usual work within WPD. By deploying the system on our IT systems, we were able to identify challenges both in terms of hardware and software, and can now ensure any future work takes on board this learning to ensure it is carried out in an efficient way.

8 Glossary

Abbreviation	Term
ANM	Active Network Management
ARIMA	Auto-Regressive Integrated Moving Average
CLEM	Cornwall Local Energy Market
CMZ	Constraint Management Zone
DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
DPS	Data Processing System
DSO	Distribution System Operator
EFFS	Electricity Flexibility and Forecasting System
ENA	Energy Networks Association
ESO	Electricity System Operator
HH	Half Hourly
kV	kiloVolt
LSTM	Long Short Term Memory
LTDS	Long Term Development Strategy
MAPE	Mean Average Percentage Error
MPAN	Meter Point Administration Number
MVA	Mega-Volt Amps
MW	Mega-Watts
MWh	Mega-Watt-Hours
NIC	Network Innovation Competition
PSC	Power Systems Consultants UK Ltd
STOR	Short Term Operating Reserve
TS	Time-Series
WPD	Western Power Distribution
XGBoost	Extreme Gradient Boosting

9 Appendix 1 – Letters of Support



Kevin McDonald
EDF Energy Customers Ltd
Energy Trading Services
Interchange House
Croydon
CR0 2AJ

20th August 2021

Sam Rossi Ashton
EFFS Project Manager
Western Power Distribution
Avonbank
Bristol
BS2 0TB

Dear Sam,

Re: Completion of EFFS trials phase and acceptance of results

EDF Energy Customers Limited offers its qualified support for WPD's EFFS project trials. This support is based on the fact that as we understand that the trials have gone as per their objectives, the project collaborated with us, and the learning has and will be of benefit to our Powershift Platform.

The energy industry faces a number of challenges and as a responsible energy company we are aware of the diverse nature of some of these challenges. In particular, the challenges faced by DNOs as they transition to DSOs, the increasing need to connect Distributed Generation and the use of flexibility within the system to deal with constraints.

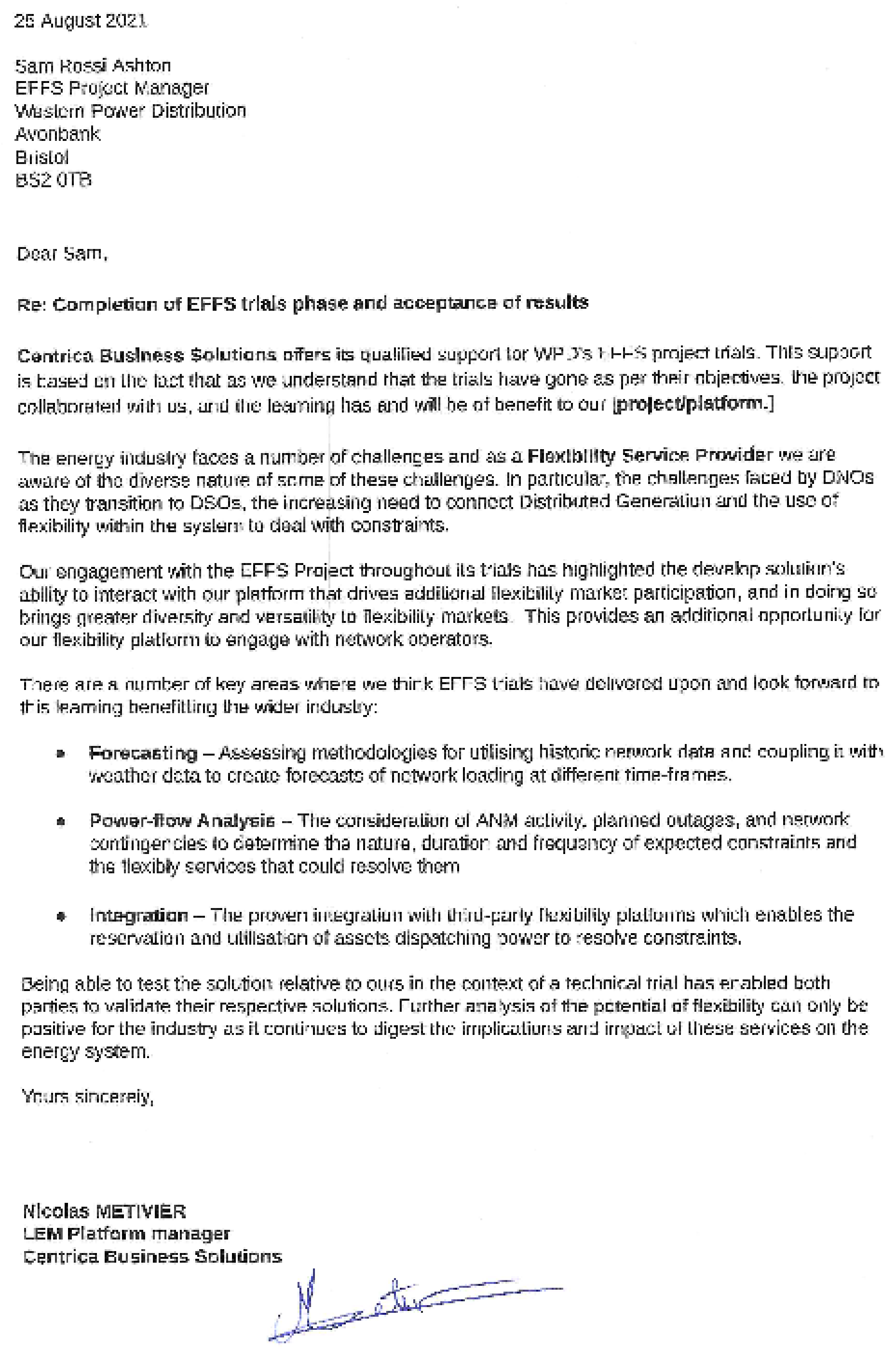
Our engagement with the EFFS Project throughout its trials has highlighted the need to develop solution's with an ability to interact with our platform that drives additional flexibility market participation, and in doing so brings greater diversity and versatility to flexibility markets. This provides an additional opportunity for our flexibility platform to engage with network operators.

There are a number of key areas where we think EFFS trials have delivered upon and look forward to this learning benefitting the wider industry:

- **Forecasting** – Assessing methodologies for utilising historic network data and coupling it with weather data to create forecasts of network loading at different time-frames.
- **Power-flow Analysis** – The consideration of ANM activity, planned outages, and network contingencies to determine the nature, duration and frequency of expected constraints and the flexibly services that could resolve them
- **Integration** – The proven integration with third-party flexibility platforms which enables the reservation and utilisation of assets dispatching power to resolve constraints.

Being able to test the solution relative to ours in the context of a technical trial has enabled both parties to validate their respective solutions. Further analysis of the potential of flexibility can only be positive for the industry as it continues to digest the implications and impact of these services on the energy system.

Yours sincerely,



25 August 2021

Sam Rossi Ashton
EFFS Project Manager
Western Power Distribution
Avonbank
Bristol
BS2 0TB

Dear Sam,

Re: Completion of EFFS trials phase and acceptance of results

Centrica Business Solutions offers its qualified support for WPD's EFFS project trials. This support is based on the fact that as we understand that the trials have gone as per their objectives, the project collaborated with us, and the learning has and will be of benefit to our **[project/platform.]**

The energy industry faces a number of challenges and as a **Flexibility Service Provider** we are aware of the diverse nature of some of these challenges. In particular, the challenges faced by DNOs as they transition to DSOs, the increasing need to connect Distributed Generation and the use of flexibility within the system to deal with constraints.

Our engagement with the EFFS Project throughout its trials has highlighted the develop solution's ability to interact with our platform that drives additional flexibility market participation, and in doing so brings greater diversity and versatility to flexibility markets. This provides an additional opportunity for our flexibility platform to engage with network operators.

There are a number of key areas where we think EFFS trials have delivered upon and look forward to this learning benefitting the wider industry:

- **Forecasting** – Assessing methodologies for utilising historic network data and coupling it with weather data to create forecasts of network loading at different time-frames.
- **Power-flow Analysis** – The consideration of ANM activity, planned outages, and network contingencies to determine the nature, duration and frequency of expected constraints and the flexibly services that could resolve them
- **Integration** – The proven integration with third-party flexibility platforms which enables the reservation and utilisation of assets dispatching power to resolve constraints.

Being able to test the solution relative to ours in the context of a technical trial has enabled both parties to validate their respective solutions. Further analysis of the potential of flexibility can only be positive for the industry as it continues to digest the implications and impact of these services on the energy system.

Yours sincerely,

Nicolas METIVIER
LEM Platform manager
Centrica Business Solutions

24th August 2021

Sam Rossi Ashton
EFFS Project Manager
Western Power Distribution
Avonbank
Bristol
BS2 0TB

Dear Sam,

Re: Completion of EFFS trials phase and acceptance of results

I am writing to confirm PSC's qualified support for WPD's EFFS project trials. This support is based on the understanding of successful trials as per their objectives, collaboration of the project with PSC, and the learning that has been and will be of benefit to any future roll out of all or part of the solution developed via the EFFS project.

The energy industry faces a number of challenges and as a leading electricity industry consultancy we are aware of the diverse nature of some of these challenges. In particular, the challenges faced by DNOs as they transition to DSOs with increasing need to connect Distributed Generation necessitating the use of flexibility services to deal with network constraints.

Our engagement with the EFFS project throughout its trials has highlighted the ability of the developed solution to interact with a variety of services on various platforms providing additional flexibility market participation and bringing greater diversity and versatility to such markets. This provides an additional opportunity for flexibility service platforms to engage with network operators.

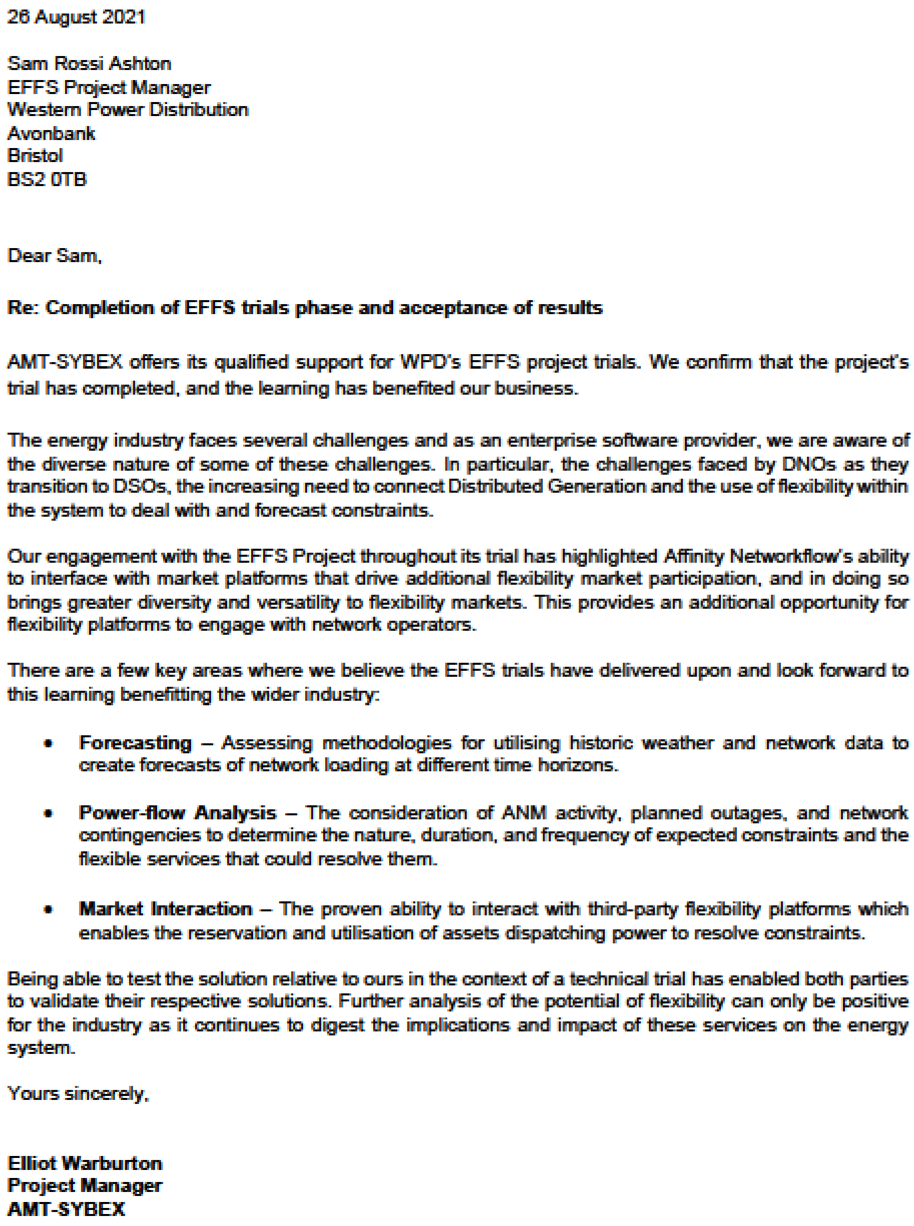
There are a number of key areas where we think EFFS trials have delivered upon and look forward to this learning benefitting the wider industry:

- **Forecasting** – Assessing methodologies for utilising historic network data and coupling it with weather data to create forecasts of network loading at different time-frames.
- **Power-flow Analysis** – The consideration of ANM activity, planned outages, and network contingencies to determine the nature, duration and frequency of expected constraints and the flexibly services that could resolve them.
- **Integration** – The proven integration with third-party flexibility platforms which enables the reservation and utilisation of assets dispatching power to resolve constraints.

Being able to test the solution relative to ours in the context of a technical trial has enabled both parties to validate their respective solutions. Further analysis of the potential of flexibility services can only be positive for the industry as it continues to digest the implications and impact of these services on the energy system.

Yours sincerely,

Jinsheng Peng
Senior Power Systems Consultant
Power Systems Consultants UK Ltd



26 August 2021

Sam Rossi Ashton
EFFS Project Manager
Western Power Distribution
Avonbank
Bristol
BS2 0TB

Dear Sam,

Re: Completion of EFFS trials phase and acceptance of results

AMT-SYBEX offers its qualified support for WPD's EFFS project trials. We confirm that the project's trial has completed, and the learning has benefited our business.

The energy industry faces several challenges and as an enterprise software provider, we are aware of the diverse nature of some of these challenges. In particular, the challenges faced by DNOs as they transition to DSOs, the increasing need to connect Distributed Generation and the use of flexibility within the system to deal with and forecast constraints.

Our engagement with the EFFS Project throughout its trial has highlighted Affinity Networkflow's ability to interface with market platforms that drive additional flexibility market participation, and in doing so brings greater diversity and versatility to flexibility markets. This provides an additional opportunity for flexibility platforms to engage with network operators.

There are a few key areas where we believe the EFFS trials have delivered upon and look forward to this learning benefitting the wider industry:

- **Forecasting** – Assessing methodologies for utilising historic weather and network data to create forecasts of network loading at different time horizons.

- **Power-flow Analysis** – The consideration of ANM activity, planned outages, and network contingencies to determine the nature, duration, and frequency of expected constraints and the flexible services that could resolve them.

- **Market Interaction** – The proven ability to interact with third-party flexibility platforms which enables the reservation and utilisation of assets dispatching power to resolve constraints.

Being able to test the solution relative to ours in the context of a technical trial has enabled both parties to validate their respective solutions. Further analysis of the potential of flexibility can only be positive for the industry as it continues to digest the implications and impact of these services on the energy system.

Yours sincerely,

Elliot Warburton
Project Manager
AMT-SYBEX

10 Appendix 2 – Test Script

EFFS - Test Script and Criteria.xlsx

11 Appendix 3 – Monthly Trials Reports - PSC

The following sections contain the monthly trial reports submitted throughout the trial phase (December 2020 to July 2021)

A.1 December 2020 (JK8349-MR-1a)

Job Status: Trials reporting for JK8349 – EFFS Tool Development

Date: m/e 31-12-20

Executive Summary – Trials Phase

The following is a status progress report for PSC's involvement in the trials phase of the EFFS Tool Development. The current project status is:

- Supported AMT-SYBEX and WPD with flexible platforms validation issues
- Provided engineering advice with respect to sensitivity factor calculations
- Recorded further development actions for the final version of the tool
- Initiated the 1st trial along with the WPD user
- Supported with errors associated with WPD's Virtual Machine (VM) being utilised
- Provided technical support and troubleshooting for the tool to ensure a smooth operation - Existing obsolete Python packages in WPD local installation were creating incompatibility issues
- Provided step-by-step guidance and explanation on the tool functionalities
- Provided training to the WPD user on successful use of the EFFS tool
- Supported WPD in exporting the tool
- Transferred the draft completed version of the EFFS tool along with the user manual

Key results this period

- EFFS tool operational and able to run studies for constraint analysis

Key learning this period

- Important to understand the target operational environment and specific requirements should be specified during the build phase.

Critical items required to stay on track

- Clarify the reservation / utilisation process with the CLEM platform following recent platform updates

A.2 January 2021 (JK8349-MR-1b)

Job Status: Trials reporting for JK8349 – EFFS Tool Development

Date: m/e 31-01-21

Executive Summary – Trials Phase

The following is a status progress report for PSC's involvement in the trials phase of the EFFS Tool Development. The current project status is:

- Investigated on the possibility of having multiple BidMrids for a particular flexible asset for CLEM platform
- Supported WPD and AMT-SYBEX with the trials strategy documentation by contributing with data on the constraint analysis procedures
- Supported WPD and AMT-SYBEX flexible services validation errors and engineering explanation on the observed non-convergent load flows
- Provided extensive support in terms of power system analysis and PSS®E sav case modifications to facilitate the meaningful execution of the trials
- Provided guidance in alternative approaches to allow the creation of multiple constraints and meaningful sensitivity factors and learnings

Key results this period

- Confirmed that CLEM implementation with single or multiple BidMrids is achievable
- Validated the impact of rating selection and sensitivity factors on constraints

Key learning this period

- Since innovation projects are undertaken before the system reaches practical constraints it is important to identify a consistent and targeted approach to artificially generating constraints

Critical items required to stay on track

- Clarify the reservation / utilisation process with the CLEM platform following recent platform updates

A.3 February 2021 (JK8349-MR-1c)

Job Status: Trials reporting for JK8349 – EFFS Tool Development

Date: m/e 28-02-21

Executive Summary – Trials Phase

The following is a status progress report for PSC's involvement in the trials phase of the EFFS Tool Development. The current project status is:

- Integrated trials findings and improvements in the final version of the tool and resubmitted to WPD
- Investigated on the possibility of relocating CLEM assets within the areas of interest in order to identify flexibility services with meaningful sensitivity factor
- Provided engineering support in terms of analysing either non convergent issues or absence of network constraints despite the scaling of the forecasted TS data
- Contributed on potential trials strategy that can be followed and analysed the impact of either modifying the PSS®E case by manually applying outages or scaling forecasted TS data in order to instigate the creation of network constraints

Key results this period

- Validated that it is possible to artificially relocate a CLEM provider elsewhere within the WPD network for the purpose of end-to-end system trials.

Key learning this period

- Service providers outside a trial region have limited practical benefit to the constraints. In future roll outs a plan for testing of these service providers and the extent of their contribution to constraints should be considered.

Critical items required to stay on track

- Investigate the best way forward in terms of virtually relocating existing flexible assets within the areas of interest
- Clarify the reservation / utilisation process with the CLEM platform following recent platform updates

Job Status: Trials reporting for JK8349 – EFFS Tool Development

Date: m/e 31-03-21

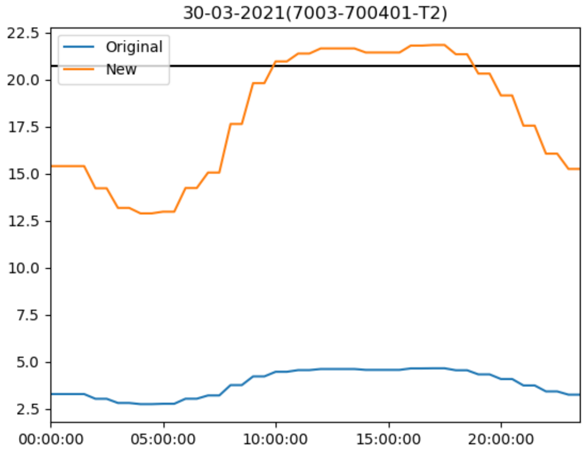
Executive Summary – Trials Phase

The following is a status progress report for PSC's involvement in the trials phase of the EFFS Tool Development. The current project status is:

- Established specific timeseries forecast to generate specific overloads that artificial CLEM assets will be able to demonstrate providing a service for.
- Adjustment to approach to determining the maximum system loading arrangements to ensure worst case contingencies are correctly identified.

Key results this period

- CLEM service identification
- Development of routine to alter the AMT-SYBEX forecast to target overloads on specific assets during contingency events (example figure below)



- Development update to EFFS to based around utilising maximum combination of all load / generation rather than maximum for week profile. To ensure this is achieved using the following approach:
  - A database is created for each 30 minute time slot that contains the following values:
    - Load 1
    - Load 1 + Load 2
    - Load 1 + Load 2 + … + Load n
    - Load 2
    - Load 2 + Load 3
    - Load 2 + Load 3 + … + Load n
    - …
    - Load n
  - For each 30 minute time slot during the week the maximum and minimum for each combination is found, i.e.:
    - Time of maximum for Load 1
    - Time of maximum for Load 1 + Load 2
    - Time of maximum for Load 1 + Load 2 + … + Load n
    - Etc.
    - Time of minimum for Load 1
    - Time of minimum for Load 1 + Load 2
    - Time of minimum for Load 1 + Load 2 + … + Load n
    - Etc.
  - From these a reduced number of time slots are selected to identify the critical contingencies.

    - The critical contingencies are then studies for every 30 minute time slot

Key learning this period

- Forecast generation and demand is not near constraints and so manual adjustment to forecast required to create meaningful trials results.
- Identified that load forecast reduction method could result in some contingencies being missed or significant increase in computational time to include them all. Investigating options to improve on this.
- The approach applied to reduce the contingency list based on the maximum and minimum demand profiles was not a reliable approach for all system conditions. An alternative approach has been tested which is returning more valuable results but has increased computation time. The increase to computation time is being looked into further to identify opportunities to resolve.

Critical items required to stay on track

- Clarify the reservation / utilisation process with the CLEM platform following recent platform updates

A.5 April 2021 (JK8349-MR-3)

Job Status: Trials reporting for JK8349 – EFFS Tool Development

Date: m/e 30-04-21

Executive Summary – Trials Phase

The following is a status progress report for PSC's involvement in the trials phase of the EFFS Tool Development. The current project status is:

- Supported weekly trials activity with forecasting and constraint identification
- Identified limitation with forecasts resulting in model non-convergence and updated tool
- Introduced updates to EFFS Tool to allow specific time steps to be investigated

Key results this period

- Successfully altered forecast and carried out analysis to identify potential CLEM services for theoretical overloads
- Successfully processed AMT-SYBEX optimised CLEM services
- Development of EFFS tool to allow improved analysis of non-convergent cases including ability to:
    - Enabled completion of analysis for convergent cases by skipping non-convergent cases
    - Ability to extract PSS®E model for specific time stamp / contingency combination
- Supported delivery of "Show and Tell" to Ofgem and WPD teams

Key learning this period

- When adjusting the forecast some contingencies are non-convergent, this is due to the extreme loading conditions to ensure some services are identified. This means that for those contingencies no service identification is possible. Further investigation into the following areas is needed to improve this analysis:
    - Output with further details of why non-convergent (i.e. tap changer iteration limits or model divergence)
    - Investigate impact of relaxing convergence tolerances
    - Reducing system loading to closer to equipment limits for more scenarios
- When selecting services, a large number are being rejected, this is thought to be due to the fact that although the service improves one contingency it may make another worse. Further investigation into this is required to provide the following information:
    - Why is the service rejected (i.e. what other contingency gets worse so that the user can override the decision if necessary)
    - What level of dispatch would help to resolve all contingencies without making any worse

Critical items required to stay on track

- Further update to EFFS tool to improve data output

A.6 May 2021 (JK8349-MR-4)

Job Status: Trials reporting for JK8349 – EFFS Tool Development

Date: m/e 31-05-21

Executive Summary – Trials Phase

The following is a status progress report for PSC's involvement in the trials phase of the EFFS Tool Development. The current project status is:

- Supported weekly trials activity with forecasting and constraint identification
- Issue has arisen with 0 MW values after data cleansing, further investigation shows that the design methodology had a gap for datasets with partial errors.
- Accepted / rejected services are not always being accepted and require further investigation

Key learning this period

For the dataset on the 16th April 2021 some data cleansing showed 0 values which were a data error rather than an actual measurement. Processing of this highlighted 2 different errors:

- Issue
    - The error values weren't actually 0MVA but were instead 0.003MVA, these were therefore assumed to be correct
    - These values were 0 for a significant chunk of the day (4 hours) but not for the entire day. The chunk of the day made interpolation between nearby points in possible, but it was not a sufficiently big enough period to require replacement with a previous value. In line with the methodology set out in the design report (JK8349-TR-1-2) they were not flagged as an issue and replaced.
- Resolution:
    - The tolerance for a 0MVA value was increase to +/-0.01MVA to increase the threshold for what is identified as a 0 value
    - The replacement process was updated to replace any values as follows:
        - If less than 3 values are missing, interpolate between them
        - If more than 3 values are missing, replace just those values with the average of values for the same day and time of the week over the previous 4 weeks
- Potential issues and further thoughts:
    - In addition to 0MVA values it appears as though the SCADA output could also become stuck at particular values. An additional check should be considered which identifies stuck values across a complete dataset
    - Replacing only the values which have failed with a previous week could result in significant step changes in the demand / generation profile. It may be more appropriate to replace the entire day, but this introduces the risk of a lot of genuine data being cleansed out of the dataset.
- Script update: This is currently going through testing and will be incorporated in v2.2 of the EFFS Tool

Critical items required to stay on track

- Further update to EFFS tool to improve data output for non-convergent cases

A.7 June 2021 (JK8349-MR-5)

Job Status: Trials reporting for JK8349 – EFFS Tool Development

Date: m/e 30-06-21

Executive Summary – Trials Phase

The following is a status progress report for PSC’s involvement in the trials phase of the EFFS Tool Development. The current project status is:

- Supported weekly trials activity with forecasting and constraint identification
- Updated scripts to better cleanse 0 MW values (JK8349-MR-4)
- Non-convergence in load flow calculations is incorrectly calculating flexibility requirements
- Project final report being prepared to summarise learning from complete trials period and recommendations for next steps in BAU implementation.

Key learning this period

For two datasets (7th June -> 13th June and 14th June -> 20th June) there were a significant number of services that were rejected even though they fell within the requested MW requirement. Further investigation into this highlighted that this was a result of non-convergence in the load flow. As reported in the trials report covering April 2021 (JK8349-MR-3) this is a result of adjusting the forecast demand to force system overloads to occur. To enable the trials to continue the error checking for non-convergence was disabled and at the time limited consideration as to the impact this might have was considered. During this trials period it has been identified to have the following impact:

- Non-convergent load flows are reported to the user through the error reporting, but the results of those cases are still considered
- Calculation of circuit overloads during non-convergent cases cannot be determine reliably but yet was still being included when identifying flexibility requirements
- Sensitivity factors cannot be calculated for non-convergent cases reliably

Typically, the non-convergencies were for one specific contingency and so the analysis for the rest of the time step would still be reliable. However, once the flexible services have been identified the same cases were run and so the non-convergent contingencies end up rejecting the services since the overload data is unreliable.

To resolve this the script has been updated to perform the following additional checks:

1. Non-convergent cases are included as an output from the tool to specify the day, time and contingency combination and reason that a case is non-convergent. The user can then consider these specific cases as to their importance to the overall flexibility analysis.
2. Cases which are non-convergent are excluded from identifying overloads, determining flexibility service sensitivity factors and acceptance of services.

Testing of these updates on the same datasets has shown now that the services previously rejected are acceptable. It also highlights that the previous requirements for very large MW flexibility values was as a result of the non-convergence.

Critical items required to stay on track

- Script update and issue for July trials / testing

A.8 July 2021 (JK8349-MR-6)

Job Status: Trials reporting for JK8349 – EFFS Tool Development

Date: m/e 12-08-21

Executive Summary – Trials Phase

The following is a status progress report for PSC’s involvement in the trials phase of the EFFS Tool Development. The current project status is:

- Supported weekly trials activity with forecasting and constraint identification
- Updated scripts to exclude non-convergent cases and included in the issue of the tool (v2.24)
- Investigated issue with package installation on WPD build
- Added in comparator to cleansed data worksheet showing only changes
- Project final report prepared and submitted with summary of learning from complete trials period and recommendations for next steps in BAU implementation.

Key learning this period

On the EFFS tool deployment, the required Python packages need to be installed to run the EFFS tool. It was identified during the trials that, to carry out this local package installation, the user is required have located the EFFS Tool package in a location which they have write permissions. The meet this requirement, the EFFS Tool was updated to create a local python package folder specific to the user that is located within the EFFS tool itself i.e. “local_packages” + (UserName). This update allows multiple users to run the EFFS tool on the same machine.

On data cleansing, an additional function was added to enable that, once the time series data has been cleansed, an output is provided along with a summary of the quality of the data processed and those values for which assumptions needed to be made. Additionally, the Quality Summary output includes a worksheet named “Comparison of Data” which contains both the raw and cleansed datasets on alternating rows. Any values which have been changed in the cleansed dataset are highlighted yellow to make it clear to the user.

During the trials, it was identified that, to allow the forecasted time series data to be successfully processed, the data of the active power and the reactive power provided in the excel sheet of forecasted time series data should have no more than 5 decimal places.

During extreme system demand and generation profiles it is possible that the PSS®E analysis engine is unable to produce a convergent load flow resulting in unreliable results for further analysis. To resolve this the EFFS Tool identifies these non-convergent cases and then excluded them from any further analysis. To ensure the user is aware of those timesteps and contingency combinations which are non-convergent an additional Excel Workbook (naming convention: *PSSE_NONCONV############.xlsx*) is produced which includes details of Day/Time of dispatch, contingency name, reason (this is the reason a non-convergence occurred as reported by PSS®E and can be utilised for further investigation) and comment (any additional comments around the non-convergence).

During a stress testing of the tool, it was identified that, when the forecast data for the stress testing are too extreme, it can lead to all the contingencies that can cause constraints to be skipped due to non-convergent load flow. As a result, the tool concluded with no constraints and no need for flexibility services. To overcome this, the forecast demand would need to be reduced and check that if the model is convergent for the intact system with the forecast.

12 Appendix 4 – Requirements Traceability Summary

Table 12 - Requirements Traceability Summary

No.	Requirement description	Outcome summary
1	Measure forecasting accuracy	Forecasts were run across all trial sites and accuracies were measured for all sites in the trials which were 21 primary substations, 2 solar farms, 1 multiple fuel type generator and 4 STOR generators in the WPD Southwest licence area, specifically in the areas surrounding Plymouth and Exeter. Due to the existing procurement timelines for the Secure flexibility service, the majority of forecasts run were a week ahead.
2	Assess forecasting horizon suitability	Forecasts were run for all defined horizons (namely day ahead, week ahead, two weeks ahead, month ahead and six months ahead). The majority were standalone activities that were not required in the downstream process of power flow analysis and procurement. This is because as detailed in WPD EFFS Gateway Review 2 Report 1.0 FINAL (page 5), only a week ahead of procurement was supported by the market platforms for the Secure flexibility service at the time of designing the trials. However, the Project has been able to conclude the suitability of different horizons based on forecast accuracy. This area will be further explored by the other TEF group partners (TRANSITION and FUSION).
3	Measure asset response time	Due to the established setup of the market platforms, direct asset control was not relevant as the market platforms manage this stage of the process for the secure service. As captured in WPD EFFS_Ofgem Annual PPR_2_v1.0 - 07-10-19 (page 2) this is due to the evolution of the market platforms and not something within the control of the Project. As an alternative, data related to asset response time were provided by the market platforms to feed into the Project learnings. This area will be further explored by the other TEF group partners (FUSION).
4	Assess the suitability of the market & directly connected interfaces to assets	Direct asset control was assessed, and the Project concluded that this form dispatch was not relevant, as the market platforms manage this stage of the process for the secure service. As captured in WPD EFFS_Ofgem Annual PPR_2_v1.0 - 07-10-19 (page 22) this is due to the evolution of the market platforms and not something within the control of the Project. This area will be further explored by the other TEF group partners (FUSION)
5	Assess energy delivery of assets upon service delivery	Due to a lack of market liquidity in the trial areas, there was no opportunity to dispatch real services. Instead, an exercise using test systems and anonymised production data has been adopted. As part of this data, the market platforms have been able to provide details of energy delivery for historic services that have fed into the Project learnings. This area will be further explored by the other TEF group partners (TRANSITION and FUSION)
6	Validate that the selection of flexibility assets by the software is optimal	This was initially limited in the week-to-week running of the trial due to a lack of market liquidity. The project overcame this by using simulated market liquidity. This was done through market platforms creating dummy available flexibility services based on anonymised production data. Desktop exercises in the stress testing also validated the optimal selection of assets, as per requirement 10.

7	Compare the actual impact on the network to the modelled impact to inform strategies for flexibility service procurement and deployment	Fulfilled during the constraint analysis process where a comparison of forecast data and historic data outputs was carried out, and this was also compared with the FlexiblePower dispatch within the area.
8	Validate the expected operating costs of flexibility services.	Data to support validation of expected operating costs of flexibility services within the trial has been limited by a lack of market liquidity. To enhance the learning, we have used the anonymised historic production pricing data from the market platforms to enhance this learning.
9	Provide output on the impact of flexibility on fault restoration to inform the P2/6 review.	The P2/6 review was completed before the trials, which made this objective obsolete. As an alternative, the Project explored the option of trialling the restore service type to assess how this impacts the overall security of supply. However, this was not possible as none of the market platforms could support this service. This was detailed in the system design documentation and communicated to OFGEM in Project Deliverable 4: Development of EFFS Design Specification document. This area will be further explored by the other TEF group partners (TRANSITION).
10	Having proven that the functions operate across several real sites, the software can be stress-tested as a laboratory exercise for conditions that can’t reasonably be recreated as part of a physical trial. This would simulate an expected scenario for 2030 with much higher volumes connected generation, more challenging load profiles, reflecting future levels of EVs and heat pumps, but also with greater availability of flexibility services”.	Exercises were carried out with a variety of scenarios and a higher number of market platforms, service providers, service requirements, and bids.

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