WESTERN POWER DISTRIBUTION

EFFS

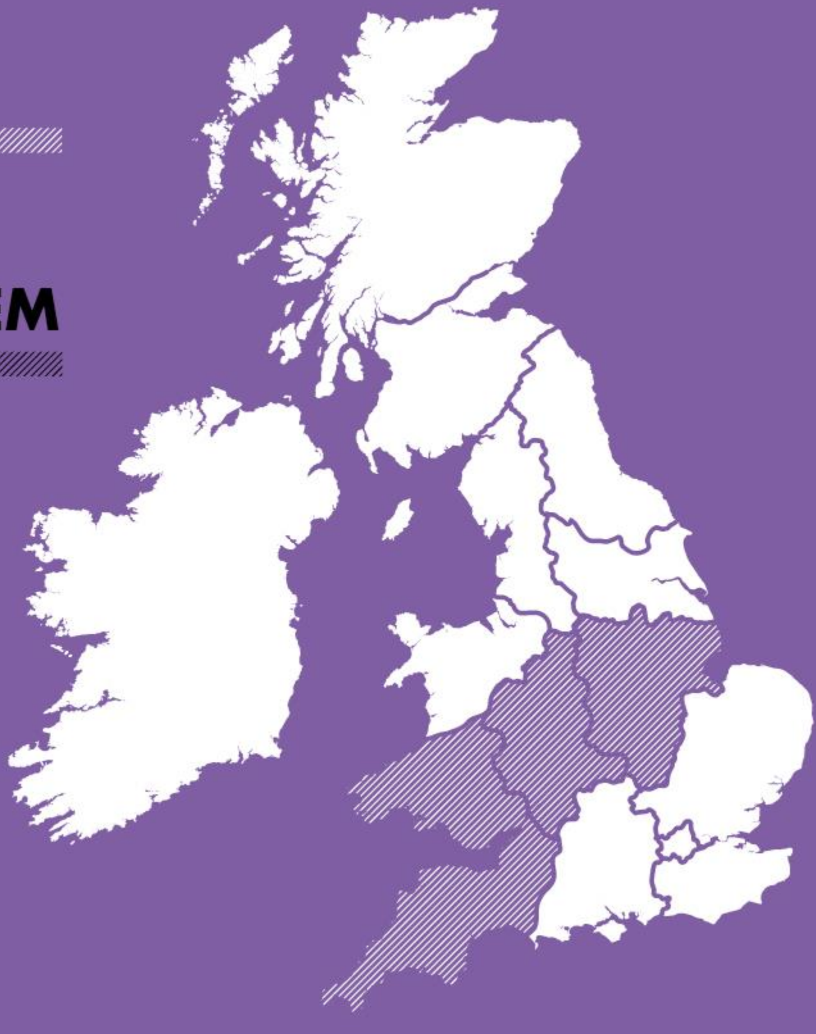
ELECTRICITY FLEXIBILITY AND FORECASTING SYSTEM

EFFS

WPD_EN_NIC_003

NIC PROJECT

SYSTEM DESIGN: SUMMARY REPORT



RIIO NIC NETWORK INNOVATION COMPETITION

Report Title	:	System Design: Summary Report
Report Status	:	FINAL REDACTED
Project Reference:	:	WPD/EN/NIC/03
Date	:	25/10/2019

Document Control		
	Name	Date
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Revision History		
Date	Issue	Status
02/10/2019	0.1	DRAFT
07/10/2019	0.2	DRAFT
08/10/2019	0.3	DRAFT
09/10/2019	0.4	REVIEW
09/10/2019	0.5	REVIEW
09/10/2019	0.6	ISSUED FOR APPROVAL
16/10/2019	1.0	FINAL
25/10/2019	2.0	FINAL REDACTED

Contents

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1 Purpose

The purpose of this document is to provide a summary of the work undertaken in the system design phase as part of the Electricity Flexibility and Forecasting System (EFFS) project. Key features of the document include summaries of the functional areas of the EFFS system design, notes on specific design choices, key design learnings, detail on the design review cycles and view on the approach to the build phase of the project. This document is a summary report aimed at a general readership; it is not a comprehensive record of the EFFS system design. This document sets the scene for how EFFS has been designed from a functional perspective and should be reviewed in combination with the respective system design documents (see documents 6 – 13 in Section 3: Related documents for further details).

2 Glossary

Term	Definition
BAU	Business As Usual
DSO	Distribution System Operator
EFFS	Electricity Flexibility and Forecasting System
ENA	Energy Networks Association
ESO	Electricity System Operator (United Kingdom)
Flexibility Platform	See Appendix 2 for details
kV	Kilovolt
kW	Kilowatt
Affinity Networkflow or Networkflow	Proprietary software suite developed, licenced and maintained by AMT-SYBEX relating to the management of flexibility services for electricity networks.
Service types	Types of peak shaving flexibility services that will be supported by EFFS (namely scheduled constraint management, pre-fault constraint management, post-fault constraint management, restoration support)
User	Users of the EFFS system will be: • **Forecaster and flexibility co-ordinator** up until the real time management, dispatch and monitoring. Note: both these roles do not currently exist but are required, as they do not map onto an existing business function. The flexibility co-ordinator role will have a very similar skill set to that of an outage planner, whereas the forecaster role will require individuals with a mathematical / statistical background and possibly some programming experience. • **Control engineer** for real time dispatch and monitoring of the network. • **System administrator** system and interface support, maintenance of master data, data cleansing.
WPD	Western Power Distribution

3 Related documents

Ref	Document title	Version	Date issued	Prepared by	Location
1	Revised EFFS FSP Redacted	2.0	06/07/2018	EFFS	Link
2	NIC 2017 Compliance Document	2.0	01/07/2018	TRANSITION, EFFS and FUSION	Link
3	DSO Requirements Specification	1.0	24/05/2019	EFFS	Link
4	Forecasting Evaluation Report	1.0	06/06/2019	EFFS	Link
5	EFFS Forecasting Validation Testing Report	1.0	17/07/2019	EFFS	Link
6	WPD_EFFS_System Design_Forecasting	2.0	25/10/2019	EFFS	Link
7	WPD_EFFS_System Design_Capacity_Engine	2.0	25/10/2019	EFFS	Link
8	WPD_EFFS_System Design_Service Management	2.0	25/10/2019	EFFS	Link
9	WPD_EFFS_System Design_Optimisation	2.0	25/10/2019	EFFS	Link
10	WPD_EFFS_System Design_Scheduling	2.0	25/10/2019	EFFS	Link
11	WPD_EFFS_System Design_Market Interface	2.0	25/10/2019	EFFS	Link
12	WPD_EFFS_System Design_Conflict Avoidance and Synergy_Identification	2.0	25/10/2019	EFFS	Link
13	WPD_EFFS_System Design_Reporting	2.0	25/10/2019	EFFS	Link

4 Background

The electricity network is changing, with higher levels of embedded generation, the emergence of storage and the uptake of low carbon technologies such as electric vehicles and heat pumps. These changes pose challenges for networks that were not designed to include them and Distribution Network Operators (DNOs) have been investigating a range of innovations to enable smarter networks, enabling low carbon generation without the cost and delays associated with traditional reinforcement.

DNOs have always had to forecast long term changes to the network demand as part of their planning activities, however these estimates were typically limited to a single estimate for peak generation and demand periods. Demand peaks normally occur during the winter with generation increasingly being during the summer with low demand and high yields from renewable sources such as solar. The widespread, and still growing connection of distributed generation on the network resulted in the need to model a wider range of time periods, and anticipation of further low carbon technology such as heat pumps and electric vehicles and the potential for Time-of-Use tariffs has made it necessary to model full 24-hour days as peak times are no longer limited to predictable windows.

The introduction of flexibility services, where connected assets may be contracted to operate at times which don't reflect a typical usage pattern adds further requirements to forecasting, driven by the need to be able to procure and dispatch flexibility services. The Electricity System Operator (ESO) has utilised flexibility for many years and involves sending short notice instructions to participants connected to the distribution system, requiring them to alter their demand or generation in return for payment. The opportunities for customers to sell this type of service is also growing with opportunities extending beyond the ESO requirements, also to DNOs and traders within energy markets. In response, DNOs' interests now extend beyond what the network power flows will be for a typical Spring weekday, for example, to include what they will be tomorrow, or next week. These forecasts need to be able to reflect local factors such as weather conditions and short-term trends that may not be apparent in the data available to DNOs, e.g. the upgrading of housing stock, changes in the local economy etc.

Recently, it has been acknowledged that managing the challenges of future networks will require DNOs to adopt the new role of Distribution System Operator (DSO). Alongside greater co-ordination with the ESO, this will involve making greater use of flexibility services to operate a far more dynamic network. The aim of Western Power Distribution's (WPD) EFFS project is to specify and trial a system that supports some of the key functions of a DSO. EFFS will focus on 33kV to 132kV networks as these are the parts of the network where the use of flexibility as an alternative to reinforcement will add greatest value and are likely to be implemented first. The design of the EFFS functions and processes can support other parties to adapt these to lower voltages.

The project has the following four objectives:

1. Enhance the output of the Energy Networks Association (ENA) Open Networks project as far as is possible within the timelines of EFFS, 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. Determine an optimum technical implementation to support those new functions;
3. Develop and test the technical implementation through software and hardware integration, as required; and

4. Trial the technical implementation. This will involve modelling the impact of flexibility services as well as proving the system. The trials will create learning relevant to forecasting the likely benefits of flexibility services and the impact of changing network planning standards.

These four objectives are reflected in the EFFS project's workstreams, which are depicted below in Figure 1: EFFS timeline.

Work Type	Workstream	Description	H1 2018	H2 2018	H1 2019	H2 2019	H1 2020	H2 2020	H1 2021	H2 2021
Implementation	1	Forecasting Evaluation, Co-ordination and Requirements	Ofgem Approval		Gateway Review 1					
Implementation	2	System Design, Development, System Test						Gateway Review 2		
Implementation	3	Onsite Testing, Trials and Conflict Management								Gateway Review 3
Implementation	4	Collaboration and Knowledge Dissemination								Closedown Report

Figure 1: EFFS timeline

The EFFS project is collaborating with two other DSO-related Networks Innovation Competition projects; TRANSITION led by Scottish and Southern Electricity Networks and Electricity North West, and FUSION led by SP Energy Networks. The collaborative body made up by the three DSO-related NIC projects of TRANSITION, EFFS and FUSION is known as the T.E.F. Group. By collaborating and sharing learnings, the T.E.F. Group will deliver better value for money and avoid unnecessary duplication.

During the EFFS project's Workstream 1 (forecasting evaluation and requirements gathering), a number of DSO requirements workshops were held to explore DSO-related activities for the planning and dispatching of flexibility services in operational timescales. Note: these were explored through the lens of World B (coordinated DSO-ESO procurement and dispatch), as defined by the ENA Open Networks Future Worlds models (see Appendix 1 for further details). The requirements workshops involved a wide range of industry stakeholders such as National Grid ESO, Scottish and Southern Electricity Networks, Electricity North West, SP Energy Networks, UK Power Networks as well as representatives of the ENA's Open Networks project. The wide range of views on the future direction of the networks industry resulted in the creation of a broad set of DSO requirements that could be useful to any DNO.

5 System design summary

The EFFS system design has been specified as part of the first activity in the EFFS project's Workstream 2 (system design, development and system test). The system design builds on the relevant DSO requirements specified in Workstream 1 and specifies the design principles for how EFFS will be delivered from a functional perspective. While some functionality detailed in the system design is generic and transferable to other DNOs, by its nature the design phase also reflects actual systems, specifically WPD ones, which make up EFFS. The activity of specifying the system design focused largely on identifying practical design options from the expertise of subject matter experts of existing systems within WPD, as well as drawing on AMT-SYBEX's Affinity Networkflow[1] functionality. The length of summaries provided in this summary report reflects the design complexity of each functional area. The system design is summarised by the functional areas in sections 5.1 to 5.8 of this document. It is also recorded in more detail in the supplementary design documents referred to in Section 3 "Related documents" document items 6 – 13 in this document. Section 5.9 provides an overview of the interfaces in support of EFFS. The system design is split into the functional areas for EFFS, which are:

- Forecasting;
- Capacity engine;
- Service management;
- Optimisation;
- Scheduling;
- Conflict avoidance and synergy identification;
- Market interface; and
- Reporting.

The functional areas were defined in the requirements phase of the EFFS project's Workstream 1 and are represented conceptually in Figure 2 below.

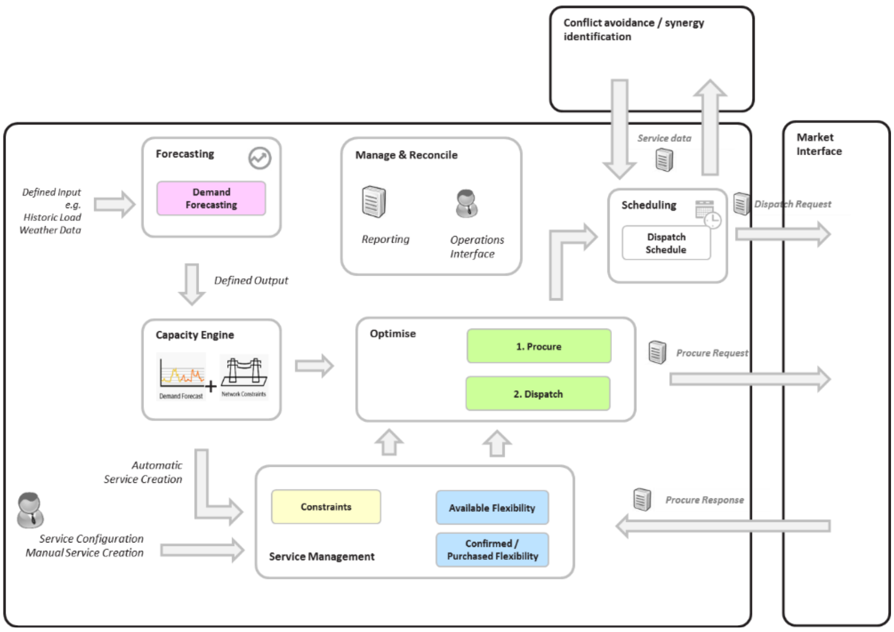

Figure 2: EFFS core functions

[1] https://www.amt-sybex.com/networkflow/

5.1 Forecasting

The project investigated several forecasting methodologies during Workstream 1 Smarter Grid Solutions (SGS) was tasked with assessing whether machine learning techniques could perform better than traditional statistical models and Capita Data Science team were tasked with providing independent validation of the proposed models and findings. This work covered a range of assets such as transformers at Grid Supply Points (GSPs), Bulk Supply Points (BSPs), Primary substations and large load customers, but also wind and solar generation sites. Forecasts for time horizons from day-ahead to six-months ahead were considered and the impact of including or excluding certain model features, such as different types of weather data, were tested.

Three forecasting approaches were evaluated:

- Extreme Gradient Boosting (XGBoost) – a machine learning approach;
- Long Short-Term Memory (LSTM) – a machine learning approach; and
- Auto-Regressive Integrated Moving Average (ARIMA) – a statistical approach.

This work concluded that while all the techniques were capable of being tailored to provide reasonable forecasts, the machine learning technique XGBoost gave the best overall balance between accuracy of the results and the effort required to set up and maintain the forecasts. It also found that, as expected, input data quality was an important factor in the quality of the forecast. Surprisingly, while the inclusion of historic weather data improved the quality of the forecasts, they were able to perform reasonably well without this data. This was thought to reflect the model determining seasonal variations from the week-of-year and month-of-year features as a proxy for weather data. However, it was anticipated that day-ahead and week-ahead forecasts would benefit from inclusion of weather forecast data, especially when the predicted weather would be different from the seasonal averages. Similarly, while time-series forecasting methods can be used for forecasting wind or solar generation, they are not the recommended method. While a time-series model may be able to determine a general relationship between the weather data and the generation output, engineering models can better represent the non-linear impacts introduced by inverters, protective control systems etc. and so are the recommended method to model wind and solar generation. Figure 3 is an example of PV generation output data that can be used[2].

[2] https://www.renewables.ninja/

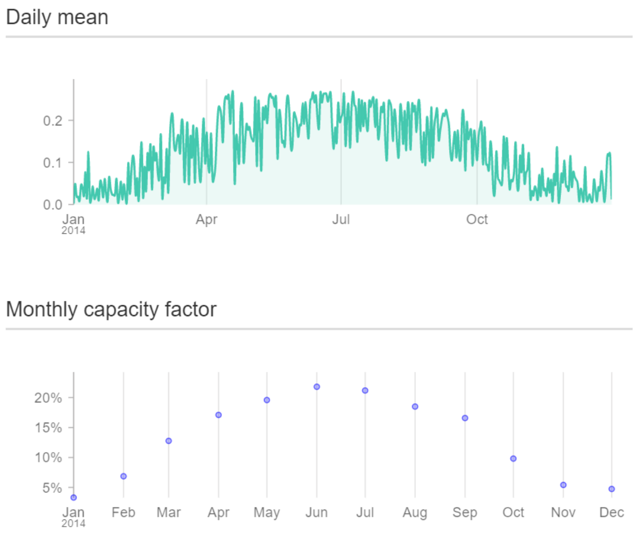

Figure 3: PV output data

During the Workstream 2 system design phase, the focus shifted from which model to implement to the practical questions around implementing the forecasting algorithm. The questions addressed and the conclusions are summarised in the following sections.

5.1.1 Data Sources

The forecasting tool will be provided with historic time-series data from existing SCADA monitoring. This is held within PowerOn[3] and is routinely exported in the form of a HISTAN file. This file can be used to provide both the initial bulk data required for setting up the models and the ongoing requirements for continuing data so that the models are working with up-to-date inputs.

Existing forecast weather data for solar and wind values will be used of to provide inputs for modelling. This is provided at BSP group granularity and therefore EFFS will need to be able to relate forecasting sites to the various weather forecast locations. The model requires additional forecast data for temperature and for the actual weather experienced. This data, along with a bulk set of historical recorded data for training the model, could be provided by Meteogroup[4] at the same level of disaggregation as the current forecasts.

The design has identified the need for a process step for data correction of the time-series data from SCADA. The system will include repositories for both raw and cleansed data with processes to identify data issues being run against the raw data. Further work is planned for the build phase to determine how this can be automated and the degree to which data correction or substitution can be automated. Options for data substitution have been explored and will be examined further in the next phase. Similarly, the work to assess the potential impact of data quality has begun with a review of the monitoring points at a representative location in the trial area.

[3] https://www.gegridsolutions.com/products/brochures/uos/PowerOn_Control.pdf
[4] https://www.meteogroup.com/sites/default/files/180807_weather_data_api_-_corp_factsheet_1.pdf

5.1.2 Accuracy monitoring

The accuracy metrics suggested by the SGS / Capita Data Science work have been adopted for continuing use within EFFS. There are two purposes to calculate accuracy metrics for the forecasts during the EFFS project. Firstly, it will increase the opportunities for learning what factors affect forecasting accuracy by providing a much larger set of results to analyse. The second reason is to see how forecasting accuracy changes over time. If the rate at which forecast accuracy deteriorates is similar across all sites, or all types of site then the process to retrain forecasts can rely on timed schedules. If, however the deterioration of forecasting accuracy varies widely between sites, then the process to identify sites that require retraining and schedule that retraining will necessarily be more complex.

With forecasts covering a wide range of time-horizons and being frequently refreshed there is the potential to calculate a large number of accuracy metrics, but to support their calculation forecasts need to be stored. For example, a forecast for three months in advance, which would be otherwise overwritten within a week, needs to be stored for three months until the actual data from the forecast date is available to calculate the accuracy metrics with. The requirements for sample sizes and retention periods have been specified for the project. Figure 4 contains an accuracy comparison for day ahead forecasts between forecast and actual HH values.

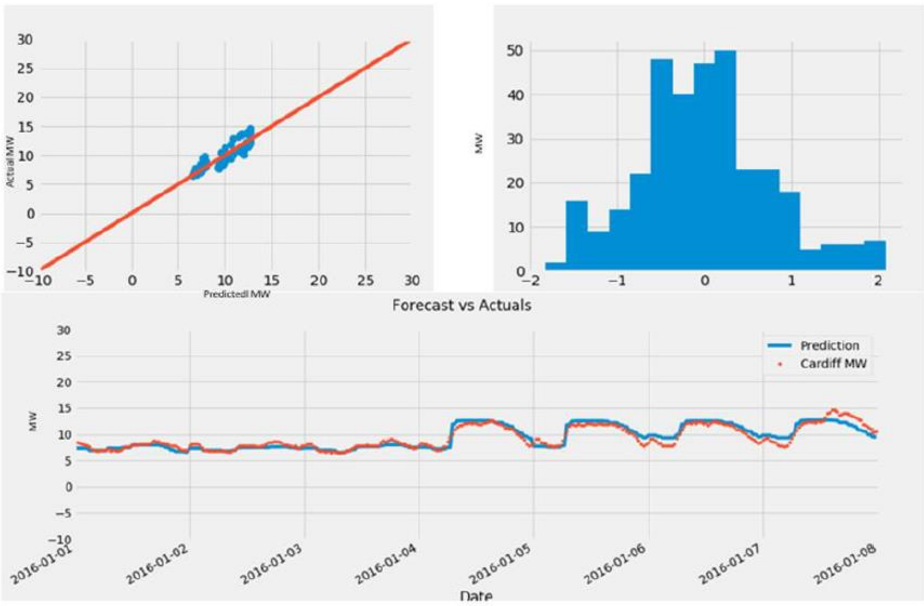

Figure 4: Forecasting accuracy monitoring

5.1.3 Forecast locations and aggregation/ disaggregation

While the forecasting algorithm was tested at a variety of locations, the PSS®E[5] power flow analysis software has the capability of aggregating power flows at one voltage level to determine the impact at a different voltage. Therefore, there is no requirement to forecast the load at a BSP transformer if the loads at all the downstream primary transformers and any customers directly connected to the 33kV networks can be forecast. Similarly, PSS®E can manage the aggregation to create a load profile for GSP transformers given the profiles of the relevant BSP transformers and any 132kV connected

[5] https://new.siemens.com/global/en/products/energy/services/transmission-distribution-smart-grid/consulting-and-planning/pss-software/pss-e.html

customers. The same process would apply to 66kV networks. While this reduces the total number of sites that require direct forecasts, it may still be useful to create a small number of forecasts at BSP or GSP transformers for validation purposes.

5.1.4 Forecasting adjustments

The time-series data that is used by the forecasting algorithms is expected to reflect network loadings for standard running arrangements. These are expected to occur for the majority of the time, and non-standard loading values due to maintenance or unplanned outages would be highlighted as outliers by the data cleansing process. However, the most onerous conditions for the network are more likely to be experienced when the network is abnormally arranged and therefore there is a need to adjust the forecasts accordingly. Forecasting the load for these non-standard arrangements using the same forecasting algorithms that are used for normal running is not practical due to the difficulties of identifying when the required running arrangements happened in the past to select the appropriate data, but also because the number of data points would be small, and in discontinuous blocks. Adjusting the load values that include the impact of embedded generation to reflect the total demand when generation is disconnected requires modelling of the embedded generation downstream of a primary substation. As generation can be added to nodes within the PSS®E model, the approach of creating virtual generators, aggregating embedded generation of different types at the primary busbars has been adopted. A similar correction factor is required to reflect that the load on each transformer at a multi-transformer site feeding different busbar sections that are joined by a bus-section circuit breaker will be different according to whether the bus-section is open or closed. A method for estimating the proportional split has been devised based on the expected aggregated load of the outgoing feeders for each busbar section.

5.1.5 Technical implementation

The forecasting evaluation performed by SGS and Capita Data Science team proposes an open source toolchain which could be used to create forecasts. AMT-SYBEX will instantiate the XGBoost forecasting model into their Affinity Networkflow product. To support the trials, Affinity Networkflow will be deployed on [redacted]. The output of the forecasting function will provide data inputs to the capacity engine function.

5.2 Capacity engine

Flexibility services are used by DNOs to provide an alternative to traditional reinforcement. While flexibility services for reactive power can be used to assist with voltage management, the primary use by DNOs is expected to be preventing thermal limits being breached. The purpose of the capacity engine is to assess the network power flows under credible scenarios which would result in onerous conditions and to determine the volume and location of flexibility services required, so that these requirements can be published to the market. The capacity engine takes the output from forecasting in conjunction with the network configuration to identify periods where flexibility is required to manage the network. In the same way that forecasting future load and generation is a relatively new requirement for DNOs, the network modelling for the capacity engine brings some new challenges. These are summarised in the set of design questions and answers in the following sections.

5.2.1 Data Sources

In order to model the power flows at a future point in time the capacity engine needs to be able to represent:

- The future “base” state of the DNO network i.e. which sections of network will be out for maintenance or abnormally fed for other reasons before any contingencies are modelled;
- Network connectivity, asset ratings and impedances;
- The future values of load and generation at the required nodes on the network;

- The future state of National Grid ESO connected assets that have a significant effect on power flow on the 132kV network;
- The set of contingencies to be modelled; and
- The remedial action schemes that are related to the contingencies to be modelled.

There are two systems within WPD containing data about planned outages on the primary networks. One is the database used by outage planners which contains details of future work, the likely impact on the network and the risk management processes that will be applied. Unfortunately, this does not provide a future view of the network that is machine readable, however the second source of this data is PowerOn, used by the control rooms for real-time network management, but also used to create advanced switching schedules. PowerOn is therefore the source of current and future switch positions that can be used to represent network running arrangements.

In terms of how assets are (normally) connected, their ratings and impedances, the “as connected” version of the PSS®E model is the best source of this data. Where ratings vary by season then the date of the future analysis will be used to select the appropriate value. Future values of load and generation are provided by the EFFS forecasting module, however there is also an input from the EFFS service register which contains details of flexibility services that may be confirmed as scheduled to operate in the future. This is likely to allow some adjustment to day-ahead or week-ahead forecasts to reflect their operation.

The future state of National Grid ESO connected assets relates to the outputs of two large power stations and whether reactive compensation devices are switched in or out. National Grid ESO provide notice of planned outages which could be used to infer the reactive compensation position and historic generation data will be used to determine representative values for modelling. The set of contingencies to be modelled is not a separate input to the capacity engine, but rather it is generated dynamically within the scripts used to automate PSS®E analysis currently.

The Remedial Actions Schemes (RAS) associated with the contingencies being modelled are created and managed within the RAS module of PSS®E.

5.2.2 Modelling future network conditions.

With the power flow analysis utilising the PSS®E network model but PowerOn being the master dataset for the current and future network configuration, there is a need to:

- match asset records between the two systems;
- update the PSS®E model to reflect the current network configuration;
- determine the likely position of switches that are operated under switching schedules immediately prior to the modelling period; and
- update the PSS®E model to reflect the future network configuration.

A clear risk to the accuracy of the future predicted network model will be the occurrence of unplanned events that are not reflected in the planned schedules. This is expected to be a greater risk for week-ahead analysis than for day-ahead analysis and assessing the impact of this on the accuracy of the specified requirements is planned during the next phase.

5.2.3 Modelling scenarios

When modelling the network far in advance the contingency analysis needs to model all potential planned outages and subsequent credible faults. However, if we are able to reflect known planned outages in the model representing the future state of the network, the requirement is simplified to modelling the credible faults in conjunction with these planned outages rather than for all possible planned outages. This is reflected in the design of the capacity engine process which assumes that planned outages will have schedules entered into PowerOn three weeks before they are due to begin.

5.2.4 Defining market requirements

The results of the power flow analysis for each contingency will identify assets that are above a threshold value of their thermal capacity for any half hour period. As the various contingencies are not expected to happen at the same time, a process is required to determine the maximum exceedance under the set of contingencies for each half hour for each asset.

Another process is required to relate the location of the thermal network issue to the locations at which flexibility services can be purchased. For example, if the thermal issue is on a particular circuit, then there may or may not be flexibility service providers connected to that circuit. It is more likely that services will be purchased that relate to transformers served by the circuit with flexibility customers being connected downstream of the transformers. While this mapping is simple for radial circuits, meshed networks will result in a more complex mapping and whether requirements are divided between sites before being published to the market or the selection of sites forms part of the optimisation process will depend on the information available from the market platforms.

5.2.5 Network sensitivity

The impact of a flexibility service on the exceedance being managed will be different for flexibility services at different locations. Analysis of this network sensitivity is required to ensure that sufficient flexibility services are procured, for example if modelling suggests the potential overload of a transformer by 1MW, it may be necessary to purchase more than 1MW of flexibility service.

Flexibility Service Location	Impact at overloaded transformer of 1MW load reduction at flexibility service location	Purchase requirement for 1MW load reduction at service location
A	950kW	1.053MW
B	900kW	1.111MW

Table 1: Flexibility service location examples

In the illustrative example in Table 1, a larger volume of flexibility services would need to be purchased at location B to ensure the 1MW load reduction at the transformer (1000/900 x 1000kW for location B as opposed to 1000/950 x 1000kW for location A). Given the different impact of the service at each location, in a fluid market, it would be reasonable to reflect this in the prices a DSO would be prepared to accept at different locations.

Additional complexity arises as these sensitivity factors are not static but rather reflect the configuration of the network and the values of load and generation at the network nodes. This suggests that the aggregated network requirements to be passed to the market will need to be adjusted to take these differing factors into account. Given the potential for purchases of flexibility services to alter the sensitivity factor for subsequent flexibility service purchases it is necessary to make simplifying assumptions to avoid the complexity of the service management becoming unmanageable and optimisation processes intractable. The proposed system design calculates the sensitivity factors for all contingencies and the next phase of the project will determine the most appropriate value to use e.g. average, worst case or reflecting a given risk factor.

5.2.6 Confirming sufficiency

Given the potential for feedback loops between the services purchased and the services required, and the use of simplifying assumptions, a confirmatory stage is included in the process to validate that the selected services are sufficient to meet the requirements.

5.3 Service management

Service management takes the output of the capacity engine and transforms that into a number of flexibility requirements to be fulfilled by the market. These are created as service instances and their following lifecycle and associated statuses are managed by the service management module in the AMT-SYBEX Affinity Networkflow product.

Also, service management stores all default parameters associated to the service types supported by EFFS (e.g. minimum bid size, maximum bid duration etc.) and will validate that what is offered by the Flexibility Platforms is a valid service instance and adheres to the defined characteristics.

During Workstream 1 the project decided to support the 4 DSO service types as defined by the ENA ON (scheduled constraint management, pre-fault constraint management, post fault constraint management and restoration). However, the scheduled constraint management use case has lead times of at least a year prior to the curtailment event, which does not align with the EFFS forecasting timelines (maximum of 6 months prior to the curtailment event). For this reason, the scheduled constraint management service type has been removed from the scope of the design and the EFFS trials.

5.4 Optimisation

The optimisation function in EFFS will be supported by an Optimisation module in AMT-SYBEX's Affinity Networkflow product. The Optimisation module is a linear algorithmic solver that enables optimisation for a number of procurement and dispatch factors, such as cost. Optimisation is performed in EFFS at the point when flexibility services are procured or dispatched. It assumes there are more services offered/available than are required by the DSO and that there is benefit in optimising the selection on a combination of financial and non-financial metrics. The Optimisation module will run for each Flexibility Management Zone (FMZ) set up in the system, assuming they align to a BSP. It will assess all potential "Available Flexibility" services against each "Required Flexibility" service.

Commercial optimisation i.e. the process of getting maximum value across multiple Flexibility Platforms whilst ensuring the service requirements are fulfilled, is the key focus of optimisation in EFFS. To reflect the dispatch principles defined for WPD's Flexible Power platform, EFFS will consider fairness and the minimisation of non-delivery of a service as optimisation criteria. While there is a lack of complete interoperability across Flexibility Platforms in terms of timelines and process, which are a condition required for carrying out cross platform optimisation, EFFS will optimise across platforms where possible.

5.5 Scheduling

The scheduling function of EFFS takes the output of the optimisation function (the proposed chosen services and associated delivery profiles that best satisfy the forecasted network requirements as per the specified optimisation parameters) for user validation and converts this into a confirmed service schedule ready to be issued to the relevant Flexibility Platforms. The key decision in this area during the project's WS1 was whether a user would want to be able to view and dispatch flexibility within EFFS or within the existing WPD control room system (PowerOn). The latter was the consensus position reached in the associated project workshop. This was based on the thinking that it would be inefficient for the control room users (who would be dispatching the post-fault services in near real time and then monitoring the network) to use two systems rather than PowerOn only. During the design phase this approach has been ratified with the relevant subject matter experts and an approach for achieving this technically defined. The approach we have adopted attempts to minimise change to PowerOn both to reduce cost, negative system performance impact and also to avoid disruption to existing user experience.

Figure 4 provides a representation of the dispatch mechanism for post fault services:

Figure 4: Dispatch mechanism for post fault services

5.6 Market interfaces

To support the trials, EFFS will interface with the following three Flexibility Platforms:

- Cornwall Local Energy Market, operated by Centrica;
- Flexible Power, developed by KiwiPower; and
- PowerShift, operated by EDF Energy.

These platforms offer access to a variety of customers required for the trial phase of EFFS. As the platforms have evolved at different times to meet different purposes, they will generate separate learnings for each platform rather than being duplicates of each other. Interfacing with multiple platforms allows for learning around the practical issues for activities such as optimisation and whether the multiple platforms act to facilitate a single open marketplace or act to subdivide the market.

Market interface instructions and associated data items were derived from the four service types defined by the ENA ON (see Appendix 3 for more details) as well as from the operational procurement and dispatch processes defined in the project. The original project assumption was that the market platforms would be interoperable and would not require bespoke interfaces. However, as an industry standard is not available, each platform has their own interface (taking advantage of any synergies between the respective platforms design where possible). This approach enables the project to execute its trials despite the lack of uniformity in the market; it is recognised however that custom interfaces would not be supported once an industry standard interface has been defined.

Once a requirement for flexibility has been identified, this will be issued to the Flexibility Platform via an agreed mechanism such as an interface. The mechanism includes a series of request / responses so that participants can bid for periods of flexibility. There are two general principles to the market interface process, namely procurement and dispatch; this was simplified to two stages from originally three which included arming. The arming data exchange has been removed following further refinement in the design phase: simplifying the process and data exchange without loss of functionality. Procurement refers to the reservation of specific flexibility service instances with a Flexibility Platform in operational timescales. The aim of the process is to have a flexibility service (or services) procured, which can subsequently be dispatched to resolve network constraint(s) or to speed up fault restoration. At this stage there is no obligation to use the service, so it may not be utilised or dispatched. Dispatch refers to the dispatching of specific flexibility services instances via a Flexibility Platform in operational timescales. The aim of this process is to dispatch a service (or services) to resolve a network constraint(s). The direct dispatch and real time control of the asset will not be carried out by EFFS; this will be the responsibility of the Flexibility Platform / service provider.

Figure 5 gives an example of the agreed signals and timelines for one of the Flexibility Platforms EFFS will interface with.

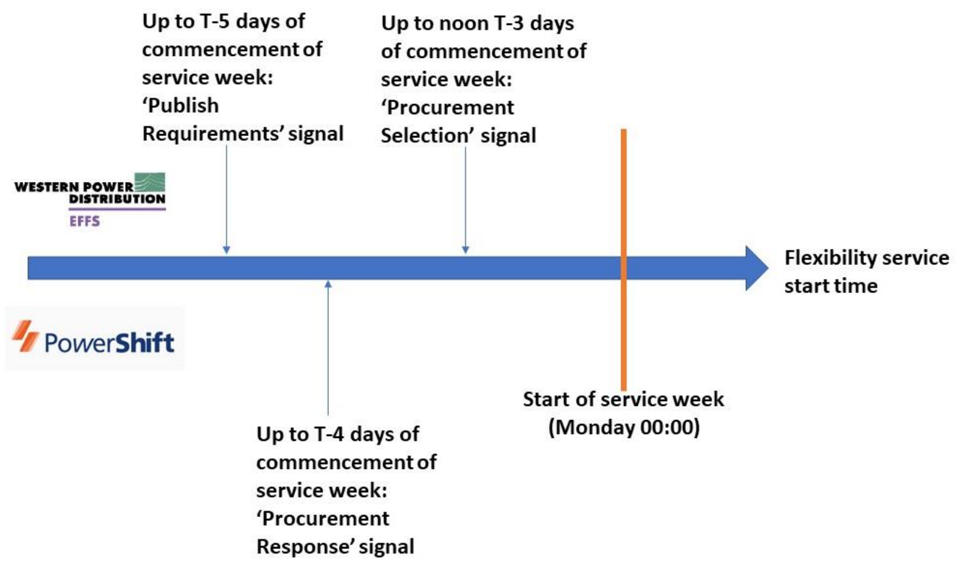

Figure 5: PowerShift timelines

5.7 Conflict avoidance and synergy identification

The ESO has utilised flexibility for many years and involves sending short notice instructions to participants connected to the distribution system, requiring them to alter their demand or generation in return for payment. The options for customers to sell this type of service are growing with opportunities extending beyond the ESO to include DNOs and traders within energy markets. As the number of flexibility service users increases, so does the potential for conflicts arising between services. There is a very clear requirement to consider how the actions of different actors within system can operate without reducing efficiency, increasing costs or presenting unnecessary risks to the system resilience, both locally and as a whole. The functionality explored surrounding conflict avoidance reflects that EFFS is designed to operate in Open Networks future world B, where DNO and ESO are both involved in the co-ordination of flexibility services and exchange data to facilitate this.

Synergies between services have also been considered in the context of how the system might identify them. This is purely to support information gathering to assist policy development. There are no activities in the scope of EFFS to reduce the services procured or scheduled on the basis that there may be a beneficial effect from a third-party service.

Key design considerations are summarised below.

5.7.1 Conflict definition

There are many types of conflict between users of the network, but they have sufficient predictability or low impacts that they can feed into the forecasting but do not necessarily cause network issues. This could for example be two embedded generators shutting down to carry out annual maintenance at the same time. The impact would result in increased demand through the upstream network to supply more electricity from elsewhere, but it wouldn't necessarily result in any real risk to the network.

Our definition of conflicts between flexibility services are events that result in flexibility services being unavailable due to scheduling errors between multiple parties, services being counteracted by third party actions and combined actions that result in network issues for either the DNO or ESO.

For example, we could have a situation where the ESO requires a Flexibility provider to start a generator to support national system balancing, but this would then trigger a nearby windfarm equipped Active Network Management (ANM) to reduce output by the same capacity and cancelling out the initial request.

5.7.2 Conflict identification

The different types of conflict require different data and approaches to identify them. For a scheduling conflict, a simple comparison can be made for the asset ID, the date and time of the service to be delivered along with the type of service being delivered (demand turn up that benefits both DNO and ESO would not necessarily constitute a conflict). Determining whether one service will negate or partially negate another will require some consideration of where the services are impacting the network and the locations of the desired change. Where possible this will use network hierarchy information, however where a simplified process is not sufficient then power flow analysis will be used to determine whether one service is reducing the impact of another.

Conflict identification and quantification would be a beneficial activity whether or not conflict resolution activities were in place as it would provide much needed information to the industry. It is quite possible that where certain types of conflict present a low risk the most practical solution is not to require one party to alter their planned use of services, but rather to factor the risk of impact of that type of service into the safety margin applied within the capacity engine.

5.7.3 Conflict resolution

The potential principles for conflict resolution have been investigated. One potential option is to compare the marginal cost of using an alternative flexibility service for both parties. For the purposes of the EFFS trial it is sufficient to simply have values that can be compared by the resolution algorithm. The methodology to calculate marginal costs is likely to be best addressed within an industry wide forum such as Open Networks. Similarly, as the objective of the EFFS trials in relation to conflict avoidance are to prove that the data exchanges and processes are sufficient this can be achieved without engineering real conflicts in services and complete system-to-system interfaces but by using representative data.

5.8 Reporting

To demonstrate the trial outcomes and learnings of EFFS, the project has defined a high-level approach to reporting. The EFFS project has adopted the principle that a limited number of pre-defined reports relating to the EFFS processes and core systems will be delivered. This is based on the known business requirements at this stage. These detailed business requirements have changed significantly since those defined in Workstream 1 due to the evolution of Flexibility Platforms plus an increased understanding of the use and management of flexibility within the operational business. For example, there was an original requirement to support a service delivery confirmation report from the Flexibility Platform to the DSO. However, working through the design it has been established that this is a settlements activity that is out of scope for EFFS. As this will follow existing BAU practises for each Flexibility Platform to provide the invoicing and billing of flexibility procured by the DSO.

In addition, there was a requirement for EFFS to compare what flexibility was requested to be dispatched with what has actually dispatched (both in terms of timeliness and also fulfilment of the energy requirement). Like the above, this falls into settlement processing and does not fit into the scope of the EFFS project. Based on this experience during the system design deliverable phase, an exhaustive suite of bespoke reports would not be appropriate as the reporting requirements are likely to evolve further as the trials progress. However, the key principles of reporting at this stage that we expect to expand upon are cost of flexibility services, timeliness of responses from Flexibility Platforms and forecasting accuracy.

5.9 Interface overview

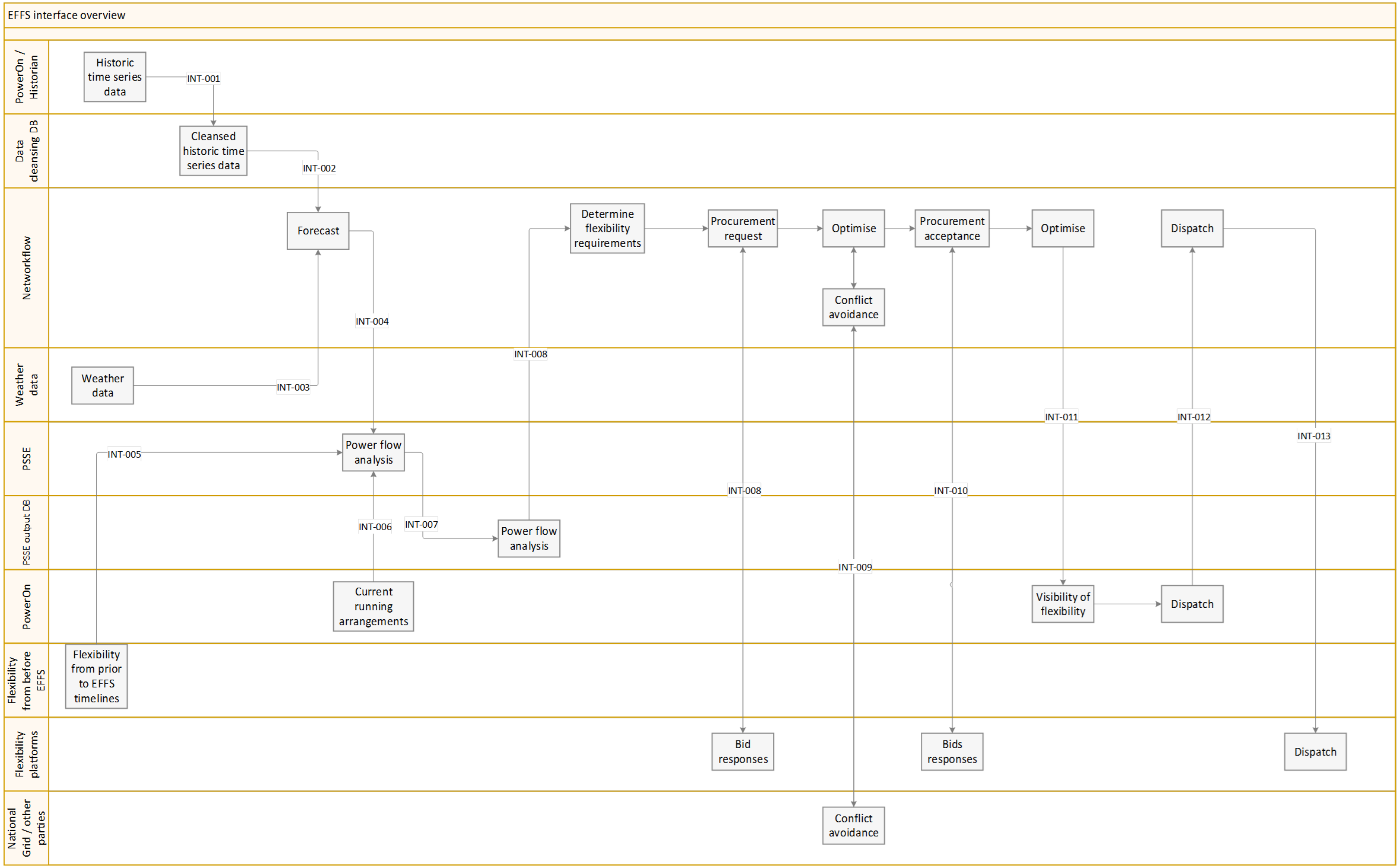

Figure 6: EFFS interface overview

6 Key review stages

The process of defining, refining and finalising the EFFS system design deliverable involved several key review stages by the core project team and relevant system owners / subject matter experts. The project placed emphasis on defining an overall system to support the trials that was practical and feasible. The key stages of reviewing the system design deliverable were:

- **Design capture reviews** – the process of capturing the design options available to the project saw the core project team interacting with the various subject matter experts of the various systems supporting EFFS. Using the requirements defined in Workstream 1, the system design options were captured and reviewed by the core project team following each interaction. These design options provided the project a foundation to support the drafting of the various system design documents.

- **First draft review** – once the system design options had been drafted, the core project team performed a first draft review of the system design documents. These reviews enabled the team to identify any outstanding design gaps or areas of uncertainty and to pursue these with the subject-matter-experts.

- **Second draft review** – following updates and revisions to the system design documents that arose from the first draft review, the system design documents were issued to the relevant system owners and subject matter experts for review. This review cycle represented a critical opportunity for the team to pursue any outstanding design gaps or areas of uncertainty in a targeted way. The team collated all review comments into a single comments log to enable an efficient and transparent method of updating the documents.

- **Final review and signoff** – the final drafts of the system design and a collated comments log were issued to the system owners for final review and signoff. The core project team supported the final reviews by holding meetings to walk reviewers through the updated design documents and elicit their final agreement.

For a view of the review cycles timeline that supported the production of the EFFS system design deliverable, please see Appendix 4.

7 Build phase

In line with the EFFS Project Direction, the system design phase of the EFFS project has produced system design deliverables that detail how EFFS will be functionally delivered. This summary design document along with the eight supplementary design documents represent the project's Ofgem deliverable 4. Due to the nature of an innovation project, such as EFFS, as well as the continuing evolution of DSO in the networks industry, it is recognised that certain areas of the system design require additional validation to ensure their feasibility. The process of translating high-level DSO requirements to functional designs demonstrated that DSO functions that appear straightforward can actually require highly complex processes to support them. The areas of forecasting, capacity engine and conflict avoidance in particular uncovered levels of complexity that were not apparent during the requirements specification phase in Workstream 1. Where this has been the case, EFFS has decided on a number of targeted options and / or assumptions in the design documents to then be optimised in the build phase.

In line with traditional software project methodologies, the next step for the project is to take the system designs and develop the necessary detailed technical designs to support the build phase. This is typical of complex software projects, particularly ones of an innovation nature. To mitigate any areas of technical uncertainty, WPD will work in an iterative and agile manner during the build phase. This is also deemed most appropriate as there is a risk that there may be some changes to requirements as a result of learnings from the T.E.F. projects and as well as from other activities that are shaping the environment for flexibility services, such as the output of the ENA's Open Networks project.

8 Contact

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Appendix 1: Overview of the Open Networks Future Worlds

The below summary is taken from the ENA ON Future Worlds consultation document.

"In 2018, the Open Networks Project showcased five potential industry structures, known as Future Worlds. Extensive work was carried out with stakeholders to define these five Future Worlds and they were modelled using the Smart Grid Architecture Model (SGAM) to further define the information flows necessary for each world to operate. These detailed definitions and the SGAM models were presented as part of the Future Worlds consultation in 2018.

Below is a high-level summary of each of the 5 Future Worlds.

World A: DSO Coordinates

In this World, the DSO takes on a central role for all active Customers and DER. It procures and activates distribution network connected flexibility resources for distribution network constraint management and for providing services to the ESO for regional and national requirements. The DSO also schedules flows to and from the electricity transmission system based on a pre-defined power exchange schedule agreed with the ESO. From a transmission perspective, the DSO behaves in a similar manner to other transmission connected parties and the services it can provide from DER connected within its networks are evaluated on a regional transmission and national level by the ESO in a non-discriminatory manner along with other transmission connected service providers.

World B: Coordinated DSO-ESO Procurement and Dispatch

In this World, flexibility resources can provide services to multiple SOs and are able to stack revenues from these differing SOs. It is recognised that, on occasion, the needs of different SOs will conflict and it will be the joint responsibility of these SOs to coordinate service procurement and dispatch activities. This will be done in a transparent manner which creates the most efficient outcome for the end consumer.

World C: Price Driven Flexibility

World B considered a World based on enhanced contracted flexibility arrangements. In World C, changes are made to price flexibility arrangements such that active parties vary their demand or generation in response to either or both energy price and network signals, such as time and location. World C has been developed cognisant of Ofgem's reform of electricity network access and forward-looking charges programme and considers potential changes to future charging and access arrangements. Given the relatively early stage of this programme and the nature of the SGAM modelling it has not been possible to define a detailed option. World C does consider high level principles for changes to charging and access arrangements that are consistent with the work of Charging Futures including:

- Ensuring greater alignment of arrangements between transmission and distribution;
- More effective influencing of user operations through network charging arrangements;
- More appropriately influencing user investments through access and user commitment arrangements; and
- Consideration of connection rights and arrangements.

World D: ESO Coordinate(s)

In this World, the ESO takes a more central role than in previous Worlds in many of the Customer facing activities of an SO. This potentially includes connection and charging arrangements as well as flexibility services (Figure 2.4). The DSO role would become more focused on identifying short term and long-term service opportunities from third-party providers which would be passed as service requests to the ESO for procurement.

World E: Flexibility Coordinator(s)

In World A, a new party, the Flexibility Coordinator, acts as an independent, neutral market facilitator for all flexibility markets. This party could either be a national entity or one of a number of standardised regional monopoly entities. The Flexibility Coordinator(s) is responsible for collecting service requirements from both DSOs and the ESO, optimising the requirements and identifying the most efficient solution. This is achieved through the use of a common platform(s) which aids transparent decision making. The Flexibility Coordinator(s) also needs to work closely with SOs through design and operation processes to ensure a coordinated system is efficiently developed and security of supply is maintained."

Appendix 2: Definition of Flexibility Platform

'Flexibility Platform' is a term used throughout this document and is deliberately generic due to the current lack of cross-industry consensus on what this role entails and the differences between the existing platforms. Whilst it is not the purpose of EFFS to specify how these platforms will operate, the project makes various assumptions about what functions they will perform throughout the document. For ease of reference these are collated in the table below. Please note that this list is not an exhaustive; it is an overview of assumed Flexibility Platform capabilities and their relationship to EFFS.

Function	Carried out by Flexibility Platform?	Required by EFFS?
Interface for registering flexible resources	Yes	Yes
Allows buyers and sellers to match their requirements	Yes	Yes
Communication with flexibility resources	Yes	Yes
Dispatch of flexibility resources	Yes	Yes
Commercial optimisation	Yes	No, as EFFS will use multiple platforms therefore needs a cross platform view
Conflict avoidance with other parties	Yes	No, as EFFS will use multiple platforms therefore needs a cross platform view
Synergy identification with other parties	Yes	No, as EFFS will use multiple platforms therefore needs a cross platform view
Settlements (payment of flexibility providers)	Yes	Yes
Measurement of flexibility providers performance	Yes	Yes

Table 2: Flexibility Platform characteristics

Appendix 3: Service type definitions

Below are the definitions of the initial services types to be supported in accordance with the ENA ON workstream 1 product 2, 'DSO Service Requirements: Definitions':

"***Scheduled Constraint Management*** *- The DSO procures, ahead of time, a pre-agreed change in input or output over a defined time period to prevent a network going beyond its firm capacity (thereby ensuring all load remains secure following the next fault). For example, a reduction in demand is procured over an evening peak period to mitigate risk of overload that might result should a fault occur on one of two in-feeds to a group*[6]*.*

Pre-fault Constraint Management *– The DSO procures, ahead of time, the ability to access a pre-agreed change in Service Provider output based on network conditions close to real-time. Utilisation is then delivered by different mechanisms, depending on whether the DSO wishes to manage network risk manually, or automatically: a. Utilisation may be instructed manually, ahead of real-time, to prevent a network going beyond its firm capacity. This will generally be a manual call based on circuit loading forecasts. For example, a Service Provider is contracted to be available to the DNO over winter evening peaks. The DNO then calls the Service Provider on days forecast to have the worst predicted loadings; or b. Utilisation may be initiated through an automated DSO system. For example, a Service Provider is contracted to be available to the DSO over winter evening peaks. The DSO system then triggers the service when the loading reaches the firm capacity.*

Post-fault Constraint Management *– The DSO procures, ahead of time, the ability of a Service Provider to deliver an agreed change in output following a network fault. Utilisation is then instructed when the fault occurs on the network (but only if loading is beyond the post-fault rating of the remaining assets). This will generally be instructed through an automated system and will utilise the short-term ratings of the assets, such that a sustainable post-fault flow can be achieved. For example, a Service Provider is contracted to be available to the DSO over winter evening peaks. The DSO system instructs the Service Provider to deliver the contracted change in output when the fault occurs.*

Restoration Support *– Following a loss of supply, the DSO instructs a provider to either remain off supply, or to reconnect with lower demand, to support increased and faster load restoration under depleted network conditions. For example, a Service Provider may be restored at minimal load to allow for other (perhaps less flexible) customers to be restored."*

The Table 3 overleaf summarises these service characteristics:

[6]This service is characterised by operating on a scheduled manner and is therefore simpler to manage and does not require sophisticated forecasting to support decision-making.

Service Characteristics	Scheduled Constraint Management	Pre-fault Constraint Management	Post-fault Constraint Management	Restoration Support
When to act	Pre-fault	Pre-fault	Post-fault	Post-fault
Triggering action	Time	DSO forecast; or Asset Loading	Network fault	Network fault
Certainty of utilisation	Very certain	Uncertain	Uncertain	Very uncertain
Efficiency of utilisation	Low	Medium	High	Low
Risk to network assets	Low	Medium	High	Low
Frequency of use	High	Medium	Low	Low

Table 3: Service characteristics

Appendix 4: Review stages – timeline

Below is the timeline of review cycles that was employed to support the EFFS system design:

	September																									October 2019													
	Mon 2nd	Tue 3rd	Wed 4th	Thu 5th	Fri 6th	W	Mon 9th	Tue 10th	Wed 11th	Thu 12th	Fri 13th	W	Mon 16th	Tue 17th	Wed 18th	Thu 19th	Fri 20th	W	Mon 23rd	Tue 24th	Wed 25th	Thu 26th	Fri 27th	W	Mon 30th	Tue 1st	Wed 2nd	Thu 3rd	Fri 4th	W	Mon 7th	Tue 8th	Wed 9th	Thu 10th	Fri 11th	W	Mon 14th	Tue 15th	Wed 16th
1) Review of first draft by core team	X	X	X	X	X		X	X																															
2) Update /revise							X	X	X	X	X		X	X																									
3) Review second draft by system owners															X	X	X		X	X	X	X	X																
4) Update /revise																									X	X	X	X	X		X	X							
5) Control room walk-through																				X	X																		
6) Finalise summary report																													X		X	X							
7) Final review and signoff by system owners																																	X	X	X		X	X	
8) Submission to Ofgem																																							X

Figure 7: System design review timelines