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EFFS

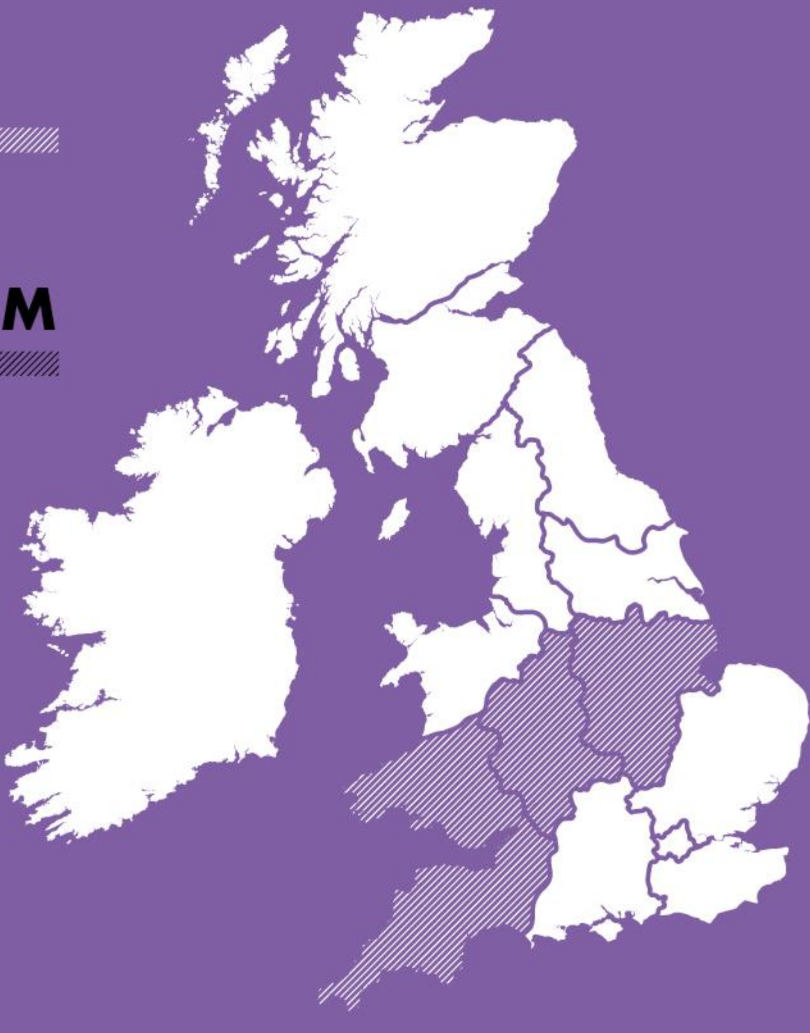
ELECTRICITY FLEXIBILITY AND FORECASTING SYSTEM

EFFS

WPD_EN_NIC_003

NIC MAJOR PROJECT

System Design: Capacity Engine



RIIO NIC NETWORK INNOVATION COMPETITION

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	Name	Date
Prepared by:	Michael Pearson	09/10/2019
Reviewed by:	Jennifer Woodruff	09/10/2019
Approved by:	Ben Godfrey	14/10/2019
	Paul Hartshorne	15/10/2019
	Jonathan Berry	16/10/2019
	Sarah Hadfield	22/10/2019

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Contents

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Telephone +44 (0) 1332 827446. E-mail wpdinnovation@westernpower.co.uk

1 Purpose of this document

The purpose of this design document is to specify how the capacity engine requirements defined in the EFFS project's DSO Requirements Specification will be delivered from a functional perspective. This design document forms one of eight system design documents (listed below), namely the capacity engine design document. The system design documents complement the System Design Summary Report, which contains an overview each functional area and the relationships between them.

- Forecasting;
- **Capacity Engine**;
- Service Management;
- Optimisation;
- Scheduling;
- Conflict avoidance and synergy identification;
- Market Interface;
- Reporting and Reconciliation.

In accordance with the EFFS Project Direction, this document forms part fulfilment of the project's fourth deliverable to Ofgem, the 'EFFS system design specification'.

2 Executive summary

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. In EFFS, the capacity engine will assess network power flows under credible scenarios, which result in onerous conditions and determine the volume and location of flexibility services required; these requirements can then 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, which are explored in this document.

3 Glossary

Term	Definition
ANM	Active Network Management

Contingency scenario	These are outage scenarios to consider when modelling the network in order to identify constraints (for example an N-1 or N-2 scenario)
	As per current WPD policy this will include the following outages and combinations:
	• The intact (normal running) network
	  ○ Each circuit fault
	  ○ Each busbar fault
	• Each arranged circuit outage
	  ○ Each arranged circuit outage followed by each circuit fault
	• Each arranged busbar outage
	  ○ Each arranged busbar outage followed by each circuit fault

Constraint	For EFFS purposes, this refers to thermal network constraints only
DSO	Distribution System Operator
EFFS	Electricity Flexibility and Forecasting System
HH	Half Hourly electricity metering
IPSA 2	IPSA 2 is a software tool for power system design and operation applications provided by IPSA Power
kV	Kilovolt
kW	Kilowatt
NIC	Network Innovation Competition
Affinity Networkflow or Networkflow	Proprietary software suite developed, licenced and maintained by AMT-SYBEX relating to the management of flexibility services for electricity networks.
MVA	Mega volt amp
MVAr	Mega volt amp reactive
mW	Milliwatt
MW	Megawatt
Network configuration	This term is used to define that network configuration has changed after a specific network contingency event.

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>Network model</td><td>An electronically held network arrangement that may be used to simulate the impact of load-flows or perform other analysis of the network under different scenarios.

Some further definition related to network models:
Switch level = a network model that contains switchgear details to allow for contingency modelling;
As built = model that reflect the current network;
Committed = As built amended for future network changes that are confirmed (i.e. not proposed).</td></tr>
<tr><td>OFAF</td><td>Oil forced / air forced cooling</td></tr>
<tr><td>PowerOn</td><td>Distribution Management System provided by GE</td></tr>
<tr><td>PSS®E</td><td>Transmission planning and analysis software provided by SIEMENS</td></tr>
<tr><td>Python Harness</td><td>A tool used by WPD to automate power flow analysis such as generating contingencies, executing the analysis and populating output files</td></tr>
<tr><td>RAS</td><td>Advanced Contingency and Remedial Action Scheme, an add on module in PSS®E</td></tr>
<tr><td>Service types</td><td>Types of constraints management services that will be supported by EFFS (namely scheduled constraint management, pre-fault constraint management, post-fault constraint management, restoration support.)</td></tr>
<tr><td>SVO</td><td>System Voltage Optimisation</td></tr>
<tr><td>User</td><td>Users of the EFFS system are anticipated to 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.</td></tr>
<tr><td>WPD</td><td>Western Power Distribution</td></tr>
<tr><td>WS1</td><td>Workstream 1 of the EFFS project (forecasting evaluation, co-ordination and requirements)</td></tr>
</table>

4 Related documents

Ref	Document title	Version	Date issued	Prepared by	Location
1	Revised_EFFS_FSP_Redacted_v2	2.0	06/07/2018	EFFS	Link
2	WPD_EFFS_DSO Requirements Specification_v1.0	1.0	24/05/2019	EFFS	Link
3	System Design Summary Report	2.0	25/10/2019	EFFS	Link

5 System overview

5.1 Core functions overview

Figure 1 provides a diagrammatic representation of the functional areas in EFFS. The functional area that is the subject of this document is circled in red.

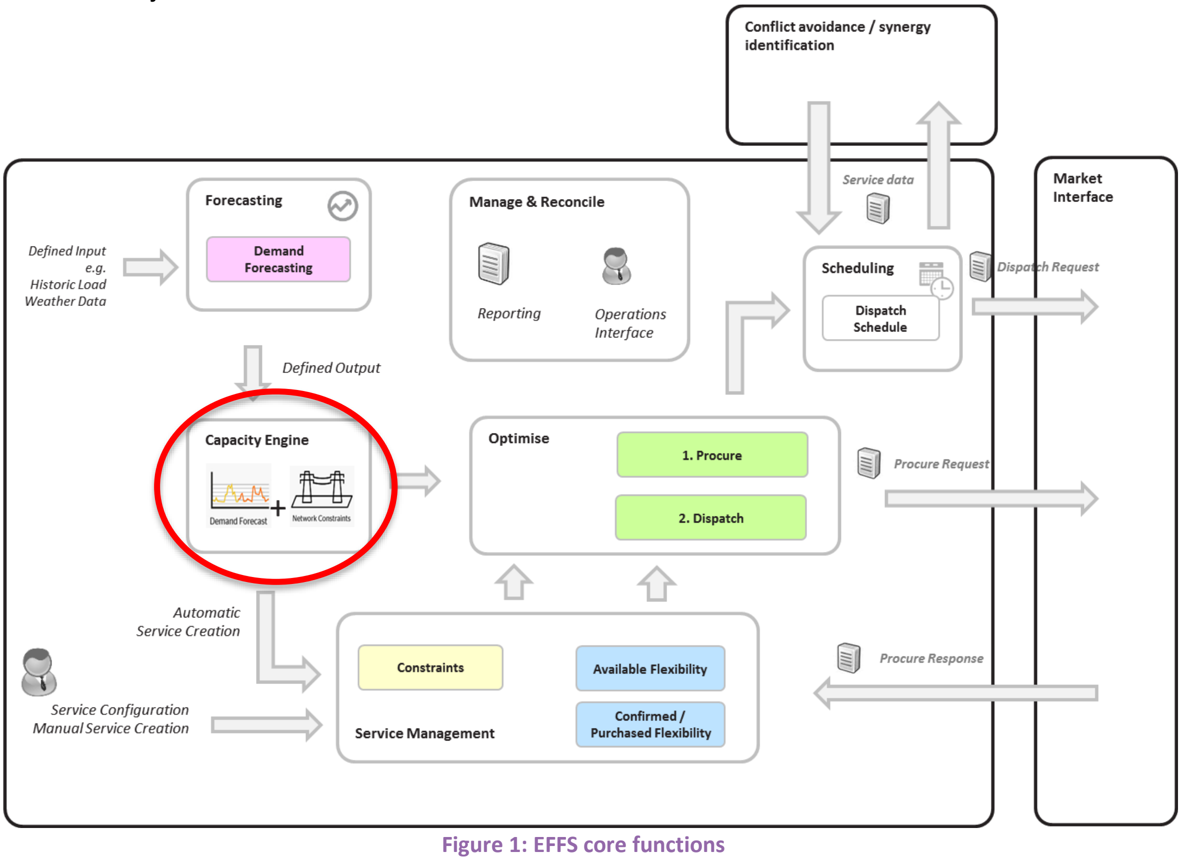

Figure 1: EFFS core functions

6 Capacity engine

6.1 Scope

In scope	Out of scope
• Calculate whether predicted load / generation exceeds ratings for each transformer or circuit set up in the system; • Full power flow and contingency analysis including consideration of anticipated activity of Active Network Management (ANM) and National Grid ESO activities; • Analysis and assessment of the network to identify constraints; • Produce multiple Half Hourly (HH) profiles of network constraints to then aggregate to establish service requirements; • Validate the service requirements; and • Validate the selected (procured, dispatched) optimal mitigation measures from flexibility platforms.	• Any other network constraints except thermal overload (although as part of the EFFS process the system user will check the power flow analysis output to ensure the proposed flexibility services to mitigate the thermal constraints do not impact negatively on the network for example voltage exceedances); • Any constraint on 11kV feeders and lower voltages; and • Smart grid solution and techniques such as System Voltage Optimisation (SVO).

Table 1: Scope for capacity engine

6.2 Description

The capacity engine function in EFFS will use network analysis and assessments that are based on operational characteristics (e.g. outages), asset characteristics (e.g. impedance and ratings) and measurements (MW, MVAr, kV, A). When assessing the status of a network, the capacity engine will use the Siemens PSS®E [1] software to carry out the following:

- Power flow analysis to calculate the power system status (loading, voltage) for specific network states (for instance base cases or contingency cases);
- Contingency analysis to determine the power system status (loading, voltage) of the network under outage scenarios. The fault (outage) scenarios are modelled and simulated in PSS®E; and
- Sensitivity analysis to check the impact of the flexible services applied at different locations interventions on loading and voltage limits at the desired point of impact.
- Validation checks to confirm that the flexibility services selected to address a network issue, or set of network issues, are sufficient to provide the required change in loading. This mitigates against unwanted interactions between services or problems from simplifying the use of sensitivity factors.

The PSS®E contingency analysis shall consider the following outages types (and combinations of outage):

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

- The intact (normal running) network
  - Each circuit fault
  - Each busbar fault
- Each arranged circuit outage
  - Each arranged circuit outage followed by each circuit fault
- Each arranged busbar outage
  - Each arranged busbar outage followed by each circuit fault

The results of the contingency analysis are checked for network splitting, non-convergence, de-energised loads, voltage limits violations, assets loading limits violations. For the purposes of EFFS, only the assets loading violations (thermal constraints) are considered for flexibility services interventions (although all non-convergence will need to be resolved in PSS®E prior to assessing thermal constraints). The location of the thermal network issue will be linked to the locations at which flexibility services can be purchased and sensitivity factors applied to the overloads to ensure that the correct amount of flexibility is procured dependent on how much the flexibility service will impact upon the constraint.

The results of outage analysis scenarios from the capacity engine will be used to define the power profile of the required flexibility services. The power profile will be a composite power profile of all individual outage scenarios as shown in Figure 2. This approach will transform the individual contingency scenarios into a composite service requirement per asset e.g. 130MW as shown in Figure 2. This will be used to procure from the flexibility market. By ensuring that the maximum requirement for any half hour under any contingency is purchased this ensures that any of the contingencies can be provided for. Purchasing for each contingency separately would lead to duplication of requirements.

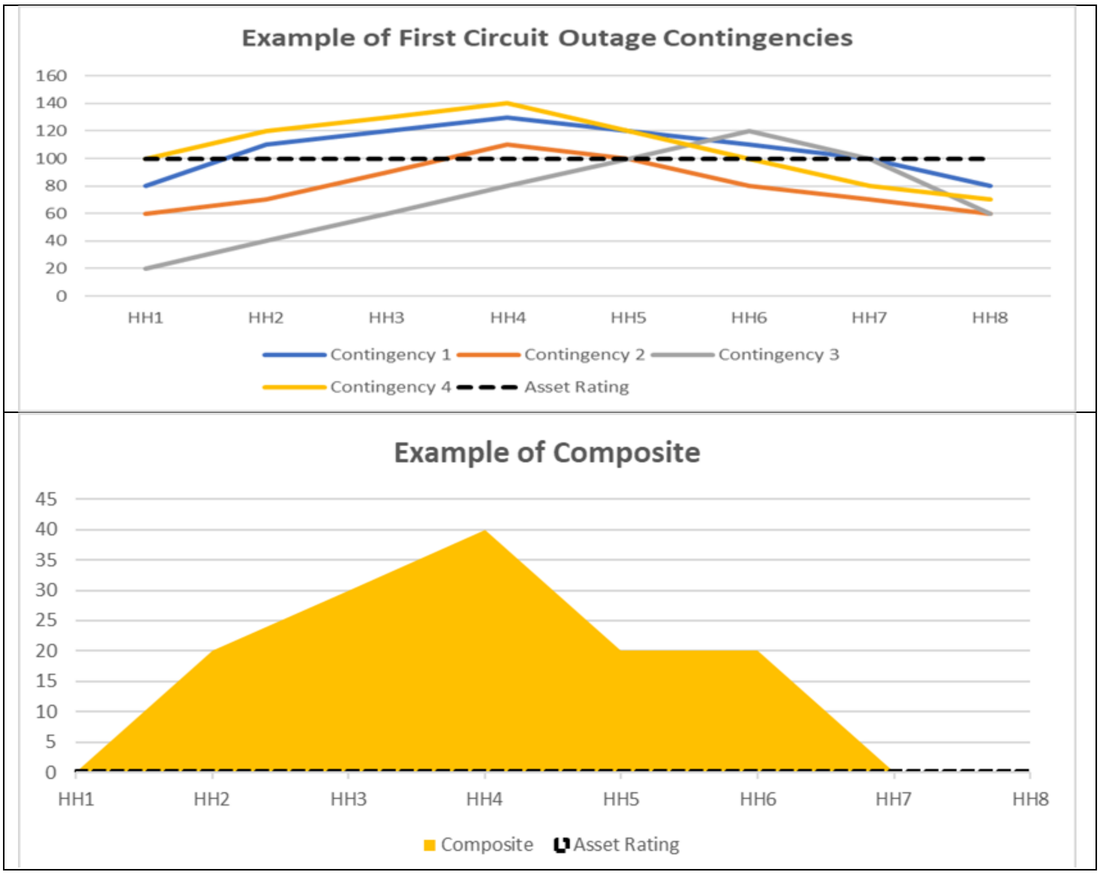

Figure 2: Example of an asset composite half-hourly (HH) MW profile from different outages scenarios

Different contingencies reflect different network states, such that the flexibility services intervention that is required to mitigate constraints under one contingency scenario might have a negative impact under a different scenario. Also, there could be multiple constraints on different assets that are interacting. Given the complexities and interactions between networks and between network assets, there is a need to double check that the flexibility services that are procured or dispatched satisfy the network requirements.

The capacity engine calculation is rerun in the same fashion but containing the selected flexibility services to check the impact on the network and the constraints. Similarly, the flexibility services dispatched after an event shall be those related to that event contingency analysis and flexibility power requirements.

6.3 Solution

6.3.1 Pre-requisites

The following pre-requisites are needed for the capacity engine function:

- An as built switch level network model needs to be available in PSS®E for power flow analysis to be carried out;
- All relevant asset ratings (seasonal for O/H lines and cables, OFAF and cyclic ratings for transformers) are available to PSS®E following current business as usual practices; and
- PSS®E must include an Advanced Contingency and Remedial Action Scheme (RAS) add-on module. The RAS module is used to reflect the mitigation measures actions needed to address the abnormal thermal situation within the current PSS®E power flow analysis.

6.3.2 Input

The capacity engine function requires the following inputs:

- Demand and load forecasts for selected assets (see latest 'WPD EFFS_System Design_Forecasting' Specification for details) will be created by Networkflow[2] as output files for PSS®E use for network modelling. Forecasts will be for normal running;
- The forecasts passed into PSS®E will be at primary transformer at the busbar level and for any customers directly connected to the 25kV, 33kV, 66kV or 132kV networks;
- A feed from a WPD service register database containing all flexibility services procured external to EFFS to be considered in power flow analysis;
- Up to date network state information (e.g. outages, switch positions, WPD reactive compensation) will be provided from PowerOn[3] into PSS®E in order to ensure the power system analysis accurately reflects the current or future network state (see Appendix 1 for details); and
- National Grid reactive compensation and expected generation for the relevant GSPs that impact the 132kV network areas proposed for the EFFS trials (Indian Queens and Langage).

[2] https://www.amt-sybex.com/networkflow/
[3] https://www.gegridsolutions.com/products/brochures/uos/PowerOn_Control.pdf

6.3.3 Output

The capacity engine function will produce the following output:

- A contingency for every asset that exceeds its thermal capacity for any HH period of study duration. This will include:

    1. HH power profiles of each asset thermal network constraints will be expressed in Amps and MVA. This will be used to ensure the appropriate requirement of flexibility services for any contingency; and
    2. Summary HH power profile of the excess current / power values for each asset for each half hour under any contingency which can be used to ensure that the flexibility services procured / utilised are sufficient for any of the events modelled (see Figure 2).

6.3.4 Assumptions

- For circuit faults, the power flow analysis will determine the correct primary transformers level to mitigate the constraint. This is based on 132kV and 33kV transformers being connected to the circuit;
- For many cases the option of manual selecting or deselecting credible contingencies as provided by the existing algorithm written is not always required;
- EFFS will use an existing WPD PSS®E License with the RAS module included; and
- The project will reuse the existing RAS scripts that are built into the existing contingency scenarios and where no RAS script exists it will be created. The existing RAS files will require editing to ensure they work on a network model that is topologically changing and will not necessarily start with normal running arrangements.

6.3.5 Power flow analysis logic

The load and generation profiles from the Forecasting module in Networkflow (see sections 7 and 8 for interface details) will be mapped to a network model in PSS®E together with other data. The results of the network analysis are processed within PSS®E and exported to an intermediary Database (DB). Networkflow will interface with this DB to extract power flow analysis results as required to determine flexibility requirements. The process map example in Figure 3 outlines the general steps of the network analysis and describes each step of the process map in detail in Table 2: Power system analysis process step descriptions.

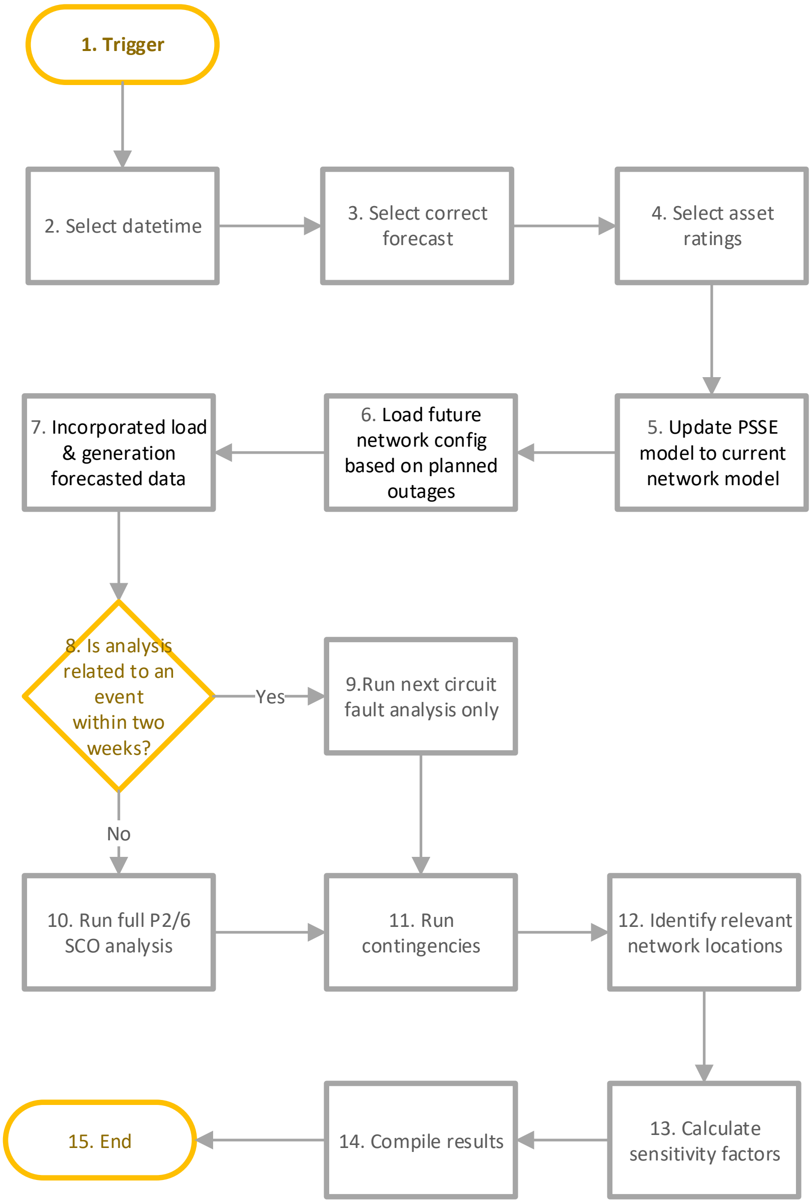

Figure 3: Power system analysis process

Key:

ID	Name	Type	Description
1	Trigger	Start Event	There are several different ways a power system analysis and capacity calculation can be triggered. This can be automatically through a: • Scheduled forecast • Conflict resolution scenario • Periodic schedule defined by a user; or Manually by a user for the following events:

			• Request by the operator • Change in network model configuration • Change in service register.
2	Select datetime	Process	The solution will determine the date for the power system analysis runs for.
3	Select correct forecast	Process	There will be several different forecasts produced for different time horizons. The Python Harness will select the appropriate forecast for the date selected (see Table 5 in Section 5.3.9 'WPD_EFFS_System Design_Forecasting' for details).
4	Select asset ratings	Process	The Python Harness will select the appropriate asset rating to be used by PSS®E. For seasonal ratings this will be determined by a lookup table that maps dates to seasons.
5	Update PSS®E model to current network model	Process	Update the PSS®E model with the current network model from PowerOn.
6	Load future network config based on planned outages	Process	After completion of the above step the solution will load the future network configuration based on planned outages.
7	Incorporate load and generation forecast data	Process	Incorporate the load and generation forecast data determined in step 3 into the PSS®E model.
8	Is analysis related to an event within two weeks?	Decision	At two weeks prior to the event it is expected that planned outages will be reflected in the PowerOn network model.
9	Run next circuit fault analysis only	Process	The solution will only use appropriate seasonal ratings and generate contingencies for the next fault. There will be no need to model all possible combinations of planned and outages and faults as network state will reflect the planned outages at that time.
10	Run full P2/6 SCO analysis	Process	The solution will be required to carry out a full Second Circuit Outage assessment (SCO) to account for future arranged outages as the planned outages are deemed not to be known to PowerOn therefore a full list of contingencies is required.
11	Run contingencies	Process	PSS®E will run the list of contingencies described in the above step, this may include new processes e.g. net load to total load conversion and mapping and apportionment of primary transformer loads to busbar loads. Any relevant pre- and post-RASs will be included.
12	Identify relevant network locations	Process	PSS®E will identify the network locations that relate topologically to a thermal constraint on an asset (i.e. a location that if flexibility services were used, they would impact upon the constraint on the asset).
13	Calculate sensitivity factors	Process	PSS®E calculates the sensitivity factors associated to the locations defined is step 12 (e.g. how much 2 MW procured at location X would impact constraint Y: a

			sensitivity factor or 0.5 would lead to 1 MW impact, a sensitivity factor of 1.0 would lead to a 2 MW impact.
14	Compile results	Process	The Python Harness will then write the results to the PSS®E intermediary database including when the PSS®E model does not converge.
15	End	End Event	All contingency scenarios and associated data are written to the intermediary PSS®E database for EFFS extraction.

Table 2: Power system analysis process step descriptions

6.3.6 Capacity calculation logic

PSS®E shall calculate the loading for each asset (transformer and cables/OHL). This shall be achieved by using the existing PSS®E functionality and relevant asset ratings (seasonal for cables/OHL / cyclic and OFAF for transformers). The project shall use safety loading factor of 95% above which it shall be considered for constraint management. PSS®E shall include logic to calculate the thermal constraint as an MVA value such as the below example:

- Rating = 50
- Safety Parameter = 47.5 (95% of 50)
- Loading = 1.10 (55MVA)
- Constraint = 7.5MVA (55 – 47.5)

The thermal constraint MVA values will be stored in the PSS®E Intermediary DB and then consumed by the Networkflow Capacity Engine module to determine the flexibility requirements for each BSP and primary substation by creating a composite requirement for flexibility based on the number of contingencies. PSS®E will submit a number of contingencies per fault scenario to the PSS®E Intermediary DB. Networkflow will receive these scenarios and amalgamate each fault scenario for each network location to create a service to procure flexibility.

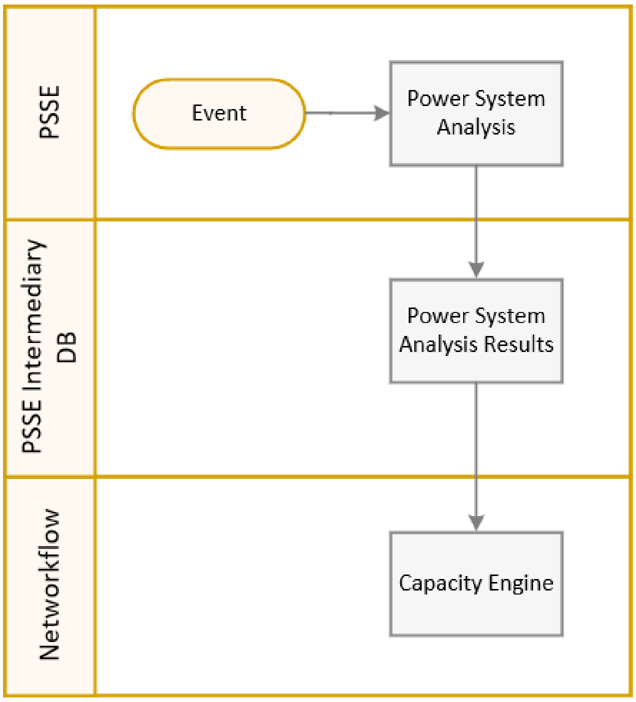

Figure 2: Capacity calculation process

6.3.7 Validation of service requirements

Following the determination of flexibility service requirements, the proposed flexibility requirements will be validated by PSS®E. The original studies will be rerun but containing the proposed service requirements. This is a composite of all contingencies in a given constraint and in order to validate that the proposed flexibility solution will resolve the constraint and will not cause issues elsewhere within the network.

6.3.8 Validation of optimisation output

Following the procurement of flexibility services and optimisation (see latest 'WPD EFFS_System Design_Optimisation' Specification for details) the proposed flexibility services will be passed from Networkflow into PSS®E as per Figure 5 below.

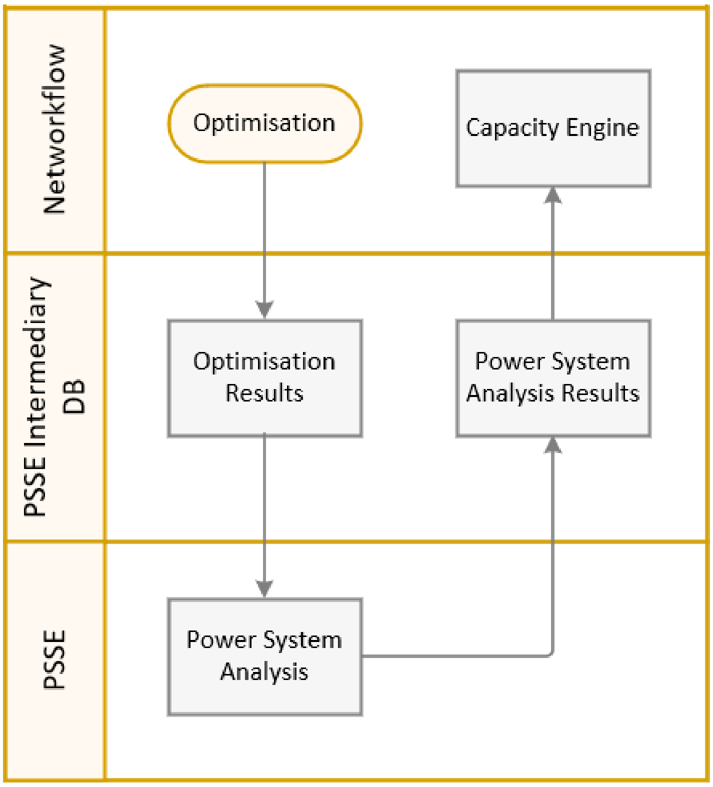

Figure 5: Flexible services validation process

Key:

The original studies will be re-run but containing the proposed optimisation solution. This is a composite of all contingencies in a given constraint and in order to validate that the proposed flexibility solution will resolve the constraint and will not cause issues elsewhere within the network. This process will be run as per sections 6.3.5 and 6.3.6 (and will use interfaces INT-004, INT-007 and INT-008).

Once the capacity engine has validated the optimised results it will update the status of the service to 'Optimised'.

6.4 Changes since DSO requirements document baselined

During Workstream 1 (forecasting evaluation, co-ordination and requirements) the assumption was made that the activity of ANM schemes could be replicated in the power flow analysis carried out in PSS®E. However, on further investigation the current ANM scheme used in the EFFS proposed trial areas is a black box from a WPD perspective as there is no detailed information on its logic and mode of action so it cannot be replicated by WPD as part of their PSS®E automation. The current ANM scheme does however integrate with IPSA 2. It is not feasible to replicate existing power flow analysis automation within IPSA 2 as there has been a strategic decision to standardise the PSS®E as the planning tool for 33kV and 132kV networks.

Therefore, the options* for EFFS to replicate ANM activity are as follows:

1. Do not consider ANM within EFFS power flow analysis;
2. Apply simplified rules / look ups to replicate ANM / in PSS®E;
3. Pass the analysis from PSS®E into a test version of IPSA (and back to PSS®E) to replicate ANM activity; and
4. Approach the provider of ANM for possible integration of their ANM system with PSS®E.

*please note the above are options that will be considered to support the trial. Due to the proprietary nature of ANM logic, the project has not been able to conclude a solution to replicate ANM in power flow analysis. However, it has been stated that no curtailment of generators is currently active in the Cornwall region. The project is progressing this option to fulfil this requirement. Please also note that network security is not the scope of EFFS, as it is only concerned with mitigating the over procurement of services.

7 Interfaces

Figure 6 below provides an overview of the interfaces to be implemented in support of the capacity engine solution.

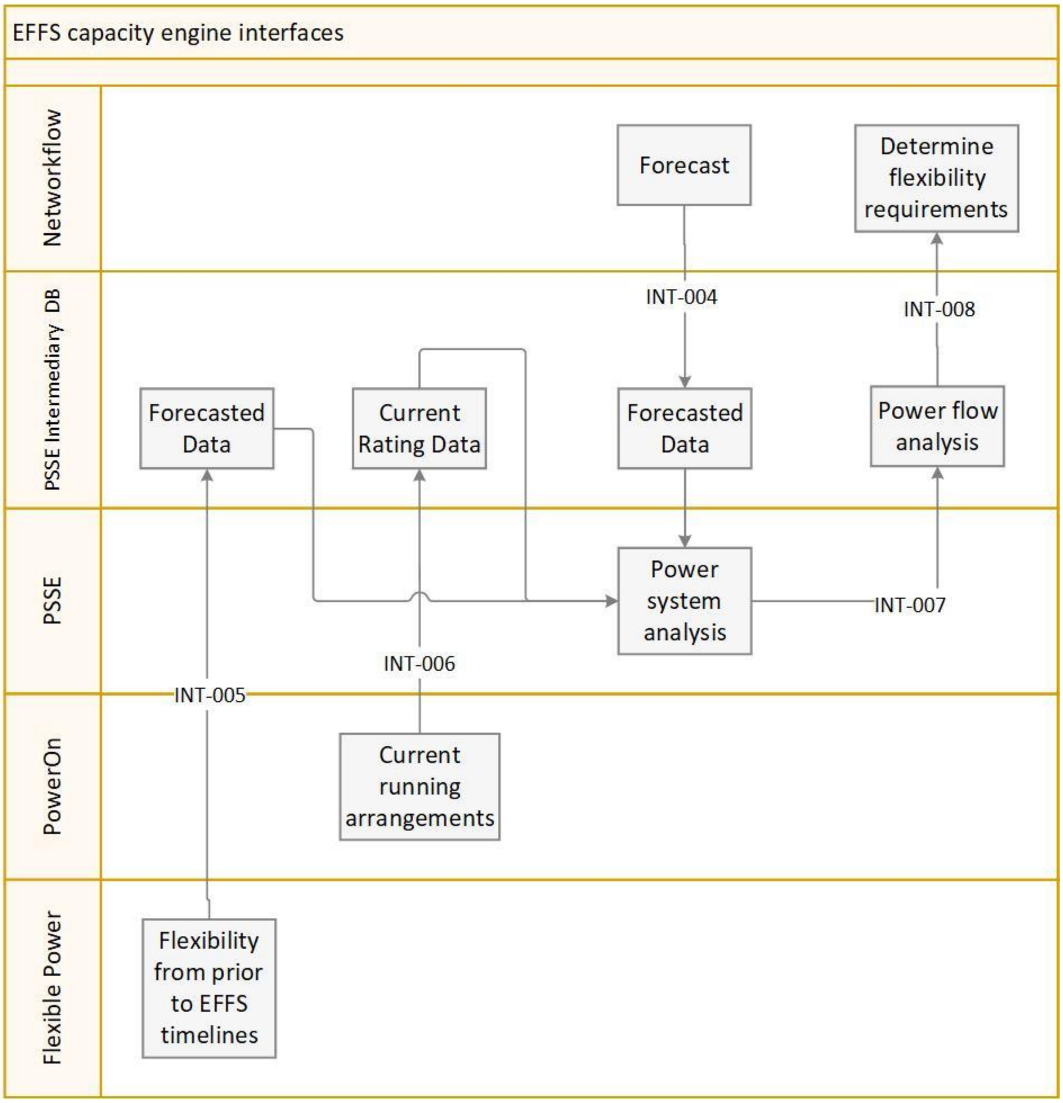

Figure 6: EFFS capacity engine interfaces

Details on the five capacity engine interfaces are specified in Table 3 below.

Interface	Source System	Target System	Type	Frequency	Data
INT-004	Networkflow	PSS®E Intermediary DB	[redacted]	Daily	Forecast load and generation data for selected equipment.
INT-005	Flexible Power	PSS®E Intermediary DB	[redacted]	Weekly	Week ahead view of available services procured via Flexible Power

INT-006	PowerOn	PSS®E Intermediary DB	[redacted]	Daily	Up to date network state information (e.g. outages and switch positions)
INT-007	PSS®E	PSS®E Intermediary DB	[redacted]	Ad hoc (as run)	Raw power flow analysis output (load and seasonal asset ratings for multiple contingency scenarios for all of modelled network area
INT-008	PSS®E Intermediary DB	Networkflow	[redacted]	Ad hoc (as run)	Converted power flow analysis output (asset loadings for multiple contingency scenarios) for selected equipment

Table 3: Capacity engine interfaces summary

8 Data items

The following section lists the data items to be contained in the interfaces described above.

The interfaces are described in an indicative, logical fashion rather than physically as this information is proprietary. The detailed physical interfaces will be agreed during the build phase of EFFS.

8.1 INT-004 Forecast output

As per 'WPD_EFFS_System Design_Forecasting' section 8.4.

8.2 INT-005 Flexibility from before EFFS timelines

Data item	Type	Cardinality	Valid set value	Notes
Transaction type	VARCHAR(50)	1	'Flexibility from before EFFS timeline's	
Transaction ID	NUMBER(10)	1		Unique ID for the transaction. Should be included in any related responses generated by the generating system
Transaction Datetime	TIMESTAMP	1		Date and Time when the request was created in the following format 'YYYY-MM-DD HH24:MI:SS.FF'
Customer ID	VARCHAR(14)	1		Customer ID will be linked to PowerOn Equip ID and PSS®E Equip ID by a lookup table held within Networkflow
Source	VARCHAR(14)	1		Where the flexibility service was procured
Measurement parameter	VARCHAR(4)	1	'MW'	

Data item	Type	Cardinality	Valid set value	Notes
			'MVAr' 'MVA'	
Service type	VARCHAR(4)	1	'SCM' 'PRCM' 'POCM' 'RS'	'SCM' = Scheduled constraint management' 'PRCM' = 'Pre-fault constraint management' 'POCM' = Post-fault constraint management' 'RS' = 'Restoration Support'
HH Datetime	TIMESTAMP	1-*		This will be defined by a DATE + TIME of the end of the HH period
Service value	NUMBER(10,3)	1-*		Will contain a '+' to indicate a positive value, a '-' to indicate a negative value.

Table 4: Data items for flexibility from before EFFS timelines

8.3 INT-006 Current running arrangements

Data item	Type	Cardinality	Valid set value	Notes
Transaction type	VARCHAR(50)	1	'Current running arrangements'	
Transaction ID	NUMBER(10)	1		Unique ID for the transaction. Should be included in any related responses generated by the generating system

Data item	Type	Cardinality	Valid set value	Notes
Transaction Datetime	TIMESTAMP	1		Date and Time when the request was created in the following format 'YYYY-MM-DD HH24:MI:SS.FF'
PowerOn Equip ID	VARCHAR(14)	1		Unique identifier for the equipment used in PowerOn
Equipment status	VARCHAR(14)	1		

Table 5: Data items for current running arrangements

8.4 INT-007 Power flow analysis output (raw)

Data item	Type	Cardinality	Valid set value	Notes
Transaction type	VARCHAR(50)	1	'Power flow analysis output'	
Transaction ID	NUMBER(10)	1		Unique ID for the transaction. Should be included in any related responses generated by the generating system
Transaction Datetime	TIMESTAMP	1		Date and Time when the request was created in the following format 'YYYY-MM-DD HH24:MI:SS.FF'
PSS®E Equip ID	VARCHAR(14)	1		Unique identifier for the equipment used in PSS®E.
Contingency ID	NUMBER(20)	1		A unique identifier to identify the specific contingency

Data item	Type	Cardinality	Valid set value	Notes
				scenario that will be used throughout the scenario's lifecycle
Contingency Scenario	VARCHAR(3)	1	'BAU' 'FCO' 'SCO'	'BAU' = Business As Usual 'FCO' = First Circuit Outage 'SCO' = Second Circuit Outage
Channel Type	VARCHAR(1)	1	'L' 'G'	'L=' 'Load' 'G' = Generation'
Units	VARCHAR(10)	1	'MW' 'MVAr' 'MVA'	
HH Datetime	TIMESTAMP	1-*		This will be defined by a DATE + TIME of the end of the HH period
Value	NUMBER(10,3)	1-*		Will contain a '+' to indicate a positive value, a '-' to indicate a negative value
Sensitivity factor	String	1-*		

Table 6: Data items for power flow analysis output (raw)

8.5 INT-008 Power flow analysis output (converted)

Data item	Type	Cardinality	Valid set value	Notes
Transaction type	VARCHAR(50)	1	'Power flow analysis output'	
Transaction ID	NUMBER(10)	1		Unique ID for the transaction. Should be included in any related responses generated by

Data item	Type	Cardinality	Valid set value	Notes
				the generating system
Transaction Datetime	TIMESTAMP	1		Date and Time when the request was created in the following format 'YYYY-MM-DD HH24:MI:SS.FF'
PSS®E Equip ID	VARCHAR(14)	1		Unique identifier for the equipment used in PSS®E.
Contingency ID	NUMBER(20)	1		A unique identifier to identify the specific contingency scenario that will be used throughout the scenario's lifecycle
Contingency Scenario	VARCHAR(3)	1	'BAU' 'FCO' 'SCO'	'BAU' = Business As Usual 'FCO' = First Circuit Outage 'SCO' = Second Circuit Outage
Channel Type	VARCHAR(1)	1	'L' 'G'	'L=' 'Load' 'G' = Generation'
Units	VARCHAR(10)	1	'MW' 'MVAr' 'MVA'	
HH Datetime	TIMESTAMP	1-*		This will be defined by a DATE + TIME of the end of the HH period
Value	NUMBER(10,3)	1-*		Will contain a '+' to indicate a

Data item	Type	Cardinality	Valid set value	Notes
				positive value, a '-' to indicate a negative value
Sensitivity factor	String	1-*		

Table 7: Data items for power flow analysis output (converted)

9 Contact

If you have any questions relating to this document, please use the following points of contact:

Future Networks Team:

Western Power Distribution,
Pegasus Business Park,
Herald Way,
Castle Donington,
Derbyshire
DE74 2TU

Email: jwoodruff@westernpower.co.uk

Appendix 1 – Network model required for power flow analysis

9.1 Power flow analysis requirements

EFFS will use power flow analysis to determine whether there is or will be an issue with the network therefore power flow analysis requires the following information:

- A network connectivity model describing how assets are connected and including whether switches and circuit breakers are open or closed as this will direct the flow of power.
- Impedance values for the assets making up the elements of the network.
- Ratings for the assets so that potential thermal constraints can be identified.
- Load and generation forecasts for points on the network - this needs to allow for adjustment to reflect items that would modify these values e.g. impact of ANM limiting the load/generation of a customer and the dispatch of flexibility services.
- Voltage limits so that a potential voltage constraint can be identified.

For the avoidance of doubt, we do not foresee EFFS being used to manage breaches of fault level, issues with harmonics or system stability.

In the future, the distribution power flow feature within PowerOn may offer an alternative to PSS®E which would simplify the interfaces required, however this was not a viable option within the timescales of the EFFS project.

1. Different variations of the network connectivity model are required for different purposes and reflect the information that may be available at the time.

    a) Normal running arrangements i.e. the network's default configuration when there are no planned or unplanned outages.
    b) Real-time / near real-time running arrangements i.e. with the configuration of the network as it is now / a short time ago.
    c) Short term future running arrangements i.e. how the network is expected to be configured taking into account any existing outages that still expected to apply at that point in time and the reconfiguration for planned outages that are known to the system.
    d) Historic network running arrangements i.e. how the network was configured at a particular point in the past.

2. Items a-c can be used as a starting point for determining future network constraints. This analysis would involve determining the unplanned outages that could realistically occur, referred to as credible faults, and reconfiguring the network to reflect the configuration of the network following those outages. This creates a set of contingency running arrangements.

9.2 Normal running arrangements

There are a number of potential sources for determining the normal running arrangements of the network so that this can be used in PSS®E.

1) The "as built" version of the PSS®E model itself should be configured to the normal running arrangements as a default.

2) Integrated Network Model (INM) which has been produced for the SouthWest region as part of the Common Information Model NIA project. This was based on an extract of connectivity and running arrangements from PowerOn but will only reflect the running arrangements at the time the model was extracted from PowerOn and so may be considerably out of date. While this old version will be replaced as the Integrated Network Model is implemented as business as usual, there is a risk that the INM would not be available in a suitable time frame for EFFS.
3) PowerOn CIM export: the current version of PowerOn used in WPD (PowerOn Version 5.2.2.9.1.26) does allow for the import of a network model in CIM format, however does not support export of the network model in CIM format. This function is to be introduced in the next version of PowerOn (PowerOn 5.3 / PowerOn Advantage).
4) PowerOn Network Viewer.

This is an upcoming feature for PowerOn allowing previous switching activity to be replayed, however this is not expected to provide access to the underlying network information in a way that would be useful to provide a network model.

POF holds a field called Trace Class for each switch / circuit breaker, which indicates whether the device is normally open or normally closed. This could be used to compare against the PSS®E initial data dump. PowerOn also hold a field called CompState which hold the current state of the device, again this could be used as a comparison against the initial data load from PSS®E. Both fields need to be validated against the South West database in order to confirm they are up to date before the PSS®E data load is taken.

9.3 Current running arrangements

To carry out power flow analysis on the network in its current state, EFFS will need to know which switches are in abnormal positions so that the network model for the normal running arrangements can be adjusted. Switch states are not currently exported from PowerOn either for present or for future states. Switch states are reflected in how switches are presented on the network diagrams within PowerOn. A switch that is open, closed or earthed could differ in symbology and/or colour. Switching positions are also report by RTUs on a regular basis and therefore this data can be extracted from the relevant RTU logs.

The second stage is a comparison to the PSS®E model and adjusting the switch positions to match.

9.4 Future running arrangements

Future running arrangements are needed to support power flow analysis ahead of time. It is expected that future running arrangements will be derived by starting with the current running arrangements as described above and adjusting this model to account for the planned switching on the network between the time at which the current running arrangements were extracted and the time of the future assessment.

Future switch states will be derived by searching for switching instructions for outages that are “approved”, where the switching items have not yet been instructed and confirmed. For the time of interest e.g. midday on 1st December 2019 then the last switching instruction relating to assets in the PSS®E model before that time should be extracted and converted to a switch status.

The same process for matching assets to those in the PSS®E model needs to apply as is used for updating the current running arrangements.

9.4.1 Potential issues

There are a number of potential issues with this approach.

1. Planned Outages may not take place. Outages are currently stored as a set of switching instructions and these outages are only ‘scheduled’ and can be cancelled right up to the minute the outage is due to take place.
2. Planned Outages may include variations. Similarly, outages could be modified to reflect conditions not known at the time of writing the schedule.
3. Unplanned Outages. Switching relating to unplanned outages will not be reflected in the forward-looking network model and could inevitably introduce inaccuracies in the future version of the model.
4. Completeness of Planned Outages. Policy suggests that while all planned outages will be set up within PowerOn a month in advance the proposed switching records would not be complete for a time horizon of six weeks in advance and therefore there will be a limit to how far in advance the model can be adjusted to a future state.