MERLIN

Modelling the Economic Reactions Linking Individual Networks

Milestone 2

FMT (MERLIN) Solution Architecture Overview

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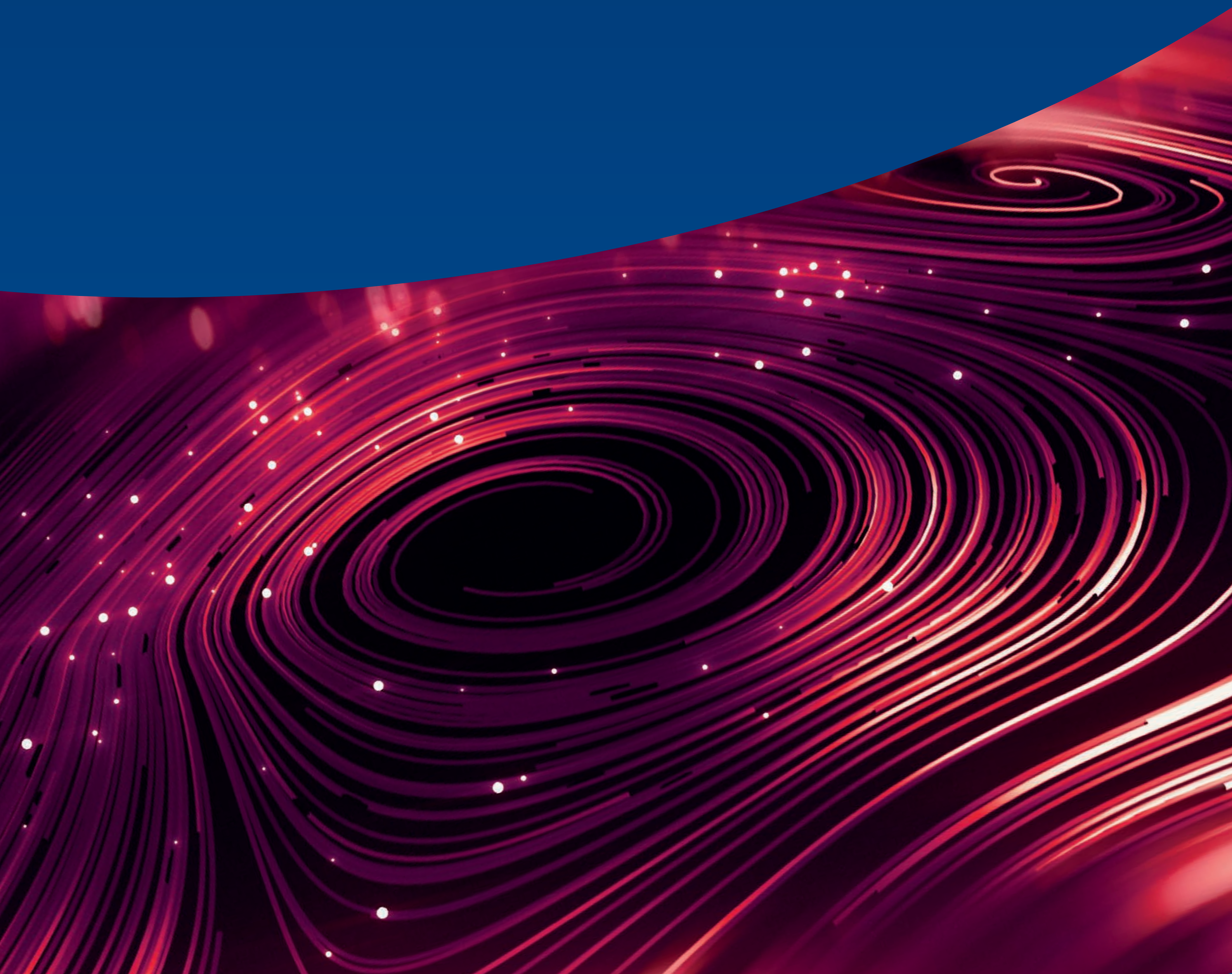

The purpose of this document is to provide some technical considerations to accompany the FMT requirements document. As the requirements are hypothetical in nature at this point, the emphasis has been on requirements rather than design in the work done so far. This document shows the solution definition for Financial Modelling Tool (FMT) to the extent that is feasible to establish at this stage.

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1. Introduction

1.1 Purpose and scope of this document

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There is an accompanying slide set. The slide set was started first, and this document was developed from it; however the slide set has been kept in step with the content of the document.

1.2 Document distribution

At the moment only the SSEN and CGI project team is listed, as a full distribution list for the document has not yet been determined.

- Rhys Williams, SSEN
- Kyle Murchie, SSEN
- CGI FMT project team

1.3 References

Document	Version
Financial Modelling Tool Requirements Specification	0.17 (4th Jun 2020)
ENA Open Networks Project 2019 – 2020 WS1A P1 ANM vs Flexibility vs Reinforcement Common Methodology	Not yet available – first deliverable July 2020

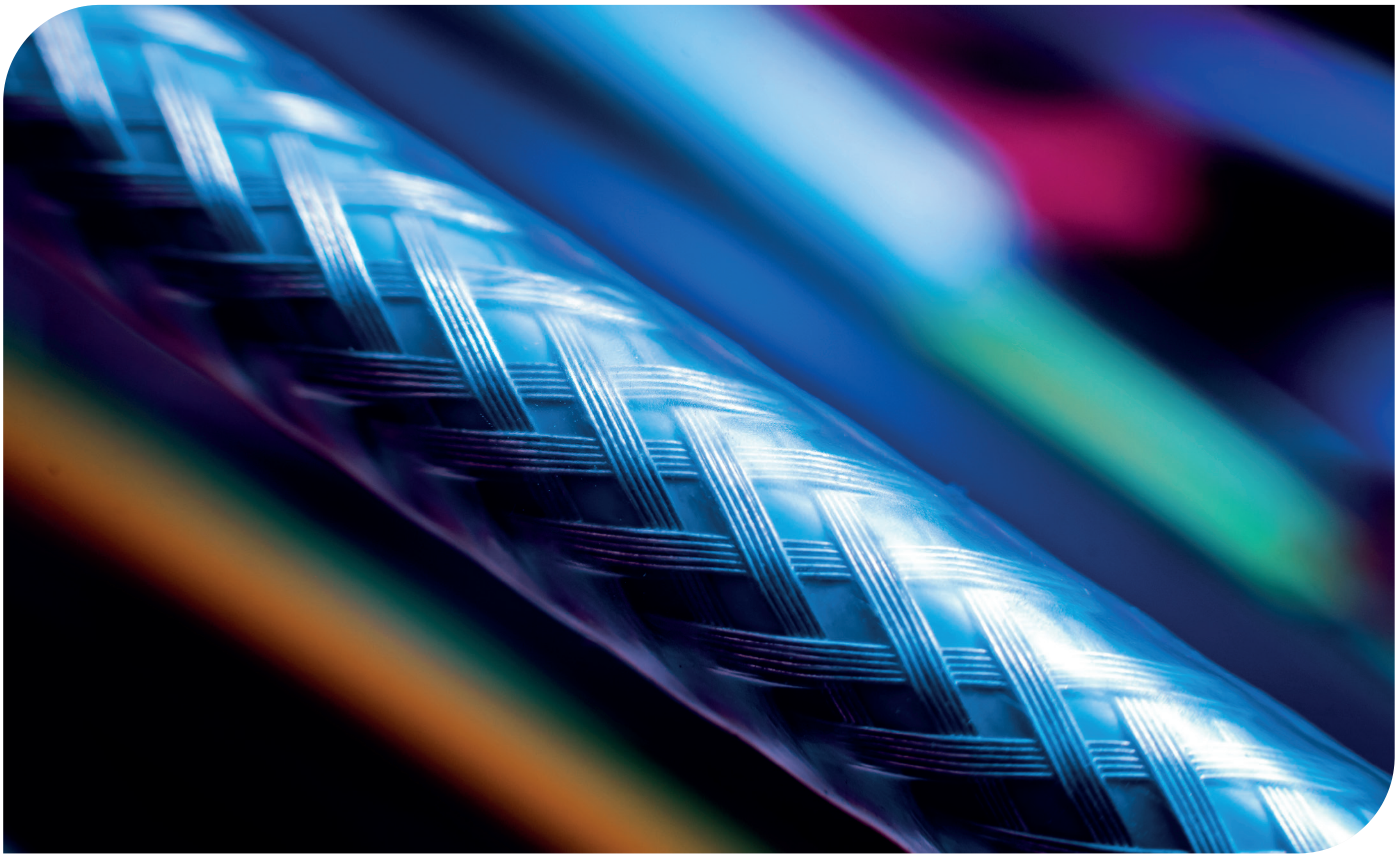
1.4 Glossary

Here is a table of terms used in this document which are particularly relevant to the MERLIN project. See also the Energy Network Association Glossary at this link: http://www.energynetworks.org/info/faqs/glossary.html.

Term	Meaning
ANM	Active Network Management
BUC	Business Use Case. A BUC with a number (e.g. BUC 32) is a reference to a specific BUC in the FMT requirements specification
DER	Distributed Energy Resource; a resource connected to the distribution network which can be used in energy flexibility as local generation or demand response
DMS	Distribution Management System; e.g. GE's PowerOn in SSEN or Schneider in ENWL
DSO	Distribution System Operator, an organisation with new responsibilities that complement a traditional DNO role
EFFS	Electricity Flexibility and Forecasting System; an Ofgem NIC project for energy flexibility, led by WPD
ENA	Energy Networks Association
ESO	Electricity System Operator; part of National Grid
FMT	Financial Modelling Tool; requirements for a tool to compare the cost-effectiveness of use of energy flexibility with physical reinforcement or creating ANM schemes on the electricity distribution network
FUSION	an Ofgem NIC project for energy flexibility, led by SPEN
MERLIN	SSEN Innovation project trialling comparison of the costs of network reinforcement and use of energy flexibility
NIC	Network Innovation Competition; Ofgem sponsorship to encourage innovation in energy distribution

1.4 References

Term	Meaning
NMF	Neutral Market Facilitator; a market for enabling use of energy flexibility in distribution-connected energy resources; "neutral" refers to enabling use of energy flexibility for third parties as well as DNOs
PSA	Power Systems Analysis; a proposed component of the TRANSITION project
T.E.F.	Shorthand for the 3 overlapping NIC projects TRANSITION, EFFS and FUSION
TRANSITION	SSEN NIC project to trial building and operating an NMF and WSC
WSC	Whole System Coordination; a component currently in scope of the TRANSITION innovation project, and expected to become more significant in future. The term "whole system" comes from ENA Open Networks Project work streams and refers to interaction between DSOs, ESO (and potentially other types of energy network), and energy flexibility markets.



2. Context

2.1 Business context

This is a short description of the solution's business context and primary business drivers. Refer to the requirements document for more details.

- The FMT is related to MERLIN, and is a documentation of longer-term requirements which will not be fully implemented until after MERLIN. Some aspects, however, will be trialled within MERLIN.
- The MERLIN project includes investigating cost comparisons with energy flexibility as an alternative to reinforcing the network.
    - There are some common aims between FMT and MERLIN; however, FMT is intended to take a longer view of theoretical requirements, without being constrained by the capabilities of particular systems at this stage
    - The MERLIN project is an innovation project, running early 2020 to early 2021
    - The requirements for MERLIN are based around the need to understand economic impacts of flexible services
- MERLIN plans to make further use of local market economics as suggested by the Baringa report on the ENA Open Networks Project Future Worlds study. This was an important reason for setting up the MERLIN project, with the aim to support the transition to a smart grid for DER integration into electricity distribution network and stimulation of other markets. The FMT would help assess and manage not only the small numbers of four-year contract services offered today, but the higher volume of DSO and importantly non-DSO trades that may impact the network physically (WSC) or economically (FMT). This quote is from Section 5.5 of the report, regarding further work:
    - "There have been some previous innovation trials which have sought to understand LV flexibility but these were a number of years ago and were focussed on testing the concept of LV flexibility rather than the economics. A greater understanding of the economics of local flexibility markets will be crucial in understanding if Stage 2 of World A is likely to be required. Further information in this area would also help to reduce the range of uncertainties placed around our quantitative analysis."
- Business functions involved include:
    - Investment planning in the distribution network (system planning, network planning), new connection requests, load forecasting, power flow analysis, flexibility market operations, procurement of energy flexibility
- Business drivers:
    - allow Ofgem's guidance to consider flexibility as an alternative to reinforcement
    - save money by postponing or avoiding network reinforcement
    - make appropriate use of energy flexibility
    - industry-wide initiatives to transition from DNO to DSO

2.2.1 Business context diagram

See the requirements specification.

2.2 Information systems context

This section describes the existing information systems landscape which will form the context of the solution to be delivered.

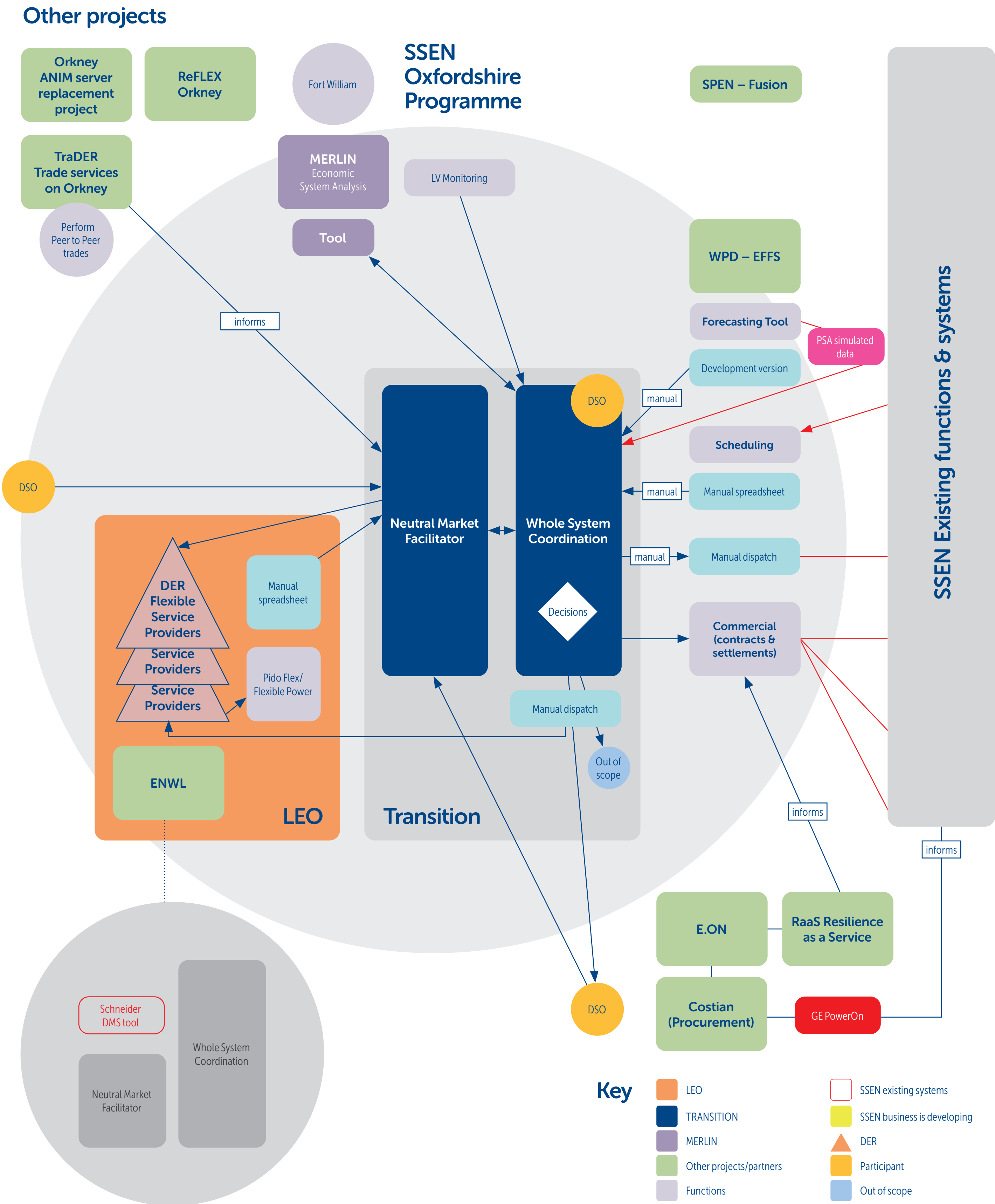
2.2.1 Overview

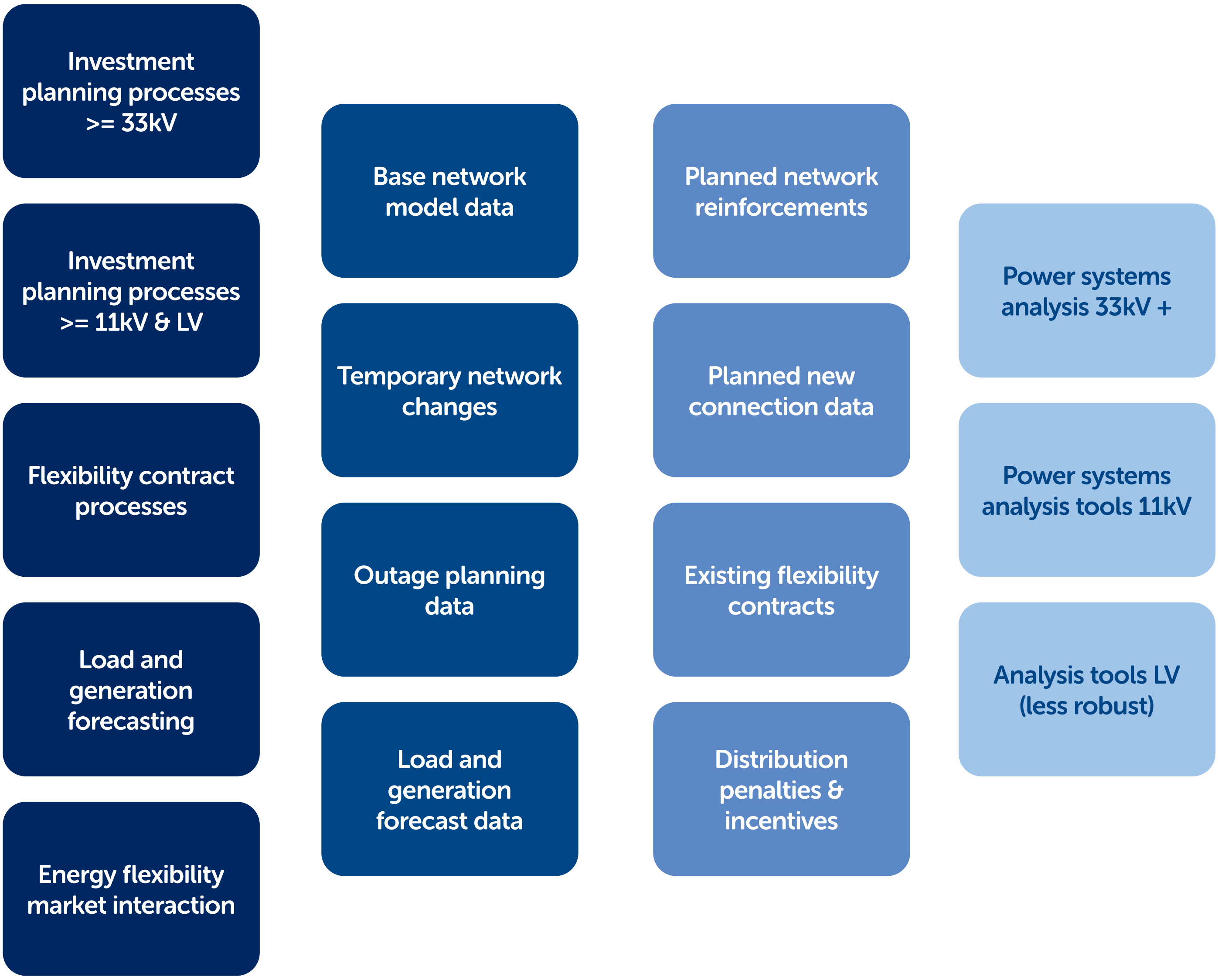
- There are several relevant projects in progress including TRANSITION, LEO and MERLIN, which are all innovation projects rather than business as usual systems, and referred to collectively as Oxfordshire projects, since all have a connection to Oxfordshire (see section 2.2.2)
- Several SSEN systems are going through upgrade programmes at the moment and may require future developments to facilitate the Smart Grid transition, which will be directed by the relevant projects listed above
- As a DNO, SSEN categorise systems into IT (standard security) and OT (higher security) systems; OT systems are closer to electricity network operations
- General principles for SSEN include reuse/buy/build hierarchy for new systems
- Cloud deployment is SSEN's preference in general, but usually on-premise deployment is necessary for OT systems

2.2.1 Oxfordshire innovation projects

This diagram shows the context for several relevant projects in progress in SSEN, including TRANSITION, LEO and MERLIN; all of these are innovation projects rather than business as usual systems.

Figure 1 Oxfordshire innovation projects context diagram





2.2.3 Relevant systems, processes & data

This diagram shows some of the SSEN systems, processes and data that are most relevant to FMT.

The term “power systems analysis” is used to align with the terminology used in the TRANSITION project; load flow analysis is another valid term.

2.3 Other architectural views and their stakeholders

Identifies the primary architectural viewpoints and their stakeholders. The architectural viewpoints are elaborated in section 5.4, to the extent that it is feasible at this stage, as in the table below.

View	Stakeholders
Operational view	Illustration of major components and interactions. Useful to gain insights into what the major components should be and what interactions with other systems would be appropriate
Delivery Breakdown view	Too early to populate at this stage, since the requirements are hypothetical, with no immediate plan to move to detailed design and implementation
Construction view	Too early to populate at this stage, since the requirements are hypothetical, with no immediate plan to move to detailed design and implementation
Security view	Too early to populate at this stage, since the requirements are hypothetical, with no immediate plan to move to detailed design and implementation. However, there has been significant engagement through the TRANSITION Project for the Whole System Coordinator and Neutral Market Facilitator upon which the FMT relies upon for many of its inputs.

Table 1 Other architectural views and their stakeholders

3. Requirements Overview

3.1 Key solution responsibilities

In summary:

- FMT will help to choose the most cost-effective way to address distribution network constraints with the data available at time of decision;
- FMT needs to compare the cost of reinforcement with the cost of ANM & flexibility contracts, and enable a user to pick the most appropriate combination by:
    - determining for how long it would be appropriate to postpone any technically valid reinforcement solution;
    - determining the anticipated utilisation period for all technically viable flexible service based solutions (utilisation frequency and duration is only a forecast and subject to change, thus the FMT must facilitate analysis and management to ensure financial sustainability);
    - determining the maximum cost to pay for flexibility for it to be cost-effective compared to reinforcement;
    - provide the ability to review decisions to use flexibility, based on updated historic data and actual flexibility usage;
    - the solution is aimed at investment planning timescales for which physical reinforcement or implementation of new ANM contracts are feasible, or short to long term timescales where use of energy flexibility markets is feasible. Immediate DMS/PowerOn options such as network reconfiguration to protect the network are not in scope;
- to do this there need to be business processes within the DNO/DSO (note that some of this may be carried out in other systems rather than FMT) which:
    - gather network model & forecast data, and use them to identify constraints;
    - calculate cost of reinforcement based on specification from planners & historic data;
    - use historic flexibility market data to estimate cost of flexibility;
    - use historic data to calculate cost of ANM (presumed to mean customer agreements and hardware enabling SSEN to reduce demand or increase supply unilaterally);
    - run analysis to make cost comparisons, including consideration of risk factors e.g. risk of non-delivery, and provide results;
    - meta requirement: do back-testing against historic data to improve algorithms
    - no non-functional requirements (e.g. SLAs) have been identified as yet

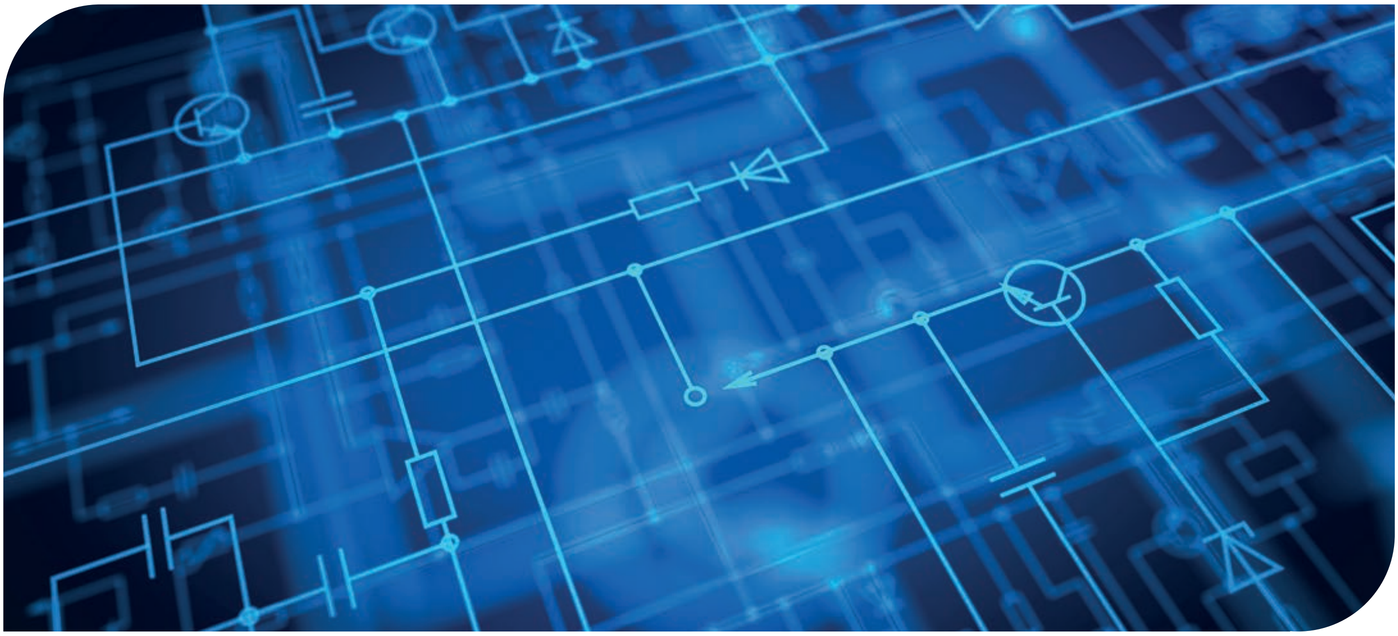
3.2 Architecturally significant requirements

This section lists key requirements which are particularly significant to the cost of the solution or carry substantial risk with respect to delivery, feasibility or acceptance.

3.2.1 Architecturally significant requirements of FMT

Requirement or group of requirements	Significance to risk and/or cost
The need to assemble historic data from multiple other systems to make available to the analysis engine	This implies the need to either store or be able to access potentially large quantities of different types of data, and data integration with multiple systems
The need for a new type of analysis which does not currently exist in SSEN.	The nature of the data analysis algorithms is unknown at this stage; it is still in progress for the MERLIN project, and in any case could be different for the longer-term requirements. The data analysis could take many different forms, e.g. something rules-based (such as where there is a shortfall of x MW for y hours a week then it will cost approximately £z), a predictive analysis approach, or a data mining approach looking for patterns in data about the electricity network. The approach chosen will make a big difference to the type of system processing required and to the types and quantities of data it would need to have available to it
The need to work at different voltage levels including 33kV & 132kV (System Planning) and probably 11kV (Network Planning). Note that the requirements are less likely to cover the LV parts of the network but this is a potential stretch target	This will require interaction with multiple systems, since different teams and tools are used for 132kV (System Planning) and 11kV (Network Planning)
There may be frequent revisiting of previous calculations, e.g. where a flexibility option was chosen over reinforcement to check whether flexibility markets changes would alter the outcome, or changes in neighbouring areas	This may lead to demanding performance requirements
The ability to change parameters and rerun calculations, as part of tuning algorithms	This may lead to demanding performance requirements

Table 2 Architecturally significant requirements of FMT itself

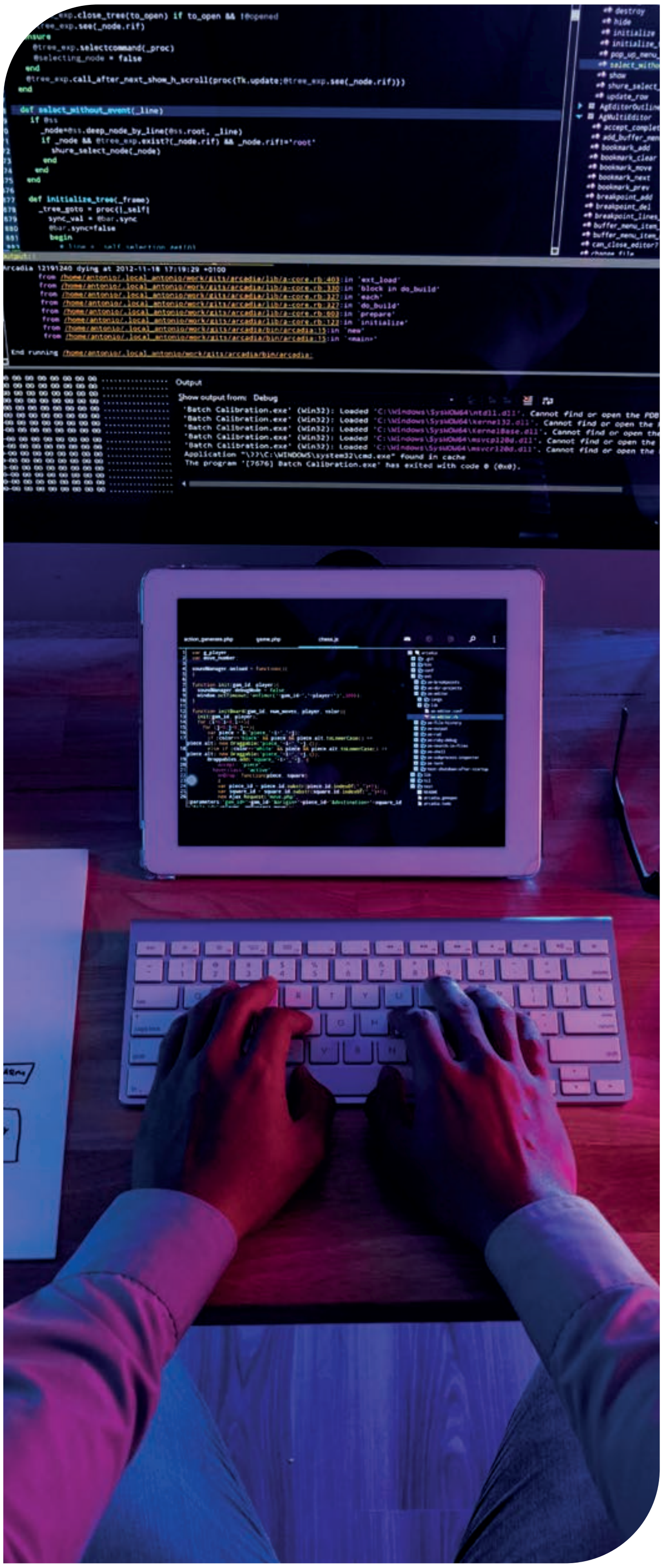


3.2.2 Implications for systems external to FMT

This section has requirements which are significant to systems with which FMT will need to interact, since in some cases FMT will be part of business processes which encompass other systems as well.

Requirement or group of requirements	Significance to risk and/or cost
Make network model data available to more systems, and have ideally the whole network available and up to date in more than just one area at a time (e.g. as in 11kV data at present)	Size and timeliness of data available to power systems analysis tools used by system and network planners.
The expected need to analyse network areas more often than at present (based on the assumption that changes in network load and demand will lead to greater need to identify constraints) will mean it is necessary to overlay flexibility contracts and pending physical option changes (reinforcements & ANM) on to the base network model and make it available for multiple systems to use (this is done locally at the moment, but may need to be made available more widely)	Changes to business processes in system and network planning to have up to date network data available all or most of the time, and potential need for centralised network model data rather than local copies managed by individual teams.

Table 3 Architecturally significant requirements implied for other systems



4. Key architectural decisions and issues

4.1 Key decisions made

This section lists all the architectural decisions that have been made, including their rationale and impact.

Given the hypothetical nature of the requirements, and the emphasis on requirements rather than design in this piece of work, not all potential issues can be resolved yet, but some architectural decisions have been made.

Issue description	Decision	Implications and/or further aspirations
Use of network topology data	There is no need to record how network assets are connected together in FMT, since all calculations requiring that are carried out by power systems analysis tools and GIS systems (e.g. forecasting supply and demand, identifying constraints). Some information about network assets will be included, e.g. sufficient location information to enable the flexibility team to know where on the network the relevant assets are, but not full network topology.	Relatively simple approach, with no need for full network topology data in FMT. It is noted that there may be a future requirement for the FMT to pin a note on a network topology system via a unique ID, yet this need is largely undefined and therefore not currently in scope.
How network asset data (cables, transformers etc) should be used within FMT	It is necessary for some data about network assets which are the subject of constraints to be included in FMT. Sufficient information needs to be included to be able to identify the assets in question, and some supplementary information including location, but it is not necessary to reproduce all asset information as would be found in Maximo, GIS (Electric Office) or planning tools e.g. PSSE.	Asset IDs (mastered in Maximo, GIS or planning tools) will be important identifiers, and need to be in common with identifiers used in other systems so that other teams such as the flexibility team have a common understanding of the assets and locations affected by constraints. Note: If a common asset ID is available it is recommended to use this; see also the issue regarding choice of asset identifiers in section 4.2.
Whether FMT requires network asset data to be pre-loaded. Pre-loading all asset data into FMT, so that it is there if ever the subject of a constraint, would be a major undertaking, and much of it would never be needed.	Asset data will be acquired as needed, and passed in at the time of creating a constraint about an asset. Where asset data is already in FMT (meaning that the asset must have been the subject of a constraint previously), if different then the new asset data is assumed to be more up to date and the older asset data will be overwritten.	This means there is likely no need for integration between FMT and Maximo (the asset database), Electric Office (the GIS) or planning tools e.g. PSSE. However, this assumption should be tested as the systems develop and NMF and WSC functionality established.
Algorithms will need tuning and it is not currently clear what the relative significance will be of many potential parameters	Need configurable parameters.	Enables ongoing adjustments as understanding of algorithms improves.

Issue description	Decision	Implications and/or further aspirations
Whether FMT will be invoked from WSC as well as system & network planning systems	Assume WSC can also be a source of new constraint information, particularly for scenarios which are too short term for reinforcement to be feasible, but potentially in investment timescales as well. Note that data about reinforcement options will not be generated by WSC itself but would need to be originated by planning systems, either passed from WSC, or directly to FMT using the interfaces provided for that purpose.	Messages between WSC and FMT are likely to be across the IT/OT boundary in future (though the initial TRANSITION innovation project implementation of WSC will be in the IT zone for pragmatic reasons).
Whether high level reinforcement and ANM budgetary cost estimates should be done within FMT	Out of scope; budgetary cost estimates will be passed in by planning systems/ people; note that ANM costs will also require the involvement of the Flexibility Solutions team.	There may be a long term aspiration for FMT to be able to do budgetary costing of reinforcement, but it would be complex and time-consuming, and is not in the present scope.
What types of decision should be recorded in FMT	Where data is presented to FMT users for decision-making, it will also enable them to record provisional decisions made and why, e.g. a decision to go to energy flexibility markets or reinforcement, with the FMT analysis results and recommendations. Details of actual contracts made to overcome specific constraints will be recorded in full in other systems, and information needed by FMT will be reflected in future updates of historic data. There is a process to reanalyse constraints, e.g. if no suitable flexibility contract could be found due to higher costs than expected, following which a new decision will be recorded, e.g. it may be changed to reinforcement due to taking into account further data.	FMT is there to support decision-making and will not record full details of all the procurement steps, quotes etc.
Multiple versions of FMT constraint analysis	It will be possible to reanalyse constraints in FMT. The date and the version of the analysis and decision to resolve the constraint will be recorded, so that it will be clear in cases where there are subsequent revisions to the initial provisional decision. Reanalysis of constraints may be triggered on request (BUC 33), and comparisons of actual flexibility usage against expected costs may be triggered by BUC 34.	After an initial provisional decision, there could be several reasons for revisiting a constraint, e.g. if the initial procurement processes suggest that the contract would be more expensive than initially anticipated, a constraint is re-analysed following updates to historical data, or a flexibility contract has been in operation for a while and the actual usage of flexibility is reviewed against anticipated usage.

Table 4 Key decisions made

4.2 Architectural issues for consideration

This section describes architectural/design issues that have been considered so far, or in other words areas where ultimately decisions will need to be made in future when the requirements are revisited and there is an intention to specify design to implement the requirements.

Some of these may have options identified, while others may be areas to explore further with no specific answers.

Description	Impact	Interim approach and/or future actions to resolve it
Of the data that FMT needs, what should be stored, and what should be obtained when needed?	Data stores and data sharing	It is a good principle to obtain data when needed rather than caching it but can be hard to set up and depends on other factors such as data volumes and how quickly required. Default assumption is to cache data provided the data sets are not too large (e.g. extensive time series data from PI).
How should historic data be moved around, and what triggers it? WSC mentioned though not core function	Data transport mechanisms	For the role of WSC, defer to the procurement process to see whether it is feasible. Other approaches include file moving tools such as SSEN's File Mover or the Oracle FusionWare enterprise service bus (ESB).
Where will network model data be mastered? Planners maintain it at the moment but multiple copies kept	May need new data stores	Records of pending network model changes will need to be made available more widely than is sometimes the case at the moment, e.g. to the flexibility team and forecasting, but specifics depend on planning systems. Note that this is relevant to wider business processes involving planning systems, the flexibility team and forecasting, but not to FMT itself.
How will local modifications to network model data be made available to others?	May need to make data sharing more formal	Probably much more interaction needed, but specifics depend on planning systems. Note that this is relevant to wider business processes involving planning systems, the flexibility team and forecasting, but not to FMT itself.
System planners largely ignore 11kV and vice versa, but not always, so they need cross-visibility	More formal connections	Probably much more interaction needed, but specifics depend on planning systems. Note that this is relevant to wider business processes involving planning systems, the flexibility team and forecasting, but not to FMT itself.
Should the whole network data be available at all times or only partial as needed?	Space, continuity, data cleansing	Probably needs to be available at all times, rather than build up as needed, but specifics depend on planning systems. Note that this is relevant to wider business processes involving planning systems, the flexibility team and forecasting, but not to FMT itself.
Is there sufficient commonality between systems to enable data about constrained assets to be passed around with common understanding, (e.g. is there a common set of asset identifiers which planning systems, WSC, FMT etc will recognise?)	Need to select identifiers which will enable users of different systems to deal with the same assets and constraints	The choice of identifiers will need to be elaborated in further design, e.g. Maximo asset identifiers may be in common between systems for assets, or GIS location identifiers and/or NRNs for location information.

System & network planning processes are not explicit systems but manual processes using other systems	System & interfaces not clearly defined	In practice there is likely to be a mixture of different styles of integration, e.g. by email, spreadsheets, manual use of web browser interfaces etc.
Use AI/machine learning? This may be necessary if the number of reinforcement versus flexibility decisions become much greater in quantity in future	Much harder to implement than manual decisions, but ultimately more productive	Manual decisions initially, with aspiration for more automation in future.
What type of data analysis algorithms? E.g. rules engine, predictive analysis or data mining approach	The type of system to build or procure could be very different	The data analysis approach being developed for MERLIN will be highly relevant; in future that should be considered and either the concepts extended or a different approach taken for the long term FMT system.
Will decisions made in FMT need to have a role in ESO/DSO interaction?	ESO/DSO interaction will be the responsibility of WSC (though not in the scope of TRANSITION so will be added in future)	Assume FMT will not be directly involved, and the extent and processes for any involvement is not clear, but WSC is included in the architecture here as interacting with FMT, which provides an opportunity for involvement in further elaboration in future.

Table 5 Architectural issues for consideration

5. Solution architecture

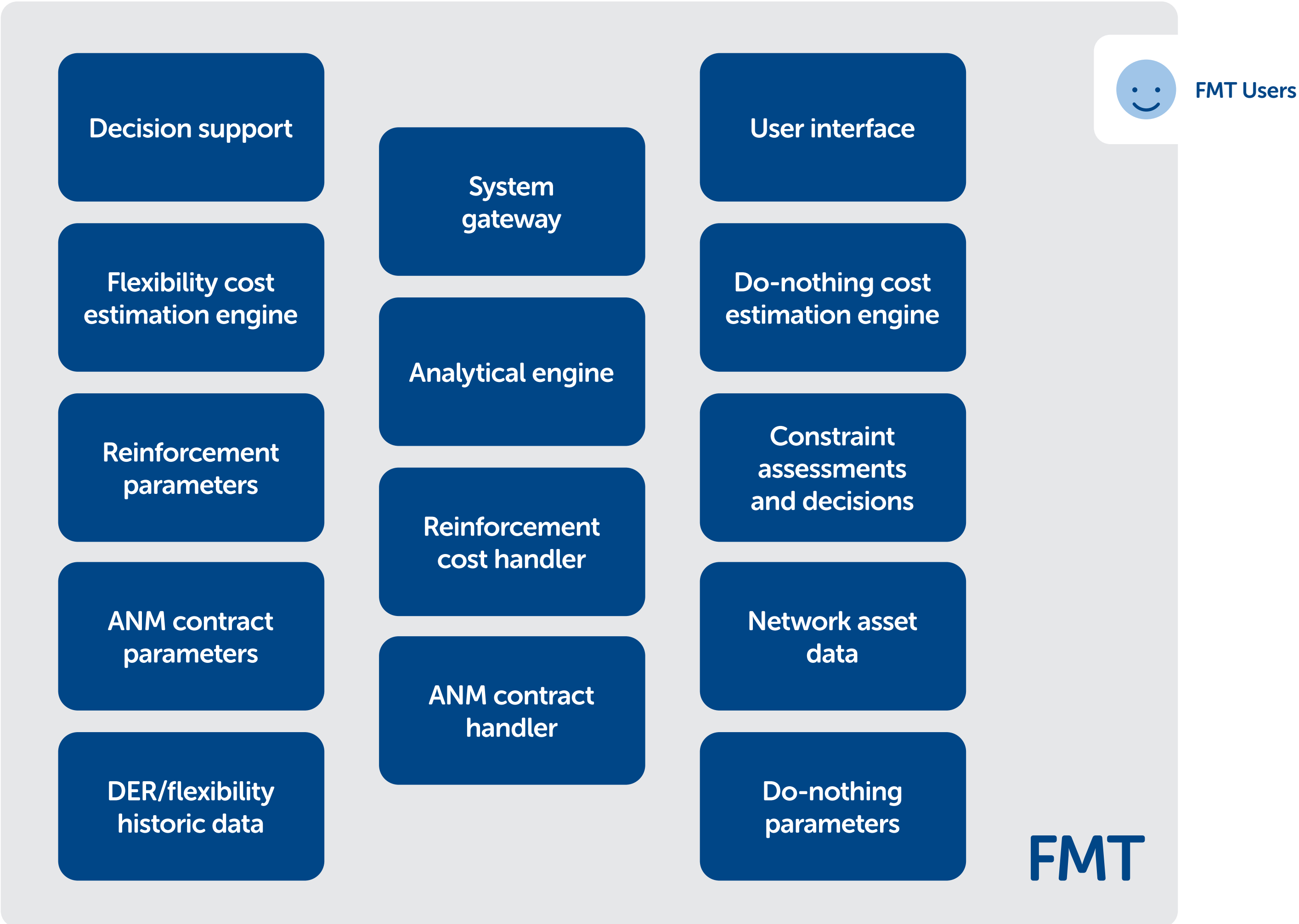


Figure 2 FMT component diagram

5.1 Component architecture

Diagram and descriptions of components identified within FMT.

5.1.1 Component diagram

Here is a suggested breakdown of the functions of FMT into sub-components. When there is a detailed design in future it will not necessarily need to be designed with exactly the same breakdown (e.g. estimation sub-components could be combined), but it illustrates the logical functions which will need to be carried out, and helps to highlight data that may be needed.

See the next section 5.2.1 for a brief description of each sub-component.

5.1.2 FMT Sub-component descriptions

FMT sub-component	Purpose
System gateway	System interface gateway to handle system messages to and from planning systems and WSC (and any other systems needed). Accepts newly-identified constraints, additional data about in-progress constraints, searches for previously-assessed constraints etc.
User interface (GUI)	User interface to enable a manual user to find details of constraints in progress, record provisional decisions and any other operations which can be done manually .
Analytical engine	Crunches through the data associated with specific constraints and historic data to produce range definitions/ ceiling figures, as specified in the requirements, for presentation to the user to assist with decision-making. Elements of this algorithm are being developed in the MERLIN project. There could be several different approaches for implementing this data analysis, e.g. a rules-based approach (such as where there is a shortfall of x MW for y hours a week then it will cost approximately £z), a predictive analysis approach, or a data mining approach looking for patterns in data about the electricity network. The approach chosen will make a big difference to the type of system processing required and to the types and quantities of data it would need to have available to it.
Decision support	Presents data to FMT users for decision-making and enables them to record provisional decisions made, e.g. a decision to go to energy flexibility markets. Note that FMT will not store details of actual reinforcement or flexibility contracts made to overcome constraints, so will record the initial decision rather than full details of the eventual outcome.
Flexibility cost estimation engine	For a given set of flexibility requirements[1] (e.g. address excess demand 1700-1900 on Fridays at a particular secondary substation, either by additional generation or demand reduction), estimate the cost of meeting it based on historic spot market and long-term contracts. [1] This could follow a standardised approach e.g. one of the 5 TRANSITION services and/or one of the ENA ONP WS4 standardised contracts?
Do-Nothing cost estimation engine	For a given constraint, estimates the cost of not meeting the constraint, based on CI and CML fines and other factors.
Reinforcement cost handler	Storage and retrieval of reinforcement cost data produced by the planning system.
ANM cost handler	Storage and retrieval of ANM cost data produced by the Flexible Solutions team.

Table 6 FMT sub-component descriptions

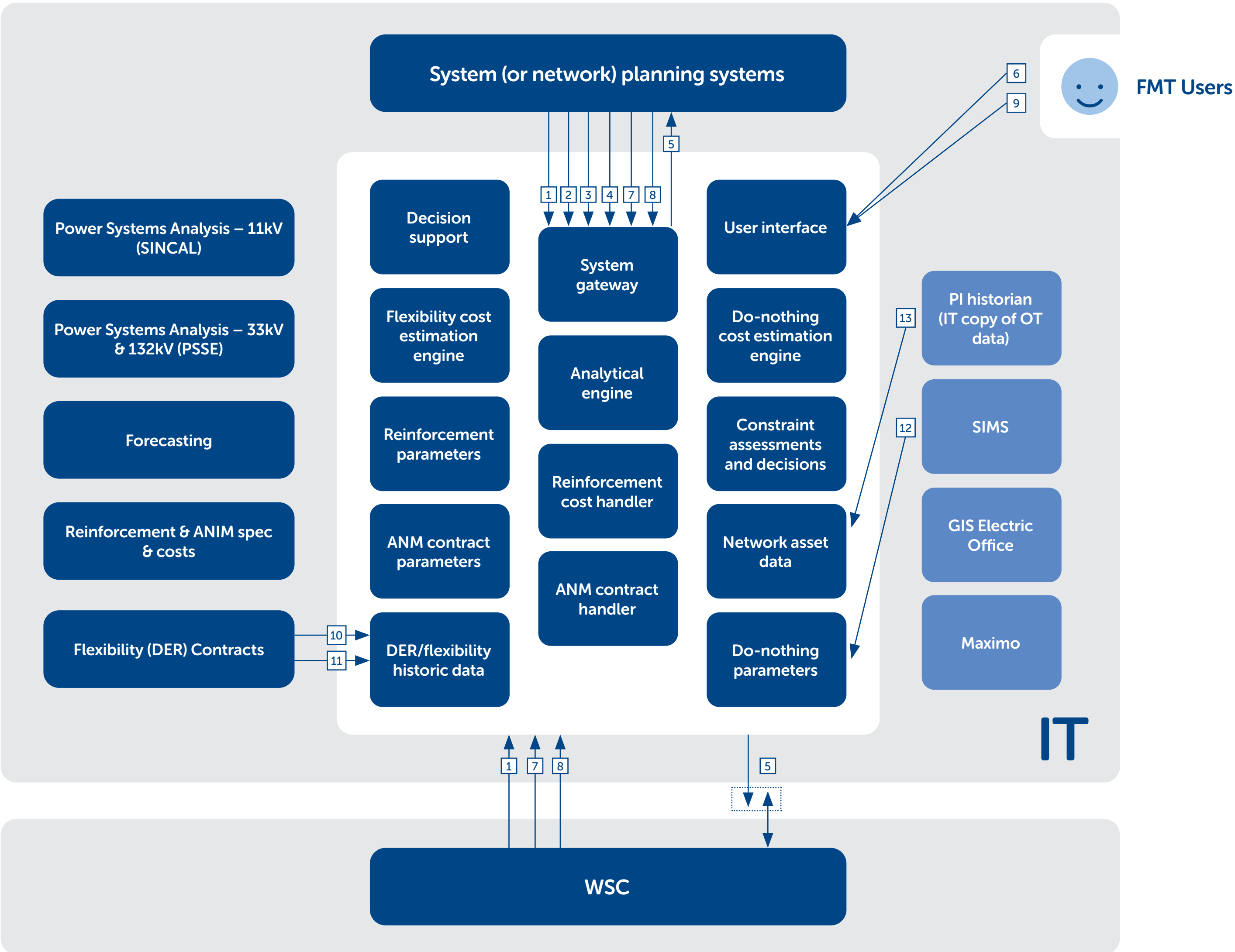


Figure 3 FMT interface diagram

5.2 System and manual interfaces

In many cases interfaces may be implemented as a system interface, manually, or both, and generally for FMT it is too early to say which, so they are combined in this section.

Selection of decisions from options provided by FMT is assumed to be a manual activity at least in the short term, though with an aspiration to automate it through AI or machine learning approaches in the longer term.

There are several different types of interactions combined in this section, primarily provision of operational data about constraints, population of historic data for use in estimation algorithms, and manual decision support interactions.

5.2.1 Interface diagram

The numbers on this diagram refer to the interface catalogue in the following section 5.2.2.

Users are shown for two interfaces (6 and 9) that are currently assumed to be manual-only. Many other interfaces may also support manual interfaces as well, but those are not shown on this diagram.

Note that WSC is shown as an OT system, and that requires an "air gap" interface when data is passed in from the IT environment. Although for the TRANSITION innovation project implementation of WSC will be in the IT zone, for pragmatic reasons, it is assumed that in the long term the intention is that WSC will be deployed as an OT system, and that is how it is represented here.

The direction of the arrows in this diagram shows the flow of data (where there is any) or the direction of the request (if it represents a command rather than a flow of data).

5.2.2 Integration styles

There are many different approaches to implementation of interfaces, and different styles will be appropriate in different circumstances.

SSEN's preferred integration styles between systems will include use of the Oracle FusionWare enterprise service bus (ESB) by default for messaging, or secure FTP-based exchange of files e.g. CSV via SFTP, for which SSEN use a "File Mover" product.

Where relevant, and where supported by products, Common Information Model (CIM) XML is preferred for exchanging data about electricity networks, using standards IEC 61968 (distribution network), 61970 (transmission network or on IEC 62325 (market operations) as appropriate.

Ideally integration between FMT and other systems such as WSC and systems used by planners would fall into one of these two categories, and would use CIM where relevant; however, some of the data is likely to fall outside existing CIM standards, in which case the feasibility of extending CIM standards may need to be examined, or non-CIM formats developed.

As some of the existing business processes in planning and the flexibility team include elements of manual processes, e.g. people using spreadsheets and web browser interfaces, it can be expected that some of the integration will include manual steps, e.g. manual selection of options from a user interface, or upload of a file of spreadsheet data via a user interface.

5.2.3 Interface catalogue

This section provides some details about the interfaces represented by arrows on the interface diagram in section 5.2.1 above. The numbers in the first column of the table are the key to the numbers on the diagram.

For an identified interface in the following table which is a data flow, the components shown as source are the sender of data in a data flow, and the destinations are recipients of data. In this case there are different ways the data flow may be achieved, e.g. it could be initiated by the source of the data or requested by the recipient of the data, and it is preferable not to specify that at the moment since it would be unnecessarily restrictive on later design.

In some cases, the interface represents a command/ trigger, or the use of a manual user interface, in which case the source is the initiator and the destination is where the action is carried out.

Where there is reference to system/ network planning, this means both systems planning (33kV and above) and network planning (11kV and below). Since these are handled by different teams, and additionally are split between northern and southern areas, in practices there will be multiple interfaces to cover all the systems and teams below, so these ID numbers represent types of interface rather than a single implementation of an interface.

ID	Purpose	Source	Dest-ination	FMT reqts ref	Across IT/OT boundary?	Type	Frequency/ how initiated
1	Present FMT with new constraint including flexibility requirement	System/ network planning, WSC or GUI	FMT	IER05	WSC: OT to IT Otherwise: within IT	Use of CIM should be explored as it should be possible to express some of the data in CIM format; however other aspects of the data would not be compatible with CIM. It may require a new bespoke format using e.g. CSV, JSON or XML Note the data includes forecast load time series data which may need to be handled differently.	On demand
2	Update constraint with new reinforcement or ANM cost	System/ network planning or GUI	FMT	IER06	Within IT	No known existing format. Probably new bespoke format using e.g. CSV, JSON or XML, or a user interface.	On demand
3	Update constraint with new reinforcement or ANM energisation dates	System/ network planning or GUI	FMT	IER07	Within IT	No known existing format. Probably new bespoke format using e.g. CSV, JSON or XML, or a user interface.	On demand
4	Update constraint with new reinforcement or ANM type data	System/ network planning or GUI	FMT	IER08	Within IT	No known existing format. Probably new bespoke format using e.g. CSV, JSON or XML, or a user interface.	On demand
5	Output constraint solution	FMT	System/ network planning, WSC or GUI	IER09	WSC: IT to OT Otherwise: within IT	No known existing format. Probably new bespoke format using e.g. CSV, JSON or XML, or a user interface.	On demand
6	Make constraint provisional decision	GUI	FMT	BUC 32	Within IT	Manual interface	Manually
7	Retrieve constraints processed by FMT (search by various criteria)	System/ network planning, WSC or GUI	FMT	BUC 33	WSC: OT to IT Otherwise: internal to application	No known existing format. Probably new bespoke format using e.g. CSV, JSON or XML, or a user interface.	On demand
8	Evaluate constraint	System/ network planning, WSC or GUI	FMT	BUC 33	WSC: OT to IT Otherwise: within IT	No known existing format. Probably new bespoke format using e.g. CSV, JSON or XML, or a user interface.	
9	Update constraint provisional decision	GUI	FMT	BUC 32	Within IT	Manual interface	Manually

ID	Purpose	Source	Dest-ination	FMT reqts ref	Across IT/OT boundary?	Type	Frequency/ how initiated
10	Update flexibility historic market data: spot market	Flexibility contracts system or GUI	FMT	IER01	Within IT	Possible use of the on CIM electricity market standard IEC 62325 should be explored for feasibility. Otherwise it may need a new bespoke format using e.g. CSV, JSON or XML, or a user interface.	On demand or scheduled update
11	Update flexibility historic market data: long-term contract data	Flexibility contracts system or GUI	FMT	IER02	Within IT	Possible use of the on CIM electricity market standard IEC 62325 should be explored for feasibility. Otherwise it may need a new bespoke format using e.g. CSV, JSON or XML, or a user interface.	On demand or scheduled update
12	Update do-nothing parameters	SIMS or GUI	FMT	IER03	Within IT	Probably manual interface, though there may be an export from SIMS.	On demand or scheduled update
13	Update historic load data for assets	PI	FMT	IER04	Within IT	Time series data, e.g. in PI data formats.	On demand where required

Table 7 Interface catalogue

5.3 Data architecture and governance

This section contains data architecture for FMT components at a conceptual level rather than logical or physical data models, and the approach to data governance requirements, and is very high level at this stage.

5.3.1 Data store population and use

This section shows the sort of data likely to be required by FMT, based on the requirements.

Data types and groups	Purpose	Data entity from requirements spec	How populated and maintained	Who/what uses it
Constraints assessed in FMT and decisions made	Predicted constraints identified by planners or via WSC	Constraint and associated information in Installed Asset, Asset Type, Network Unit	Created when new constraint data is passed in planners or WSC by use of interface 1	Planners identify them & take the lead on making an initial decision. A constraint may be passed on to the flexibility team for more detailed costing and procurement
Constraints assessed in FMT and decisions made	Provisional decisions made (there may be multiple rounds, distinguished by version and date)	Constraint	Records decisions made manually via interfaces 6 & 9	Recorded for future reference by multiple teams e.g. planning team, flexibility team, WSC etc
Constraints assessed in FMT and decisions made	Reinforcement & ANM spec and associated costs (may be multiple rounds with different accuracy of costing)	Physical Option	Provided by planners via interfaces 2, 3 & 4	Created from data passed in by planners, used by FMT analytical engine for assessments
Constraints assessed in FMT and decisions made	Flexibility solution (may be associated with multiple rounds of costing)	Flexibility Option	Created as part of evaluating a constraint	Created by FMT flexibility cost estimation engine based on the constraint's flexibility requirements; used by FMT analytical engine for assessments
Constraints assessed in FMT and decisions made	Estimated costs for using spot market for flexibility option to address constraint	Spot Price	Created as part of evaluating a constraint	Created by FMT flexibility cost estimation engine based on the constraint's flexibility options and spot price historic data; used by FMT analytical engine for assessments
Constraints assessed in FMT and decisions made	Estimated costs for entering into long term flexibility contract to address constraint	Long-term Contract Price	Created as part of evaluating a constraint	Created by FMT flexibility cost estimation engine based on the constraint's flexibility options and long-term contract historic data; used by FMT analytical engine for assessments

Constraints assessed in FMT and decisions made	Predicted do-nothing costs (or incentives) if constraint not addressed	Forecast Do-nothing Costs	Created as part of evaluating a constraint	Created by Do-Nothing cost estimation engine based on the constraint's flexibility options and do-nothing historic data; used by FMT analytical engine for assessments.
Network data	Specific portion of the overall distribution network, e.g. 132kV system below a specific GSP	Network Unit	Created or updated as part of creation of a new constraint	Used to identify which system or network planning team has responsibility for it.
Network data	A specific physical asset (e.g. a line or transformer)	Installed Asset. Note that this includes forecast load time series data	Created or updated as part of creation of a new constraint	A single constraint is associated with one or more assets, and the assets drive the cost of avoiding the constraint e.g. by flexibility or reinforcement. Asset details are passed in when a constraint is passed to the FMT and the asset details are not already known to the FMT (i.e. loaded as the need arises, rather than a bulk load of asset data).
Network data	A generic physical asset	Asset Type	Created or updated as part of creation of a new constraint	Classification of an asset for additional help with cost comparison
Historic data	Historic spot price data	Spot Price	By flexibility team via interface 10	Used by FMT to estimate costs for specific flexibility requirements
Historic data	Historic long term contract price data	Long-term Contract Price	By flexibility team via interface 11	Used by FMT to estimate costs for specific flexibility requirements
Historic data	Historic outage data	Historic Outages	By planners via interface 13	Historic data about an asset; may be of use in do-nothing costing.
Calculation parameter data	CI and CML penalty data	Fine Rate	By planners and/or SIMS via interface 12	Used by FMT to estimate do-nothing costs associated with a constraint.

Table 8 Data store population and use

5.3.2 Types of data storage

Data is likely to be stored in conventional relational databases such as Oracle or Microsoft SQL Server. Time series data obtained from OsiSoft PI may be formatted differently, though time series data can also be stored in relational databases if appropriate.

Depending on the approach to data analysis, different forms of storage may be needed for feeding data analysis algorithms, particularly if large amounts of data are involved using a data mining approach.

5.3.3 Use of identifiers

ID information from the asset database (Maximo) and location information from the GIS (Electric Office) are identifiers which should be in common use within SSEN already.

When a new constraint is uploaded to FMT by planners or WSC, a constraint ID will be created within FMT. This constraint ID can then be used to provide later updates e.g. new reinforcement costs, or request further assessments e.g. at a later date when more flexibility market historic data is available. Search facilities will be available to find constraint IDs if needed.

5.3.4 Data governance

The table in section 5.3.1 above includes a column which indicates how each type of data is populated and maintained.

The interface catalogue in section 5.2.3 has a column showing the frequency of updates and how the interface is initiated.

Styles of integration for moving data between systems is briefly described at a high level in section 5.2.2.

More specific choices would need to be made when it is feasible to do more detailed design.

5.4 Other architectural views

A more detailed solution architecture would include other views such as an operational view (showing an architectural decomposition of the solution at work) a deployment view (how the FMT components will be deployed e.g. cloud-based or on-premise, and IT or OT), and security architecture.

However, given that it is too early to do any detailed architecture and design work at this stage, there is little content of that sort available in the scope of this particular piece of work.

5.4.1 Operational views – interaction diagrams

The following interaction diagrams illustrate how FMT would be used in conjunction with other systems.

In these diagrams, the arrows point from the system (or manual process) that initiates a request to the system (or process) that receives and handles the request. No arrow is shown for the data being returned in response to the request. See the interface slides further down this slide set for indications of the types of data involved.

The numbers on the arrows indicate sequences, and do not correspond to the numbers used in the interface diagram in section 5.2.1 or the interface catalogue in section 5.2.3.

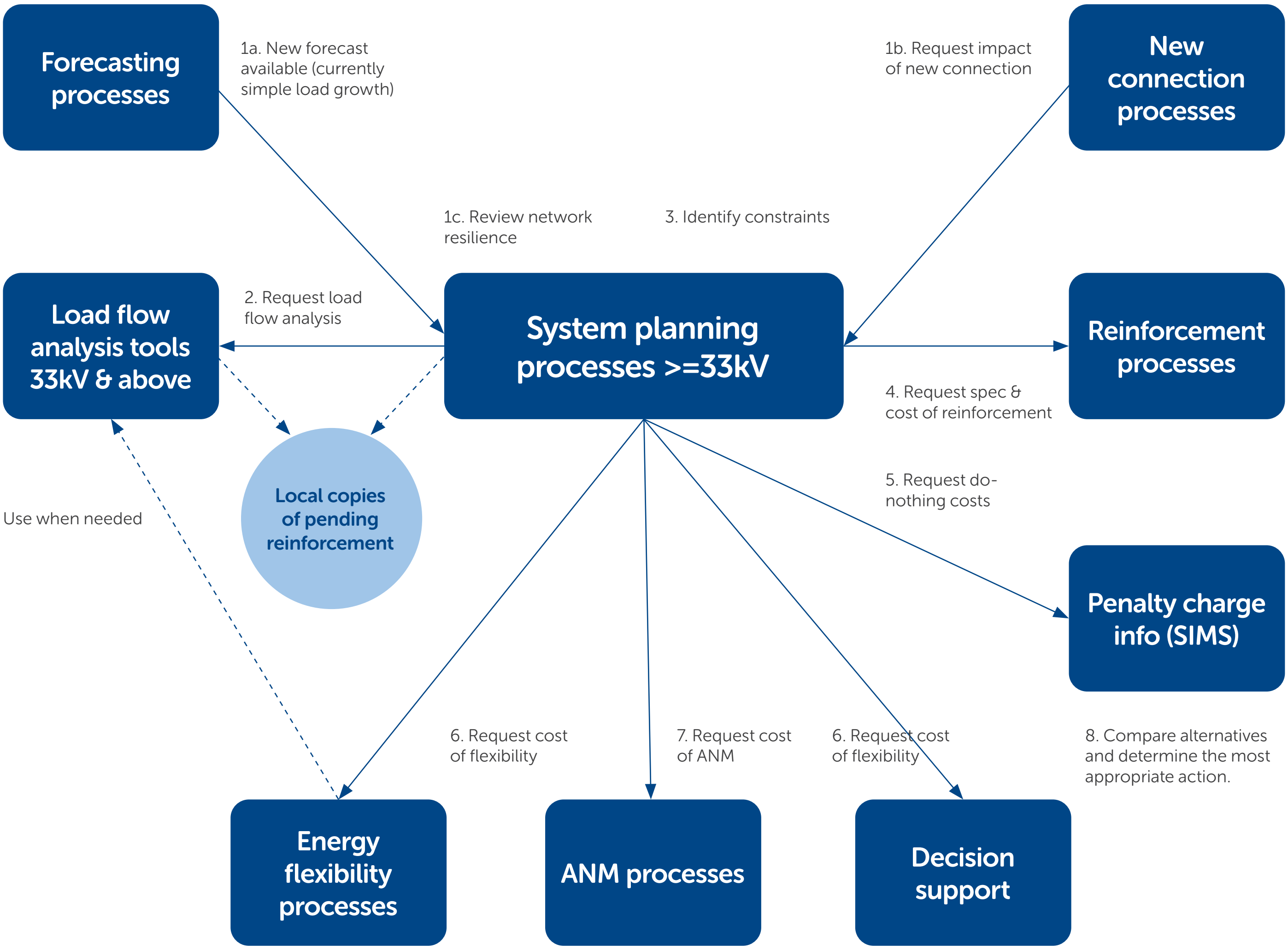


Figure 4 As-is 33kV planning interaction diagram

5.4.1.1 As-is system Planning (33kV)

This is a rough representation of processes at the moment (pre-FMT).

The boxes here may represent systems or collections of manual processes (e.g. people using spreadsheets). The boundaries are slightly artificial in some cases, with component areas separated out in order to enable processes to be shown as happening within FMT components in later diagrams.

5.4.1.2 Interactions (33kV); FMT – analysis phase (no WSC)

This shows a notional breakdown of components and data caches which could comprise FMT, with requests going from planners directly to FMT. However, note that there is another possibility whereby requests will be routed via WSC (see section 5.4.1.5).

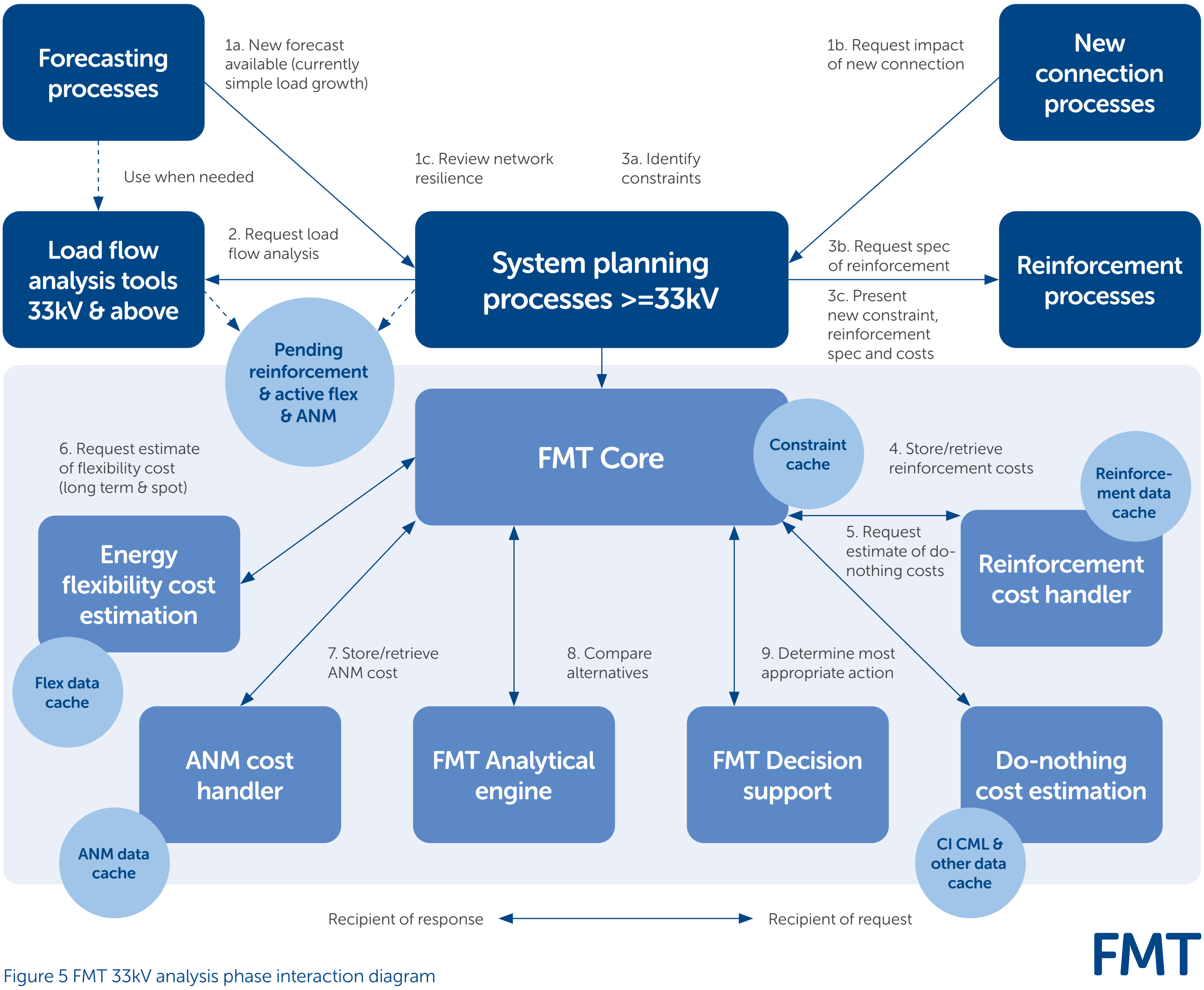


Figure 5 FMT 33kV analysis phase interaction diagram

The blue database shape represents a comprehensive and widely available set of data about in-progress reinforcement and ANM projects, and flexibility contracts, which will be available to planners and for estimation purposes. This should be more available than with current arrangements where data is kept more locally. The current arrangements work at the moment but when there is far more use of energy flexibility in future, the data needs to be more widely available.

5.4.1.3 Interactions (33kV); FMT – decision

This interaction diagram shows decision-making leading to recording a provisional decision of how to resolve a constraint, and following this procurement of the chosen solution will start, which happens outside FMT (shown as alternatives 10a, 10b or 10c in the interaction diagram).

The term provisional indicates that a decision has been made to initiate procurement processes, e.g. a decision to go to energy flexibility markets or reinforcement. There is no process for the user to later return and record details of actual contracts made to overcome specific constraints, since details of physical procurement or energy flexibility contracts will be handled by different systems and processes.

After an initial provisional decision, there could be several reasons for revisiting the decision, e.g. if the initial procurement processes suggest that the contract would be more expensive than initially anticipated, a constraint is re-analysed following updates to historical data, or a flexibility contract has been in operation for a while and the actual usage of flexibility is reviewed against anticipated usage.

The date and the version of the analysis and decision to resolve the constraint is recorded, so that it will be clear in cases where there are subsequent revisions to the initial provisional decision.

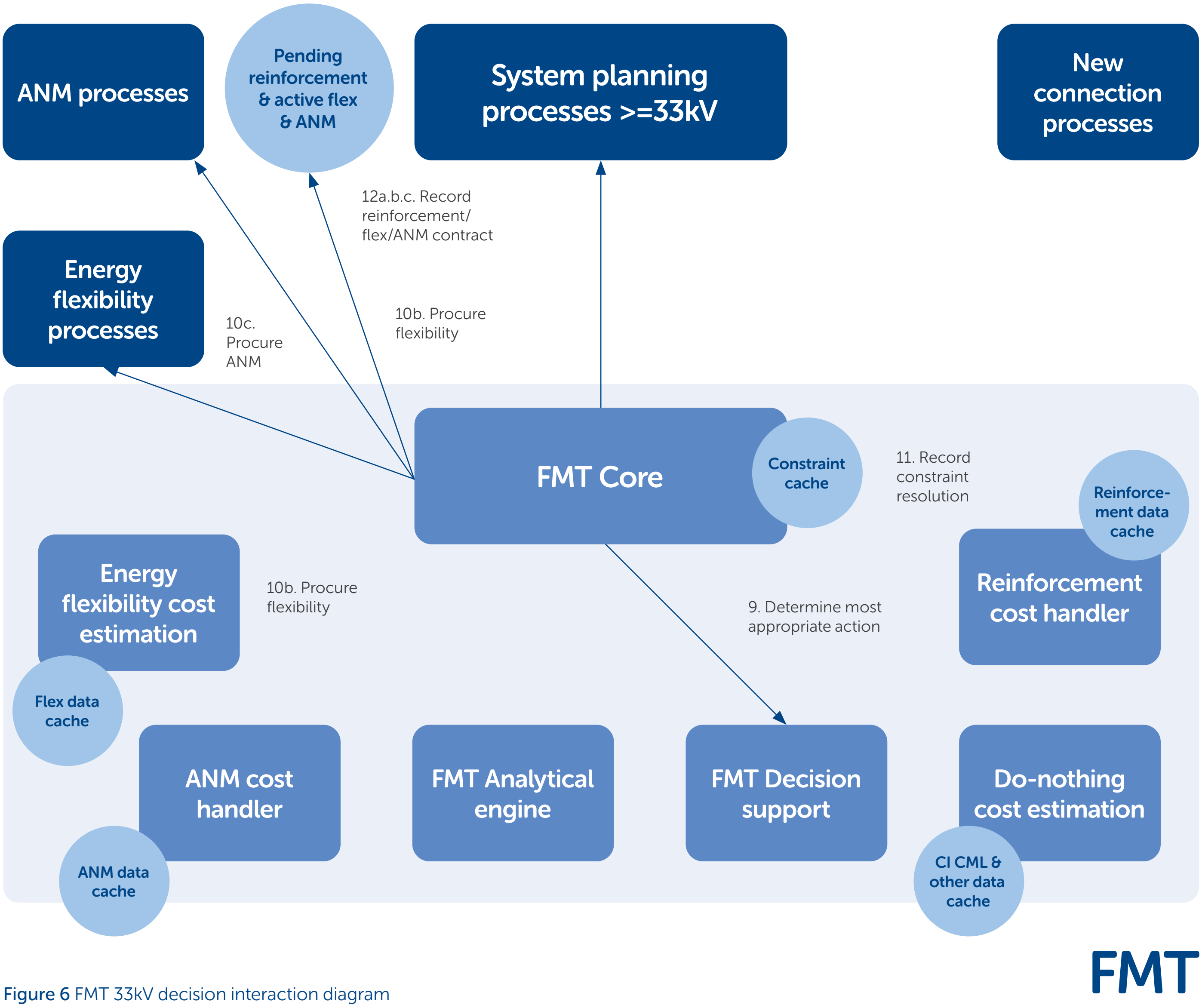


Figure 6 FMT 33kV decision interaction diagram

5.4.1.4 Interactions (33kV); FMT – new reinforcement costs

This shows the interactions where system planners have produced a new estimate of reinforcement costs (e.g. a more accurate estimate), as described in BUC 33 Review Analysis, which triggers further evaluation against flexibility costs etc.

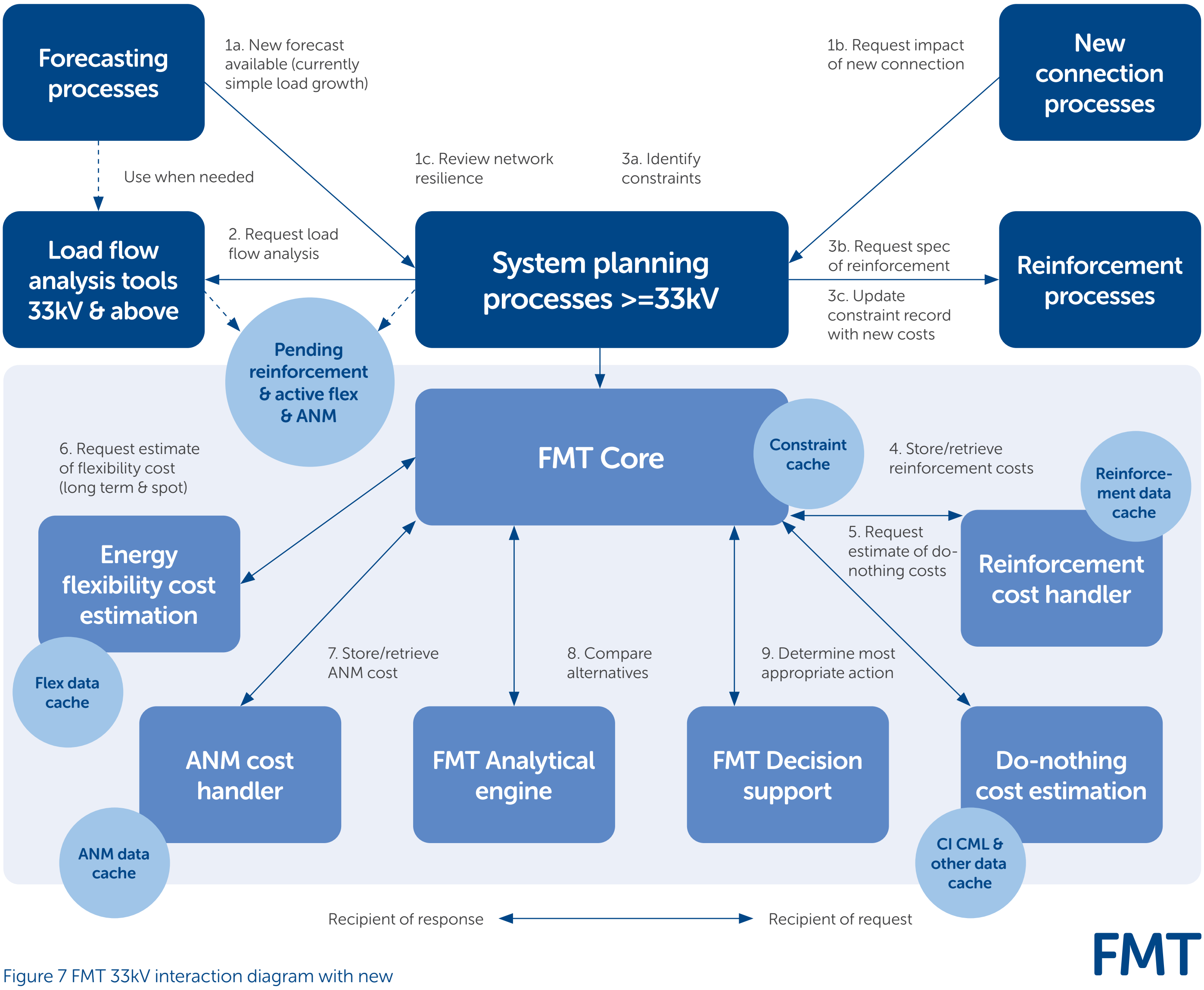


Figure 7 FMT 33kV interaction diagram with new reinforcement costs

5.4.1.5 Interactions (33kV); FMT – constraint analysis via WSC

This shows constraints identified by system planners, including reinforcement costs, being routed via WSC, e.g. to enable ESO/DSO interaction to take place.

Whether system and network planners should interact directly with FMT or via WSC is a point of discussion. Both approaches are possible within the scope of the requirements.

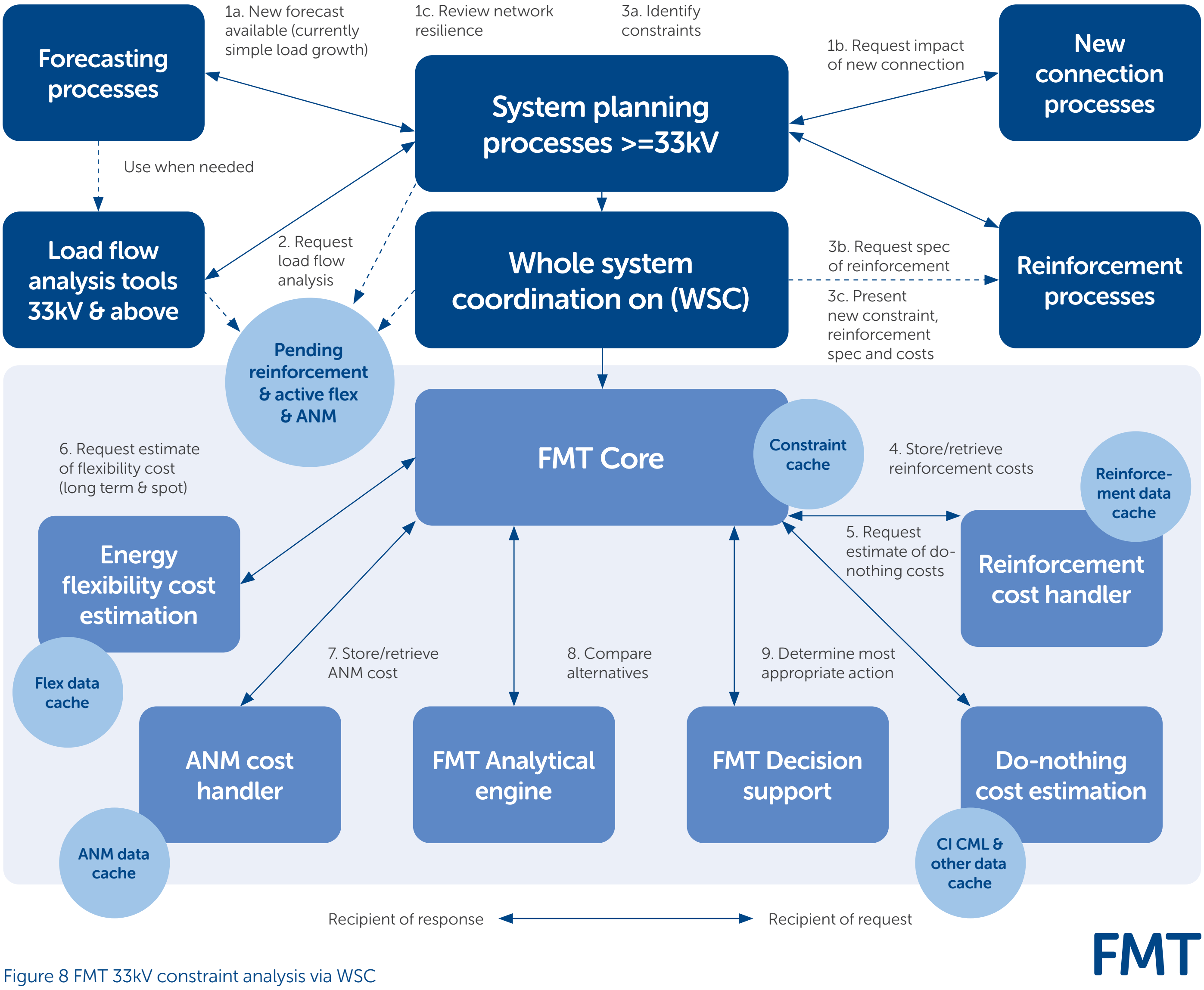


Figure 8 FMT 33kV constraint analysis via WSC interaction diagram

5.4.1.6 Interactions (33kV); FMT – analysis phase with interim need

This has an optional alternative continuation of the analysis sequence (starting from A3d), where an interim period is identified, for cases in which a constraint is predicted to be an issue before a physical mitigation (reinforcement or new ANM solution) could be constructed, leaving energy flexibility or payment of CI and CML fines as the only alternatives.

This diagram shows interaction via the WSC rather than directly by planners.

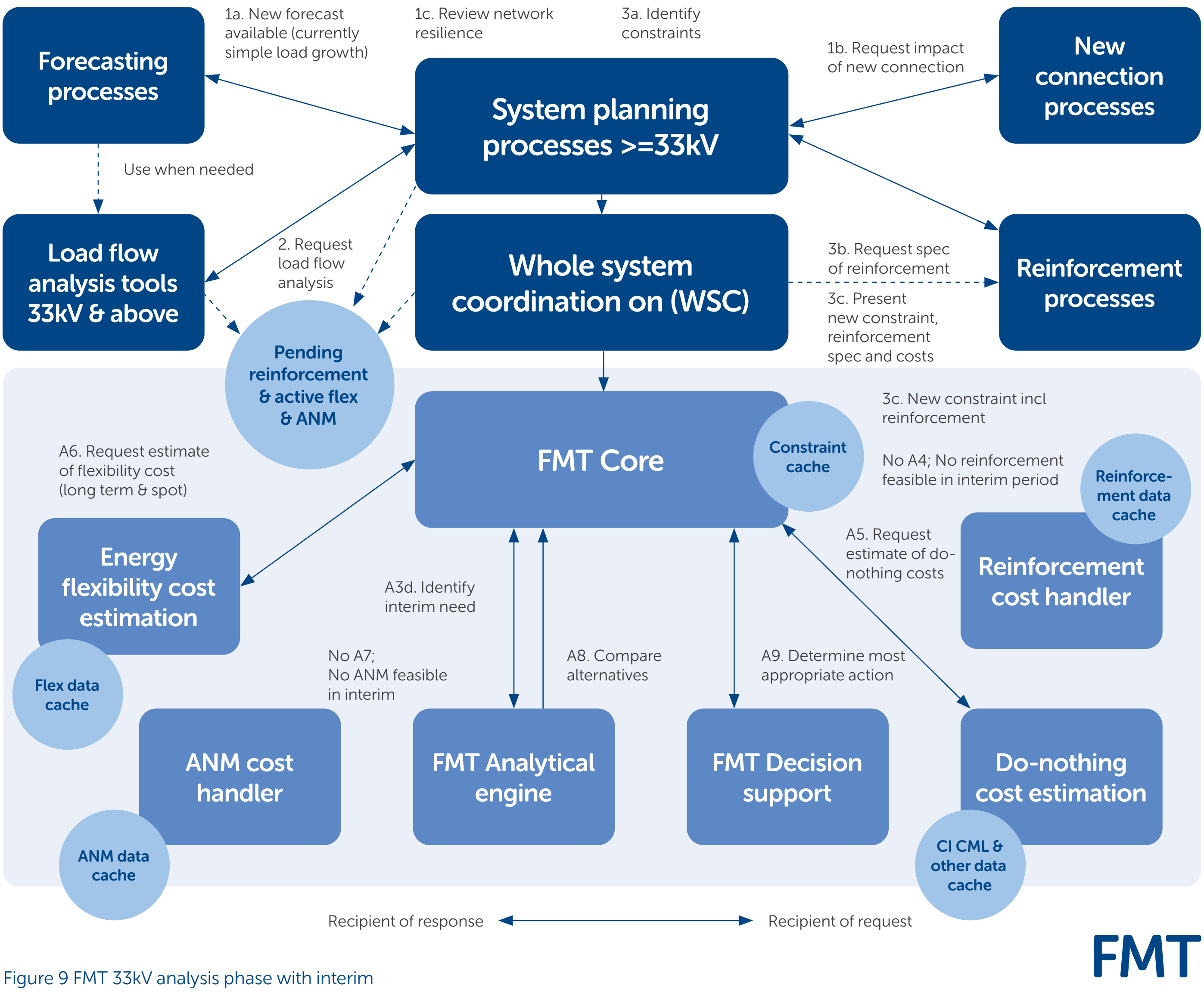


Figure 9 FMT 33kV analysis phase with interim need interaction diagram

5.4.1.7 WSC use of FMT where reinforcement not feasible

This diagram shows use of FMT for analysis of relatively short-term constraints identified via WSC, e.g. where triggered by information from NMF about a new flexibility contract having been struck.

This is also analogous to the earlier slide showing an interim period for cases where a constraint will be an issue before reinforcement can be carried out and where reinforcement and ANM solutions (i.e. requiring physical construction) are not feasible so there is no involvement from planners.

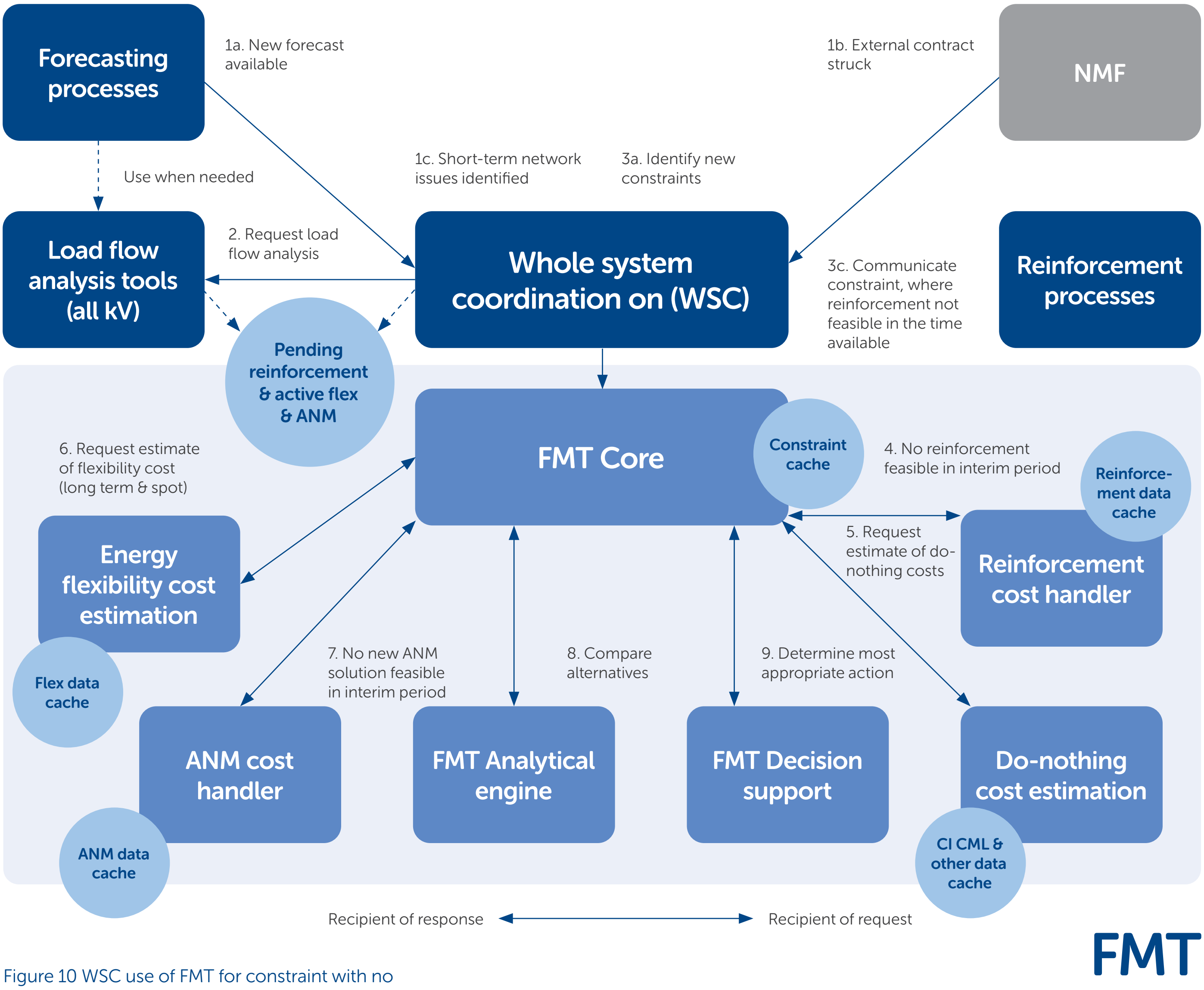


Figure 10 WSC use of FMT for constraint with no reinforcement interaction diagram

5.4.1.8 WSC use of FMT to revisit previous decision

This shows WSC (which may mean a WSC human user or potentially as a system interface) prompting re-evaluation of decisions to use energy flexibility made previously via FMT, as described in BUC 33 Review Analysis. Existing reinforcement & ANM costs will be used, and energy flexibility and do-nothing costs will be compared using the latest historic data.

If, based on the updated analysis, a user decides to change the decision made about a previous constraint, then a new decision may be recorded, which follows the same process as an original decision as shown in section 5.4.1.3.

Note that constraints may also be reanalysed as a result of automatic processes within FMT (see BUC 34 Flexibility Usage Analysis).

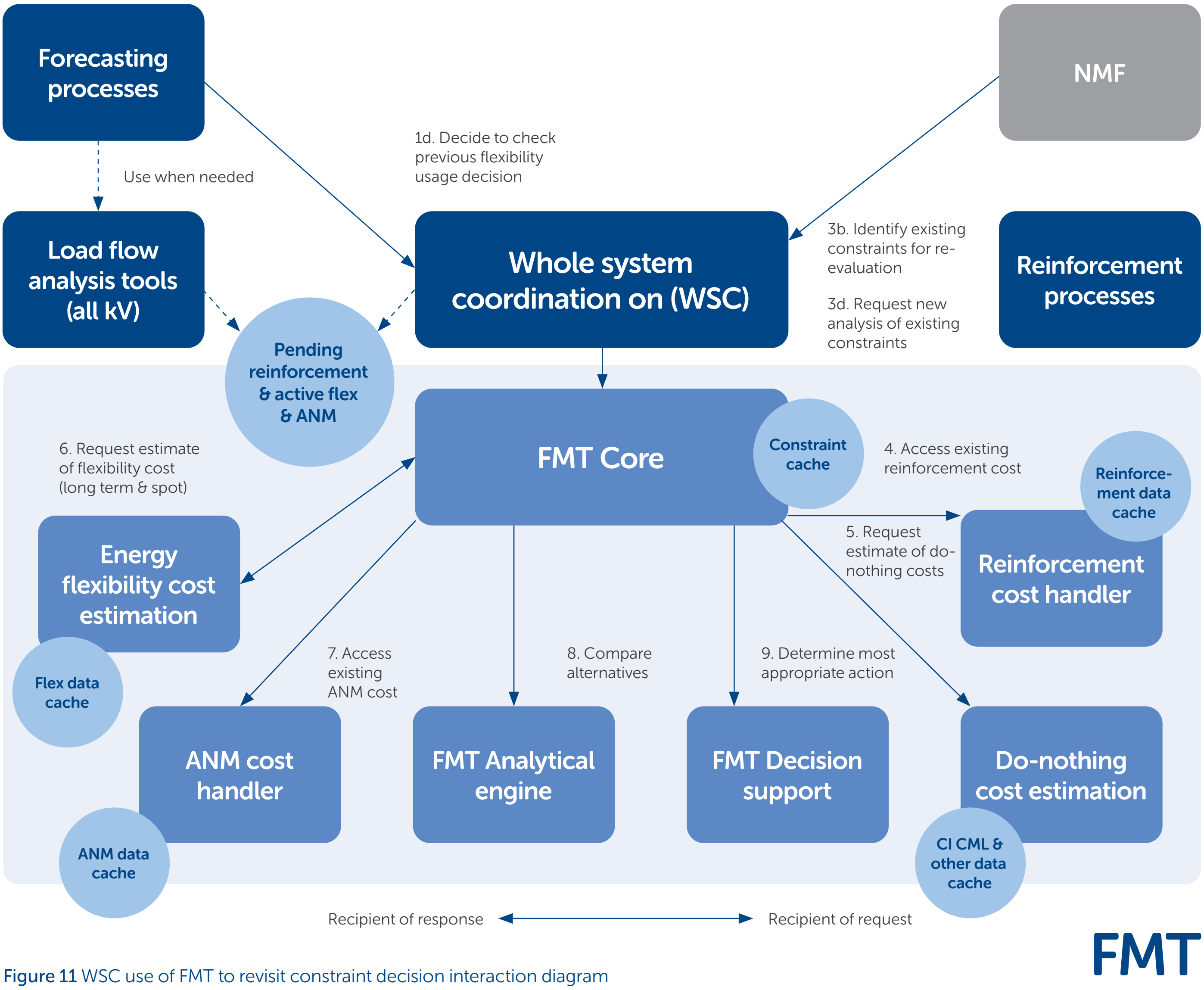


Figure 11 WSC use of FMT to revisit constraint decision interaction diagram

5.4.1.9 Interactions (11kV); FMT – analysis phase

This diagram is for examining whether there are any differences in process flows comparing system planning (33kV and above) and network planning (primarily 11kV, and potentially LV as well); the conclusion so far is that the process flows are the same in principle at this level of detail, though the teams, areas of the network and tools involved will be different.

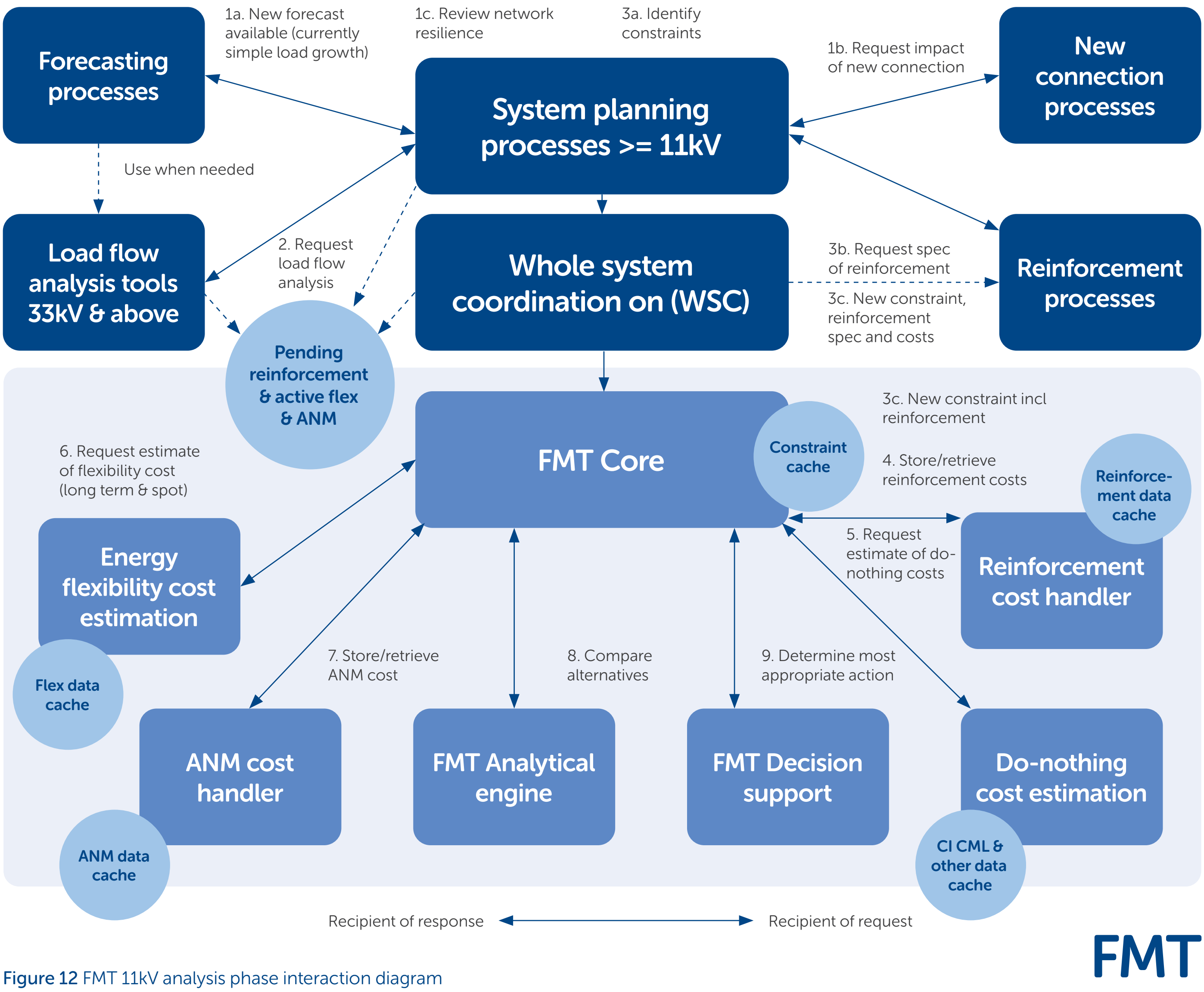


Figure 12 FMT 11kV analysis phase interaction diagram

5.4.1.10 Interface additional information

The following tables show additional information about the interfaces between sub-components of FMT that are suggested on the interaction diagrams in this section, keyed by the arrow numbers on the interaction diagrams. Only sequence numbers within scope of FMT sub-components are included in the table.

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Interfaces on analysis diagrams

Sequence	Initiator	Target/ responder to request	Purpose	Types of data in request sent by initiator	Types of data sent in response
3c	System planning	FMT core	Present new constraint	Constrained asset(s), reinforcement spec	Ack
4	FMT core	Reinforcement cost handler	Store reinforce-ment cost estimate	Constrained asset(s), dates	Ack
5	FMT core	Do-nothing cost estimator	Request do-nothing cost estimates	Constrained asset(s), dates	Do-nothing costs
6	FMT core	Energy flex cost estimator	Request spot flex cost estimate	Constrained asset(s), dates	Spot flex costs & risk factors
6	FMT core	Energy flex cost estimator	Request long term contract flex cost estimate	Constrained asset(s), dates	Long term flex costs & risk factors
7	FMT core	ANM cost handler	Store ANM costs estimate	Constrained asset(s), dates	Ack
8	FMT core	FMT analytical engine	Analyse alternatives	Constrained asset(s), dates, reinforcement cost, spot flex costs, long term contract flex costs, ANM costs, do-nothing costs	Break-even flex costs, latest reinforcement date
9	FMT core	FMT decision support	Make constraint resolution decision	Constrained asset(s), dates, break-even flex costs, latest reinforcement date	Constraint resolution decision

Interfaces on analysis update & review diagrams

Sequence	Initiator	Target/ responder to request	Purpose	Types of data in request sent by initiator	Types of data sent in response
3c	System planning	FMT core	Update constraint with new costs	Constrained asset(s), reinforcement spec	Ack
3d	FMT analytical engine	FMT core	Identify interim need (i.e. before physical solution feasible)	Constrained asset(s), dates	Ack
9	FMT core	FMT decision support	Make new resolution decision for constraint	Constrained asset(s), dates, break-even flex costs, latest reinforcement date	Constraint resolution decision

Interfaces on decision processing diagrams

Sequence	Initiator	Target/ responder to request	Purpose	Types of data in request sent by initiator	Types of data sent in response
10b	FMT Core	System Planning	Procure reinforcement	Constrained asset(s), reinforcement option	Ack, contract details
10c	FMT Core	Energy flex	Procure long term flex contract	Constrained asset(s)	Ack, contract details
10c	FMT Core	Energy flex	Record spot market details	Constrained asset(s)	Ack, contract details
10a	FMT Core	ANM Costing? PowerOn? Manual?	Set up ANM details	Constrained asset(s)	Ack, contract details
11	FMT Core	N/A	Record constrained asset resolution	Constrained asset(s), resolution type	Ack
12b	FMT Core	Pending reinforcement & active flex & ANM database	Record reinforcement contract	Constrained asset(s), reinforcement contract	Ack
12c	FMT Core	Pending reinforcement & active flex & ANM database	Record flex contract	Constrained asset(s), resolution type	Ack
12c	FMT Core	Pending reinforcement & active flex & ANM database	Record ANM details contract	Constrained asset(s), resolution type	Ack

Data use by component

Component Data	Load flow analysis tools	Fore-casting	System planning	Reinforce-ment spec & costing	Energy flex processes	ANM costing processes	FMT analysis & decision support	Master system of data type
Network topology	Use; Cache	Use; Cache	Use	Use	Use	Use		PowerOn
Location of network assets	Use; Cache	Use; Cache	Use	Use	Use	Use		GIS
Condition of network assets			Use	Use				Maximo
Forecast network demand & supply	Use; Cache	Generate	Use					Fore-casting
Historic network demand & supply	Use; Cache	PI?	Use					PI?
Reinforcement cost historic			Use	Generate; Store			Use	Reinforce-ment costing
Identified constraints	Generate		Use; Cache	Use	Use	Use	Use	System planning

Data use by component continued

Component Data	Load flow analysis tools	Fore-casting	System planning	Reinforce-ment spec & costing	Energy flex processes	ANM costing processes	FMT analysis & decision support	Master system of data type
Reinforcement committed contracts			Use; Cache				Use	System planning
Reinforcement pending contracts			Use; Cache				Use	System planning
Flexibility spot contract historic					Use	Use	Use	Energy flex
Flexibility long term contract historic					Use	Use	Use	Energy flex

5.4.2 Solution implementation

The FMT requirements represent a new sort of system with no direct equivalent in SSEN.

The need for FMT derives from the need to compare physical reinforcement of distribution networks with use of energy flexibility when making investment decisions. As use of energy flexibility and flexibility markets for electricity distribution networks is relatively new, there is no mature market for a system of this sort.

There is an ENA Open Networks Project working in this area in 2020 (WS1A P1 ANM vs Flexibility vs Reinforcement Common Methodology), but since the deliverable of a paper outlining the first iteration of common decision making criteria and methodology will not be released until July 2020, at the time of writing there are no results available from that work.

In the absence of further information, it is assumed that to acquire one now would include at least some new bespoke development or extension of an existing product or platform. However, the ENA project may lead to development of new systems.

5.4.3 Deployment – FMT instance for tuning algorithms

At the time of writing, there has been little use of energy flexibility contracts in SSEN, and there is expected to be a big increase in variation of patterns of demand and supply on distribution networks in future, so the sort of algorithms required for use in FMT is still experimental.

It is expected that an installation of FMT will be needed for tuning algorithms and specifying parameters, by feeding historic scenarios into it, examining the results from FMT and comparing to actual outcomes, in order to improve parameter choices etc.

It is likely that this situation will still be partly the case when FMT is first deployed for production use, so it may be that a tuning version of FMT will continue to be needed in parallel to the live/production instance of FMT. The functionality is expected to be the same, but with more flexibility in permission to change the data and configuration.

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Appendices

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Modelling the Economic Reactions Linking Individual Networks

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