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Loadsense Operational Logic

ea technology

RIIO NIC NETWORK INNOVATION COMPETITION

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Contents

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1   Introduction

1.1   Purpose

Within the OpenLV Project, Loadsense is designed to utilise information within the LV-CAP™ platform, (e.g. monitored data or processed outputs) to determine whether to implement network meshing of two adjacent substations, based on a preconfigured set of logical rules.

The purpose of this document is to detail the proposed logic to be embedded within the Loadsense application and summarise the rationale behind it.

1.2   Background

1.2.1   OpenLV

The OpenLV Project, a Network Innovation Competition (NIC) project submitted by Western Power Distribution (WPD) to Ofgem in 2016, was awarded funding and commenced in January 2017. The full bid submission, queries from Ofgem's Expert Panel, associated responses and the Project Direction, can be found on Ofgem's website[1].

The purpose of the project is to test and demonstrate the functionality of a software platform, LV-CAP™, (Low Voltage Common Application Platform) developed by EA Technology to facilitate cost effective deployment of monitoring and automation capability to the low voltage (LV) electricity distribution network.

LV-CAP™ is a distributed intelligence platform, developed to facilitate the gathering and processing of network data, and implementing actions to benefit the network whilst removing the requirement for high volumes of data transfer.

The OpenLV project is designed to demonstrate the platform's capabilities, utilising three methods.

- **Method 1** will demonstrate the capability to deliver network benefits through Network Capacity Uplift in response to Dynamic Thermal Rating of the monitored transformers.
- **Method 2** will make network data available to community groups and interested individuals. At a minimum, the platform will be used to gather and process data for communities, providing the information they desire without the need to transmit all data gathered.
- **Method 3** will provide third parties a platform to test new algorithms, or demonstrate the ability to control network assets, (e.g. battery storage solutions) through the LV-CAP™ platform, without the need for additional equipment and monitoring capabilities.

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[1] https://www.ofgem.gov.uk/publications-and-updates/electricity-nic-submission-western-power-distribution-openlv

2 LV-CAP™ platform architecture

2.1 LV-CAP™ software platform overview

The LV-CAP™ is a hardware agnostic software platform designed to be a hardware agnostic solution to the challenge of cost effectively deploying multiple smartgrid products from different suppliers in a single substation.

LV-CAP™ enables deployment of a single set of hardware to monitor the network and make the gathered data available to multiple software applications running on the platform. This enables a single investment in the hardware to support deployment of multiple solutions to benefit the network.

Applications can be developed by multiple manufacturers and generate bespoke datasets and / or control various unrelated network assets without any application being influenced or affected by another although outputs can be shared.

Figure 1 shows the concept of this approach, with a single data marketplace receiving and distributing the data produced by each application within the platform.
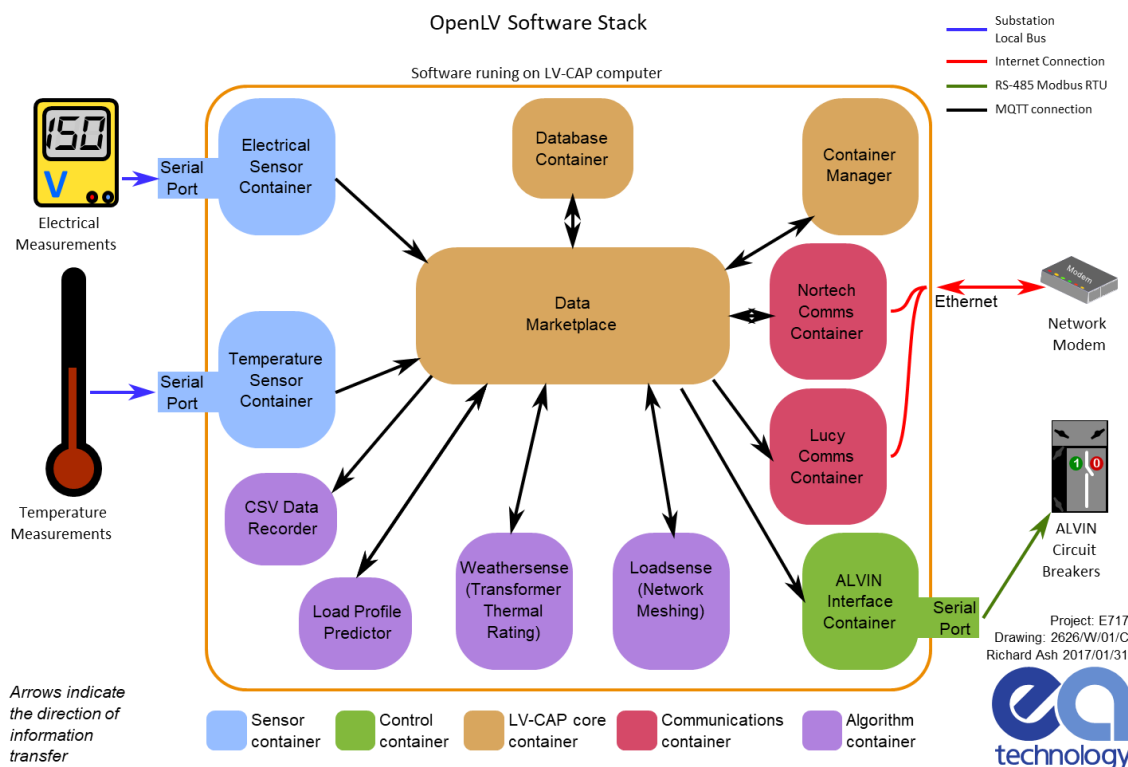
Figure 1: LV-CAP™ platform communication flows

Figure 2**Error! Reference source not found.** simplifies this diagram (Figure 1) for the purpose of demonstrating the effective data flows within the platform to enable the Method 1 element of the trials.
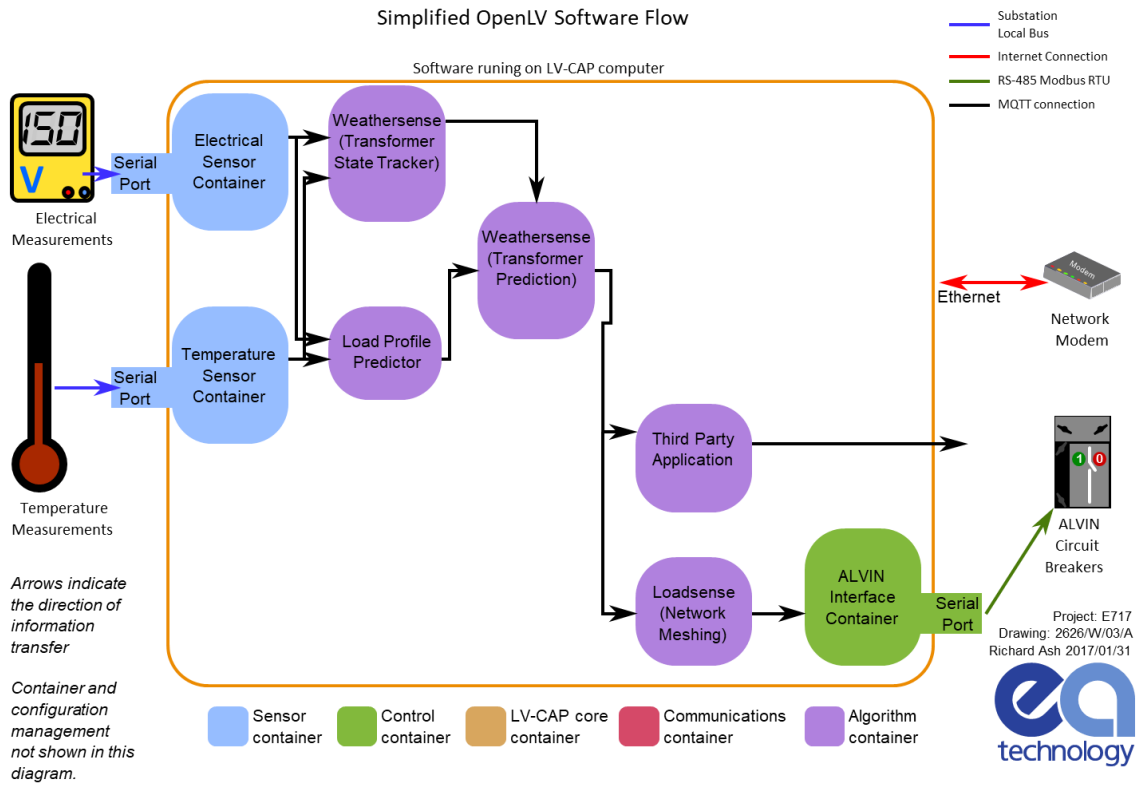
Figure 2: LV-CAP™ Method 1 – Intra-container data flow

3 OpenLV Trials

3.1 Method 1 Overview

The Method 1 trials will demonstrate that the platform monitors the network in real-time, processes the collected data to determine dynamic ratings of the monitored assets, determine the need for action to provide additional network capacity, and implement that action when appropriate.

To demonstrate this, the deployed trial hardware will utilise monitored data to predict future network load, calculate the available capacity of the transformers, and when necessary, automatically share the feeder load between two transformers through network meshing. This will be achieved through direct control of ALVIN Reclose™ circuit breakers installed in the substations at either end of the utilised feeder.

The approach for Method 1 is depicted in Figure 3.
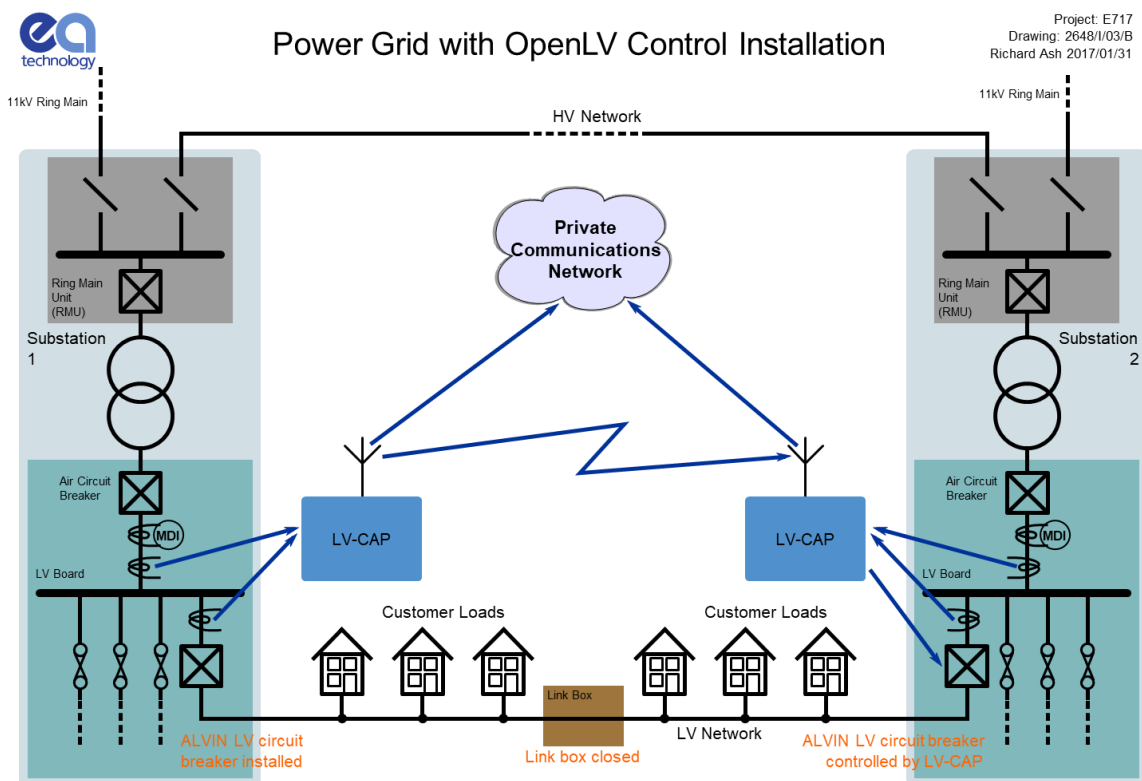
Figure 3: OpenLV Solution Overview

The LV-CAP™ system to be deployed within the OpenLV Project will configured such that one substation (Substation 1) will be 'always connected' to the feeder (except in fault conditions) whereas the other substation (Substation 2) will be connected and disconnected in accordance with the system determinations.

In this configuration, the linked network can be in one of two states, meshed or un-meshed; on the basis that when meshed the two substations will share the load equally[2], the distribution of load will conform to one of the below states.

Table 1: Proportion of Feeder Load by Substation

	State 1 Un-Meshed Network	State 2 Meshed Network
Substation 1	100% of feeder load	50% of feeder load
Substation 2	0% of feeder load	50% of feeder load

3.1.1 Network meshing requirements

The process for implementing automated network meshing requires the operation of multiple elements, both hardware and software, within the 'OpenLV Solution'. These elements are summarised briefly, but detailed explanations are provided in other documentation produced as part of the OpenLV Project.

The **monitoring hardware** deployed within the project measures the voltage and current passing through the transformer and the feeder being meshed, passing this information to the industrialised PC hardware running the LV-CAP™ platform. Monitoring of the ambient temperature and specific temperatures of the transformer is also to be undertaken.

The LV-CAP™ platform must have **interface applications** to receive the measurements from the associated hardware and 'pass' them to the LV-CAP™ platform for storage.

A storage application is required to organise and store the data received from all applications within the platform.

A **load profile predictor** application is required to utilise historical load and predict the load profile for the future.

An application for the calculation of **dynamic thermal ratings** of the transformer is required to determine if, or when, given the forecast load profile, the transformer will experience excessive temperatures (overheating).

As meshing of the LV network affects the transformers at either end of the feeder in question, it is necessary for a **peer-to-peer communications** application to enable load data for the linking feeder to be shared between 'adjacent' platforms.

The **Loadsense** application[3], directly or indirectly, utilises the outputs of the above elements to inform the decision of whether to mesh or de-mesh the network, or to leave it in the current state.

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[2] An equal split in load is unlikely, but it will be possible to determine the proportional loading on a pair-by-pair basis for the sites where ALVIN Reclose™ units are deployed.

[3] The proposed logic for implementation within the Loadsense application is detailed in Section 0.

The **network meshing** application responds to the commands from the Loadsense application, instructing the ALVIN Reclose™ devices to operate accordingly, meshing and de-meshing the feeder as required.

Figure **4** demonstrates the data handling process and subsequent decision point for whether to initiate network meshing or otherwise for a given pair of connected LV networks.

Monitoring
- Electrical Sensor
- Temperature Sensor

Processing
- Weathersense (Transformer RTTR)
- Load Profile Predictor
- Peer-to-Peer Data Feed

Decision

Loadsense

Action

ALVIN Interface
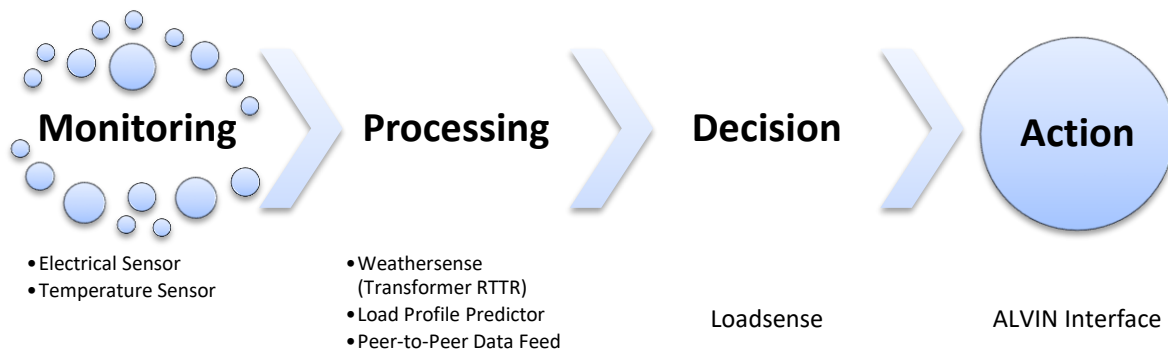
Figure 4: **LV-CAP™ Method 1 – Effective data flow and decision points**

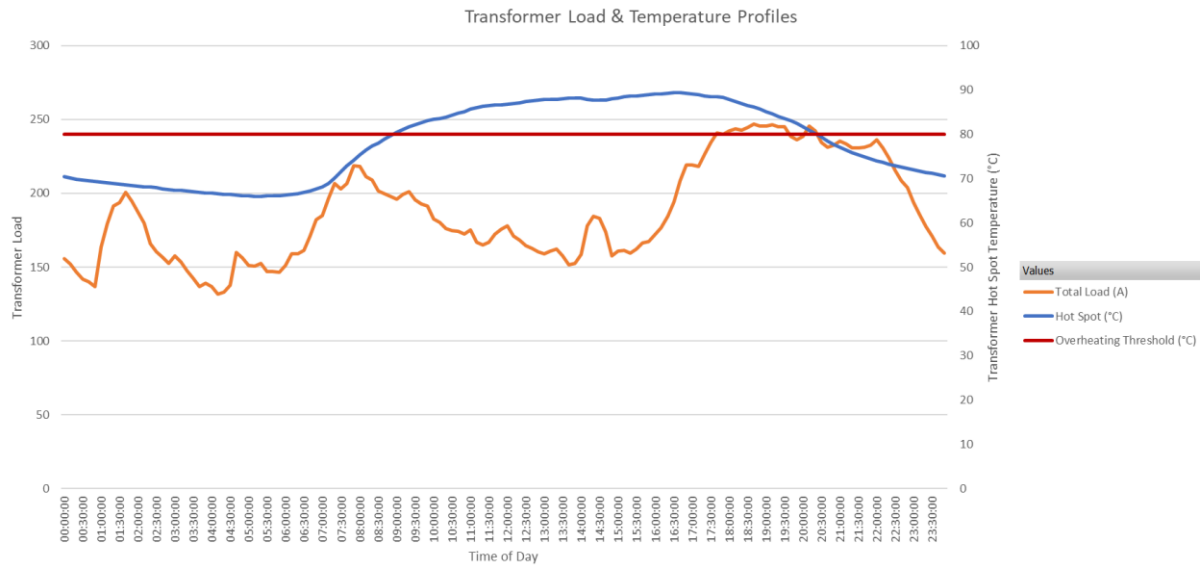### 3.1.2 Thermal profiles in a transformer

The temperature of a transformer increases and decreases as transformer load rises and falls, with the ambient climate of the environment also having an effect. Lower temperatures and higher wind speeds provide cooling effects and increase a transformer's capacity.

A more detailed explanation behind this process has been provided by multiple Low Carbon Network Fund Projects prior to OpenLV; a good example of this is the Customer Led Network Revolution's Lessons Learned Report on Real Time Thermal Rating[4].

Within the OpenLV Project, a predicted temperature profile will be generated by the Weathersense application container, starting at the most recent temperature value and calculating the response to the predicted load profile. An example of these data sets is shown in Figure 5 below.

It can be seen that the 'Hot Spot' temperature broadly dips overnight when the transformer is under least load, and when ambient temperatures tend to be lower. During the day, with higher load requirements and a higher ambient temperature, the 'Hot Spot' temperature increases.

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[4] http://www.networkrevolution.co.uk/wp-content/uploads/2014/12/CLNR-RTTR-Lessons-Learned-Report.pdf

Figure 5: Transformer load and temperature profiles.

Figure 5 also shows an 'Overheating Threshold', a value exceeded by the predicted transformer temperature in this example.

Comparing this threshold point for each substation against the forecast profile will be utilised to determine whether to mesh the connected networks or not.

The impact and relative difference between transformer temperature and the 'Overheating Threshold' can be varied on an individual substation basis through directly adjusting the threshold value or calculating the profile for a lower capacity transformer.

As an example, reducing the calculated transformer capacity would result in a higher peak temperature for any load, the equivalent of lowering the threshold value.

This approach will be used to 'tune' operation of the Loadsense application on a site-by-site basis, in line with the methodology detailed below in section 4. Lowering the threshold on a Substation 1 location will increase the frequency of meshing implementation whereas lowering it on a Substation 2 location will decrease the frequency.

4 Loadsense application

The Loadsense application is envisaged to ultimately enable the LV-CAP™ platform to 'decide' how to best support the LV network through the implementation of a range of Smart Grid solutions.

In a Business-As-Usual (BAU) scenario, this may be using one or multiple solutions connected to the networks in question.

Within the OpenLV Project, the Loadsense application to be developed is intended to be the 'first step' towards this solution. Therefore, the logic to be developed as part of the OpenLV Project is intended to be relatively simple, in that it will only be considering the status of two connected substations and the impact of network meshing on those assets.

4.1 Operational approach

The Loadsense logic to be implemented within the OpenLV Project is built upon the two below assertions.

- The default state for the system shall be un-meshed, to maintain a network state as close as possible to the current network unless actively changed.
- Network meshing shall only be initiated where doing so will prevent either transformer from being in an 'overload state', or reduce the extent to which it is overloaded, in comparison to the alternative (unmeshed) state.

4.1.1 Process

The Load Profile application automatically runs every 30 minutes, utilising historical load data to predict the load profile for the next period. The period will initially be assigned as four hours but may be adjusted during the project on a site-by-site basis.

Two profiles will be produced for each substation, (reference Table 1), based on the total forecast load for the Transformer for each potential state.

As only Substation 1 has the data necessary to determine the feeder load profiles for 100% and 50% loading, these profiles must be passed to Substation 2 via the peer-to-peer communications link.

Substation 2 can then calculate the thermal profiles for the Transformer assuming 0% and 50% load on the feeder.

- Substation 1 will calculate profiles for providing:
  - State 1: 100% of the feeder's load – to determine a profile for the event meshing is not initiated; and
  - State 2: 50% of the feeder's load – to determine a profile for the event meshing is initiated.
- Substation 2 will calculate profiles for providing:
  - State 1: 0% of the feeder's load – to determine a profile for the event meshing is not initiated; and
  - State 2: 50% of the feeder's load – to determine a profile for the event meshing is initiated.

The Loadsense application in Substation 1 will determine whether the network is required to be meshed to alleviate demand on the connected transformer. This decision will be passed to Substation 2 where it will be combined with an equivalent calculation and the decision to mesh, or otherwise, will be taken.

After publication of these load profiles to the message broker within each LV-CAP™ platform, the Weathersense Application utilises them, along with the most recently calculated transformer temperature to forecast the temperature profile for the next period for each scenario.

The Loadsense application on the LV-CAP™ platform in Substation 2 will then take the decision whether to implement the mesh, based on whether it is requested by Substation 1 and possible without exceeding the assigned threshold for the SS2 connected Transformer.

Figure 6 depicts the process for calculating the load profiles for each substation and determining whether to initiate meshing, or otherwise, of the network.

Thresholds to make this decision will be defined on a site-by-site basis, setting the thresholds artificially low to increase the frequency of meshing implementation within the OpenLV Project.

These thresholds will result in each substation being assigned a predicted status based on the predicted thermal profile for both possible states.

- **Overload** – The connected transformer is currently exceeding the assigned 'overload threshold' or is forecast to do so within the next period.
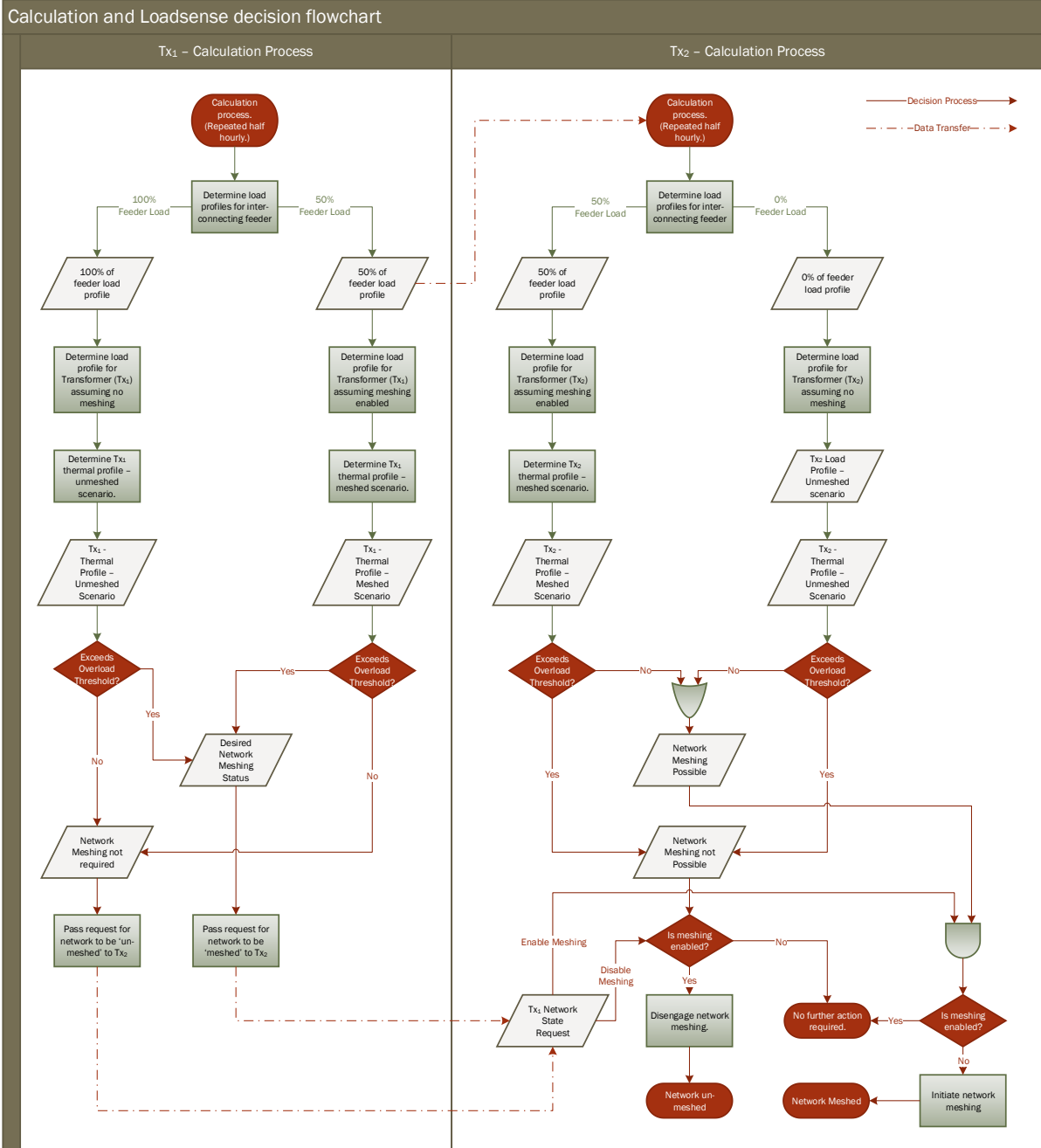- **Spare Capacity** – The connected transformer is below and is forecast to remain below the 'overload threshold.'

Figure 6: Loadsense decision flowchart

4.1.2   Decision logic

There are nine possible states for the complete system, derived from the individual states of each substation and how they respond to the implementation of the network meshing.

The temperature of each substation can either be forecast to exceed the 'overload threshold' or not depending on which scenario (meshed or unmeshed) is applied. The system calculates the outcome for all possibilities and selects the more desirable outcome.

The most desirable option is always for the system to be unmeshed, therefore, if there is no need to reduce load on substation 1, meshing will not be initiated.

Furthermore, meshing will not be initiated if this will introduce an overload state to substation 2.

Table 2 details the possible states and whether meshing will be implemented in each case.

Only two occasions occur where the system will autonomously mesh the LV network, with most conditions resulting in an un-meshed state.

For the avoidance of doubt, a 'network meshing event' will only be initiated where there is sufficient capacity in one transformer to accept the anticipated load transfer from another. Specifically, where the net result will be the moving of the 'overload' from one transformer to another, the project will not undertake network meshing.

This will avoid the system switching between meshed and un-meshed states and simply moving the 'overload' repeatedly between substations. The supporting transformer must be predicted to remain in either the 'Spare-capacity' or 'Within limits' states whilst the network is meshed for the system to operate.

If the conditions vary from the predictions to such an extent that the supporting network is pushed into an 'overload' state or forecasts change such that an 'overload' state is anticipated, then the system will revert to normal operation, (i.e. a non-meshed state) at the next calculation point.

It is emphasised that the logic outlined is not the only approach that could be implemented in the Loadsense application, but it has been selected as the least variation from current business-as-usual practices to demonstrate the capability of the LV-CAP™ system.

Loadsense Operational Logic

Table 2: Loadsense operational logic

Scenario	State 1: Un-meshed		State 2: Meshed		Enable Meshing	Description
	Substation 1	**Substation 2**	**Substation 1**	**Substation 2**		
	Load: 100%	**Load: 0%**	**Load: 50%**	**Load: 50%**		
1	Okay	Okay	Okay	Okay	No	Neither SS1 or SS2 exceed 'overload threshold' in a meshed or un-meshed state.
2	Okay	Okay	Okay	Thermal Threshold Exceeded	No	SS1 does not exceed 'overload threshold' whether the network is meshed or not. SS2 exceeds 'overload threshold' only if meshing is initiated.
3	Okay	Thermal Threshold Exceeded	Okay	Thermal Threshold Exceeded	No	SS1 does not exceed 'overload threshold whether the network is meshed or not. SS2 exceeds 'overload threshold' without meshing; will be exacerbated if meshing is initiated.
4	Thermal Threshold Exceeded	Okay	Okay	Okay	**Yes**	SS1 exceeds 'overload threshold' without meshing but will be below the threshold if meshing is initiated. SS2 does not exceed 'overload threshold' whether the network is meshed or not.
5	Thermal Threshold Exceeded	Okay	Okay	Thermal Threshold Exceeded	No	SS1 exceeds 'overload threshold' without meshing but will be below the threshold if meshing is initiated. SS2 exceeds 'overload threshold' only if meshing is initiated.
6	Thermal Threshold Exceeded	Okay	Thermal Threshold Exceeded	Okay	**Yes**	SS1 exceeds 'overload threshold' whether the network is meshed or not although exceedance will be reduced. SS2 does not exceed 'overload threshold' whether the network is meshed or not.
7	Thermal Threshold Exceeded	Okay	Thermal Threshold Exceeded	Thermal Threshold Exceeded	No	SS1 exceeds 'overload threshold whether the network is meshed or not. SS2 exceeds 'overload threshold' only if meshing is initiated.
8	Thermal Threshold Exceeded	Thermal Threshold Exceeded	Okay	Thermal Threshold Exceeded	No	SS1 exceeds 'overload threshold' without meshing but will be below the threshold if meshing is initiated. SS2 exceeds 'overload threshold' without meshing; this will be exacerbated if meshing is initiated.
9	Thermal Threshold Exceeded	Thermal Threshold Exceeded	Thermal Threshold Exceeded	Thermal Threshold Exceeded	No	SS1 exceeds 'overload threshold' whether the network is meshed or not. SS2 exceeds 'overload threshold' without meshing; this will be exacerbated if meshing is initiated.