CHARGE

Definition, Refinement and Design of EV Smart Charging Connection Solutions

Final report

The Charge Project
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2. Introduction

The Charge Project is designing and demonstrating innovative Smart Charging Connection (SCC) solutions for electric vehicle (EV) charging. The SCC solutions will provide EV chargepoint developers with a greater range of connection options and accelerate the roll-out of public EV charging infrastructure.

2.1. Project Background

Through the Charge Project, SP Energy Networks (SPEN) is accelerating the process of planning and connecting EV charging infrastructure at the lowest-possible cost to GB electricity customers. This is achieved by maximising the use of existing assets and deploying innovative approaches to the connection and management of EV uptake across the SP Manweb licence area. The Charge Project combines learnings from other EV charging projects with expertise from the world of transport planning. This learning will be coupled with a targeted selection of innovative EV chargepoint connection trials for a range of practical situations.

SCC solutions will provide EV chargepoint developers with a greater range of connection options and accelerate the roll-out of public EV charging infrastructure.

The Charge Project merges the disciplines of transport planning and electricity network planning to create an overarching plan of where EV chargepoints will be required and how the network will be impacted by their connections. This facilitates better planning of electricity networks and provides vital information for all sectors involved in helping the UK transition to low carbon transport.

The project uses driver behaviour and journey statistics to form a view of the likely demand draw from multiple EV chargepoint installations in various uses (e.g., car park, forecourt, destination), helping distribution network operators (DNOs) assign more appropriate design values during the connection process.

The Charge Project includes three methods:

- **Method 1:** Strategic transport and network planning
- **Method 2:** Tactical solutions to support EV connections
- **Method 3:** The development of the ConnectMore software tool.

Smarter Grid Solutions (SGS) is responsible for Method 2, which designs and demonstrates SCC solutions that enhance the flexibility of EV charging and support improved hosting of charging infrastructure without expensive reinforcement.

Previous phases of the Charge Project have defined a 'smart solutions toolbox' of flexible EV charging solutions, which will be demonstrated through trials in subsequent phases of the project. These solutions were then defined as SCCs.

The Charge Project has consulted with stakeholders across the distribution networks and EV domain, using learning from this process to refine SCC offerings. This has established two forms of SCC:

- **Customer-led SCCs:** in which the customer is responsible for managing EV chargepoint consumption against pre-agreed, fixed import limitations
- **DNO-led SCCs:** in which the customer must manage EV chargepoint consumption against a varying import threshold that reflects prevailing network conditions.

For each of the above SCCs there are multiple forms of solution that can be deployed, with varying degrees of complexity and capacity release.

2.2. Document Objectives and Structure

This document is targeted at a range of stakeholders, including EV chargepoint operators (CPOs) and developers, DNOs, and Ofgem. The objective is to report on the learning derived through the Successful Delivery Reward Criteria (SDRC) 4 project stage. SDRC 4 has identified and explored suitable EV connection solutions for different locations and charging types. It has defined the SCC schemes, established their functional specification, as well as implementation requirements and design (for both DNOs and EV chargepoint developers), and gathered stakeholder feedback for refinement of the solution concepts.

The document presents learning from SDRC 4 through the following structure:

- **Section 3** details the refinement of smart charging concepts identified earlier in the project, assessing the viability of smart charging concepts against customer need in different network connection scenarios. The smart charging concepts are refined into a series of SCCs, which are supported with examples.
- **Section 4** presents a summary of the key findings from stakeholder feedback insights, in which user considerations, SCC viability and implementation challenges are highlighted.
- **Section 5** presents a summary of the customer requirements for implementation of customer-led SCCs and the design and deployment architecture for these solution types.
- **Section 6** presents the design of DNO-led SCCs, detailing the components and control philosophy required for implementation. The deployment architecture is presented alongside commentary on DNO requirements for business-as-usual (BAU) implementation.

3. Smart Charging Solutions: Description and value case

The Charge Project has identified a series of SCC options for accelerated and low-cost integration of EVs into distribution networks. Ultimately, the value of SCCs as an alternative to network reinforcement is dependent on several factors, highlighted in Figure 1.

The following sections describe the alignment between draft definitions of smart charging solutions against the different characteristics associated with constrained EV chargepoint installations. The draft smart charging solutions have been refined into a portfolio of SCC solutions that will be specified, designed, and tested as part of the Charge Project.

Cost of SCCs

- SCC costs must be lower than that of conventional network reinforcement
- Where SCC is a temporary solution ahead of reinforcement, cost must be proportional to additional energy delivered in the short term

SCC Capacity Release

- Viable capacity release must be close to the capacity requested by the customer
- Excessive curtailment is undesirable

Speed of Connection with SCCs

- The speed at which a customer gains an SCC must be quicker than that of the conventional reinforcement alternative

SCC Technical Readiness

- SCCs must be technically viable and use existing proven hardware/software/communications links
- SCCs will require technology deployments across both DNO and CPO systems

Figure 1: SCC Value Factors

3.1. Alignment of Smart Charging Concepts to EV Chargepoint Constraint Network Cases

An aspiration of the Charge Project is to identify a range of viable SCCs that can be offered for every permutation of connection request for public EV charging infrastructure. Doing so would provide customers with alternative options to reinforcement across all EV connection scenarios.

To ensure that SCCs provide suitable coverage, a comprehensive matrix of all potential EV chargepoint connection characteristics was developed. The matrix lists key characteristics associated with the network connections and EV chargepoints. An extensive review across each permutation of constraint and suitable solutions was performed, identifying and refining a range of viable SCCs.

3.1.1. Smart Charging Concepts

An initial draft definition of smart charging concepts was derived earlier in the Charge Project. The following concepts were refined (which are presented in Section 3.2):

A. Supervised Time Managed Network Constraint

This solution curtails chargepoint demand at certain times of the day or year based on the risk of constraints emerging as identified in offline network studies. Site chargepoint demand must not exceed a limit that varies at different times of the day, reflecting the changing risk of overload on the wider network. It requires no communication links, DNO-owned hardware or centralised distributed energy resources management system (DERMS) platform. The responsibility for managing the curtailment sits with the CPO, with the DNO fulfilling a supervisory role only once the curtailment limit has been identified via the studies. As an example, the DNO would utilise network studies alongside secondary substation monitoring to both identify the curtailment required and supervise its ability to avoid the network constraint once operational.

B. Dynamically Managed Simple Network Constraint

This solution dynamically curtails the chargepoint demand on radial networks, based on measurements taken at a single network constraint location. It solely utilises a DNO-owned local controller to derive the curtailment signal to be issued to the CPO. It requires the creation of a secure communication channel between the local controller and the CPO's chargepoint management system (CPMS).

C. Dynamically Managed Complex LV Network Constraint

This solution dynamically curtails the chargepoint demand on meshed low-voltage (LV) networks based on measurement points from multiple constraint locations. It utilises a central DERMS platform to coordinate the measurement point data to derive a curtailment signal, which is sent to the CPO via a DNO-owned local controller. It requires the provision of a central DERMS platform with direct access to LV substation monitor data and a secure link to the DNO local controller and, likewise, from the local controller to the CPO.

D. Dynamically Managed HV/EHV Network Constraint

This is similar to Solution C, but designed for high-voltage (HV) and extra-high-voltage (EHV) networks. This solution will, as far as practical, utilise existing data from supervisory control and data acquisition (SCADA), and may deploy a more resilient/advanced local controller.

E. Dynamically Managed Customer Network Constraint

This solution is essentially a customer-owned and -operated load management system that curtails chargepoints based on the customer's total site demand, ensuring they do not exceed their agreed declared supply capacity (DSC). This solution is applicable to any type of DNO network (HV/LV/meshed/radial) in which the risk of the customer exceeding their DSC does not lead to wider network issues. It requires no communication links, DNO-owned hardware or DERMS platform.

F. Customer Network Constraint Dynamically Managed by DNO Locally

This is as per Solution E, but the customer looks to the DNO to provide the load management system via a local controller. This is only expected in the infancy of the uptake of SCCs, whereas long-term customers will opt for solutions from third parties as they become more prevalent.

G. Customer Network Constraint Dynamically Managed by DNO Centrally

This concept is as per Solution F, but with the inclusion of a secure link to the DERMS platform (cloud or non-cloud) that will enable the DNO to assess the performance of the solution and adjust settings remotely. It is unlikely to be required beyond trial unless additional value is identified by the inclusion of the link.

H. Dynamically Managed Complex LV Network Constraint Utilising Direct Link to CPMS

This is a new inclusion, as per Solution C, but mitigates the need for a DNO-owned local controller and utilises a direct link between the DERMS platform and the customer's CPMS.

3.1.2. Network Cases: Site Characteristics

The possible network deployment cases for SCCs are characterised by the description variables presented in Figure 2. These variables create a matrix of possible connection characteristics, and the LV connection equivalent matrix is presented in Table 1.

Voltage Level	**Low Voltage (LV) Connections:** Customer connects to the LV network
	High Voltage (HV) Connections: Customer connects to the HV network
Network Topography	**Radial Networks:** A feeder is supplied via a single substation
	Simple Interconnected: A feeder is supplied via two substations
	Complex Interconnected: A feeder is supplied via more than two substations
Constrained Network Ownership	**Customer Network Constraint:** The required reinforcement is on the customer side of the meter
	DNO Network Constraint: The required reinforcement is on the DNO side of the meter
Constraint Locations	**Single Network Constraint:** Only one network asset requires SCC monitoring to manage constraints
	Multiple Network Constraint: More than one network asset requires SCC monitoring to manage constraints
Shared or Dedicated Network	**Dedicated Connection:** The constraint is at an asset that only supplies EV chargepoints
	Shared Connection: The constraint is at an asset that supplies EV and conventional loads
Presence of DER	**Customer Connection without DER:** The customer connection only consists of energy consumption (demand) devices
	Customer Connection with DER: There is generation or energy storage assets behind the meter at the customer connection

Figure 2: Network Cases: Descriptor Variables

	Network Topography	Constrained Network Ownership	Constraint Location(s)	Dedicated or Shared Network	DER Present
1	Radial	DNO	Single	Shared	✓
2	Radial	DNO	Single	Shared	✗
3	Radial	DNO	Single	Dedicated	✓
4	Radial	DNO	Single	Dedicated	✗
5	Radial	DNO	Multiple	Shared	✓
6	Radial	DNO	Multiple	Shared	✗
7	Radial	DNO	Multiple	Dedicated	✓
8	Radial	DNO	Multiple	Dedicated	✗
9	Radial	Customer	Single	Shared	✓
10	Radial	Customer	Single	Shared	✗
11	Radial	Customer	Single	Dedicated	✓
12	Radial	Customer	Single	Dedicated	✗
13	Radial	Customer	Multiple	Shared	✓
14	Radial	Customer	Multiple	Shared	✗
15	Radial	Customer	Multiple	Dedicated	✓
16	Radial	Customer	Multiple	Dedicated	✗
17	Interconnected	DNO	Single	Shared	✓
18	Interconnected	DNO	Single	Shared	✗
19	Interconnected	DNO	Single	Dedicated	✓
20	Interconnected	DNO	Single	Dedicated	✗
21	Interconnected	DNO	Multiple	Shared	✓
22	Interconnected	DNO	Multiple	Shared	✗
23	Interconnected	DNO	Multiple	Dedicated	✓
24	Interconnected	DNO	Multiple	Dedicated	✗
25	Interconnected	Customer	Single	Shared	✓
26	Interconnected	Customer	Single	Shared	✗
27	Interconnected	Customer	Single	Dedicated	✓
28	Interconnected	Customer	Single	Dedicated	✗
29	Interconnected	Customer	Multiple	Shared	✓
30	Interconnected	Customer	Multiple	Shared	✗
31	Interconnected	Customer	Multiple	Dedicated	✓
32	Interconnected	Customer	Multiple	Dedicated	✗

Table 1: Example Characteristic Matrix: LV Connection

3.1.3. Mapping Smart Charging Connections: Assessment Example

SPEN and SGS undertook mapping of the network scenarios reflected in Table 1 against the characteristics of smart charging solutions. This process identifies requirements to manage each form of constraint by asking the following questions:

- Could the curtailment limit be a static value as opposed to dynamic?
- If a static limit, could the required curtailment be identified by network studies alone?
- Could the network constraint be mitigated by a predetermined curtailment level at set periods of time?
- If a dynamic limit, are the necessary network measurement locations accessible/readily available?
- What SCC solution has the potential to minimise curtailment?
- Can the SCC solution be delivered solely by the customer's systems?
- Is the SCC capable of minimising curtailment by coordinating with a local distributed energy resource (DER), be it on the customer or DNO network?

An example of this assessment is presented below, with the network case illustrated in Figure 3.

Figure 3: LV Radial Topography, Constraint on DNO Network at a Single Location on a Circuit Shared by Existing Customers and the Chargepoints to be Curtailed

Could the curtailment limit be a static value as opposed to dynamic?

Dynamic only, given that the constraint and resulting capacity available are influenced by the load of other customers on the circuit, which cannot be curtailed.

If static, could the curtailment be identified by network studies alone?

N/A

Could the network constraint be mitigated by a predetermined curtailment level at set periods of time?

Potentially, dependent on the consistency of the load profile on the surrounding network. If, as shown in Figure 3, the surrounding load is predominantly domestic properties, there could be an opportunity to identify acceptable curtailment levels at set periods of time through network studies and monitoring.

If dynamic, are the necessary network measurement locations accessible/readily available?

Yes, given that the constraint is on the DNO network and most likely accessible within the substation via standard measurement devices, e.g., a current transformer.

What SCC solution has the potential to minimise curtailment?

A DNO-operated SCC that generates a dynamic set point based on the live load on the network.

Can the SCC solution be delivered solely by the customer's systems?

Potentially, if timed curtailment has the potential to alleviate the network constraint.

Is the SCC capable of minimising curtailment by considering the presence of DER, be it on the customer or DNO network?

A time-based SCC could benefit from DER if it is on the customer's network, provided it has the potential to support demand at periods of curtailment. DER on the wider DNO network cannot be factored into the curtailment studies undertaken.

A dynamically managed constraint would allow any export of DER on the DNO and customer networks to be considered to maximise the capacity released.

This exercise considered a single network topography and constraint location scenario, both with and without DER, i.e., two of the 32 identified scenarios. It found that there were two potentially viable SCCs available to meet the requirements:

- **A time-managed scheme,** in which the DNO would undertake curtailment studies to identify what capacity could be made available and when. This scheduled access to capacity would be written into the connection agreement and become the responsibility of the customer to manage. The DNO would supervise only to ensure compliance.
- **A simple dynamically managed scheme,** identifying the real-time capacity of the network to minimise chargepoint curtailment, whilst mitigating the risk of changing load patterns on the network.

3.1.4. Mapping Solutions to Network Characteristics

Each of the solutions A-H has potential for application to multiple scenarios; however, the mapping of their viability varied. Often the solution's viability depends on the granular details of the connection. A prime example is the viability of Solution (A), in which, whilst the solution's simplicity would be desirable, its ability to release capacity would be heavily dependent on the surrounding load profile. If the load profile was highly variable, the curtailment limits would have to be very conservative, which could make it unviable.

Similarly, the adoption of (H) would reduce the need for additional DNO hardware to operate, increasing the viability by lowering the solution cost. Its viability, however, depends on the development and integration of DNO and the customer's CPMS.

Given the intention to trial solutions as part of the Charge Project, there is a desire to focus efforts on developing the solutions that are the most viable and beneficial to the customer. To this end, each of the solutions proposed for the 64 network scenarios presented in Table 2 and Table 3 are ranked in terms of their viability. For each scenario, two viable solutions were identified:

- The ***minimal viable product (MVP)***: the solution that typically has the highest technology readiness level and simplicity and lowest cost and time to deploy.
- The ***Optimum***: the solution that has the potential to provide the greatest access to network capacity and minimise curtailment, has the greatest potential for scalability, and ensures network security.

Table 2 highlights the findings of this assessment for the LV connection scenarios.
The key findings were:

- Only solutions (A), (B), (C) and (E) are identified as either the MVP or the Optimum.
- All the scenarios that considered a constraint on the customer network identified (E) as both the MVP and Optimum solution.
- Wherever possible (A) is consistently the MVP for all constraints on the DNO network.
- Solution (B) was the Optimum solution when the network topography was radial and there was a single constraint location to manage.
- For interconnected networks and multiple DNO network constraint locations, (C) was consistently the Optimum solution.
- Solutions (F), (G) and (H) were viable options for a range of scenarios.
- Solution (D) was not considered, as it is for HV and above.

Key	Viable	MVP	Not Viable	Optimum	MVP & Optimal

	Network Technology	Constrained Network Ownership	Constraint Locations	Dedicated or Shared Network	DER?	A	B	C	D	E	F	G	H
1	Radial	DNO	Single	Shared	No DER	MVP	Optimum	Viable	Not Viable	Not Viable	Not Viable	Not Viable	Viable
2					DER	MVP	Optimum	Viable	Not Viable	Not Viable	Not Viable	Not Viable	Viable
3				Dedicated	No DER	MVP	Optimum	Viable	Not Viable	Not Viable	Not Viable	Not Viable	Viable
4					DER	MVP	Optimum	Viable	Not Viable	Not Viable	Not Viable	Not Viable	Viable
5			Multiple	Shared	No DER	MVP	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
6					DER	MVP	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
7				Dedicated	No DER	MVP	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
8					DER	MVP	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
9		Customer	Single	Shared	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
10					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
11				Dedicated	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
12					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
13			Multiple	Shared	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
14					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
15				Dedicated	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
16					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
17	Inter-connected	DNO	Single	Shared	No DER	MVP	Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
18					DER	MVP	Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
19				Dedicated	No DER	MVP	Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
20					DER	MVP	Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
21			Multiple	Shared	No DER	MVP	Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
22					DER	MVP	Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
23				Dedicated	No DER	MVP	Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
24					DER	MVP	Viable	Optimum	Not Viable	Not Viable	Not Viable	Not Viable	Viable
25		Customer	Single	Shared	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
26					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
27				Dedicated	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
28					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
29			Multiple	Shared	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
30					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
31				Dedicated	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
32					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable

Table 2: LV Connection Scenarios: Solution Assessment

Key	Viable	MVP	Not Viable	Optimum	MVP & Optimal

	Network Technology	Constrained Network Ownership	Constraint Locations	Dedicated or Shared Network	DER?	A	B	C	D	E	F	G	H
1	Radial	DNO	Single	Shared	No DER	MVP	Optimum	Not Viable	Viable	Not Viable	Not Viable	Not Viable	Viable
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3				Dedicated	No DER	MVP	Optimum	Not Viable	Viable	Not Viable	Not Viable	Not Viable	Viable
4					DER	MVP	Optimum	Not Viable	Viable	Not Viable	Not Viable	Not Viable	Viable
5			Multiple	Shared	No DER	MVP	Not Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
6					DER	MVP	Not Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
7				Dedicated	No DER	MVP	Not Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
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9		Customer	Single	Shared	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
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13			Multiple	Shared	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
14					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
15				Dedicated	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
16					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
17	Inter-connected	DNO	Single	Shared	No DER	MVP	Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
18					DER	MVP	Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
19				Dedicated	No DER	MVP	Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
20					DER	MVP	Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
21			Multiple	Shared	No DER	MVP	Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
22					DER	MVP	Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
23				Dedicated	No DER	MVP	Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
24					DER	MVP	Viable	Not Viable	Optimum	Not Viable	Not Viable	Not Viable	Viable
25		Customer	Single	Shared	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
26					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
27				Dedicated	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
28					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
29			Multiple	Shared	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
30					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
31				Dedicated	No DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable
32					DER	Not Viable	Not Viable	Not Viable	Not Viable	MVP & Optimal	Viable	Viable	Not Viable

Table 3: HV/EHV Connection Scenarios: Solution Assessment

Table 3 details the assessment of HV and EHV connections cases, where the proposed MVP and Optimum are like the LV connections case. The key distinction in these cases is that the utilisation of a central controller (DERMS platform) will always deliver the Optimum solution.

3.2. Further Refinement of SCC Concepts

The uptake and success of SCCs is dependent on the acceptance and willingness of customers to adopt them. As such, communication and stakeholder engagement need to ensure that functionality of SCCs is clear and, as far as practical, simple to understand. The Charge Project's engagements highlighted that across solutions A–H there exist subtle differences that may cause undesirable confusion and distraction from the key functions and benefits of each solution.

To counteract this, the solutions were further refined into a smaller set of clearly defined solutions reflecting the solution functionality as opposed to component parts. This is especially beneficial given that the sources of network data and communication channels available is constantly evolving.

This final functional grouping exercise halved the number of solutions and broadly split them into two separate factions, namely, **customer-led SCCs** and **DNO-led SCCs**. These are presented in Figure 4.

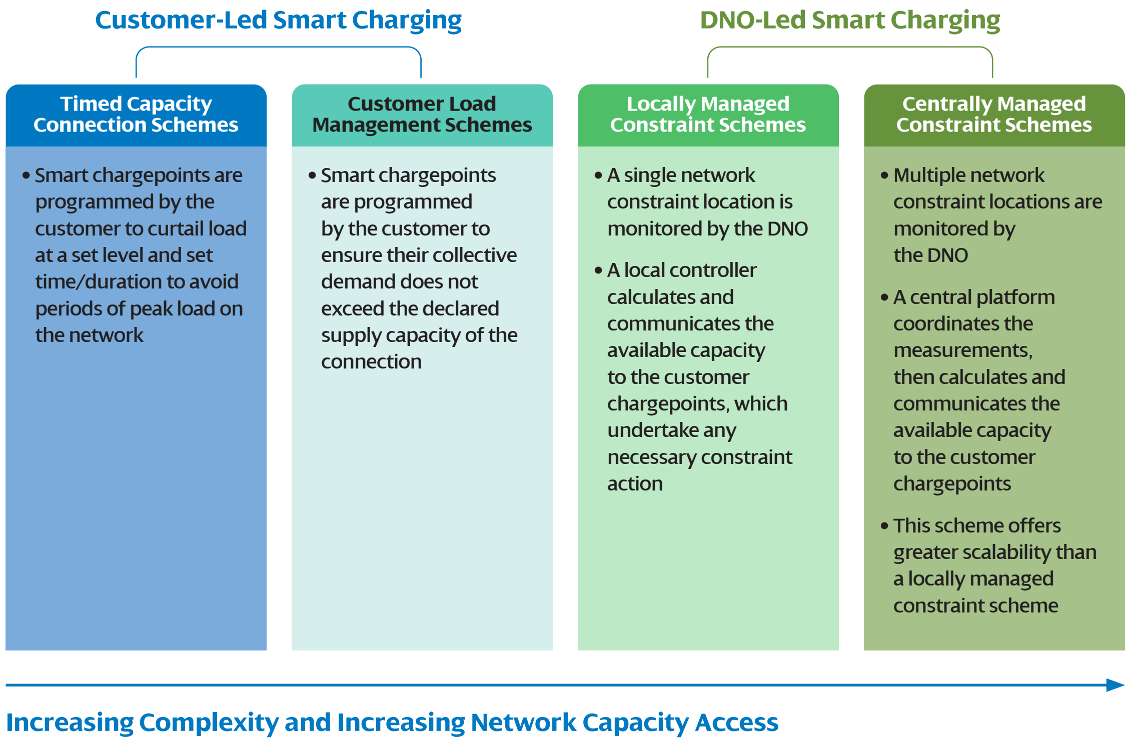

Figure 4: Refined SCC Summary

The following sections provide descriptions of each of the refined SCCs.

3.2.1. Timed Capacity Connection Scheme: Functionality

The following sections describe the functional concept behind timed capacity connection (TCC) schemes and the anticipated application cases that present the greatest benefit from their implementation.

It is noted that the maximum resolution of TCC time steps is expected to be half-hourly. This reflects the resolution of historical network measurements that will be applied in the design study performed by the connection design engineer. For consistency, the document presents the TCC time-step resolution as half-hourly, although in practice a lower resolution, such as hourly, may be applied.

3.2.1.1. Scheme Concept

Under TCCs, EV chargepoints that share the same network connection are programmed by the CPO to curtail their collective demand for a set time window that coincides with the window of peak loading on the local DNO network. The time, duration and scale of this curtailment are determined by the DNO via a detailed constraint analysis and defined within the DNO-customer connection agreement.

The existence of network constraints will be raised by the DNO design engineer during the connection application process. If a TCC is to be explored, the DNO design engineer will perform a study to identify the available network capacity headroom in each half-hour across a day of half-hourly peak demands. The half-hourly headroom study involves identification of the peak historical network loading observed in each half-hour window of the day[1]. The available headroom for the new connection is derived for each of these windows. Note that the expectation of half-hourly resolution reflects the highest granularity of control to be established for the TCC scheme.

The output from the DNO constraint analysis is a profile of available import headroom for each half-hour of the day, based upon the highest peak-demand conditions for each window. This half-hourly profile represents the time-varying demand capacity within which the EV CPO must maintain site consumption. The TCC limitation profile is detailed in the customer connection offer, in that maintaining consumption within the varying TCC limit becomes a condition of the site connection.

The EV CPO customer has responsibility for maintaining site demand within each half-hour limit. The CPO must demonstrate there is capability for the monitoring and control of EV chargepoint consumption within the TCC profile limits. If there is other non-EV load behind the meter, this must be incorporated into the measurement of total site demand.

The TCC allows the customer to install a greater-rated capacity of EV charging capability whilst avoiding reinforcement. However, the site will be subject to import restriction during the half-hours of reduced capacity, as defined in the timed profile.

1. The detailed design process for all SCCs will be established at a later stage of the Charge Project.

3.2.1.2. TCC Scheme Example

An example of TCC implementation is based on an EV chargepoint development seeking connection to a radial LV feeder, requiring 28kVA of network capacity.

Figure 5 illustrates the loading on the feeder across a day consisting of the peak demand.

- The ***pre-EV loading*** dataset shows the existing peak loading across the day, prior to connection of the EV chargepoint development.
- The ***post-EV loading*** dataset shows the peak loading across the day, after taking account of the 28kVA of capacity sought by the new EV chargepoint development.
- The ***capacity limit*** reflects the 80kVA thermal limitation on the LV feeder, which must not be exceeded.

Figure 5 shows that the connection of the new EV chargepoint development will, under conditions in the peak-demand day, put the network at risk of exceeding the 80kVA thermal LV limitation. This risk exists between 17:30 and 21:00 during the evening. However, during other periods in the day, there is sufficient network headroom for the site to operate at its full 28kVA rated capacity. Application of a TCC scheme must apply reduced-capacity operation during the constraint window.

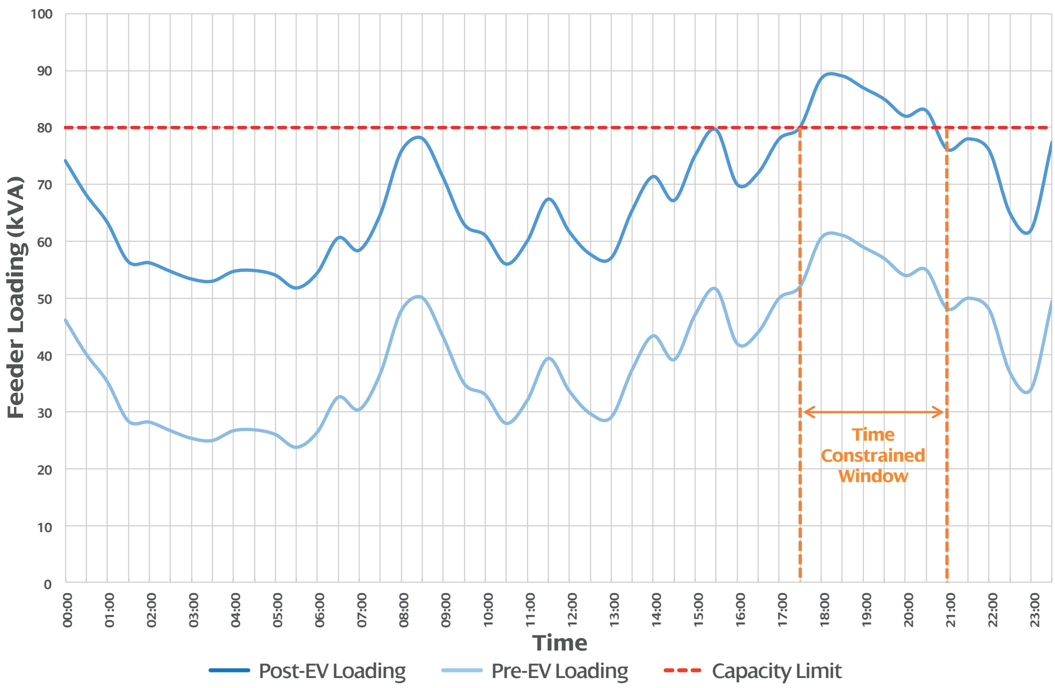

Figure 5: TCC Example – Feeder Loading

Figure 6 highlights the calculation of available headroom, in which:

- The ***network headroom*** dataset illustrates the available headroom on the network across the peak-demand day, at a half-hourly granularity.
- The ***timed connection profile*** dataset illustrates the available capacity that the new development can access (whilst rated at 28kVA) at a half-hourly granularity.
- The ***firm headroom limit*** illustrates the fixed connection capacity that would be feasible under a conventional ***firm*** connection solution.

Observing the comparison between the ***timed connection profile*** and the ***firm headroom limit*** highlights the additional network capacity that can be harnessed through implementation of the TCC scheme.

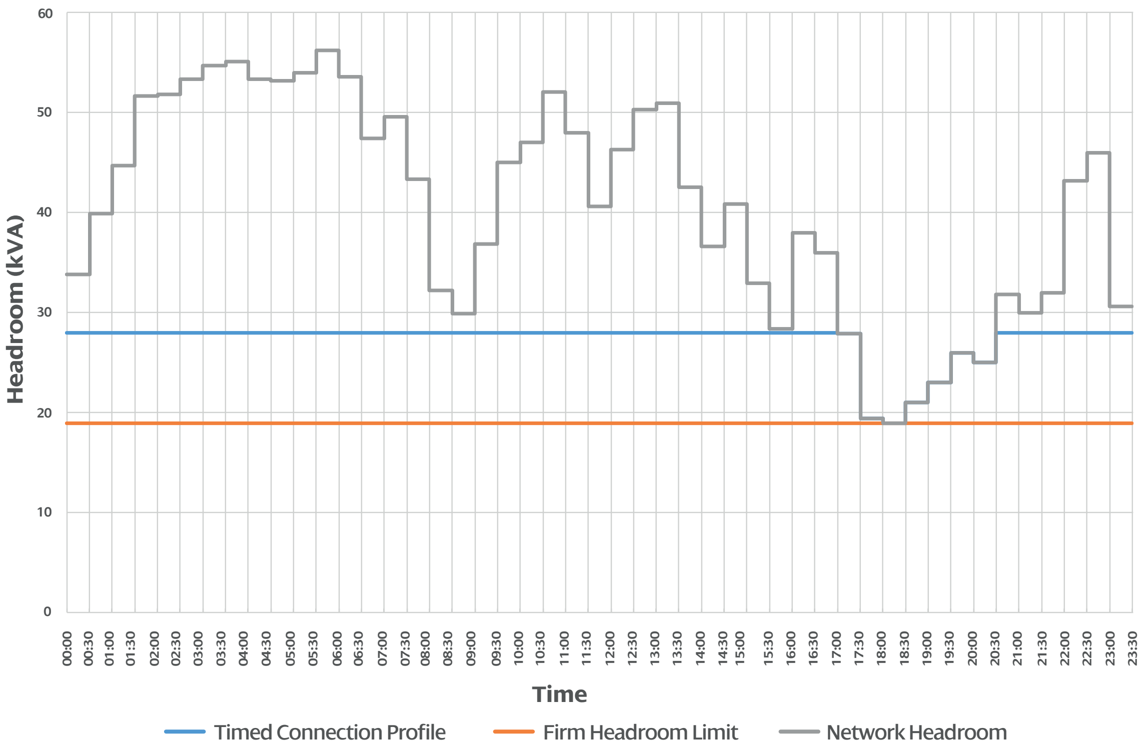

Figure 6: TCC Example – Customer Headroom

3.2.2. Customer Load Management Scheme: Functionality

The following sections describe the functional concept behind customer load management (CLM) schemes and the anticipated application cases that present the greatest benefit from their implementation.

3.2.2.1. Scheme Concept

CLM schemes are another relatively simple form of SCC, used exclusively to prevent chargepoints from causing customers to exceed their DSC. Whilst the connection DSC reflects the ***firm*** capacity of the network, i.e., it is based upon assessment of worst-case network conditions, the CLM scheme allows the CPO to install a rated capacity of chargepoints greater than the DSC. Under a CLM scheme, the CPO is responsible for coordinating chargepoint demand to always maintain overall consumption within the site DSC.

Assuming the customer has a connection with a suitable DSC, there are no requirements for additional DNO network studies to accommodate a CLM scheme

Where the customer site solely consists of EV chargepoints, there is only a requirement for the CPO to coordinate the consumption across the chargepoints. Thus, through monitoring of each chargepoint, it is possible to derive an aggregated total EV chargepoint demand, which must be managed within the DSC limit.

Where the customer site has non-EV chargepoint loads, the CPO must incorporate visibility of the non-EV loads into the coordination of EV chargepoint consumption. The CPO control system must coordinate the EV consumption to reflect the total demand from the site, including non-EV loads (which may also provide a demand reduction function).

Assuming the customer has a connection with a suitable DSC, there are no requirements for additional DNO network studies to accommodate a CLM scheme. It is the responsibility of the connecting customer to assess the viability of the CLM scheme and ensure it can maintain site demand within the DNO-specified DSC limit.

The DNO will assess risk to the wider network due to non-compliance and identify the level of monitoring that will allow SPEN to maintain visibility and audit the site's operation within DSC or TCC thresholds.

The ability to operate a CLM to coordinate chargepoint consumption in real time is becoming more commonplace amongst smart chargers, but there are significant variances between how readily available they are between CPOs. As with the TCC scheme, the CLM can either be programmed locally or administered by a remote CPMS. There is no requirement for a direct link to DNO systems, and in some cases, there is no need for additional hardware, which makes the complexity and costs of the scheme relatively low.

3.2.2.2. CLM Scheme Example

An example of CLM implementation is based on the same scenario as presented for TCCs in Section 3.2.1.2. In this example, the EV chargepoint development is seeking connection to the same radial LV feeder, requiring 28kVA of network capacity.

As in the TCC example, Figure 5 illustrates the loading on the feeder across a day consisting of the peak demand.

- The ***pre-EV loading*** dataset shows the existing peak loading across the day, prior to connection of the EV chargepoint development.
- The ***post-EV loading*** dataset shows the peak loading across the day, after taking account of the 28kVA of capacity sought by the new EV chargepoint development.
- The ***capacity limit*** reflects the 80kVA thermal limitation on the LV feeder, which must not be exceeded.

Figure 7 shows that the connection of the new EV chargepoint development will, under conditions during the peak-demand day, put the network at risk of exceeding the 80kVA thermal LV limitation. The peak demand occurs at approximately 18.00. The available headroom under these worst-case conditions is 18.9 kVA. The DSC is therefore established as this figure of ***firm*** headroom, derived under worst-case demand conditions. At 18:00, the CPO must maintain site consumption within the 18.9 kVA threshold, with more EV charge demand headroom expected at other times of the day.

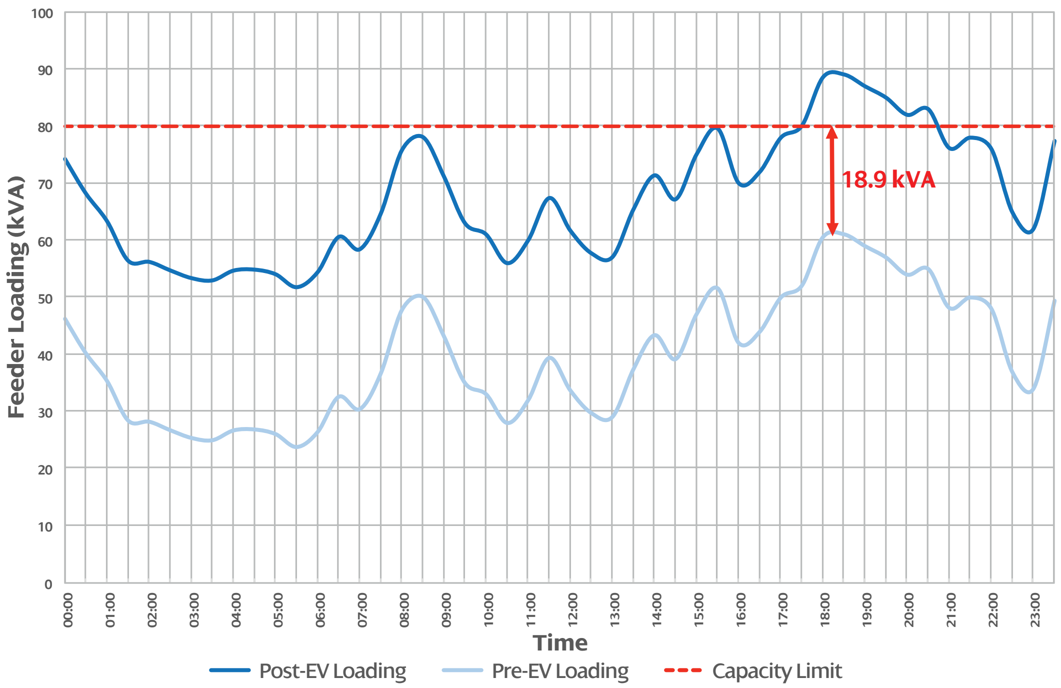

Figure 7: CLM Example – Feeder Loading

3.2.3. DNO-Led SCC Solution: Functionality

The DNO-led SCCs are delivered in two formats:

- **Locally managed constraint (LMC) schemes:** deployed where the chargepoint site load is only constrained by a single capacity pinch point on the network. It consists of a field-based control solution.
- **Centrally managed constraint (CMC) schemes:** deployed where the chargepoint site load is constrained by multiple capacity pinch points on the network, or where multiple chargepoint sites are under simultaneous control. This solution consists of a centrally located DNO control solution that communicates with multiple field devices.

Each DNO-led SCC solution provides the monitoring and control capability that allows EV chargepoint sites to achieve a connection with capacity above the traditional ***firm*** network capacity. The capacity available to the EV chargepoint site varies in real time, reflecting the network loading conditions. Of all SCC types, the DNO-led SCCs provide the greatest level of capacity to EV chargepoint customers.

Both the LMC and CMC schemes deliver the same functionality, albeit applied to marginally distinct cases and achieved through different designs. A single DNO-led SCC concept is presented reflecting both LMC and CMC schemes, with distinctions detailed in Section 3.2.3.3.

3.2.3.1. DNO-Led SCC Concept

DNO-Led SCCs offer an alternative to conventional connection solutions by offering non-firm access to network capacity beyond the conventional ***firm*** capacity limit. The solutions are achieved through the dynamic monitoring of network operation and, when the network is nearing constraint conditions, real-time control of demand at participating EV chargepoint sites.

DNO-led SCCs are derived from the control philosophy behind active network management (ANM), which is responsible for the flexible connection of generation sites in constrained network areas. Through the real-time control of customer sites, it is possible to harness the latent capacity of networks.

When an EV chargepoint customer connection triggers network constraints, conventional connection solutions will require reinforcement of network infrastructure to raise the ***firm*** headroom capacity of the network to equal the desired EV chargepoint connection capacity. Under DNO-led SCCs, monitoring infrastructure is established at the constrained network assets (e.g., those that would traditionally be reinforced) to provide real-time measurement of metrics such as power flow through the asset.

DNO-Led SCCs require deployment of a DNO control system to receive the measurements of network parameters from the constrained network assets and:

- Identify when the network is nearing undesirable constraint conditions
- Identify the demand reduction actions at each EV chargepoint site that will ensure pre-emptive action is taken to stop the network from entering constraint conditions
- Issue the demand reduction set points actions to EV chargepoints, and release them once the real-time available network capacity increases sufficiently

The DNO-side control functions are achieved via a DERMS solution. The DERMS that may be deployed for additional functions beyond delivery of SCCs, such as generator-flexible connections and coordination of flexibility services; however, only the SCC delivery functions are covered in this document.

Participation in DNO-led SCCs requires a customer EV chargepoint site to coordinate the energy consumption across chargepoints during times of constraint. When the network is nearing constraint conditions, the DERMS solution issues a demand reduction set point to the EV CPO. However, the maximum level of constraint will reflect the value of difference between the firm headroom of the connection and the SCC-delivered non-firm capacity of the EV chargepoint site.

DNO-led SCC solutions are more commercially and technically complex than customer-led SCCs, as they require integration of DNO systems with those of the CPO. The trade-off to this increased complexity is greater access to the available network capacity and greater certainty for the DNO that it is developing and managing a secure and efficient network for CPOs and other customers.

3.2.3.2. DNO-Led SCC Solution Example

An example of a DNO-led SCC consists of an EV chargepoint development seeking direct connection to a distribution substation that consists of a single 11/0.4 kV, 500kVA-rated transformer. The EV chargepoint site has rated capacity of 250 kVA, and the existing peak loading on the distribution transformer is 350 kVA, with a minimum demand of 125 kVA.

The available ***firm*** headroom at the substation is 150 kVA – the remaining capacity at the 500 kVA transformer considering the 350 kVA peak load. Under the traditional ***firm*** planning regime, any EV chargepoint connection above the 150 kVA firm headroom will trigger reinforcement.

Through deployment of a DNO-led SCC, the full 250 kVA can be installed at the EV chargepoint site, with the import between 150 and 250 kVA managed in real-time to reflect network conditions.

A ***pre-EV*** and ***post-EV*** network illustration is presented in Figure 8 and Figure 9. An example of a peak-demand daily curve is presented in Figure 10, where the inclusion of 250 kVA EV chargepoint demand on top of the existing demand profile is illustrated. During the periods of constraint condition, when total substation demand exceeds the rated capacity of 500 kVA, demand from the new CPO site will need to be restricted.

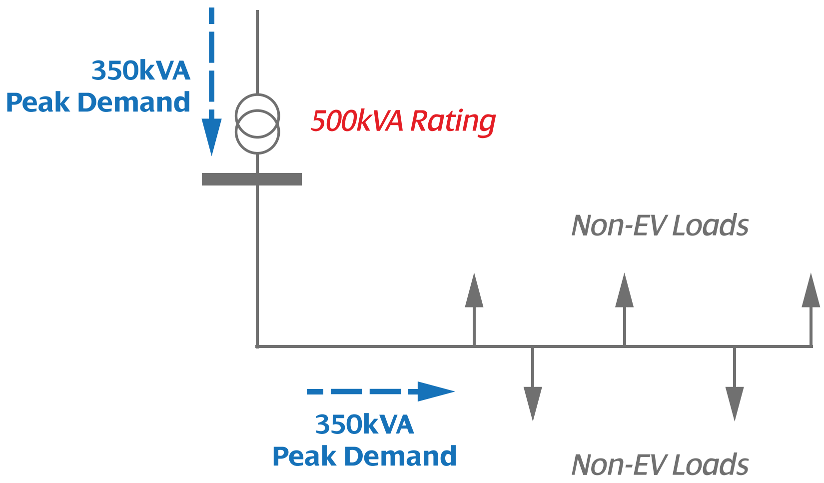

Figure 8: Pre-EV Network Example

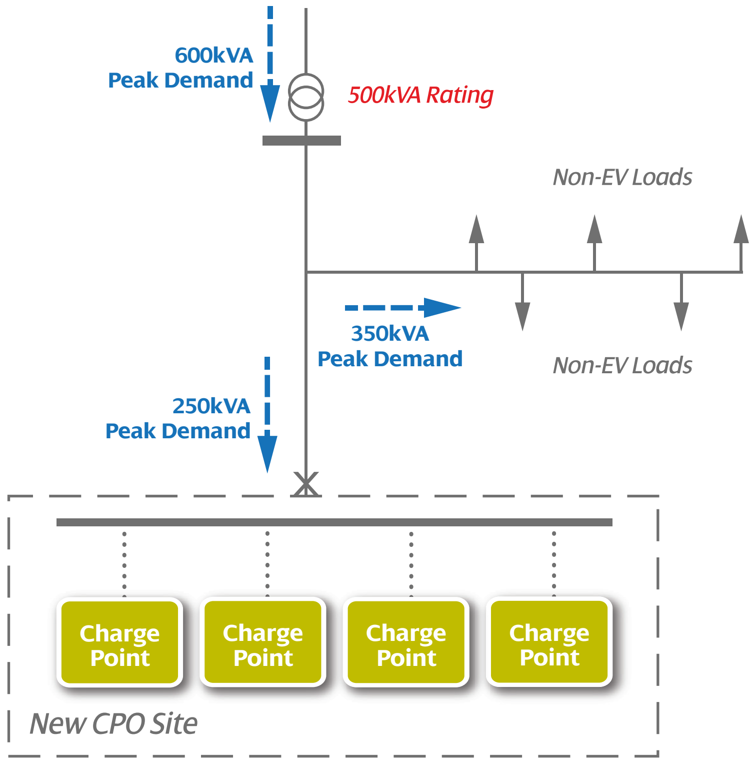

Figure 9: Post-EV Network Example

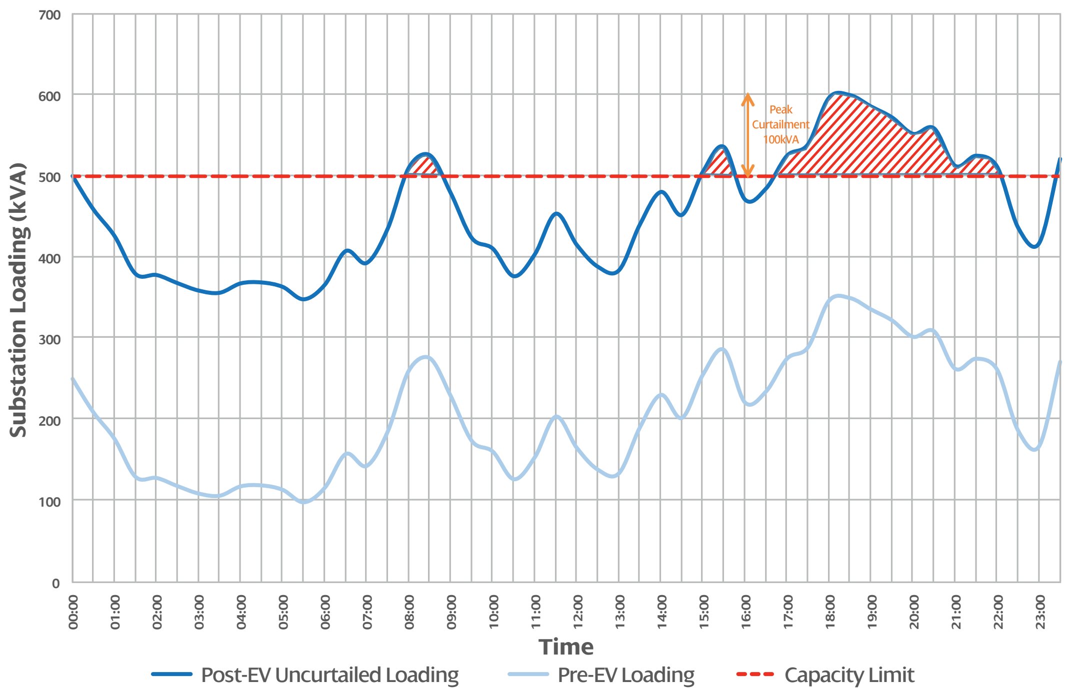

Figure 10: Example Day Plot of Curtailment

3.2.3.3. Distinction Between Locally Managed and Centrally Managed Constraint Schemes

Locally managed constraint schemes (LMCs) can be deployed where the EV chargepoint load is only likely to stress a single location on the network. As such, there is an opportunity to include the control functionality that derives and communicates the set point to the CPMS into the monitoring solution.

Centrally managed constraint schemes (CMCs) can be deployed where the EV chargepoint load has the potential to stress multiple locations on the DNO network. Similarly, it could be deployed in cases in which multiple EV chargepoint sites were being managed against common network constraints. A central platform is required to coordinate and assess multiple measurements from the network and derive and communicate a resulting set point to the CPMS. The central platform takes the form of a DERMS, which is used by the DNOs to manage flexible distributed generation (DG) connections (active network management).

4. Stakeholder Insights

The Charge Project has engaged with parties including original equipment manufacturers (OEMs), CPOs, chargepoint installers, chargepoint owners, and local authorities around the topic of SCCs.

This engagement process has provided a wealth of insight into the technical, commercial, and social challenges; risks and opportunities pertinent to various SCC schemes; their broader adoption; and how they sit alongside the market-driven provision and procurement of flexibility services.

The gathering of stakeholder insights is a crucial step in fully understanding the opportunities and risks associated with SCCs. The feedback generated is vital in shaping the roll-out of SCCs, and has helped to:

1. Refine the SCC definition
2. Tailor different SCC solutions to specific stakeholder types
3. Define the value case of SCCs
4. Understand technology prerequisites for SCCs and development requirements
5. Identify gaps in/challenges to SCC uptake

The following sections describe the stakeholder insights associated with specific SCC solutions, and further general insights into technology readiness, timing of need and roll-out, principles of network access, and alignment with flexibility services markets.

4.1. Stakeholder Insights: Timed Capacity Connections (TCC)

4.1.1. Insights

Initial engagements have provided the following insights into TCC schemes:

- The simplicity of the TCC scheme is appealing, particularly as it provides greater access to the network without the need to integrate with DNO systems.
- Although this functionality should be increasingly commonplace in smart chargers, it is not uniformly available, and there are few examples of TCC schemes in the UK at present.
- Some customers agree that TCCs are highly applicable to residential on-street locations, but the level (i.e., total capacity being installed) to which these types of chargepoints are currently being deployed does not necessitate an SCC.
- It is anticipated that residential end users will become familiar with and accepting of the TCC restrictions on charging, although engagement will be required to raise awareness of them.

- This engagement would also explain the benefit of TCCs to the customer, i.e., faster and wider deployment of a charging infrastructure with lower cost and reduced disruption.
- Their acceptance would be further enhanced if there were enough chargepoints and load diversity that a limited number of end users could prioritise their charging and effectively 'opt out' of being curtailed – even if this meant paying extra (i.e., scheduled charging). The ability to offer this will depend on the level of curtailment, as in some extreme cases, it could be 0kW.
- The business case for on-street chargepoints is the hardest to justify, as their utilisation is dependent on EV uptake being high in the local area, and the revenue from the energy provided is relatively low compared to that from rapid chargepoints. They also need to have minimal impact on the movement of pedestrians. As such, there is presently a high uptake of low-cost chargepoints that have a small footprint and can be deployed with minimal disruption. Often, they are incorporated into existing street furniture, such as street-lighting columns, and provide a 'slow' AC charge (<5kW).
- At present, the trade-off of the reduced cost and size is the intelligence of the chargepoints, which impacts their ability to provide TCC functionality.
- The deployment of on-street residential chargepoints is typically led by local authorities, whose primary aim is to maximise the coverage provided with the limited funding available to them. As such, it is typical that on-street residential schemes will only install two to four AC chargepoints per street. These might be 'slow' (<5kW) or 'fast' (7–22kW) chargepoints. Either way, typical power consumption is relatively low and can often be accommodated by the existing network. So although TCCs are very applicable for on-street schemes, they will only be required when they are deployed at scale or the necessary charging power increases.
- There are already several examples of TCCs being deployed for large depot charging sites in the UK, including a bus depot in London facilitated by UK Power Networks (UKPN).
- Engagement with several depot fleet operators highlighted that they all had near-term plans to electrify their fleet of vehicles, with most intending to utilise overnight charging. As such, if a TCC facilitated a faster and/or cheaper connection on the proviso that overnight charging would not be curtailed, fleet operators would be very keen to adopt it.
- Some of the fleet operators went as far as saying they would be willing to adopt a TCC that curtailed their import to almost nothing during the working day if it facilitated several MVA of capacity in the evening.
- There is currently a lot of focus on the development and deployment of solutions that will facilitate smart charging of depot EVs. Several solutions are now commercially available, with some fleet operators looking to develop their own in-house solutions.

- The development and trial of solutions to facilitate flexible connections for depot EVs is a major component of the Optimise Prime NIC project being undertaken by UKPN and its partners[2].
- Unlike the on-street schemes, there appears to be a more near-term uptake of SCCs with depots. The simplicity of non-curtailment during the required charging period of fleets makes TCCs a very attractive option to customers and end users.
- The Optimise Prime project also looks at the provision of profile capacity constraints. This is a variant of TCC that utilises forecasting to assign the half-hourly curtailment limits a day ahead. This increased level of sophistication provides further access to available network capacity.
- Although a TCC scheme could be used to manage constraints on a customer's local network, most customers would opt for a CLM scheme, as this would provide them with greater capacity access.
- The major risk to both the DNO and CPO is that the assumption of a status quo of network loading changes and the defined curtailment period and scale is no longer sufficient to mitigate the risk of a network constraint. In this eventuality, there will be a requirement for either the conditions of the TCC to be revised or the network reinforcement to be undertaken. Transparency on this issue and an agreement on the responsibilities of each party will be required upfront, ahead of any connection taking place.
- For DNOs, the risk is reliance on the customer operating and maintaining the TCC to ensure the network remains within its operational limits. The question was raised regarding what level of risk would be allowed before the DNO would insist on inclusion of monitoring or a form of back-up protection/inter-trip to guard against non-compliance.
- An additional risk to DNOs and participating CPOs is the impact of a changing demand profile. Changes to the underlying demand profile as existing users alter their energy consumption will vary the capacity available to TCC customers; therefore, the times and levels of constraint in the TCC profile may change in future.
- For the CPO, the risk is related to end-user acceptance and commercial performance of the TCC. Until it is operational, it will be difficult for the true impact of the curtailment to be ascertained.

2. https://www.optimise-prime.com

4.1.2. Challenges

There are no major barriers to provision and adoption of TCCs. However, customers, CPOs, installers and DNOs require more practical experience of their implementation to facilitate the necessary changes to existing policies and processes, inform technical requirements, and generate appropriate messaging to raise awareness of them.

Commercial Challenges

- **Economic** - At present, there isn't a detailed understanding of the business case for TCCs vs conventional reinforcement connections in terms of cheaper connection costs vs lost revenue from curtailment.
- **Legal** - There is limited scope within existing connection offers to facilitate TCCs - new contracts will have to be established that highlight responsibilities and recourse for non-compliance.
- **Policy & Process** - Present DNO policies and processes do not include provision of TCCs.

Technical Challenges

- **Performance** - It is not currently understood whether smart chargers can provide the necessary requirements to reliably operate a TCC.
- **Curtailment Assessment** - No established process is in place to assess network suitability to accommodate a TCC and the curtailment required.
- **Network Security** - Little experience of long-term reliability

(i) Can the CPO provide sufficient fail-safe capability, or does this need to be established by the DNO?

(ii) How can the long-term compliance of the TCC be monitored by the DNO?

Societal Challenges

- **Customer & End-User Acceptance** - Will TCCs provide the required charging to meet the needs of end users?
- **Awareness** - To gain traction, there needs to be greater awareness of TCCs across the supply chain.

Figure 11: Challenges for TCC Implementation

4.2. Stakeholder Insights: Customer Load Management (CLM) Connections

4.2.1. Insights

Initial engagements have provided the following insights into CLM schemes:

- The ability to operate CLMs is becoming more commonplace in the smart chargers being deployed in the UK. However, the functionality available varies significantly by OEM and CPO.
- It is typical that AC chargepoints at the same physical location and on the same electrical circuit can provide the CLM functionality with minimal need for additional technology. EV chargepoints can typically communicate among themselves to adhere to either a static or dynamic set point.
- Coordination of AC chargepoints spread out over several circuits and locations would necessitate a separate controller to orchestrate the adherence to a set point.
- Similarly, it is more likely that DC chargepoints would require a separate controller to provide CLM functionality.
- Introduction of a dedicated controller for AC and/or DC chargepoints provides additional performance benefits and functionality, including scheduling of charging, integration of DERs and further fail-safe options. As such, it is increasingly common for them to be installed at large charging hubs and depots.
- Static-limit CLM functionality is increasingly available from smart chargers. The functionality is often utilised by chargepoint owners to avoid standing charges for half-hourly metering by ensuring the total demand of their chargepoints does not exceed 69kW. This is particularly commonplace for EV charging locations that offer both 50kW DC and 22/43kW AC charging.
- Static-limit CLMs often utilise a satellite and hub configuration to communicate between themselves and manage their collective energy demand. Every chargepoint can function as the 'hub', which makes the scheme resilient to loss of communication from any of the chargepoints.
- Dynamic-limit CLMs require a hardwired signal to be passed from a meter to the master chargepoint. These are often not at the same location, and installation is typically not possible without undesirable disruption.
- Dynamic-limit CLMs also utilise a satellite and hub configuration but require a dedicated hub chargepoint to integrate with the signal from the site's electricity meter. Because of this, the scheme has lower resilience compared to static-limit schemes.
- Sites operating both AC and DC chargepoints would often only look to deploy the CLM to the AC units, while providing the DC units with unconstrained access.

For customers looking to adopt a CLM, there are several risks that need to be carefully considered and managed:

- Will the CLM provide sufficient capacity for the chargepoints to meet the requirements of their end users, and will the capacity be available at the times it is required? This is especially important in relation to paying end users, as opposed to charging staff or fleet vehicles.
- The failure of a CLM could result in both financial penalties for breaching the DSC and loss of the site supply, which would risk the security of supply to the site's other loads. It is therefore essential that the CLM has suitable fail-safe measures integrated into and alongside it to prevent its failure from causing wider issues.
- Where the failure of a CLM could lead to issues on the wider network, there might be additional requirements from the DNO to ensure appropriate fail-safe measures are in place.
- The selection of the smart charger must be made with or after the decision to adopt a static or dynamic CLM. The suitability and readiness of the smart chargers to provide this functionality varies significantly. In many cases, it will be impossible to retrofit this functionality once the chargepoints have been installed.
- There is potential that smart charging cables could, by proxy, provide this functionality retrospectively. However, these will come at an additional cost.
- Adoption of a dynamic CLM might also cause unacceptable disruption to the customer, as it often requires a hardwired link between a meter measuring the live total site demand and the chargepoints.

For DNOs, the following risks must be carefully considered and managed:

- There is risk of becoming reliant on the customer operating and maintaining the CLM to ensure that it stays within its DSC. Excursions beyond the DSC could pose a threat to the network's operational limits, especially if multiplied across several sites in the same network area.
- The widespread adoption of CLMs could result in a masked load growth and erosion of load diversity on the network.
- There is also an inherent risk that customers could install CLMs without informing the DNO.

4.2.2. Challenges

As with TCCs, there are no major barriers to provision and adoption of CLMs. However, customers, CPOs, installers and DNOs require more practical experience of them. Doing so will facilitate the necessary changes to existing policies and processes, inform technical requirements, and generate appropriate messaging to raise awareness of them.

Commercial Challenges

- **Economic** - At present, there isn't a detailed understanding of the business case for CLMs vs conventional reinforcement connections in relation to cheaper connection costs vs lost revenue from curtailment.
- **Legal** - There is limited scope within existing connection offers to facilitate CLMs - new contracts will have to be established that highlight responsibilities and recourse for non-compliance.
- **Policy & Process** - Present DNO policies and processes do not include provision of CLMs. Should DNOs introduce a 'Connect and Notify' policy?

Technical Challenges

- **Performance** - It is not currently understood whether smart chargers can provide the necessary requirements to reliably operate a CLM. It is also not clearly understood whether smart chargers and the associated CPMS can provide close-to-real-time control where site security is critical.
- **Curtailment Assessment** - The responsibility sits with the customer/installer, both of which might not be equipped to carry this out, and may need guidance/support. The implications of getting it wrong could be significant.
- **Network Security** - Little experience of long-term reliability.

(i) Can the CPOs provide sufficient fail-safe capability, and what standards should be put in place?

(ii) How can the long-term compliance of the CLMs be monitored by the DNO?

(iii) Should DNOs develop a Type Test Register of CLM solutions to avoid the requirement for witness testing or functionality testing?

Societal Challenges

- **Customer & End-User Acceptance** - Will CLMs provide the required charging to meet the needs of end-users?
- **Awareness** - To gain traction, there needs to be greater awareness of CLMs across the supply chain.

Figure 12: Challenges for CLM Implementation

4.3. Stakeholder Insights: DNO-led SCCs

4.3.1. Insights

Initial engagement has provided the following insights into the LMC and CMC (DNO-led) schemes:

- There is little experience or trials of DNO and CPO systems for public chargepoints being integrated in the UK. No immediate examples outside of the endeavours of the Charge Project and Optimise Prime could be cited.
- The closest example is the trials undertaken to control domestic chargepoints under Western Power Distribution's Electric Nation project.
- Although some customers could see the value of having the option of DNO-led SCC schemes available to them in the long term, they do not have an immediate need for them. At present and in cases in which network access is limited, the connection customer would opt to shift its focus to an alternative site or tailor its demand to meet the available capacity. In time, customers' ability to select sites on this basis will reduce, and their interest in DNO-led SCC schemes will increase accordingly. Customers' preference is to have certainty of a fixed DSC and manage consumption within this limit.
- Integration of DNO and CPO systems will require additional investment and resources from the CPO. Given that this is not an immediate area of concern, this development is not presently a priority of CPOs.
- In general, there is reticence amongst customers (and CPOs especially) about establishing the required system integration and giving DNOs any level of control over their assets. This concern focuses primarily on how the DNO signals could interfere with their commercial proposition to end users or impact the charging of essential fleet vehicles.
- The reticence diminished slightly with the realisation that they were in full control of how their chargepoints responded to the DNO set-point signal, i.e., the DNO would not control individual chargepoints and decide which would be curtailed. This would solely be done by the CPMS, configured to meet the needs of the CPO and its end users.
- A major risk/concern for customers is that they have less certainty and control over the occurrence of a curtailment signal. Unlike the TCC, which provides a fixed but uniformly applied constraint window, and the CLM, which is largely driven by its own load, the LMC/CMC curtailment signals could be impacted by faults, temporary running arrangements, or increased external network loads, with all these factors beyond the customer's visibility or control. There is an inherent risk that the DNO curtailment signal will coincide with peak charging and have an unacceptable impact on paying end users or fleet EVs.

- Discussions on DNO-to-CPO integration have highlighted that the method will vary significantly by CPO. For some, it would likely be a direct link to a 'hub' chargepoint capable of interpreting the set-point and controlling the adjacent 'satellite' chargepoints. Other CPOs will require integration with a physical on-site CPMS, which is particularly common at large charging sites. Lastly, and increasingly common, would be integration of the DNO signals with a CPO cloud-hosted CPMS, which may prove to be the simplest, cheapest, and most extensible option, but have less robust on-site fail-to-safes.
- Questions remain of the reliability, latency and responsiveness that can be expected from all the different integration methods, particularly when sending signals over a cellular network or the internet.
- At present, there is not a standard protocol for communication between the DNO and CPO. However, discussions with customers highlighted several protocols that had been developed to allow this communication pathway, which will be covered in greater detail in section 4.4.2. The main protocols to be mentioned are:
    - **OpenADR** (Automatic Demand Response)
    - **OSCP** (Open Smart Charging Protocol)
    - **OCPI** (Open Charge Point Interface)
    - **OPC UA** (Open Platform Communications Unified Architecture)
- The ability to operate the chargepoints in a DNO-led SCC is predominantly dictated by the CPO's CPMS, rather than the hardware itself. There are, however, some exceptions to this, and it is essential that the chargepoint hardware can communicate externally.
- Because of the reticence of some customers to adopt a DNO-led scheme and tackle the development challenges, the scale of the benefit delivered needs to be suitably large in terms of cost or reduction in time to connect. A good example of this would be facilitating a connection at a lower voltage, e.g., at 11kV as opposed to 33kV.
- The acceptability of a DNO-led SCC would also be higher where the site includes integral DER that could backfill the energy required in the event of an external network constraint.
- For customers and DNOs alike, there is a security risk associated with integration of their systems.
- For DNOs, there is a reliance on the customer responding to constraint signals to maintain the quality and security of the network supply. An automated process is essential to fail-safe and remove non-compliant chargepoints from the network before they cause disruption to surrounding customers on the network.

As DNOs have nothing they can directly control on the customer's side of the connection, a fail-safe scheme will ultimately trip off the customer's incoming supply to secure the wider network. This is a major risk for the customer that could result in lost revenue, disruption to the charging of fleet vehicles, and reliance on staff to manually re-energise the site. As such, agreed mechanisms are required for monitoring and remediating chargepoint response.

- DNOs will also have to consider how future network programmes impact the schemes and ensure that the proposition to the customer is not detrimental to future network development. This is applicable to all SCCs in different ways, although the LMC and CMC methods have the benefit of being actively managed and, therefore, can be adapted and extended over time.
- As with the other schemes, selection of the smart charger must be in parallel with or after the decision to adopt an LMC or CMC. The suitability and readiness of smart chargers to provide this functionality varies significantly. In many cases, it will be impossible to retrofit this functionality once the chargepoints have been installed.
- Investment in a DERMS platform and its ongoing operation will only be cost-effective if deployed at scale, and if the reuse/extension of DERMS for SCC implementation can be factored into ongoing DNO DERMS programmes.

4.3.2. Challenges

DNO-led SCCs are unavoidably more complex and challenging to deliver than their customer-led counterparts, but they should provide the greatest access to the available capacity on the network.

It is crucial for the DNO to ensure that the process of SCC optioneering and implementation follows well-established and consistent design processes.

Commercial Challenges

- **Economic** - At present, there is not a detailed understanding of the business case for DNO-led SCCs vs conventional reinforcement connections. The business case, especially at low voltage, needs to be fully understood due to the complexity of the DNO-led schemes and level of integration required between DNO and CPO systems (which is currently not mainstream).
- **Legal** - There is limited scope within existing connection offers to facilitate DNO-led SCCs - new contracts will have to be established that highlight responsibilities and recourse for non-compliance. Contractually, it is more complicated where non-compliance affects network security/ other customers. In cases in which multiple CPOs operate within the boundaries of the same network constraint(s), contractual agreement over what gets curtailed first, and by how much, must be established.
- **Policy & Process** - Present DNO policies and processes do not include provision of DNO-led SCCs.

Technical Challenges

- **Performance** - It is not currently understood whether smart chargers can provide the necessary requirements to reliably operate a DNO-led SCC.

i) Integration of DNO and CPO systems requires development, and no stardardised method has been established,

ii) It is not clearly understood whether smart chargers and the associated CPMSs can provide close to real-time control where site/network security is critical.

- **Curtailment Assessment** - No established process is in place to assess network suitability to accomodate DNO-led SCCs and the curtailment required.
- **Network Security** - Little experience of long-term reliability.

i) Can the CPO provide sufficient fail-safe capability, or does this need to be established by the DNO?

ii) How can the long-term compliance of the DNO-led SCC be monitored by the DNO?

(iii) Robust security measures need to be in place when integrating with critical DNO systems.

Societal Challenges

- **Customer & End User Acceptance** -

i) Current lack of acceptance from CPOs to receive and comply with a DNO signal.

ii) Will DNO-led SCCs provide the required charging to meet the needs of end users?

- **Awareness** - To gain traction, there needs to be greater awareness of DNO-led SCCs across the supply chain.

Figure 13: Challenges for DNO-led SCC Implementation

4.4. Further Insights

While not attributable to one specific SCC, the following topics were routinely raised during the definition of SCCs and subsequent customer engagement. The following sections highlight the preliminary considerations arising from these discussions.

4.4.1. When Will the Need for Smart Charging Connections Become Prevalent?

The underlying response from customers is that they can see the benefit of SCCs and want them available as a connection option. However, the present scale of deployments and ability to be selective over locations means SCCs are not immediately required for consideration in most cases.

This ability to be selective is due to the nature of current deployments. At present, many of the chargepoint installations have been made by CPOs and local authorities. CPOs are looking to establish sites that can generate sustainable revenue, which has often precluded the installation of high volumes of chargepoints during the infancy of EV uptake. These installations are not tied geographically to any specific location. Similarly, local authorities are looking to establish a high level of coverage of public chargepoints, rather than high volumes of chargepoints at hubs. They also have the benefit of the flexibility to choose from multiple locations where they own the land, where there is network capacity, and where there are no planning objections. Given the immediate choice between offering an SCC or opting for reduced capacity or an alternative site, both CPOs and local authorities would choose the two latter options.

CPOs are looking to establish sites that can generate sustainable revenue, which has often precluded the installation of high volumes of chargepoints during the infancy of EV uptake.

Depot charging hubs are an exception to this. There is a growing trend to electrify vehicles that charge at a depot location – for example, delivery vans, bin lorries, buses and taxis. These depots tend to be bound to a geographic location, so there is little option to move the charging hub to a location with more abundant capacity. As such, it is very likely that the immediate uptake and utilisation of SCCs will be predominantly at depot locations. At present, most of these fleets are operational during the day. It is therefore expected that overnight charging will be predominantly utilised, thus making TCC schemes a perfect fit for this application.

The initial uptake of SCCs is therefore likely be when customers with fixed geographic locations, such as workplace, leisure, and retail locations, look to install a high volume of chargepoints. This will be driven by their customers', i.e., end users', adoption of EVs.

4.4.2. What Communications Protocols Are Used to Facilitate Data Transfer Between DNOs and CPOs

A key consideration for DNO-led SCCs is the secure method of communication between DNO and CPO. As previously mentioned, several protocols have been highlighted as providing such a pathway.

EV Charging Standards and Electricity Demand Protocols:

- **OpenADR**, an American protocol, is being gradually adopted worldwide. OpenADR facilitates common information exchange between electricity service providers, aggregators, and end users.

Examples of its use are:

- Sending price and load control signals, which can be used for decreasing or increasing the power consumption of individual devices.
- Sending reports – in the EV context, this can be standardised metering data from a chargepoint (for example, for monitoring and validating performance) and use times for forecasts, etc.

OpenADR can be implemented at the CPMS level and provide a single demand signal for the EV site, so this is suitable for the main use case. However, none of the CPOs engaged with the project can provide OpenADR support at this time.

Other relevant protocols are:

- **OSCP** (Open Smart Charging Protocol) is an open communication protocol between the CPMS and DNO. The protocol can be used to communicate a time interval prediction or schedule of the local available network capacity to the CPO, which can fit the charging profiles of the EVs within the boundaries of the available network capacity.
- **OCPI** is an open standard that provides a mechanism for exchange of data, primarily intended for EV roaming support between CPOs and e-mobility service providers (eMSPs) to provide roaming customer billing. A smart charging profile can be issued to control the charging rate of an EV charging session at a single chargepoint. OCPI is most likely used by the CPMS for communication with individual chargepoints.

It is important to retain flexibility in the delivery solution, and there is currently no clear market leader, as this field is still in development. At present, none of the CPOs engaged with the project can provide external protocol support between DNO and CPMS, so this is an area that would require future development at both ends to support communications.

4.4.3. Smart Charging Connections and the Principles of Access

An important design consideration for SCC roll-out is the curtailment impact following changes to the demand profile or new connections to the wider network.

In the case of customer load management SCCs, the customer has a DSC envelope that it can operate within regardless of wider network conditions. If more customers connect, or local network demand increases, it will not impact the customer's ability to operate within the DSC envelope. Saturation of network capacity with contracted CLM demand also provides a strong first-comer advantage that does not scale well to a wider customer base. However, saturation would most likely trigger load-related reinforcement, which would release additional capacity.

TCCs and DNO-led SCCs (LMCs and CMCs) seek to utilise the remaining capacity on the network, releasing greater volumes of capacity. Addition of new connections to the same network would only be possible if they had no detrimental impact on the level of curtailment encountered. This would only likely be possible via reinforcement, which would ultimately increase the capacity available and reduce the curtailment experienced by the EV chargepoint sites. Some CPOs and customers may accept higher curtailment as a late-comer connection, but this is likely to occur in special circumstances (e.g., DER on site to make up curtailed service or a business model that can adapt to the patterns of higher curtailment).

It is likely that for the immediate future, DNOs will continue to operate access on the last-in first-out (LIFO) principle, which is used for other flexible connections such as those for distributed generation.

The principles of access for TCCs and DNO-led SCCs become more complicated when the demand of existing customers connected prior to the chargepoints increases or changes profile. Commercially, these customers have the right to increase or change their demand profile if they do not exceed their DSC. Curtailment levels for TCCs, LMCs and CMCs would remain a risk and require monitoring and possibly mitigating.

It is likely that for the immediate future, DNOs will continue to operate access on the last-in first-out (LIFO) principle, which is used for other flexible connections such as those for distributed generation. It should be noted that market-based capacity access and curtailment trading are currently being explored by several DNOs.

For TCCs where network loading levels are not managed in real time, a change to the surrounding load would not be apparent to the customer. The DNO would need to remain vigilant through monitoring to ensure that the TCC curtailment level was still appropriate. If it was found that the TCC was increasingly unlikely to prevent a network constraint, the DNO would likely prioritise the network for load-related reinforcement, as opposed to changing the TCC curtailment level or curtailment period.

A change to the surrounding load for DNO-led SCCs would be apparent to the connection customer because the frequency and scale of curtailments would increase. The implications of load growth should be considered at the DNO curtailment analysis stage, in order to understand the sensitivity of estimated constraint to changes in the underlying load profile.

It is important to emphasise that over time, changes to the network load are inevitable. For this reason, SCCs are more likely to be an interim solution ahead of network reinforcement. The offering of SCCs requires transparency to the customer. The customer needs to fully understand the commercial implications of adopting an SCC and ensure this understanding is not lost through change of ownership (of the assets). Offering SCCs requires the DNO to be vigilant, to not only protect the needs of the customer, but also the security of the network. DNO monitoring of the network, applying conservatism to the curtailment analysis, periodic reviews of network load growth and, lastly, load-related reinforcement, may all be necessary to effectively manage change.

4.4.4. Interaction of Smart Charging Connections and the Flexibility Services Market

There has been a strong interest from customers in discussing the opportunities for chargepoints to generate income via provision of flexibility services. Customers were keen to understand the impact of SCC adoption on this opportunity.

At present, there are no established policies that define the acceptable interactivity of flexible connections and provision of flexibility services. Logic suggests that a customer should not be compensated for providing a flexibility service that is mandated by its flexible connection (and where the benefit has already been received in the form of a quicker and/or cheaper connection).

CLM connections only manage customer demand within the DSC envelope. Should there be a request for a local or national network load relief flexibility service, there is no apparent barrier to participation.

Customers with TCCs and DNO-led SCCs already benefit from a flexible connection that reduces their own connection cost and/or shortens connection timescales. The SCC customer will be constrained during periods of high loading on the local distribution network. DNO evaluation of flexibility requirements must consider non-compensated curtailment of SCCs prior to identification of the need for compensated flexibility services from other sources. This balance is not currently captured in regulation or connections policies.

Stakeholder discussions highlighted that the biggest challenge for CPOs looking to provide flexibility services would be their ability to demonstrate the consistency of load reduction delivery on demand. The present levels of chargepoint utilisation will not align with demand reduction requirements, as the baseline demand before a flexibility service activation event might be zero if no EV was connected and charging.

No SCCs would prevent the customer from adopting a time-of-use tariff if the tariff does not result in the customer contravening its curtailment obligation.

4.4.5. Readiness of Smart Chargers and Chargepoint Operators

The ability to provide SCC functionality is neither uniform nor standardised across the current smart charger market. Smart chargers' ability to adhere to dynamic limits, whether generated internally or externally, needs further development. Significant technical development is required from CPOs and OEMs for chargepoints to provide this functionality. Development of SCC functionality is competing for resources within these organisations that are currently engaged with developing e-mobility functionality. As such, SCC-readiness capabilities are not presently the highest priority for CPOs and OEMs.

There is an underlying reticence from CPOs to consider a DNO-led solution at present, which will slow down their development and deployment. This is a barrier that will need to be overcome if SCCs are to be an effective tool in enabling maximum network capacity access and greater breadth of connection options for customers.

Development of a standard protocol and a standard set of interface signals for DNO-to-CPO communications would be a major enabler for provision of flexible connections.

Development of a standard protocol and a standard set of interface signals for DNO-to-CPO communications would be a major enabler for provision of flexible connections. At present, CPO systems do not widely include the functionality to accept external smart charging-related signals, either locally at the physical chargepoint level or centrally at the CPMS level. There is a need for a preferred industry-standard communication technology and corresponding preferred protocol to be adopted within the industry.

The ability to quickly and safely isolate CPO sites in response to safety-related DNO trip requests, following detection of DNO network overload conditions, is also an aspect that CPOs must develop and implement accordingly to ensure site safety. It is important that CPOs are sufficiently aware of the wider DNO safety aspects and prepared for the DNO-led safety actions and financial implications of lost charging during periods of site isolation.

Access to highly granular chargepoint data is currently limited (or simply not available). This impacts the current level of understanding of EV charging demand profiles for various charging types. To facilitate the uptake of all SCCs (particularly in assessing their suitability and curtailment requirements), sharing of detailed datasets should be encouraged.

5. Customer-Led SCC Implementation

Customer-led SCCs are delivered in two formats:

- **Timed capacity connection schemes:** in which the EV chargepoint site must follow a predefined profile of half-hourly import limitations.
- **Customer load management schemes:** in which the EV chargepoint site must maintain site consumption within a fixed, predefined import limit – the DSC.

For each customer-led SCC solution, the EV chargepoint site can install chargepoin infrastructure with a total capacity greater than the traditional ***firm*** network capacity, albeit with the need for coordination of demand below the DSC.

5.1. Customer-Led SCC Solutions: Requirements

The following section presents the requirements for implementation of customer-led SCC solutions.

The requirements outline the necessary technology components, EV chargepoint control functionality and communications infrastructure required to deliver the customer-led SCC solutions. The distinction between DNO and customer-side requirements is highlighted throughout.

TCC and CLM schemes share requirements and have similar architecture. The ***requirements*** and ***architecture*** are presented for both scheme types, with scheme-specific nuances illustrated in the requirement descriptions.

5.1.1. Customer-Led SCC Solutions: Components

The components required to deliver customer-led SCCs are presented in Table 4.

Component Name	Owner	Description
EV Chargepoints	Customer	Individual chargepoints located at the customer site. Units may vary in kW rating at a single site.
Non-EV Load	Customer	Loads at the customer site that are not associated with EV charging.
Chargepoint Management System (CPMS)	Customer	Control system responsible for coordination of EV chargepoint energy consumption. Receives import measurements and issues control signals in real time to EV chargepoints when curtailment is required.
Site Import Measurement (Customer)	Customer	Monitoring device responsible for real-time measure-ment of power consumption for the entire customer site.
Site Import Measurement (DNO)	DNO	Monitoring device located at the DNO meter, providing real-time measurement of site demand.
Data Historian	DNO	DNO historian responsible for logging measurements of demand at the customer site. Used for auditing pur-poses to ensure connection conditions are being met.

Table 4: Customer-Led SCC Components

5.1.2. Customer-Led SCC Solutions: Customer Requirements

The customer-side requirements for implementation of a customer-led SCC are summarised in Figure 14. This functionality is delivered by a customer-side CPMS, which is the customer's responsibility for design and implementation. All requirements reflect functionality that must be delivered from the CPMS.

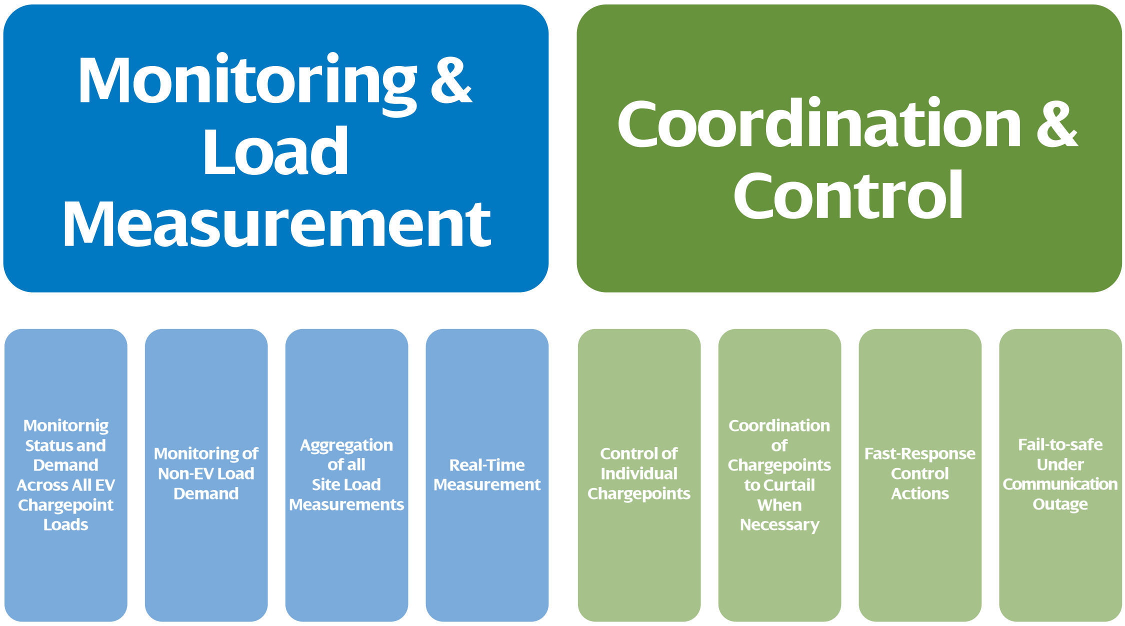

Figure 14: Customer Requirement Themes

5.1.2.1. Monitoring and Load Measurement

In summary, the ***monitoring and load measurement*** requirements ensure that the customer site can approximate the site demand at a sufficiently high resolution that allows trigger of control actions when the site is at risk of exceeding the DSC/TCC limit. The resolution of this monitoring will be specified by the DNO prior to connection. The requirements consist of:

The customer must have visibility of energy consumption across all EV chargepoint loads. To deliver the necessary coordination and control of EV chargepoints, the CPMS requires visibility of the EV connection status and device import at each chargepoint. This observes the charging status of each chargepoint (whether an EV is connected and rate of charge).

Non-EV loads or energy production at the customer site must be measured. Where ancillary loads or DER exist, there is a need for the CPMS to monitor the energy consumption/production from these elements. Visibility of ancillary consumption/production is required for derivation of the total site demand, which is the parameter that must be maintained within the DSC/TCC limits.

Load measurements must be aggregated to derive total site demand. There must be visibility of the aggregated total site demand, including combined EV chargepoint loads and any non-EV ancillary demand. The site total demand is the metric that must be maintained within the DSC/TCC limits.

The CPMS must derive or directly measure this parameter, via either:

- aggregation of individual measurements from EV chargepoints, non-EV loads, and DER
- direct measurement of demand at the point of connection with the DNO network

Measurements must be delivered at temporal high resolution. The measurements, described above, must provide the CPMS with an accurate and up-to-date measurement of loading across the site. High-resolution measurement is required to reduce latency in the control loop and allows the CPO to operate site demand closer to the TCC or DSC limit.

5.1.2.2. Coordination & Control

The coordination and control requirements ensure that the customer site can implement the necessary control actions at speed of response sufficient to maintain the site demand within the DSC/TCC limits.

The CPMS must be able to control consumption at each chargepoint. Each installed chargepoint must have the functionality to reduce energy consumption during a charging event. This reduction must be triggered via receipt of an external command from the CPMS to curtail demand.

The CPMS must be able to coordinate consumption across multiple chargepoints. Where multiple chargepoints exist at the customer site, there is a requirement to coordinate implementation of curtailment actions when there is a risk of exceeding the DSC/TCC limit. CPOs refer to this as ***grouping*** chargepoint consumption.

The coordination of chargepoint curtailment is delivered through the CPMS. Coordination of multiple chargepoints may take the form of:

- Curtailing chargepoints on a cyclic basis: e.g., cycling through curtailment of chargepoints across 10-minute intervals
- Prioritising consumption at specific chargepoints, constraining low-priority chargepoints, e.g., maintaining supply to higher-rated chargepoints for priority fast charging
- Applying a uniform granular reduction in consumption across all chargepoints

Control actions must be within sufficiently fast response times. Following identification of site demand nearing a TCC or DSC limit, the process of identifying necessary chargepoint curtailment actions and then implementing them must be fast enough to bring site demand to a safe state below the TCC/DSC limit.

The faster the response, the closer the customer can run the site demand to the DSC/TCC limit, as there is confidence that the demand can be quickly maintained within the specified capacity limit through a robust mechanism.

The CPMS must include fail-to-safe functionality under a communications outage. The CPMS and each individual chargepoint must include functionality to enter a fail-safe state under an outage of the communications link between components in the customer-side control infrastructure. The fail-safe functionality ensures that the loss of communications or CPMS functionality does not put the site at risk of exceeding the DSC or TCC limits. A fail-safe level of consumption must be established at each individual chargepoint, reflecting the level of consumption at which site DSC or TCC limits would be maintained should the communications or CPMS functionality fail.

5.1.3. Customer-Led SCC Solutions: DNO Requirements

The DNO requirements for implementation of a customer-led SCC are summarised in Figure 15. This functionality is less onerous than the customer-side requirements and utilises existing DNO infrastructure.

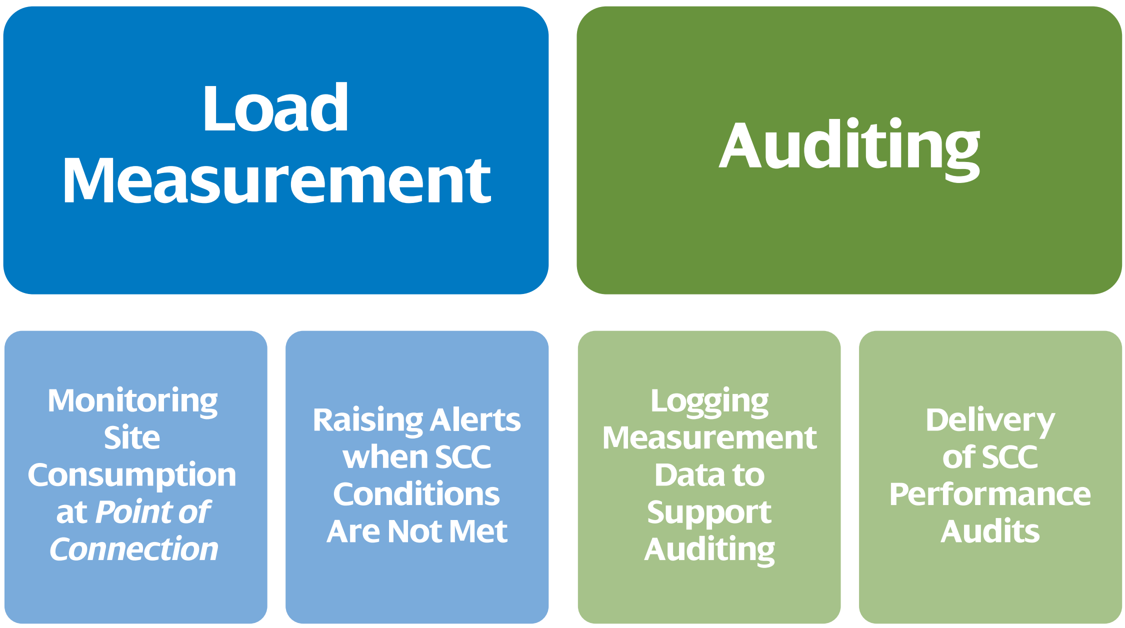

Figure 15: DNO Requirement Themes

5.1.3.1. Load Measurement

Load Measurement requirements ensure that the DNO has visibility of site demand and, if required, can perform occasional auditing to ensure the SCC solution is maintaining site demand within the DSC/TCC limits.

Monitoring site consumption at the point of connection. There is need for DNO visibility of the site consumption to ensure demand is maintained within the DSC/TCC limit. This must be measured from a DNO monitoring asset to guarantee validity of the demand measurement value (as opposed to demand measurement provided by the customer). The DNO measurement device must be installed at the point of connection.

Raising alerts when SCC conditions are not met. In larger-scale connections (>1 MVA), the DNO may choose to link the site measurement with its distribution management system. This will allow an alert to be raised to control operators when an undesired condition is observed. Alerts may be issued when the DSC/TCC limit is exceeded several times or for a sustained period.

5.1.3.2. Auditing

The ability of a DNO to audit SCC performance is crucial to the secure operation of the network. Only through delivery of recurring audits will the DNO have confidence that the customer site is maintaining demand within the DSC/TCC limits. Where customer sites do not operate within the conditions of their connection, there is risk of overloading network assets or triggering protection devices, with safety and outage implications for wider users of the electricity system.

Logging measurement data to support auditing. DNO measurement data must be logged within a data historian, which will allow DNO engineers to review SCC performance. This does not require a real-time transfer of data from the field to the historian, as the audits will only take place periodically, or be triggered by an undesired event or observation of undesired network conditions. Sub-1 MVA sites connected to the LV network will be monitored via a half-hourly meter, audited by an internal team at the DNO.

Delivery of SCC performance audits. The DNO will occasionally perform audits of the SCC's performance using the measurement datasets logged in the historian. In the audits, the DNO engineer will review the historical site demand metrics (such as peak half-hourly or daily peak loading) against the DSC/TCC limitations. In the case of a TCC, the half-hourly loading must be compared against the half-hourly demand limitation profile, introducing incremental complexity in the auditing process.

5.2. Customer-Led SCC Solutions: Deployment Architecture

TCC and CLM schemes share the same requirements for implementation, and are therefore presented as sharing a single deployment architecture. The deployment architecture illustrates the interfaces between the components that deliver customer-led SCCs.

5.3. Customer-Led SCC Deployment Architecture

Deployment architecture consists of the components presented in Table 4 (page 40). The architecture is illustrated in Figure 16.

The components are associated with ***ownership*** and ***locational*** boundaries where:

- **Field** components are located at the customer site or on the local distribution network.
- **Enterprise** components are in a centralised location, either hosted on cloud infrastructure (likely in the case of the CPMS), or within central server room infrastructure (likely in the case of the DNO historian).
- Assets within the **DNO** boundary are owned, operated, and maintained by the DNO.
- Assets within the **customer** boundary are owned, operated, and maintained by the customer.

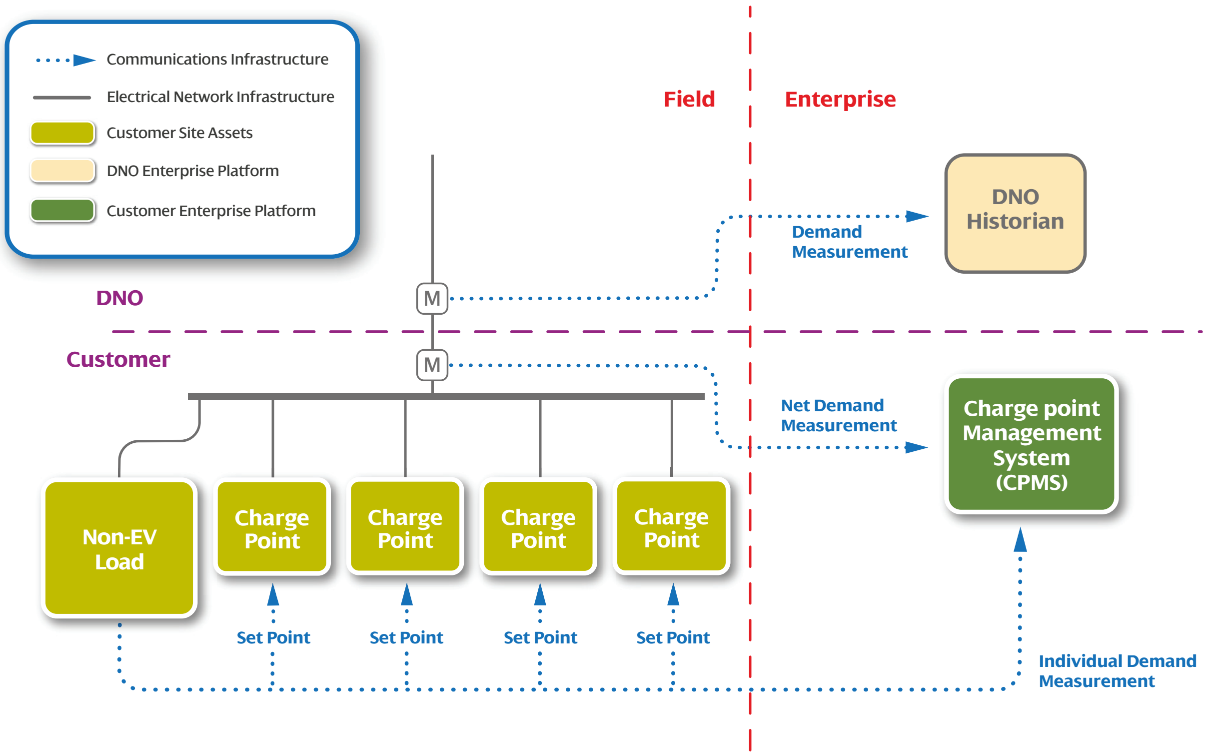

Figure 16: Customer-Led SCC Deployment Architecture

Interfaces between components are summarised in Table 5.

Component	Inputs (Source Location)	Inputs (Dataset)	Outputs (Destination Location)	Outputs (Dataset)
EV Chargepoints	CPMS	Demand Curtailment Set Point	CPMS	chargepoint Demand Measurement
Non-EV Load	-	-	CPMS	Non-EV Demand Measurement
Chargepoint Management System (CPMS)	EV Chargepoints Non-EV Load Site Import Measurement (Customer)	Chargepoint Demand Measurement Non-EV Demand Measurement Customer Site Demand Measurement	EV Chargepoints	Demand Curtailment Set Point
Site Import Measurement (Customer)	-	-	CPMS	Customer Site Demand Measurement
Component	**Inputs (Source Location)**	**Inputs (Dataset)**	**Outputs (Destination Location)**	**Outputs (Dataset)**
Site Import Measurement (Customer)	-	-	Data Historian	DNO Site Demand Measurement
Data Historian	Site Import Measurement (DNO)	DNO Site Demand Measurement	-	-

Table 5: Architecture: Component interfaces

DNO infrastructure consists of site ***import measurement*** device(s) and a ***data historian***. Both are standard DNO assets and do not require additional technology deployment. The existing field communications network will establish the interface between the measurement device(s) and data historian.

At the customer site, the EV chargepoints issue device status and consumption datasets, and during constraint conditions, will receive curtailment set points from the CPMS.

The CPMS is responsible for aggregation of load measurements and coordination of chargepoint curtailment, highlighted in Figure 17. It is noted that whilst the chargepoint coordination function requires visibility of the site-aggregated demand, in order to identify cases when the site is nearing the import limits, it also requires visibility of the individual status and demand at each EV chargepoint to allow coordination of sufficient chargepoint curtailment to avoid constraint conditions.

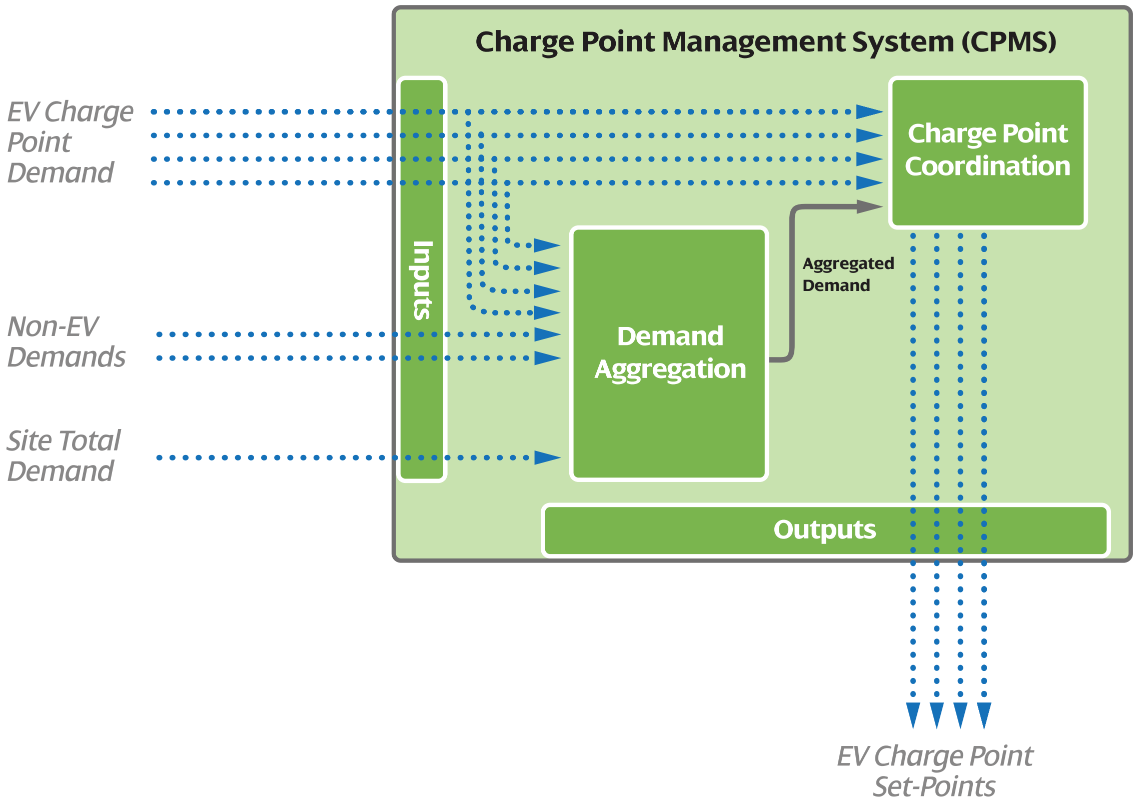

Figure 17: Chargepoint Management System Interfaces and Functions

5.3.1. Communications Infrastructure

The communications infrastructure ensures the data can be exchanged between components, described in the following sections.

5.3.1.1. Customer Communications Infrastructure

Customer-side communication infrastructure is not specified by the DNO, but must have performance levels sufficient to ensure the requirements detailed in Section 5.1.2 are met.

Communications between chargepoint devices and the CPMS will often use Open Charge Point Protocol (OCPP), an application protocol for communication between EV chargepoints and their centrally located control/management systems.

5.3.1.2. DNO Communications Infrastructure

At the DNO, the communication infrastructure requires one-way exchange of information from field-monitoring devices to the data historian, and for larger sites, to the control room via the distribution management system (DMS).

The information exchanged across this interface is not utilised within a control loop, so the communication link is not time critical. It is anticipated that data exchange across the communications link will utilise a DNO-standard protocol such as DNP3.

6. DNO-Led SCC Implementation

DNO-led SCCs are delivered in two formats:

- **LMC schemes:** deployed where the chargepoint site load is only constrained by a single capacity pinch point on the network. It consists of a field-based control solution.
- **CMC schemes:** deployed where the chargepoint site load is constrained by multiple capacity pinch points on the network, or where multiple chargepoint sites are under simultaneous control. This solution consists of a centrally located DNO control solution that communicates with multiple field devices.

Each DNO-led SCC solution provides the monitoring and control capability that allows EV chargepoint sites to achieve a connection with capacity above the traditional ***firm*** network capacity. The capacity available to the EV chargepoint site varies in real time, reflecting the network loading conditions. Of all SCC types, DNO-led SCCs provide the greatest level of capacity to EV chargepoint customers.

The following sections present the design of DNO-led SCCs, detailing the solution components, control philosophy, implementation architecture, and considerations for BAU roll-out.

6.1. DNO-Led SCC Design

This section describes the design features of Smarter Grid Solutions' DERMS solution, which is being deployed to demonstrate DNO-led SCCs as part of the Charge Project.

6.1.1. DNO-Led SCC Solutions: Components

The components required to deliver DNO-led SCCs are presented in Table 6. Note that the ***central DERMS*** platform is only deployed in the CMC scheme case.

Component Name	Owner	Description
EV Chargepoints	Customer	Individual chargepoint located at the customer site. Units may vary in kW rating at a single site.
Non-EV Load	Customer	Loads at the customer site that are not associated with EV charging.
Chargepoint Management System (CPMS)	Customer	Control system responsible for coordination of EV chargepoint energy consumption. Receives import measurements and issues control signals to EV chargepoints in real time when curtailment required.
Site Import Measurement (Customer)	Customer	Monitoring device responsible for real-time measure-ment of energy consumption across the full customer site.
Site Import Measurement	DNO	Monitoring device located at the DNO meter, providing real-time measurement of site demand.
Data Historian	DNO	DNO historian responsible for logging measurements of demand at the customer site. Used for auditing purposes to ensure connection conditions are being met.
Field DERMS Controller	DNO	DNO DERMS controller, located either in a field substation or on the DNO side of the meter at the EV CPO site.

Component Name	Owner	Description
Central DERMS	**DNO**	DERMS platform controllers, hosted on server infrastructure at a central DNO IT location. Sits as part of the operational technology (OT) infrastructure. Responsible for calculation and issue of EV CPO SCC set points and delivery to CPMS.
Measurement Point	**DNO**	DNO field-monitoring infrastructure, providing real-time measurement of the network parameter, such as voltage or power flow.
Distribution Management System (DMS)	**DNO**	DNO system providing oversight of wider system operation and asset status. The DMS provides the UI that is used by control room engineers to supervise and manage network operation.

Table 6: DNO-Led SCC Components

6.1.1.1. DERMS System Components

The key components of the DERMS system that delivers the DNO-led SCC functionality are:

- Central DERMS platform: The enterprise DERMS platform that delivers multiple network control functions, centrally located at a DNO IT infrastructure site.
- Field DERMS controller: The field controller that delivers local monitoring and control functions, located at the CPO site (DNO side of the meter) or a substation local to the CPO site.

The following sections describe these components in further detail.

6.1.1.1.1. Central DERMS Platform

The central DERMS platform is hosted on dual-redundant servers, allowing 'hot-standby' automatic fail-over in the event of a server outage. This ensures continuity of SCC service delivery during equipment outage events.

The central DERMS platform delivers the SCC monitoring and control functions for the CMC scheme cases of DNO-led SCC deployment. The following functions are delivered by the central DERMS platform:

- Real-time control algorithm
- Custom logic pre-processor
- Dispatch application

Real-time control algorithm. The real-time control algorithm manages multiple power flow or voltage flow constraints on the DNO network through control of the EV chargepoint loads, via the CPO CPMS. The control algorithm utilises measurement points to monitor the constraints and derives real-time set-point control actions when predefined thresholds are exceeded at a measurement point (MP). The real-time set-point control consists of a single aggregated chargepoint demand set-point value that defines the total combined load available to the CPO site.

Custom logic pre-processor. The pre-processor is a software application that provides an engine for performing custom logic on the DERMS system. This allows the specification of bespoke SCC control functions within the DERMS platform, above and beyond the standard SCC functionality delivered in the real-time control algorithm.

Dispatch application. The dispatch application creates set-point requests for the demand at a CPO site based on predefined schedules or user-specified set points. The dispatch application does not use an algorithm to calculate the set points and is not based on real-time measurements. This allows intervention from control room engineers to establish manual set points for CPO sites to follow.

6.1.1.1.2. Field DERMS Controller

The field DERMS controller is located on the DNO side of the meter at the customer site. The controller consists of an RTU, ancillary I/O and uninterruptable power supply (UPS) equipment that is housed in a wall-mountable, sheet-steel secure enclosure.

The functions delivered by the field DERMS controller include:

- Monitoring the CPO site load
- Fail-safe and non-response actions
- Local MP constraint management

Monitoring CPO site load. The field DERMS controller interfaces with a DNO-side measurement device at the CPO site point of connection (PoC). This measurement provides real-time visibility of demand at the CPO site. Whilst CPO site-demand measurements can also be provided directly from the CPO CPMS, the receipt of direct measurement to the field DERMS controller provides confidence in measurement validity, as it is from an auditable DNO asset.

In situations when direct control of the CPO is required, the field DERMS controller will be deployed.

Fail-safe and non-response actions. For CMC deployments, the field DERMS controller provides fail-safe control in the event of communications loss between the field DERMS controller and the central DERMS platform. During a communications outage with the central DERMS platform, the field DERMS will move into a fail-safe state that issues a safe set point to the CPO.

Under both CMC and LMC deployments, the field DERMS controller can respond to events when the CPO CPMS fails to respond to a demand set point within a sufficient period. Under such non-response events, the field DERMS controller will take a further escalated action to disconnect the EV chargepoint site via the circuit breaker at the customer meter. This local control action ensures that regardless of the status of communications links between the CPO site and central DERMS platform, there is functionality to deliver local control and maintain network security.

Local MP constraint management. In the case of LMC schemes, the local DERMS infrastructure can host the real-time constraint management algorithm. Through direct communication with a network MP at a constraint pinch point, the local DERMS controller identifies necessary control actions and issues set points to the CPMS. The local constraint management functionality delivered in LMC schemes allows for delivery of SCC functionality without the complexity of integration with a central DERMS platform.

6.1.2. DNO-Led SCCs: DERMS Control Philosophy

The Smarter Grid Solutions DERMS control philosophy applied to SCCs follows similar concepts to other demonstrated approaches to network constraint management. The following section describes the key components of the DNO-led SCC control philosophy:

- Observing network status: ***measurement points***
- Identifying appropriate control actions: the ***algorithm calculation engine***

6.1.2.1. Measurement Points

The measurement point state machines are responsible for monitoring current, voltage or power measurements and issuing control requests to either resolve a breach of a defined threshold or allow a CPO site to release to its preferred set points after resolving a breach.

Figure 18 illustrates a set of thresholds that could be configured within the state machine. These thresholds correspond to measured current, power or voltage at a specific monitoring location on an electrical power network.

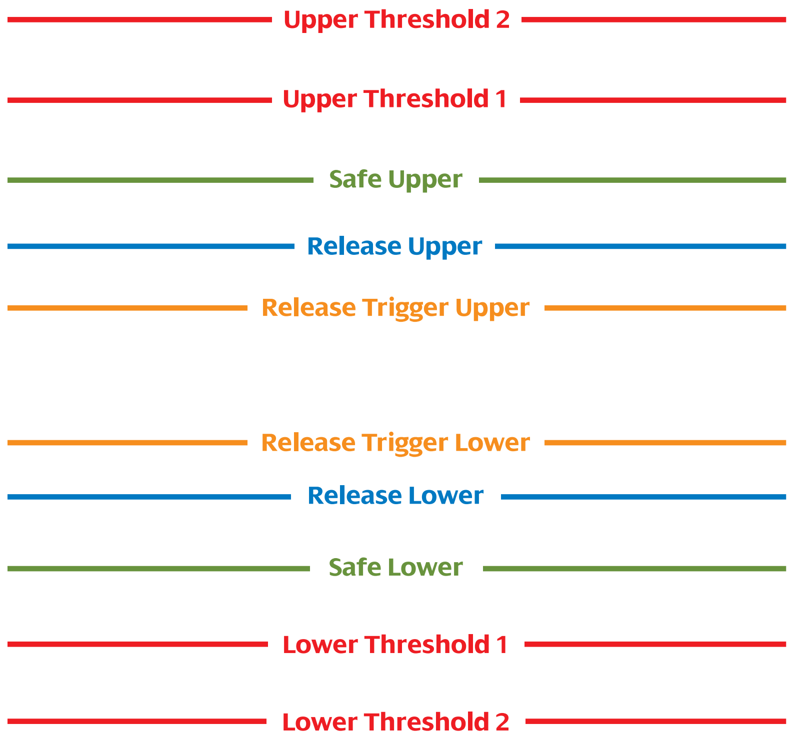

Figure 18: Thresholds

6.1.2.1.1. Upper and Lower Thresholds

The red ***upper*** and ***lower*** thresholds correspond to physical limitations on the operation of the power network. ***Upper*** thresholds are levels that the monitored value should not exceed, and ***lower*** thresholds are levels that the monitored value should not fall below. An example of thresholds on a real system is power flow constraints, in which upper thresholds are used to control export limits at the constraint location, while lower thresholds control import limits.

6.1.2.1.2. Releasing

When there are no thresholds attempting to regulate the measured value, the MP issues requests to the control algorithm to allow CPO sites to move back towards their preferred set points, while keeping the measured value within safe limits.

The release process is initiated when there are no thresholds actively regulating the measured value and the measured value is within the ***release trigger zone***, identified by its lower and upper limits on the diagram. The release process always involves issuing a control request that is bidirectional (i.e., 'the measured value may move up by X or down by Y'). The amount of release in each direction is also constrained by a ***ramp value***, which ensures that CPO sites are released in a controlled manner.

As with the regulating process, the release process repeats at configured time intervals until the measured value is detected to be outside the ***release zone***, identified by its upper and lower limits on the diagram. The release process is restarted when the measured value falls within the ***release trigger zone***. The dead band between the limits of the two release zones avoids continuous regulate and release cycles.

6.1.2.2. Algorithm Calculation Engine

The algorithm calculation engine is responsible for satisfying requests issued by MPs and allocating control actions to the corresponding CPO sites to solve the constraint at the MP based on the principles of access (PoA). A constraint can be caused by either thermal or voltage limits.

The following control actions passed to this engine tell the algorithm which actions should be used to solve a specific constraint. Each of these actions are associated with a distinct calculation by the algorithm calculation engine.

- **Trip:** Trip a circuit breaker if the CPO site has one. This is an indiscriminate trip, and the algorithm cannot determine the effect that the trip has had on the measured value at the constraint until the response time has elapsed.
- **Smart Trip:** Trip a circuit breaker at the CPO that provides measurement data. This operation can use the measured value at the device to determine the anticipated effect that the trip operation will have at the constraint location. This allows a set of actions to be defined that only trip the appropriate number of devices to resolve the constraint, and no more.

- **Close:** Close a circuit breaker if it has been tripped.
- **Power Control:** Modify the power set point of a device by:
  - o Regulating for upper or lower thresholds
  - o Releasing devices back to their preferred set points

The algorithm calculation engine is responsible for determining how many of these actions are required to achieve the target being set by the MP and the exact set points that need to be issued for each action.

6.1.3. DNO-Led SCC Solutions: Deployment Architecture

CMC and LMC schemes present distinct approaches to the delivery of SCCs and are therefore presented as distinct deployment architectures. The deployment architecture illustrates the interfaces between the components that deliver DNO-led SCCs.

When presenting the deployment architectures, components are associated with ***ownership*** and ***locational*** boundaries, where:

- **Field** components are located at the customer site or on the local distribution network
- **Enterprise** components are in a centralised location, either hosted on cloud infrastructure (likely in the case of the CPMS), or within central server room infrastructure (likely in the case of the DNO historian)
- Assets within the **DNO** boundary are owned, operated, and maintained by the DNO
- Assets within the **customer** boundary are owned, operated, and maintained by the customer

6.1.3.1. CMC Deployment Architecture

The CMC scheme deployment architecture consists of the components presented in Table 4. The architecture is illustrated in Figure 19.

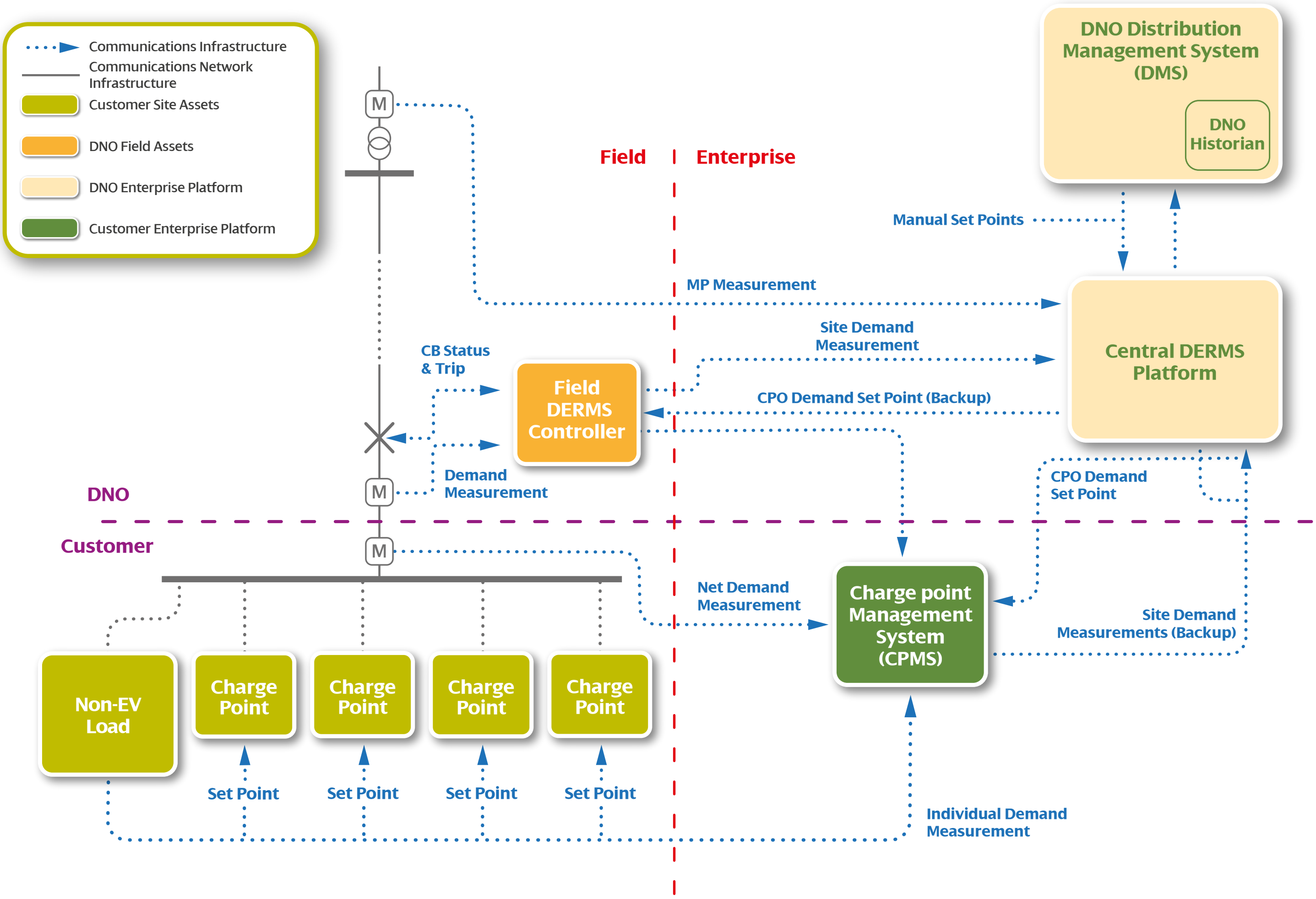

Figure 19: DNO-Led SCC Deployment Architecture (CMC)

6.1.3.2. LMC Deployment Architecture

The LMC scheme deployment architecture consists of a subset of the components presented in Table 4. The architecture is illustrated in Figure 20.

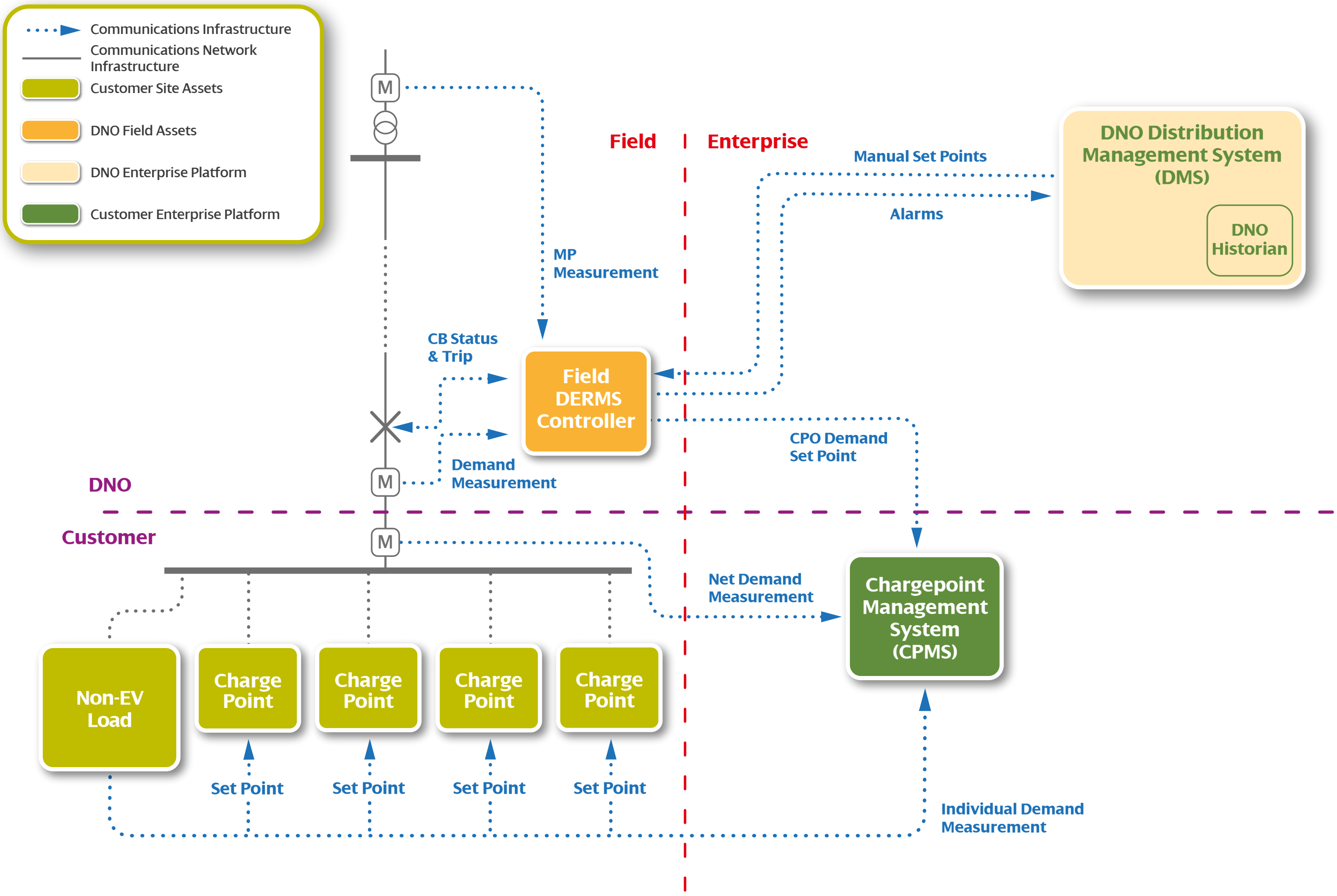

Figure 20: DNO-Led SCC Deployment Architecture (LMC)

6.1.4. BAU Delivery for SPEN

Future Charge Project deployments to the SPEN network will be made using the centralised ANM system. This is a Strata deployment on a standard SPEN operating system build. The system has completed external penetration testing, and the delivery process has completed the failure mode effects analysis (FMEA).

As far as possible, external data will be gathered using the same systems and processes that SPEN currently uses for BAU systems. If new processes or methods are required, these changes will be subject to SPEN governance, for any cybersecurity impacts. We expect that communication of set points to CPOs will require the most scrutiny, and that this will use an agreed secure API. It will be reviewed once there are operational sites.

6.1.5. BAU Delivery for Other DNO Environments

If a DNO plans to deploy a DNO-led solutions, and that deployment does not have existing infrastructure, the system to support it will require the ability to read measurement points for constraints to manage charging operations against them.

This could be achieved with a central system, systems in the field, or a combination of both.