System description Smart Charging in Practice



Version	Changed by	Changed at	Change
C0.1	Lennart Verheijen	25-03-2013	Eerste opzet
C0.2	Hans de Boer	10-04-2013	Referentie Architectuur
C0.3	Hans de Boer	24-04-2013	Referentie Architectuur
C0.4	Paul Klapwijk	21-05-2013	Plaatjes toegevoegd, opmaak aangepast
C0.5	Paul Klapwijk	24-05-2013	Plaatjes gecorrigeerd, opmaak aangepast
C0.6	Lennart Verheijen	18-06-2013	Teksten in lijn gebracht met laatste inzichten
C0.7	Lennart Verheijen	17-01-2014	Translated document to English and added some content

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1. Goal Description

The purpose of this document is to give a description of the environment in which smart charging can take place (Section 2 and 4) and to elaborate on the reference architecture on which the Open Smart Charging Protocol was based (Section 3).

2. Market model

2.1 Current market

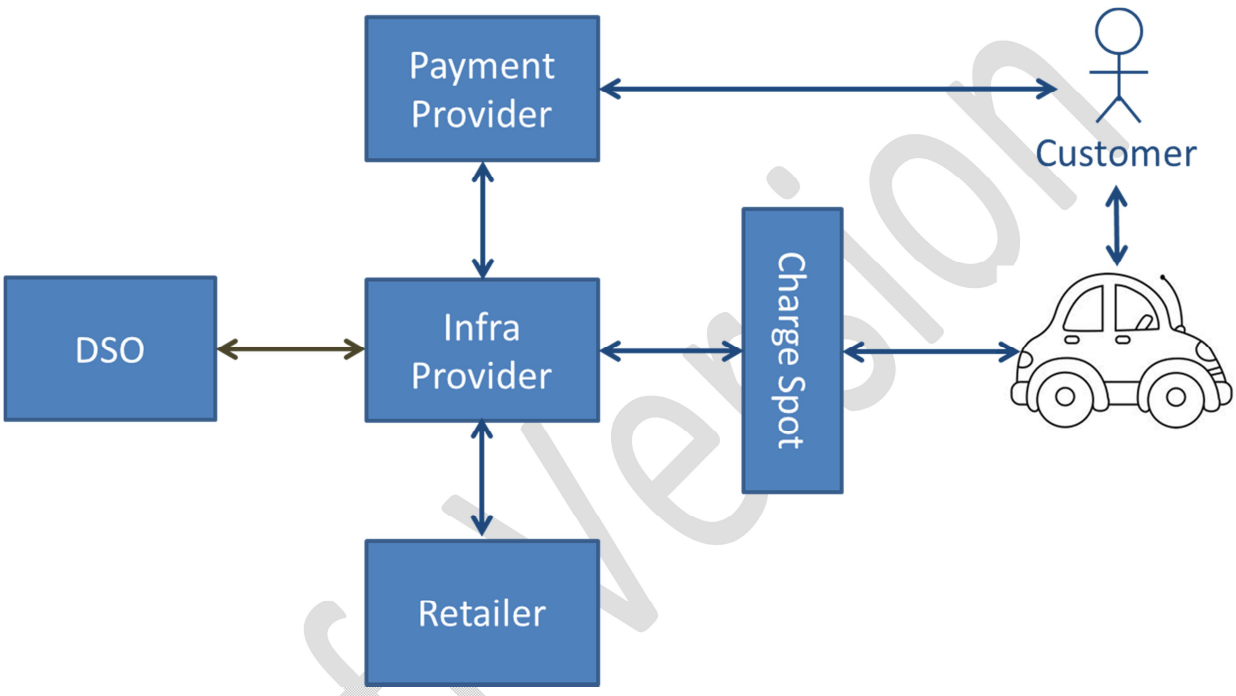


Figure 1. Simplified version of the current market model

In the current market model there are several roles that play a part in the charging process of the electric vehicle

Infra Provider (IP)
The IP is the party that manages the charge spot and also the back office of the charge spot. In the current market model the infra provider is also the party that owns the grid connection and thus pays for the energy. If smart charging is applied the IP is the party that needs to send control signals to the charge spot in order to execute smart charging.

Payment Provider
The Payment Provider is the party with which the EV-driver has a contract. This party takes care of all the processes necessary for the driver to be able to charge. The driver only needs to have a contract with the payment provider, all payments go through this party. The payment provider also takes care of interoperability: the driver can charge at any charge spot. If the payment provider has specific SLA's with the infra provider hey could also make offers to the driver about potential benefits if the driver is willing to be smart charged.

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Distribution System Operator (DSO)
The DSO manages the distribution network and has the interest of not overloading the (local) grid. In order to do this the DSO sends a (time varying) capacity forecast to the Infra Provider, thus informing the IP about the available capacity per 15 minutes for charging EVs for the next 24 hours (or other quantities, this is up to configuration).
The IP needs to respect this forecasts, otherwise the breaker will be overloaded and all power on the cable is lost. The alternative is of course that the DSO lays more or thicker electricity cables into the ground but this is a very costly operation. If on one cable more infra operators are active the DSO can also make an FRAND division of the available capacity over the different operators.

Retailer
The retailer supplies the electricity to the charge spot and sends the invoice to the IP. It is possible that the prices for electricity are not constant but vary over time (might even be different every 15 minutes). This could be one of the incentives for smart charging. The role of retailer might also be fulfilled by local energy cooperations.

2.2 Potential future market

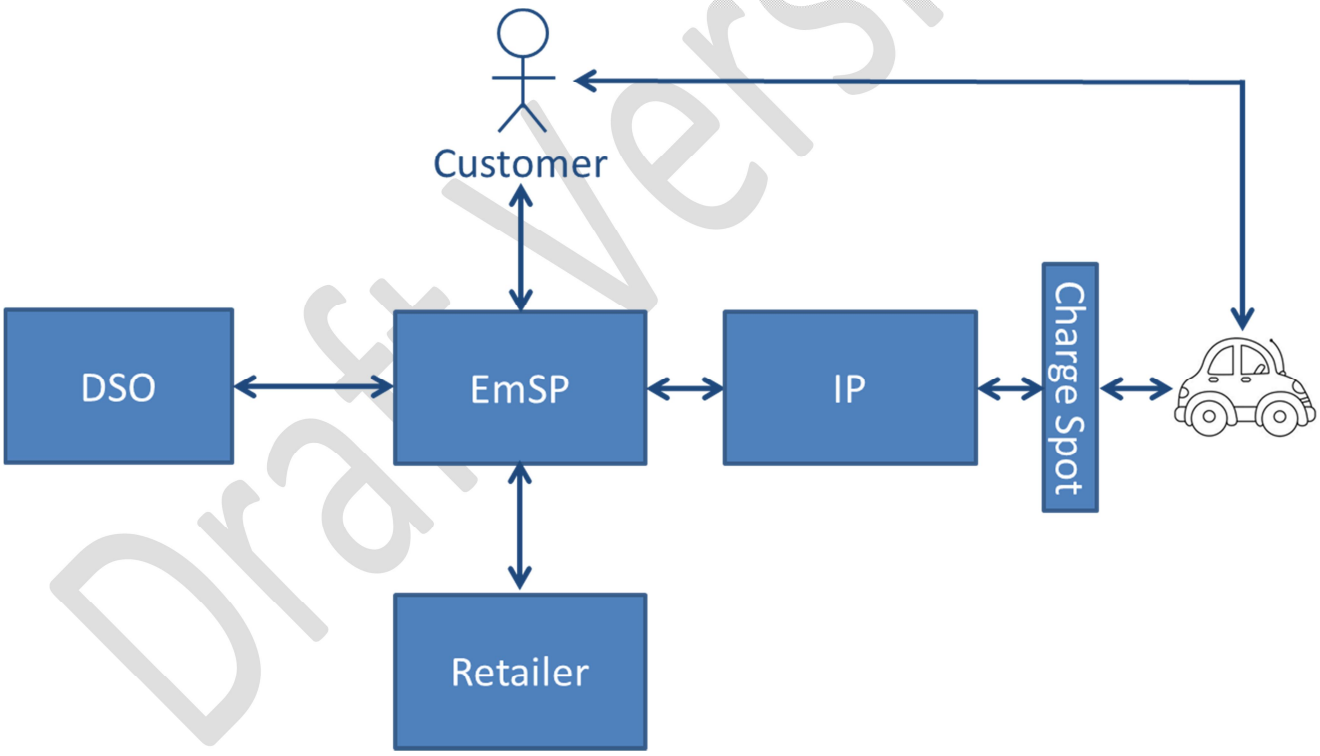


Figure 2. Potential future market model which includes logical allocation

In the current market the party who owns the grid connection is the one that pays for the electricity. There are certain developments at DSO level to change that and not make the owner of the grid connection pay (solely) for the consumed electricity but the one that actually uses this electricity. This is the basic principle behind logical allocation.
This would yield a different market model as shown in Figure 2 (simplified version). This would imply some changes for the roles in this picture

Distribution System Operator (DSO)
Role does not change compared to Figure 1

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E-mobility Service Provider (EmSP)
This is basically the new role of the payment provider. However, where in Figure 1 the E-mobility Service Provider could not do much more than administrative functions, it is now in the centre of the smart grid. It can communicate with the DSO about limits of the available capacity and perhaps also bout financial incentives. It can also do smart charging based on dynamic prices from the retailer. Since the EmSP is now the one paying for the electricity it is suddenly much less dependent on the infra provider and can offer more interesting/flexible SLA's to the customer. It can also incorporate the customers preferences like time of departure.

Infra Provider (IP)
The IP will still need to have an energy contract for the charge spot's own consumption (and to be able to cope with possible (rounding) errors in the logical allocation). For the rest the IP does the technical maintenance of the charge spot and installs new charge spots. It needs to have a backoffice to execute the smart charging commands received by the EmSP and it will probably charge the EmSP an installation fee for each charge session.

Retailer
In principle the role does not change. However, since due to logical allocation all consumption from all customers of the EmSP is summed together, the retailer now has one very large contract with the EmSP instead of many small contracts with the IP. This is interesting because buying in large quantities is cheaper, it becomes easier to predict the consumption and there might even be a tax benefit. Furthermore, smart charging becomes very interesting since in such large quantities there suddenly is a lot of value in flexibility for the retailer.

3. Reference architecture

The purpose of a reference architecture is the give an abstract description of smart charging as part of the standard EV installation and charge infrastructure, now and in the future. In this reference architecture:

- there are no initial limitations or restrictions for making realistic implementation choices, both in hardware, software and protocols.
- we focus on essential functional building blocks: the necessary core functionalities, the division between these functionalities and the primary functional information exchange.

We distinguish three different installation environments:

- dedicated grid connection, at which one or several charge spots are connected. This is the environment which is used for nearly all public charge spots, most 3-phase chargers at home, the larger semi-public charge stations (e.g. at diners along the highway) and sometimes for larger charge stations at offices.
- Home connection. Standard 1x35A, 1x40A or 3x25A at which a single (sometimes dual) type 2 mode 3 charge spot of 1x16A, 3x16A or 1x32A is connected.
- Office connections larger than 3x35A, at which multiple type 2 mode 3 charge spots of 1x16A, 3x16A, 1x32A or 3x32A are connected.

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Contrary to the market models in Section 2, the reference architecture makes no distinction in which role has what functionalities. The focus is on the smart charging functionality, which enables setting the charging speed. The reference architecture gives a functional, technical approach, which can support multiple market models.

In all installation environments the billing must be possible by both the owner of the grid connection as by the EmSP. A company could for instance wish to pay for the charge sessions at an employee's home. A home-owner can have good reasons to have his visitors pay for their own (possibly large) consumption through their EmSP.

In fact we don't know what the electric 'petrol' station of the future will look like, whether there will be a lot of home charging of whether there will be concentrated charge stations. It seems a logical assumption that batteries become cheaper and that their capacity will increase. Large scale utilization of EVs could very well also mean faster charging, which could in turn increase the number of dedicated grid connections with variable capacity. The reference architecture needs to be sufficiently abstract to support most developments.

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3.1 Schematic overview

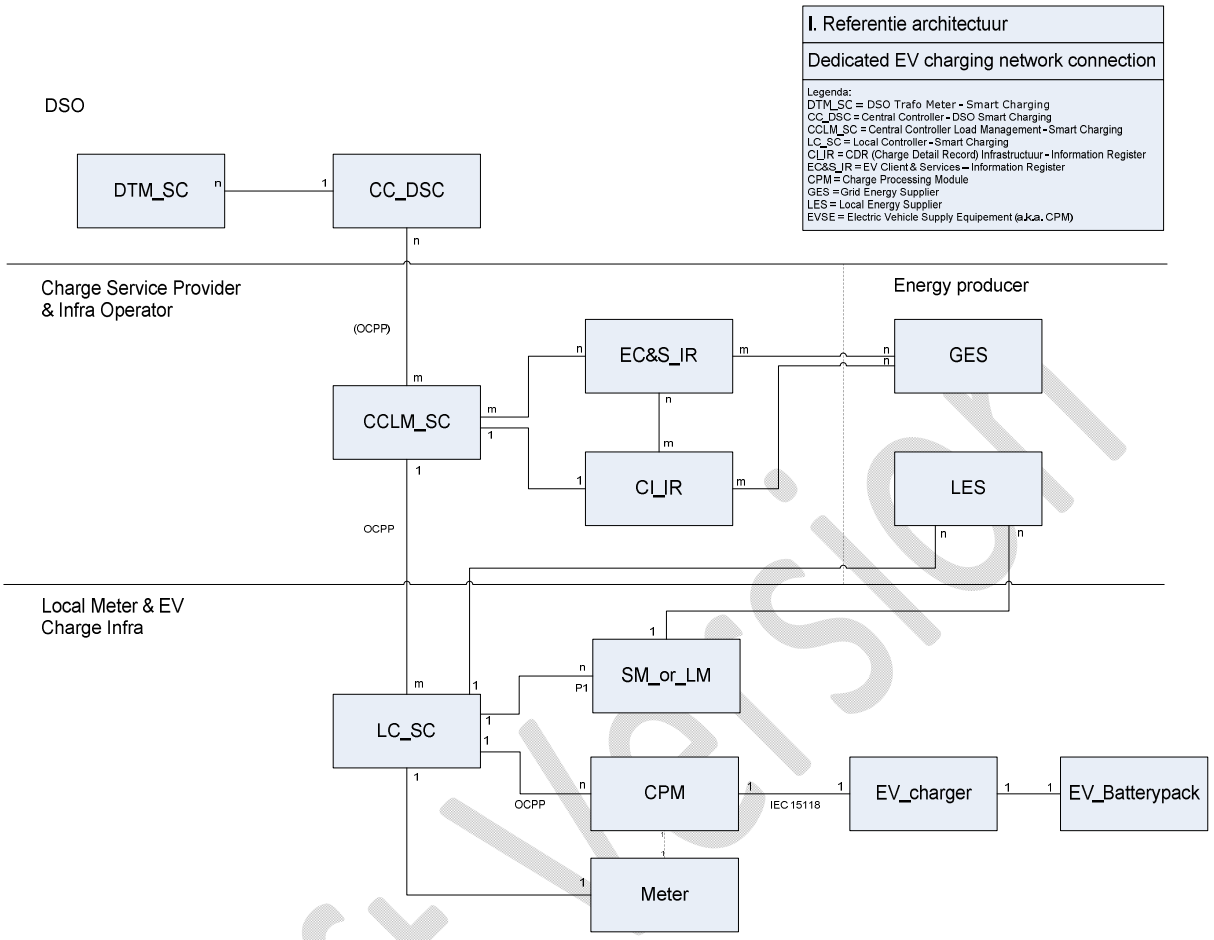


Figure 3. Reference architecture

DTM_SC stands for DSO Transformer Meter - Smart Charging. The DTM_SC contains the following functionalities:

- Measures the electricity consumption at the transformer station and all connected LS-cables (measures multiple quantities, like U, I, cos(φ), kVAh, etc.)
- Communicates with the CC_DSC about the electricity measurements and detects when communication with CC_DSC is no longer possible.

CC_DSC stands for Central Controller - DSO Smart Charging. The CC_DSC contains the following functionalities:

- Knows the maximum capacity of the grid connection of each LC_SC (part of provisioning process of the LC_SC)
- Knows and communicates with all CCLM_SCs or detects that communication with CCLM_CS is no longer possible
- Knows the maximum capacity of each DSO Transformer and every LV-cable of each DTM_SC (part of provisioning process of the DTM_SC)
- Knows the topology of the network (knows which LC_SC belongs to which CCLM_SC, DTM_SC and which LV-cable). (part of provisioning process)
- Knows and communicates with all DTM_SCs about the status of the capacity-consumption (of the DSO transformer station and all connected LV-cables) or detects that communication with a DTM_SC is not possible.

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- Knows and communicates with CCLM_SC about the active charge capacity (in A or kW) with respect to the network topology or detects that communication with a CCLM_SC is not possible.
- Gets input about weather information (this line is not part of the reference architecture) and calculates the local production based on this input.
- Can send the CCLM_SCs a (time-varying) periodic forecast of the maximum available charge capacity (in A or kW) for the coming 24 hours in blocks of 15 minutes.
- Autonomously calculates, based on all available information, whether or not the capacity forecast needs to be updated and can, if needed, send a new capacity forecast to the CCLM_SCs.
- The CCLM_SCs can also request an updated capacity forecast (which the CC_DSC will provide)

CCLM_SC stands for Central Controller Load Management - Smart Charging. The CCLM_SC contains the following functionalities:

- Knows the maximum capacity of the grid connection of each LC_SC (part of the provisioning process of the LC_SC)
- Knows and communicates with all LC_SCs or detects that communication with a LC_SC is not possible.
- Receives a capacity forecast from the DTM_SC for each LV-cable.
- Knows the topology of the network (knows which LC_SC belongs to which DTM_SC and which LV-cable). (part of the provisioning process)
- Knows and communicates with all CC_DSCs about the status of the capacity-consumption of each LC_SC or detects that communication with a DTM_SC is not possible.
- Measures the active electricity consumption (in kWh) via the LC_SC
- Can instruct the LC_SCs to change the charging capacity with x (A or kW)
- Autonomously calculates, based on all available information, whether or not the charge rate should be altered and translates this into instructions for the LC_SCs.

LC_SC stands for Local Controller - Smart Charging (usually, but not necessarily, placed inside the charge spot). The LC_SC contains the following functionalities:

- Knows (from the CCLM_SC) the maximum capacity of the grid connection (part of provisioning process)
- Knows and communicates with all CP Modules (part of provisioning process)
- Knows via the CP Modules at which charge points are active and which ones aren't
- Measures for each charge spot, via the kWh-meter, the charge rate and the duration of each active charge session for all charge spots
- Can order the CP modules to alter the maximum charge current to the EV (higher or lower)
- Receives instructions from the CCLM_SC to alter the maximum charge current with x (A or kW)
- Can detect whether the communication with the CCLM_SC is active or lost
- Remembers future charge instructions from the CCLM_SC in order to be able to execute those when the connection with the CCLM_SC is lost
- Can, in case of no connection with the CCLM_SC, autonomously calculate whether or not the charge rate should be altered and translates this into instructions to the CP modules.

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CI_IR stands for CDR (Charge Detail Record) Infrastructure - Information Register. The CI_IR contains the following functionalities:

- Produces CDRs based on charge-information (conform the agreed upon format in The Netherlands) en enriches this information with Smart Charging Detail Records (SCDR) from the CCLM_SC
- Registers the CDRs after they have been produced

EC&S_IR stands for EV Client & Services – Information Register. The EC&S_IR containes the following functionalities:

- Registers the services and data of every customer
- If applicable in the agreed upon market model, the EC&S_IR exchanges information about the customer and his energy supplier to the CCLM_SC of the Infra Provider where the customer wants to charge

CPM stands for Charge Processing Module. The CP Module is an already existing and specified entity with the following functionalities:

- Knows the maximum capacity in Amps and the number of phases which the charge spot can utilize. These values can be altered by instructions coming from the LC_SC
- Communicates with the charger in the EV based on the mode 3 protocol

GES stands for Grid Energy Supplier. The GES is the energy supplier that has an energy contract with the owner of the grid connection or, depending on the market model (see Figure 2), directly with the E-mobility Service Provider. The GES has the following functionalities:

- Manages all price information of all its energy contract parties
- Knows the energy contract party. Generally this is the owner of the grid connection. If this is not the case, then there will first be established a control-connection between the CCLM_SC and EC&S_IR, in order to enable publishing price information as input for smart charging, with permission of the end-customer.

LES stands for Local Energy Supplier. The LES might be a PV-installation on the roof of the building in which the EV charge infrastructure is installed.

In the Appendix some of the main processes of the above mentioned functionalities are described (no activity, start charging & stop charging).

3.3 Time division

The easiest way to do dynamic allocation of capacity is by using 'Time Division'. This can be done by dividing capacity into blocks of 15 minutes and 16A. These blocks can be divided dynamically over the CCLM_SCs by the CC_DSC. Every Infra Provider (or E-mobility Service Provider) can dynamically allocate capacity to the EVs that want to charge based on this division. This last allocation might be done with a different granularity (e.g. 5 minutes per block).
The signal from the CCLM_SC to the LC_SC could be more flexible than 16A blocks. An EV can charge with 0A but charging currents between 0 and 6A are not possible (due to

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configurations in the PWM-signal that the mode 3 protocol uses). For charge currents higher than 6A the charge current can have a precision of 10mA.
The assumption is that in general EVs will charge with the maximum current that is set on the CPM by the LC_SC, but this is not necessarily the case. Within the given maximum current the EV can follow its own charge plan (when EVs would have this functionality in the future or for instance when the EV is nearly fully charged).

N.B.: The mode 3 protocol does not support to dictate to the EV how many phases can be used for charging. It is only possible to give the CPM a maximum current, this maximum will hold for all three phases.

4. Use cases

This section gives a short description of the three use cases which can be supported within the given reference architecture of Section 3.

4.1 Dedicated grid connection

One or several charge spots are connected to a dedicated grid connection. This is the environment which is used for nearly all public charge spots, most 3-phase chargers at home, the larger semi-public charge stations (e.g. at diners along the highway) and sometimes for larger charge stations at offices.

The benefit of this environment is that there is no other energy consumption besides the charge spots on the grid connection, so most of the time there is no need for complicated measurements and the available capacity for EVs is always the same.
This is however not the case in every situation, as is shown in Figure 4 (the values in this Figure are an example). In this figure there is a dedicated grid connection for EVs, but the sum of all grid connections exceeds the total capacity of the transformer, so there might be situations in which even the dedicated connection does not provide a stable capacity forecast.

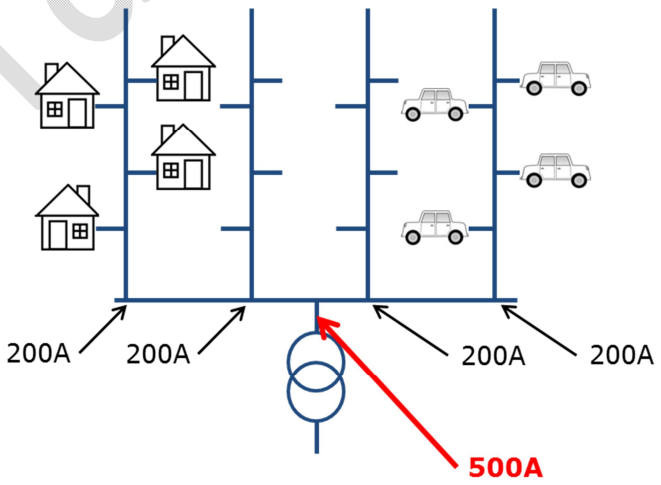


Figure 4. Example of a dedicated grid connection for EV which might not always be fully available

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4.2 Charging at home

In this situation the EV is connected to a home charger (Figure 5). As in Section 4.1 the sum of the capacity of the different groups exceeds the grid connection. This could mean that smart charging is used to decrease the EV's charge rate when for instance the microwave is switched on. It could also mean that the charge rate is increased once solar panels start producing energy.

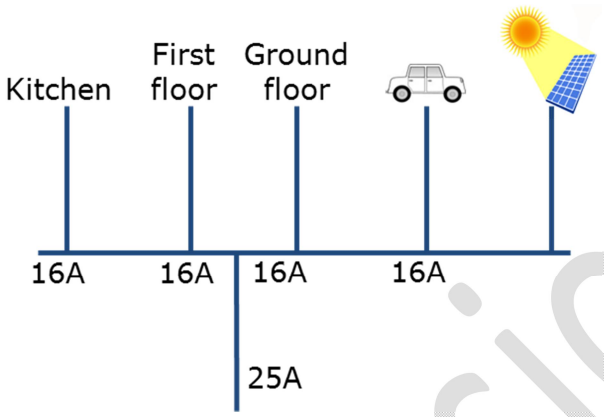


Figure 5. EV charging at home

4.3 Office charging

Office charging is basically the same as charging at home, except that there instead of one EV there are several.

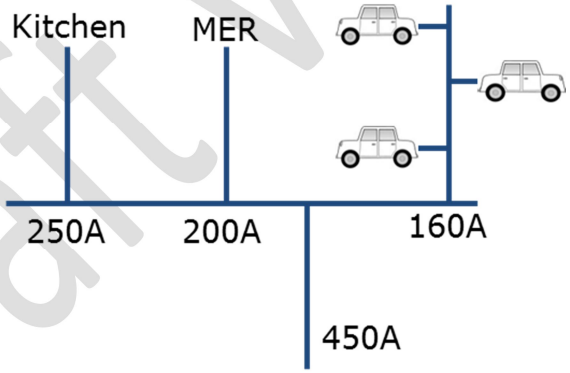
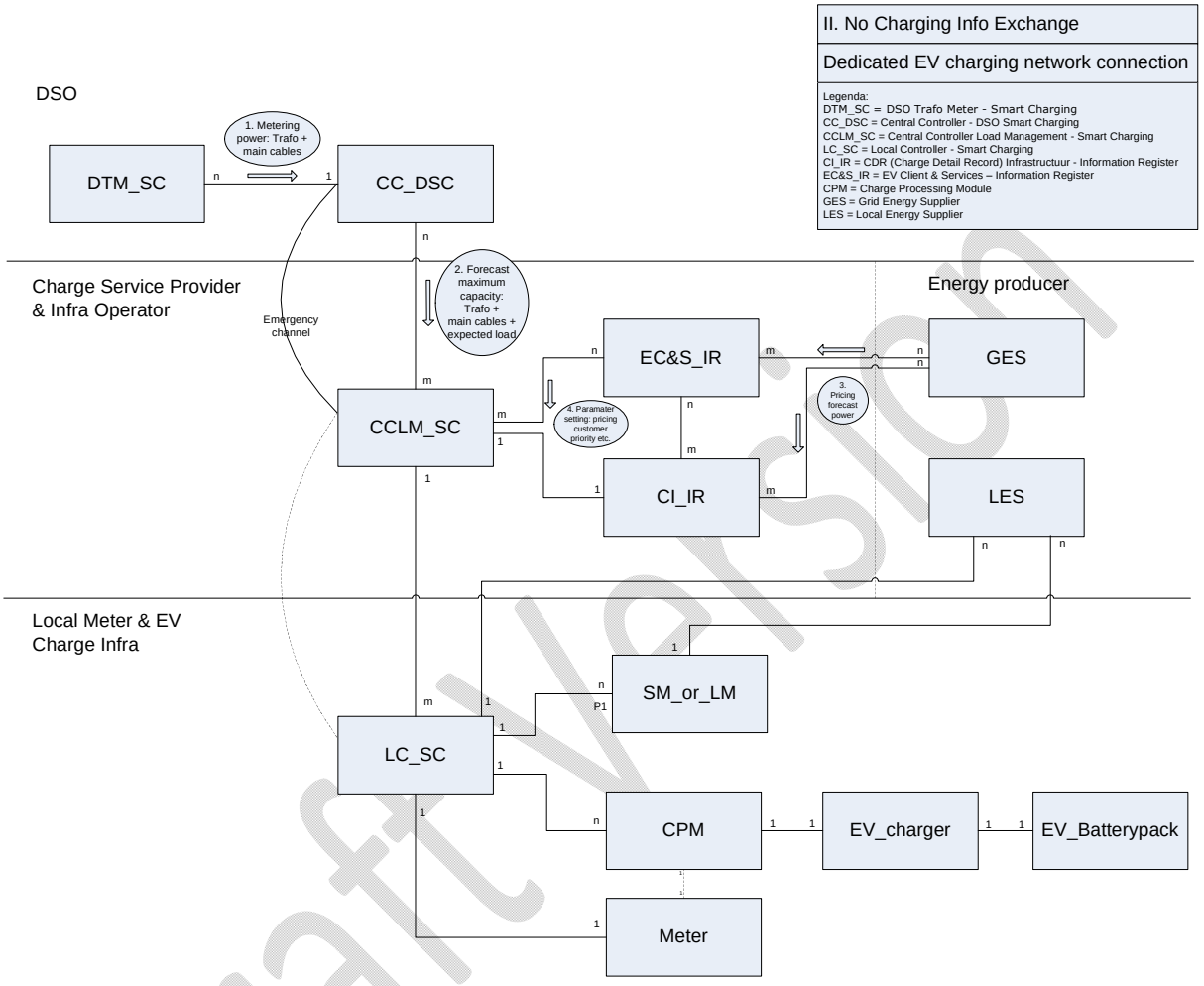


Figure 6. EV charging at the office

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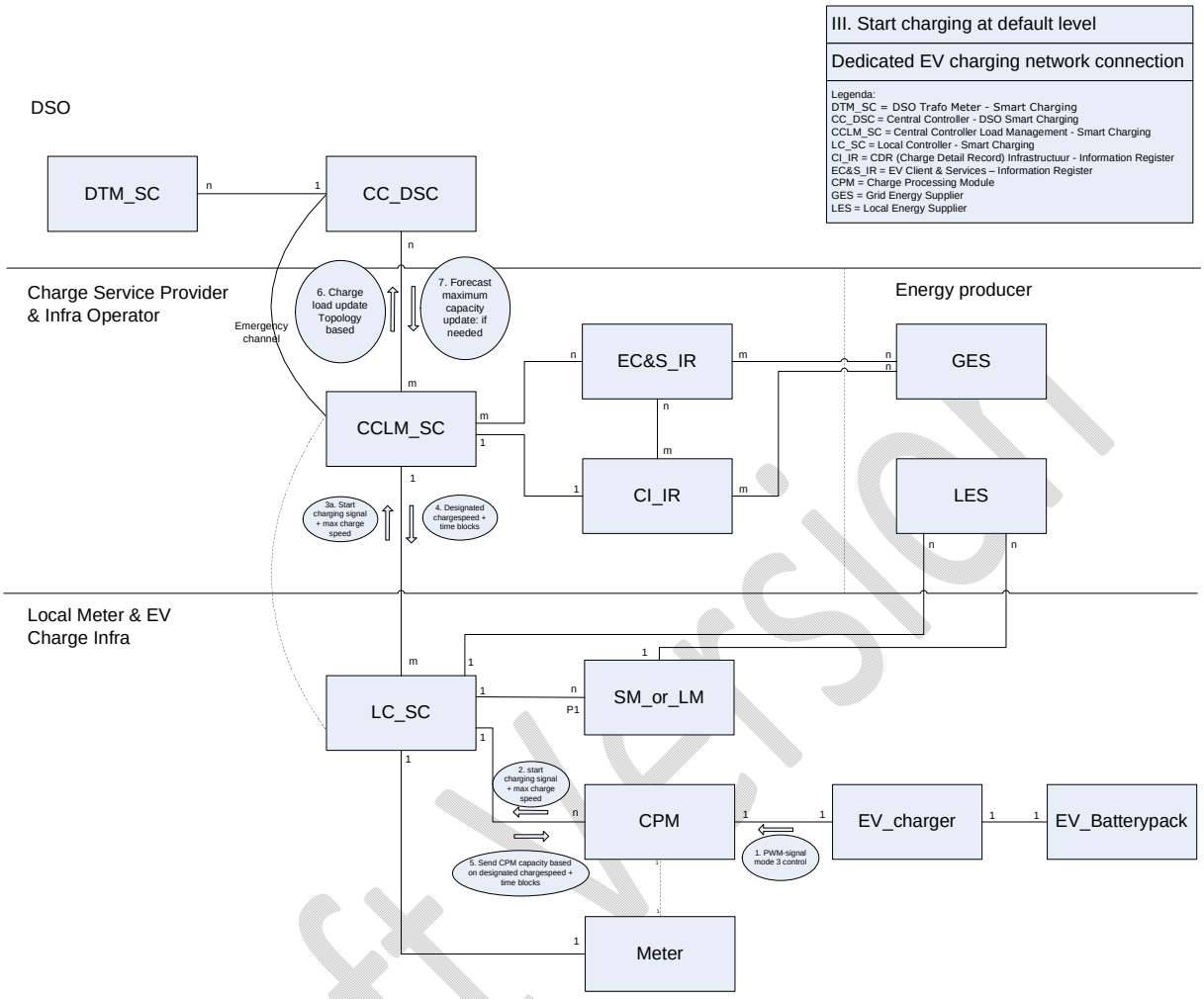
Appendix A

No Charging info exchange



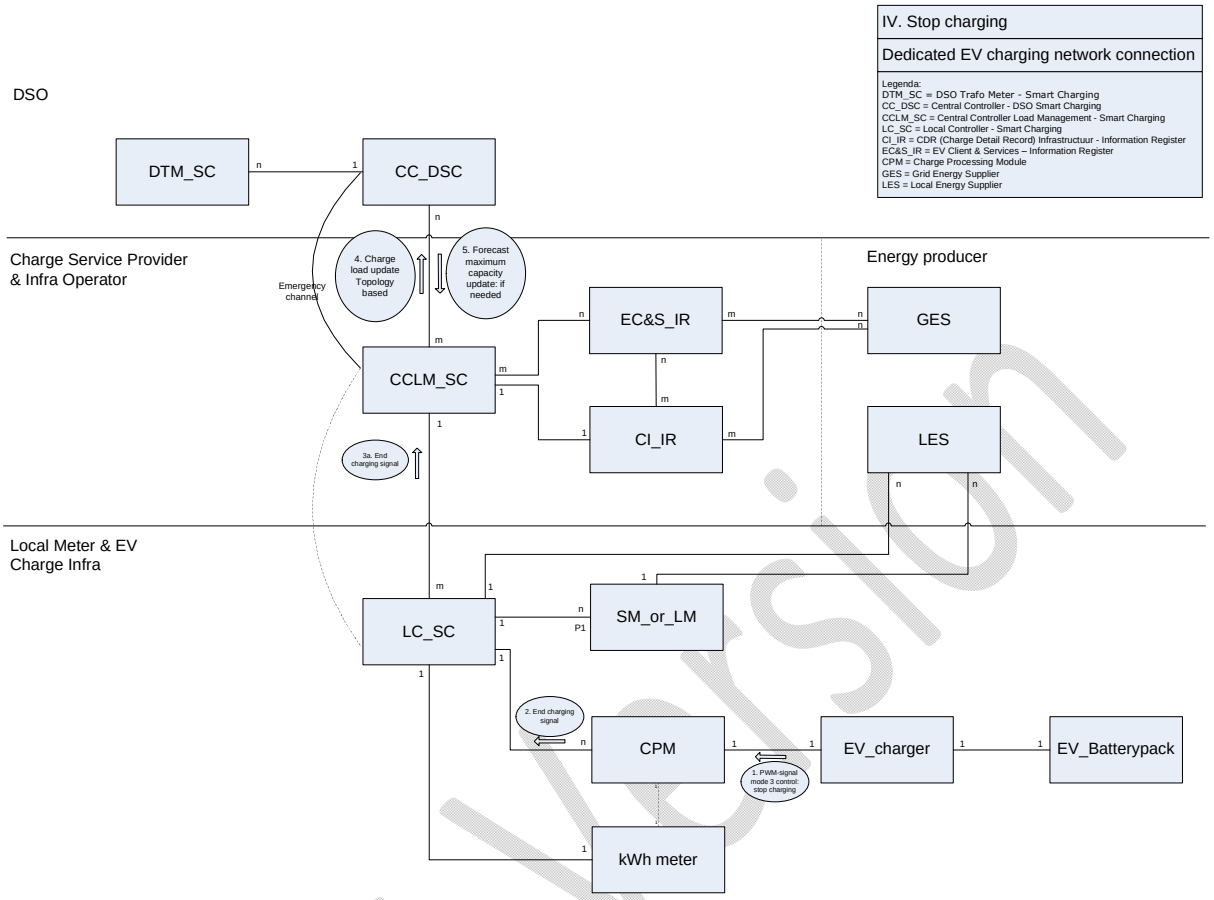
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Start Charging at default level



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Stop Charging



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